Lecture Notes on Data Engineering and Communications Technologies 13

Fatos Xhafa
Santi Caballé
Leonard Barolli *Editors*

Advances on P2P, Parallel, Grid, Cloud and Internet Computing

Proceedings of the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017)

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Lecture Notes on Data Engineering and Communications Technologies

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The aim of the book series is to present cutting edge engineering approaches to data technologies and communications. It publishes latest advances on the engineering task of building and deploying distributed, scalable and reliable data infrastructures and communication systems.
The series has a prominent applied focus on data technologies and communications with aim to promote the bridging from fundamental research on data science and networking to data engineering and communications that lead to industry products, business knowledge and standardisation.

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Editors

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Welcome Message from 3PGCIC-2017 Organizing Committee

Welcome to the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017), which will be held in conjunction with BWCCA-2017 International Conference, from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain.

P2P, Grid, Cloud and Internet computing technologies have been established as breakthrough paradigms for solving complex problems by enabling large-scale aggregation and sharing of a variety of computational resources and services.

Grid computing originated as a paradigm for high-performance computing, as an alternative to expensive supercomputers. Since late 80s, Grid computing domain has been extended to embrace different forms of computing, including Semantic and Service-oriented Grid, Pervasive Grid, Data Grid, Enterprise Grid, Autonomic Grid, Knowledge and Economy Grid.

P2P computing appeared as the new paradigm after client–server and Web-based computing. These systems are evolving beyond file sharing toward a platform for large-scale distributed applications. P2P systems have as well inspired the emergence and development of social networking, B2B (Business to Business), B2C (Business to Consumer), B2G (Business to Government), B2E (Business to Employee), and so on.

Cloud computing has been defined as a "computing paradigm where the boundaries of computing are determined by economic rationale rather than technical limits." Cloud computing is a multi-purpose paradigm that enables efficient management of data centers, time-sharing, and virtualization of resources with a special emphasis on business model. Cloud computing has fast become the computing paradigm with applications in all application domains and providing utility computing as a service.

Finally, *Internet computing* is the basis of any large-scale distributed computing paradigms; it has very fast developed into a vast area of flourishing field with enormous impact on today's information societies. Internet-based computing serves thus as a universal platform comprising a large variety of computing forms.

The aim of the 3PGCIC conference is to provide a research forum for presenting innovative research results, methods, and development techniques from both theoretical and practical perspectives related to P2P, Grid, Cloud and Internet computing.

Based on the reviewers' reports, the Program Committee selected 38 papers (30% acceptance rate) for presentation in the conference and publication in the Springer Lecture Notes on Data Engineering and Communication Technologies Proceedings.

Many people have helped and worked hard to produce a successful 3PGCIC-2017 technical program and conference proceedings. First, we would like to thank all the authors for submitting their papers, the PC members, and the reviewers who carried out the most difficult work by carefully evaluating the submitted papers.

The General Chairs of the conference would like to thank the PC Co-chairs Jordi Conesa, Open University of Catalonia, Spain, Nicola Capuano, University of Salerno, Italy, and Xu An Wang, CAPF University, China, for their great efforts in organizing a successful conference and an interesting conference program. We would like to appreciate the work of the Workshop Co-chairs Pere Tuset, Open University of Catalonia, Spain, Flora Amato, University of Naples, Italy, and Tomoki Yoshihisa, Osaka University, Japan, for supporting the workshop organizers. Our appreciations also go to all workshops' organizers for their hard work in successfully organizing these workshops.

We thank Shinji Sakamoto, Donald Elmazi, and Yi Liu, Fukuoka Institute of Technology, Japan, for their excellent work and support with the Web Submission and Management System of conference.

We are grateful to Prof. Marta Aymerich, Open University of Catalonia, Spain, and Prof. Makoto Takizawa, Hosei University, Japan, Honorary Co-chairs, for their support and encouragement.

Our special thanks to Isaac Woungang, Ryerson University, Canada, Zahoor Khan, Higher Colleges of Technology, United Arab Emirates, and Deborah Richards, Macquarie University, for delivering an inspiring keynotes at the conference.

Finally, we would like to thank the Local Arrangement at Open University of Catalonia, for making excellent local arrangement for the conference.

We hope you will enjoy the conference and have a great time in Barcelona, Spain!

Santi Caballé
Leonard Barolli
3PGCIC-2017 General Co-chairs
Jordi Conesa
Nicola Capuano
Xu An Wang
3PGCIC-2017 Program Committee Co-chairs

Welcome Message from 3PGCIC-2017 Workshops Chairs

Welcome to the Workshops of the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC 2017), which will be held from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain. The objective of the workshops was to present research results, work on progress, and thus complement the main themes of 3PGCIC 2017 with specific topics of Grid, P2P, Cloud and Internet computing.

The workshops cover research on Simulation and Modelling of Emergent Computational Systems, Multimedia, Web, Streaming Media Delivery, Middleware of Large Scale Distributed Systems, Network Convergence, Pervasive computing, and Distributed Systems and Security.

The 3PGCIC-2017 workshops are as follows:

1. The 10th International Workshop on Simulation and Modelling of Emergent Computational Systems (SMECS-2017)
2. The 8th International Workshop on Streaming Media Delivery and Management Systems (SMDMS-2017)
3. The 7th International Workshop on Multimedia, Web and Virtual Reality Technologies and Applications (MWVRTA-2017)
4. The 7th International Workshop on Adaptive Learning via Interactive, Cognitive and Emotional approaches (ALICE-2017)
5. The 5th International Workshop on Cloud and Distributed System Applications (CADSA-2017)
6. The 4th International Workshop on Distributed Embedded Systems (DEM-2017)
7. The 3rd International Workshop on Signal Processing and Machine Learning (SiPML-2017)

We would like to thank all workshop organizers for their hard work in organizing these workshops and selecting high-quality papers for presentation at workshops, the interesting programs and for the arrangements of the workshop during the conference days.

We hope you will enjoy the conference and have a great time in Barcelona, Spain!

Pere Tuset
Flora Amato
Tomoki Yoshihisa
3PGCIC-2017 Workshops Chairs

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Welcome Message from SMECS-2017 Workshop Organizer

On behalf of the Organizing Committee of 10th International Workshop on Simulation and Modelling of Engineering & Computational Systems, we would like to warmly welcome you for this workshop, which will be held in conjunction with the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017), from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain.

Modeling and simulation have become the de facto approach for studying the behavior of complex engineering, enterprise information, & communication systems before deployment in a real setting. The workshop is devoted to the advances in modeling and simulation techniques in fields of emergent computational systems in complex biological and engineering systems, and real-life applications.

Modeling and simulation are greatly benefiting from the fast development in information technologies. The use of mathematical techniques in the development of computational analysis together with the ever greater computational processing power is making possible the simulation of very large complex dynamic systems. This workshop seeks relevant contributions to the modeling and simulation driven by computational technology.

The papers were reviewed and give a new insight into latest innovations in different modeling and simulation techniques for emergent computational systems in computing, networking, engineering systems, and real-life applications. Special attention is paid to modeling techniques for information security, encryption, privacy, authentication, etc.

We hope that you will find the workshop an interesting forum for discussion, research cooperation, contacts, and valuable resource of new ideas for your research and academic activities.

Leonard Barolli
SMECS-2017 Workshop Organizer

SMECS-2017 Program Committee

Workshop Organizer

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Welcome Message from MDMS-2017 Workshop Organizers

It is my great pleasure to welcome you to the 2017 International Workshop on Streaming Media Delivery and Management Systems (SMDMS-2017). We hold this 8th edition of the workshop in conjunction with the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017), from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain.

The tremendous advances in communication and computing technologies have created large academic and industry fields for streaming media. Streaming media have an interesting feature that the data stream continuously. They include many types of data like sensor data, video/audio data, stock data. It is obvious that with the accelerating trends toward streaming media, information and communication techniques will play an important role in future network. In order to accelerate this trend, further progresses of the researches on streaming media delivery and management systems are necessary. The aim of this workshop is to bring together practitioners and researchers from both academia and industry in order to have a forum for discussion and technical presentations on the current researches and future research directions related to this hot research area.

I would like to express my gratitude to the authors of the submitted papers for their excellent papers. I am very thankful to the Program Committee members who devoted their time for preparing and supporting the workshop. Without their help, this workshop would never be successful. A list of all of them is given in the program as well as the workshop Web site. I would like to also thank to 3PGCIC-2017 Organizing Committee members for their tremendous support for organizing the workshop.

Finally, I wish to thank all SMDMS-2017 attendees for supporting this workshop. I hope that you have a memorable experience you will never forget.

Tomoki Yoshihisa
SMDMS-2017 Workshop Chair

SMDMS-2017 Program Committee

Workshop Chair

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Welcome Message from MWVRTA-2017 Workshop Organizers

Welcome to the 7th International Workshop on Multimedia, Web and Virtual Reality Technologies and Applications (MWVRTA 2017), which will be held in conjunction with the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017), from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain.

With the appearance of multimedia, Web and virtual reality technologies, different types of networks, paradigms, and platforms of distributed computation are emerging as new forms of the computation in the new millennium. Among these paradigms and technologies, Web computing, multimodal communication, and tele-immersion software are most important. From the scientific perspective, one of the main targets behind these technologies and paradigms is to enable the solution of very complex problems such as e-Science problems that arise in different branches of science, engineering, and industry. The aim of this workshop is to present innovative research and technologies as well methods and techniques related to new concept, service, and application software in Emergent Computational Systems, Multimedia, Web and Virtual Reality. It provides a forum for sharing ideas and research work in all areas of multimedia technologies and applications.

We would like to express our appreciation to the authors of the submitted papers and to the Program Committee members, who provided a timely and significant review.

We hope that all of you will enjoy MWVRTA 2017 and find this a productive opportunity to exchange ideas and research work with many researchers.

Kaoru Sugita
Leonard Barolli
MWVRTA 2017 Workshop Co-chairs

MWRTA-2017 Program Committee

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Welcome Message from ALICE-2017 Workshop Organizers

Welcome to the 7th International Workshop on Adaptive Learning via Interactive, Cognitive and Emotional approaches (ALICE-2017), which will be held in conjunction with the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017), from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain.

Many researchers argue that learners must be meaningfully engaged in the learning process for effective learning to occur. Engaging learners long enough to see them through to the end of a course is one of the most significant issues faced today by learning developers. Learning tools and resources are today more effective, interactive, and easily accessible than in the past. Nevertheless, the current generation of students is native speakers in the language of digital media and their expectations are even higher. New learners expect to be in control of their learning experience while in a supportive and cooperative environment. They expect the course material to be motivating, challenging, well linked to their prior knowledge, and relevant to everyday lives and careers.

The 7th International Workshop ALICE 2017 aims at providing a forum for innovations in adaptive technologies for e-learning especially designed to improve the engagement of students in learning experiences. Works that combine adaptive techniques with approaches based on gamification, affective computing, social learning, storytelling, interactive video, and new forms of assessment are welcome as well as works describing approaches based on educational data mining, learning, and academic analytics aimed at improving learners' motivation and teachers' experience also taking into account aspects related to multimedia and security. Special emphasis is given to approaches based on P2P, Parallel, Grid, Cloud and Internet computing as well as on computational intelligence and knowledge-based technologies. Empirical results from real users in learning and training settings are particularly welcome in order to evaluate and discuss the impact of the proposed innovations.

Santi Caballé
Nicola Capuano
ALICE-2017 Workshop Organizers

ALICE-2017 Program Committee

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Welcome Message from CADSA-2017 Workshop Organizer

Welcome to the 5th International Workshop on Cloud and Distributed System Applications (CADSA-2017), which will be held in conjunction with the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017), from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain.

This International Workshop on Cloud and Distributed System Applications brings together scientists, engineers, and students for sharing experiences, ideas, and research results about Domain Specific Applications relying on Cloud computing or Distributed Systems.

This workshop provides an international forum for researchers and participants to share and exchange their experiences, discuss challenges, and present original ideas in all aspects related to the Cloud and Distributed Systems applications design and development.

We have encouraged innovative contributions about Cloud and Distributed computing, like:

- Distributed computing Applications
- Cloud computing Applications
- Collaborative Platforms
- Topologies for distributed computing
- Semantic Technologies for Cloud
- Modeling and Simulation of Cloud computing
- Modeling and Simulation of Distributed System
- Distributed Knowledge Management
- Distributed computing for Smart Cities
- Distributed computing for E-Health
- Quality Evaluation of Distributed Services

Many people contributed to the success of CADSA-2017. First, I would like to thank the Organizing Committee of 3PGCIC-2017 International Conference for giving us the opportunity to organize the workshop. Second, I would like to thank our Program Committee members, and, of course, I would like to thank all the authors of the workshop for submitting their research works and for their participation. Finally, I would like to thank the Local Arrangement Chairs of the 3PGCIC-2017 conference.

I hope you will enjoy CADSA workshop and 3PGCIC International Conference, find this a productive opportunity for sharing experiences, ideas, and research results with many researchers, and have a great time in Barcelona, Spain.

Flora Amato
CADSA-2017 Workshop Chair

CADSA-2017 Program Committee

Workshop Chair

Flora Amato	University of Naples “Federico II,” Italy

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Welcome Message from DEM-2017 Workshop Organizers

Welcome to the 4th International Workshop on Distributed Embedded systems (DEM-2017), which will be held in conjunction with the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017), from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain.

The tremendous advances in communication technologies and embedded systems have created an entirely new research field in both academia and industry for distributed embedded software development. This field introduces constrained systems into distributed software development. The implementation of limitations like real-time requirements, power limitations, memory constraints within a distributed environment requires the introduction of new software development processes, software development techniques, and software architectures. It is obvious that these new methodologies will play a key role in future networked embedded systems. In order to facilitate these processes, further progress of the research and engineering on distributed embedded systems is mandatory.

The International Workshop on Distributed Embedded Systems (DEM) aims to bring together practitioners and researchers from both academia and industry in order to have a forum for discussion and technical presentations on the current research and future research directions related to this hot scientific area. Topics include (but are not limited to) virtualization on embedded systems, model-based embedded software development, real time in the Cloud, Internet of Things, distributed safety concepts, embedded software for (mechatronics, automotive, health care, energy, telecom, etc.), sensor fusion, embedded multicore software, distributed localization, distributed embedded software development, and testing. This workshop provides an international forum for researchers and participants to share and exchange their experiences, discuss challenges, and present original ideas in all aspects of distributed and/or embedded systems.

I would like to appreciate the Organizing Committee of the 3PGCIC 2017 International Conference for giving us the opportunity to organize the workshop. My sincere thanks go to Program Committee members and to all the authors of the workshop for submitting their research works and for their participation.

I hope you will enjoy DEM workshop and have a great time in Barcelona, Spain.

Peter Hellinckx
DEM 2017 Workshop Chair

DEM-2017 Program Committee

Workshop Chair

Peter Hellinckx	University of Antwerp

Program Committee Members

Paul Demeulenaere	University of Antwerp, Belgium
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Joachim Denil	McGill University, Canada
Maarten Weyn	University of Antwerp, Belgium

Welcome Message from SiPML-2017 Workshop Organizers

Welcome to the 3rd International Workshop on Signal Processing and Machine Learning (SiPML-2017), which will be held in conjunction with the 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017), from November 8–10, 2017, at Open University of Catalonia, Barcelona, Spain.

The workshop brings together engineers, students, practitioners, and researchers from the fields of machine learning (ML) and signal processing (SP). The aim of the workshop is to contribute to the cross-fertilization between the research on ML methods and their application to SP to initiate collaboration between these areas. Machine Learning plays an important role in the transition from data storage to decision systems based on large databases of signals such as the ones obtained from sensor networks, Internet services, or communication systems. These systems imply developing both computational solutions and novel models. Signals from real-world systems are usually complex including the ones from speech, music, bio-medical, and multimedia, among others. Thus, SP techniques are very useful for these types of systems to automate processing and analysis techniques to retrieve information from data storage. Topics of the workshop range from foundations for real-world systems, and processing, such as speech, language analysis, biomedicine, convergence and complexity analysis, machine learning, social networks, sparse representations, visual analytics and robust statistical methods.

We would like to thank the 3PGCIC 2017 International Conference for giving us the opportunity to organize the workshop. The time and efforts of the PC members of the workshop as well as of the authors of the workshop for submitting their research works and for their participation are highly appreciated.

We wish you enjoy the workshop at the 3PGCIC-2017 Conference and have a pleasant stay in Barcelona, Spain.

Ricardo Rodriguez Jorge
Jolanta Mizera-Pietraszko
SiMPL-2017 Workshop Co-chairs

SiPML-2017 Program Committee

Workshop Chairs

Ricardo Rodriguez Jorge	Autonomous University of Ciudad Juarez, Mexico
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3PGCIC-2017 Keynote Talks

InterCloud and HetNet for Mobile Cloud Computing in 5G Systems: Design Issues, Challenges, and Optimization

Isaac Woungang

Ryerson University, Toronto, Canada

Abstract. Emerging 5G systems will be featured by a closer collaboration between mobile network operators and Cloud service providers to meet the communication and computational requirements of modern mobile applications and services in a mobile Cloud computing (MCC) environment. In this talk, we will show how the marriage between heterogeneous wireless networks (HetNets) and multiple Clouds (referred to as InterCloud) stands out as an effective response for the mobile data deluge. First, we review the building blocks of a HetNet and an InterCloud as well as the resource management entities in both domains. Second, we will discuss on how they can be orchestrated to better support the task offloading process. Third, we will identify the key design criteria and challenges related to interoperation between an InterCloud and a HetNet. Finally, we will introduce a novel revenue sharing approach for a coalition between a mobile network operator and Cloud service providers and show that using the Shapley concept, this approach can achieve the maximum revenue for the coalition by optimally associating the users to the Clouds through the base stations.

Advancements in Internet of Things (IoT); Design Challenges and Importance of Fog Computing over Cloud Computing

Zahoor Ali Khan

Higher Colleges of Technology,
Abu Dhabi, United Arab Emirates

Abstract. Advancements in the field of Internet are increasing at a remarkable rate. Currently, only 1% things are connected via Internet. Internet of Things (IoT) is a new revolution which will interconnect approximately 50 billion computing and non-computing devices (things) by 2020. Advances in IoT bring new challenges of managing this real-time sensor data. In this talk, we will focus on these challenges with their possible solutions. The importance of Fog computing over Cloud computing in IoT will also be analyzed with the demonstration of real-life scenarios.

Intelligent Virtual Agents for Education and Training

Deborah Richards

Macquarie University, Sydney, Australia

Abstract. This talk will provide an overview of the types and uses of intelligent virtual agents. Intelligent virtual agents (IVAs) have been a growing area of research within the field of artificial intelligence in the past 20 years. An IVA is a piece of software, generally considered to be autonomous in some way, that imitates the behavior of a human or animal and is embodied within a virtual environment. A primary aim in the field of virtual agents is the creation of believable characters that are useful in their situated paradigm (e.g., games, narratives, education, assistive computing). There is a significant body of work in the area of believable characters which may be known as pedagogical agents, embodied conversational agents, artificial companions, talking heads, empathic or listening agents depending on their function, level of sophistication, or the particular research focus such as emotion and appraisal systems or language technology. The talk will provide an overview of the field, including my research concerning IVAs and memory, emotions and collaborative learning for applications such as debriefing and reminiscing, border security officer training, scientific inquiry and science education, real estate assistance, museum guidance, and adherence to treatment advice.

Contents

The 12th International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC-2017)

Home Energy Management by Differential Evolution and Enhanced Differential Evolution in Smart Grid Environment

Fatima Tariq, Samia Abid, Muhammad Talha, Musa Ahmad, Haq Nawaz, Ayesha Areej, and Nadeem Javaid(✉)

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Abstract. This paper introduces Home Energy Management System (HEMS) which is the most revolutionary application of Smart Grid (SG) technology. It allows consumers to schedule the appliances according to their desires and requirements without effecting their living comfort along with the advantage of reducing electricity expenses. As a result, Peak to Average Ratio (PAR) is reduced for the benefit of utility. This paper focuses on optimizing power consumption in residential sector using Demand Side Management (DSM) strategy. Authors estimate the performance of Home Energy Management System (HEMS) by using optimization techniques: Differential Evolution (DE) and Enhanced Differential Evolution (EDE) and Real Time Pricing (RTP) signal is used for the calculation of electricity bills. As there is always a tradeoff between two parameters, so in our approach there exists a tradeoff between User Comfort (UC) and electricity cost. Simulation results show that in terms of waiting time DE performs better than EDE, however EDE performs better in terms of cost.

1 Introduction

In early times, the households were simple, most of the work was done manually and simple machines were used in industrial sector. In the past few years, with the development in technologies, human life has been relieved in different aspects. From 1970 to 1990 there was a drastic increase in power demand which urged the need to find alternate sources to meet the demand. This issue is not worthy because traditional power system are becoming incompatible to these changes. Therefore, smart grids are introduced which enables bidirectional communication between utility and consumers. Smart grids include smart meter, smart appliances and smart homes. Smart grid is shown in Fig. 1. Smart meter provides exchange of information between consumers and utility. This information is used for optimization of energy in smart homes. For energy optimization in smart grid, DSM is one of the most important strategy. DSM is most important feature in implementation of smart grid technology.The main components of DSM are shown in Fig. 2. This revolution of smart grid allows user to take

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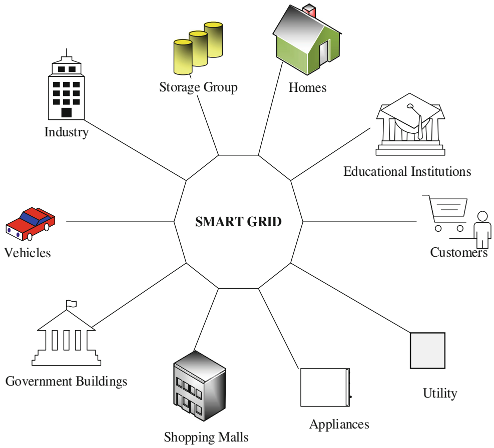

Fig. 1. Components of DSM

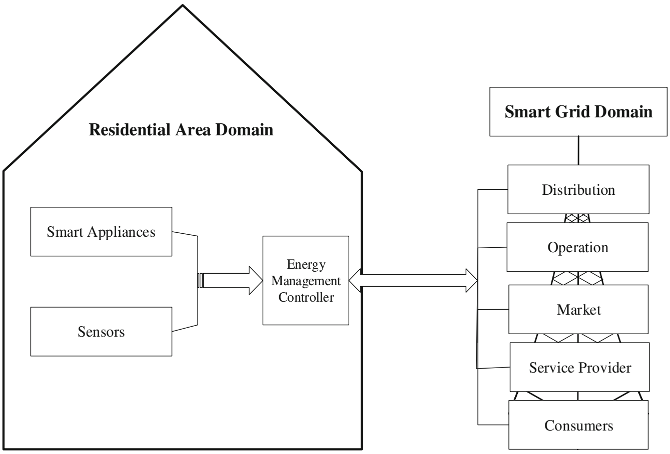

Fig. 2. Components of DSM

intelligent and optimal decision for their power consumption. DSM approach enables the user to shift their load from on peak hours to off peak hours and provides benefit to both user and supplier. DSM provides equilibrium between demand and supply which reduces the likelihoods of blackouts and plays a very important role in reducing power consumption, electricity cost and PAR.

DSM could be developed by various different technical approaches. In this paper, authors shift the load on the basis of pricing signals. Dynamic pricing rates such as Time of Use (ToU), Inclined Block Rate (IBR), Critical Peak Pricing (CPP) and Real Time Pricing (RTP) reflect the relationship between demand and supply. Pricing rates encourages the users to shift the appliances from on peak hours to off peak hours. This shift benefits both the utility and consumers. Among all pricing tariffs RTP is the most proficient pricing scheme for electricity markets.

Rest of the sections are organized as: Sect. 2 shows the literature review in SG, Sect. 3 highlights the problem addressed in the paper, and Sect. 4 incorporates the proposed solution and optimization techniques used in the paper. Simulations and results are described in Sect. 5 and finally, Sect. 6 gives the conclusion and research in future work.

2 Related Work

Many researchers around the world worked to optimally schedule appliances in smart grid. Some of the related work in this regard is as follows:

In [4], author proposed an efficient model using Multiple Knapsack Problem (MKP) for residential area. Author addressed the problem of electricity bill reduction at the cost of increased computational time. In this paper author have used three heuristic optimization techniques: Genetic Algorithm (GA), Binary Particle Swarm Optimization (BPSO), and Ant Colony Optimization (ACO) to achieve their objectives. Time of Use (ToU) tariff model is used with Inclined Block Rate (IBR) to calculate electricity bills for end users. Appliances considered are; fixed, shiftable and elastic appliances. Integration of RESs and Energy Storage System (ESS) has also been discussed in this paper. The objective function of proposed model is to minimize electricity bills, user comfort, energy consumption and PAR reduction with integration of RESs. By applying heuristic algorithms author have reduced electricity bill, reduced PAR and energy consumption is minimized. With the integration of RES, GA performs better than BPSO and ACO. In this paper user comfort is minimized however waiting time is still very large for end users. In [3], author have proposed a general architecture of energy management for scheduling appliances in homes. Demand Response information is received by Home Gateway that is transferred to an Energy Management Controller (EMC). In this paper author addressed the problem of high PAR with RTP. By combining RTP with IBR electricity cost and PAR is reduced. Appliances are categorized as Automatically Operated Appliances (AOA) and Manually Operated Appliances (MOA). Nine AOA are considered, as one appliance is used more than one time in a day so total 16 appliances are scheduled. 1 h is divided into 5 time slots, so the time resolution is 12 min and 1 day has 120 slots. In this paper GA is used to optimize operation start time of all AOAs. As there is a tradeoff in between electricity price and Delay Time Rate (DTR), the author has just focused on the reduction of electricity price and PAR so the DTR is compromised.

In [2], author have proposed a consumption scheduling mechanism for load management in smart grid. Author addressed the problem of scheduling power consumption. The proposed mechanism will be able to minimize the peak hourly load and satisfy both the user preferences and specific needs of all appliances. Appliances are categorized as; non-shiftable, time-shiftable and power-shiftable appliances. Integer linear programming is used to formulate the constraints of power pattern. The scheduling scheme proposed is suitable for fixed price scenario where the operators can achieve load control without hurting consumer's preferences to reduce the peak load. Author considered 7 appliances and define user preferences and power requirements of particular appliance. After applying all the constraints, integer linear programming problem is solved and optimal scheduling is achieved. Author also performed simulations for the four houses and each house has similar appliances. When multiple homes take part in scheduling, a more balanced hourly load is achieved. By reducing the PAR, the scheduling mechanism proposed is able to reduce maximum load. The assumption of fixed price is very old, now a days price rate changes in on and off-peak hours. In [6], author addressed the problem of trade-off between waiting time and electricity price. Author assumed that consumers are equipped with energy control systems, and devices are installed inside the smart meters and connected to a communication network. Day ahead pricing is used, so electricity prices are declared in advance of a time. On the basis of which consumers can normalize the operation of appliances to reduce the electricity price. Three operational modes are discussed in the paper. In the operation mode I, without considering discomfort level consumer minimizes the payments. Only discomfort is considered by consumers in operation mode II, without considering the payments. In the 3rd mode consumer achieves a preferred trade-off between the payments and the uneasiness. By the comparison of day-ahead price and flat price rate, it is concluded that day-ahead price can reduce the peak load, the PAR, the electricity payments and the average price comparing with the flat price rate. In this paper, integration of RESs is neglected by the author.

In [1], an energy management controller based on heuristic algorithm is designed by the author for residential area in smart grid. Five heuristic algorithms GA, BPSO, Bacterial Foraging Optimization Algorithm (BFOA), Wind Driven Optimization (WDO) and the hybrid Genetic Wind Driven (GWD) algorithm proposed by author are assessed in this paper. These algorithms are used for scheduling load between off-peak hours and on-peak hours. Author addressed the problem of user comfort maximization, cost minimization and computational complexity of algorithms. RTP is used for maximization user comfort and minimizing cost and PAR. Multiple homes are considered with three types of appliances: fixed, elastic and shiftable appliances. Class A contains fixed load appliances, while elastic and shiftable appliances are included in class B. Appliances are scheduled using the frame format which consist of eight bit pattern. Each appliance is assigned a priority bit in order to reduce the peaks during on-peak hours. Simulation scenarios for single home and multiple homes are discussed in the paper. Each home has 12 appliances. Energy consumption of hybrid GWD is better than WDO. GWD also performs better than other algorithms in terms of electricity cost and PAR reduction due to combination of crossover and mutation. To reduce the cost user comfort is also compromised at some level. The main flaw of this paper is that there is no proper plan for organizing appliances using scheduling bits and integration of RESs is also neglected. In paper [8], for optimization of residential energy load without hurting user comfort author proposed mathematical optimization model of household energy units. Along with minimum electricity cost, user comfort is maximized by implementing WDO. Knapsack problem (K-WDO) algorithm is used by authors for maximization of electricity bill and peak reduction. Author addressed the problem of trade-off between user-comfort and electricity cost. The model proposed uses hourly electricity prices (ToU) in combination with user's desires. Author assumed six appliances, when the scheduling process starts, appliances turn on immediately. After one hour of working, the remaining hours are rescheduled by EMC when the electricity price is low. K-WDO and K-PSO are used for minimizing energy consumption and PAR reduction. WDO algorithm is efficient in reducing electricity bill and waiting time as compared to PSO, which has high convergence time. User comfort is neglected in this paper, as the main focus of author is electricity cost reduction. In [9], author addressed the problem of meaningful balance between energy saving and comfortable lifestyle for a smart Home Energy Management System (HEMS). An intelligent DSM is discussed that minimizes the electrical peak load and cost of electricity. A Multi Objective Mixed Integer non-Linear Programming (MOMILP) is developed for optimal usage of energy in a home. Three dependent objectives: energy saving, user's convenience rate and Thermal Comfort Level (TCL) are considered in a home. This paper includes a moderate sized house in a domestic micro-grid with Home Automation Energy Management System (HAEMS) and collection of schedulable appliances. Performance is calculated by six scenarios, focusing upon each household based on the proposed approaches. Optimization problem is solved by benefits from HAEMS to smart controller. PAR is not considered by author in this paper which is the major drawback. In [10], an efficient HEMS model has been proposed which is comprised of two types of appliances: Real time appliances and Schedulable appliance. Author addressed the problem of energy optimization to minimize the cost by scheduling the load within limited scheduling hours. By utilizing Dijkstra Algorithm, lower complexity is achieved which impacts the scheduling of the appliances within limited hours. ToU is taken under consideration to balance load according to on-peak hours and off-peak hours. Computational efforts are done to provide better results in contrast to the non-optimized schemes. DijCostMin Algorithm and Sub-Optimal Algorithm are considered to evaluate the most efficient computational mechanism as these techniques above are only applicable for multiple homes. The performance of the various proposed solutions have attained significant reduction in electricity cost and decreases computational complexity. PAR reduction is not considered in this paper, as it benefits both the utility and the consumer. DSM is obtained by optimizing the consumption of energy in home by HEMS in smart grid environment. In paper [7] author addressed the problem of scheduling of appliances in smart home. A six layered model: Comprehensive Home Energy Management Architecture (CHEMA) has been proposed by authors in this paper. Four of the layers are implemented in MATLAB and next two layers are planned for future work. The proposed architecture has multiple options of appliance scheduling, for reducing peak load user's energy consumption. First layer is used for basic parameters and scheduling of appliances. Second layer is used to discuss the cases for energy minimization and its results are used for theft and fault detection in third layer. Forth layer is used for green effects to encourage the user to reduce energy consumption. Author used ToU pricing tariff in this model. PAR has been neglected in this paper by authors.

The problem of power trading and scheduling of load with deployment of Renewable Energy Resources (RERs) has been addressed in this paper [5]. According to the model, excess generation of electricity is offered by users to other users with a properly nominated price. Author considered a game theoretic approach for modeling the interaction between users. The problem in selection of offered price and output generation is formulated as linear mixed-integer program and to tackle this problem author adopted the generalized Bender's decomposition approach. Based on the demand requirement of user, each user appliances can be set as must-run and controllable. Further controllable appliances are categorized as: Interruptible and Non-Interruptible. There is a competition between users with excess amount of energy to sell their generations. For the better utilization of RERs and match demand and supply, author assumed each user with a storage device. An approximate dynamic programming approach has been proposed by author to schedule the operation of must-run, interruptible controllable and non-interruptible controllable appliances. Appliances are scheduled independently to reduce the complexity of the scheduling algorithm. In this paper users are encouraged to integrate RERs, however the cost of implementation of RERs is neglected and there is no system for storage of excess generation of electricity.

In [11], distributed EMS was designed by author for the optimal operation of micro grids. This is being compared with the existing distributed approaches. Discrete-time model with a finite horizon is used in this paper. The goal of the EMS is to manage the power flows in order to: (1) minimize cost of production of electricity, cost storage of energy and purchasing price of energy from smart grids; (2) minimize the discomfort of consumers and (3) minimize the blackouts. In this paper, author considered both renewable and conventional distributed generation. Batteries are considered as distributed storage in the micro-grids. Two types of loads are considered: interruptible and deferrable loads. Minimization of operational cost while providing consistent and first-class power to the loads is the main objective of micro-grid operators. The result shows the fast convergence of the proposed distributed EMS. Consequently, the whole scenario may lead to uncertainty in processing times, prices and changes in demands. In [12], on the basis of Lyapunov optimization the author has modeled the online energy management as a stochastic optimal power and proposed an online EMS. An online EMS consists of Virtual queue design, Lyapunov optimization, and performance gaps in the optimizations. Authors used greedy algorithm to minimize the cost at each time individually. The results show that an online EMS surpasses greedy algorithm and is close to an optimal offline algorithm. The online EMS may leads to the security and reliability problems as well as it may not assure the quality of service for users.

3 Problem Statement

Electricity plays an important role in our daily life. Whether it is at residential, commercial or industrial level, our daily routines depend on the use of electricity. As discussed earlier due to the industrial revolution human life has changed radically. Even the modern means of transportation has been revolutionized by electricity and modern communication like radio, email and internet etc. heavily depends on electricity. Other than the varying behavior of energy consumption the steady increase in world population, unexplored RER and aging infrastructure of existing power system has led to severe energy crisis. So a secure, environmental friendly and home designed plan is the most important need of the world. Which lead to the evolution of smart grid. Smart grid provides a bidirectional communication between user and utility to fulfill the demand of available resources. Smart grid is provoked in order to make enhancement in maintenance, preparation and procedure of the electricity supply. DSM is known as the amendments made by the consumers demands for energy usage by using various methods. The main reason behind DSM is to convince the user to consume energy in off peak hours rather than in on peak hours for reducing electricity cost. Most of the time cost is minimized and PAR is ignored which shift the appliances in off peak hours and burden the utility. Therefore, in this work optimization techniques are used which have considered PAR reduction to benefit the utility and electricity expenses are also reduced for the benefit of user. While trying to minimize the cost, most of the schedulers shift the load in on peak hours and neglect the PAR. This type of load shifting can reduce the cost, however PAR is increased which may lead to shortage of electricity. So appliances are scheduled in such a manner that it provides benefit to both the consumer and utility.

4 System Model

In contrast with conventional grid, smart grid provides bi-directional communication between consumer and utility and smart homes contains smart meters. Smart meters are used to facilitate the consumer, as consumers can inform utility about their energy consumption outline. Consumers are encouraged to arrange their energy consumption outline in such a manner that minimum of electricity cost is charged and this is known as DSM. In past years, many optimization techniques have been implemented for scheduling of appliances in smart homes. In this work, single home is considered with sixteen appliances. Appliances can be Interruptible and Non-Interruptible. One time slot is divided into five time slots. So, each hour is divided 12 min and one day has 120 time slots. RTP tariff is used for calculation of electricity bills. The main objectives of this paper are to reduce PAR, reduction of electricity bills and maximization of user comfort. Many optimization techniques have been used to change electricity bill.

4.1 Optimization Techniques

The optimization techniques used by the authors to find optimal solution are as follows:

(1) DE: DE is a heuristic algorithm based upon population. It is efficient in many ways like convergence is fast and it helps to solve real world problems. DE involves three main operations: mutation, crossover ad selection. First of all it generates initial population randomly. Than for each target vector, randomly select three vectors which are distinct from each other. Multiply difference of two vectors with constant factor and then it is added to the third to form mutant vector. For the generation of trial vector, elements of mutant and target vector are exchanged. Compare target vector with the trial vector, the one with the

```
Initialization (popsize,D,MaxItr,xl,xu)
for i = 1 → popsize do
    Mutant= r11+0.5*(r21-r31);
end for
for i = 1 → D do
    for j = 1 → MaxItr do
        if rand(1)≥ 0.3 then
            Y11(1,i)=r11(1,D);
        else
            Y11(1,i)=Mutant(1,D);
        end if
    end for
end for
for i = 1 → D do
    if rand(1)≥ 0.6 then
        Y21(1,i)=r11(1,i);
    else
        Y21(1,i)=Mutant(1,i);
    end if
end for
for i = 1 → D do
    if rand(1)≥ 0.9 then
        Y31(1,i)=r11(1,i);
    else
        Y31(1,i)=Mutant(1,i);
    end if
end for
for i = 1 → D do
    Y41(1,i) = rand(1)*r11(1,i);
end for
for i = 1 → D do
    Y51(1,i)=rand(1)*Mutant(1,i)+(1-rand(1))*r11(1,i);
end for
```

Algorithm 1. EDE for generation of trial vectors better fitness is admitted to the next generation. All the steps are continued until it reaches some stopping criteria.

(2) EDE: EDE is the enhanced version of DE. In comparison with DE, EDE generates five trial vectors as shown in Algorithm 1. First three trial vectors are generated by taking three cross over rates instead of one. Fourth trial vector is generated to increase the convergence speed of technique. Diversity of search space is increased by last trial vector. By performing all three operations: mutation, crossover ad selection, the vector that has minimum fitness value is selected for next generation.

5 Simulations and Discussions

Simulation is performed on MATLAB by considering 16 appliances. No. of appliances are total nine and one appliance is used more than once in one day so, total 16 appliances are scheduled. Appliances are divided in two categories: Automatic and manually operated appliances. Only manually operated appliances are scheduled here. These appliances can be Interruptible and Non-Interruptible. One time slot is divided into five time slots. So, each hour is divided 12 min and one day has 120 time slots [3]. It is very useful for consumers to save energy consumption in homes. The shortest Length of Operation Time (LOT) of any appliance is set to be 12 min. Each appliance should be assigned LOT which is multiple of 12 (Table 1).

For example, if dish washer needs to operate 20 min than LOT should be set as 2 which is equal to 24 min. RTP tariff is used for calculation of electricity bills. In EDE scheduled appliances electricity cost is reduced because EDE balance the load by shifting appliances from on peak hours to off peak hours. RTP price signal is used for scheduling of appliances and total electricity cost of appliances

Table 1. Description of symbols

Symbols	Description
popsize	Size of Population
D	No. of Appliances
MaxItr	Maximum no. of Iteration
xl	Lower bound
xu	Upper upper
Y11	1st trial vector
Y21	2nd trial vector
Y31	3rd trial vector
Y41	4th trial vector
Y51	5th trial vector
Mutant	Mutant vector

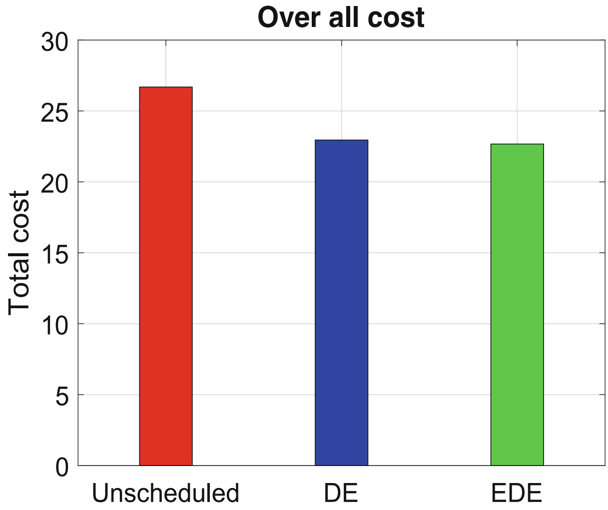

Fig. 3. Total electricity cost

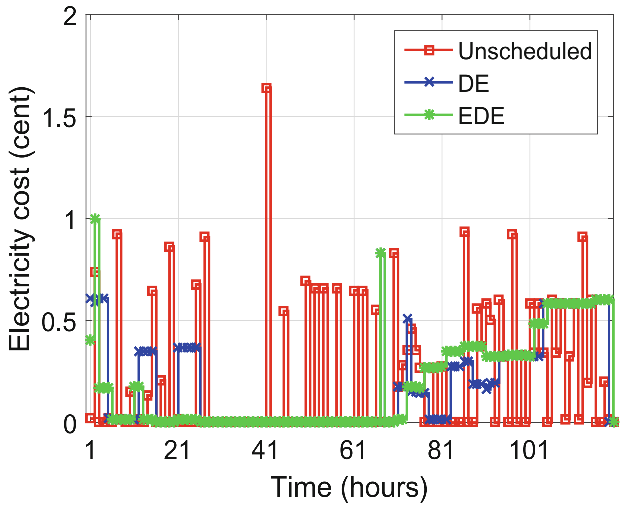

Fig. 4. Electricity cost per hour

is shown in Fig. 3 and electricity cost per hour is shown in Fig. 4. Figure 5 shows that in unscheduled load, load is increased during peak hours that increases the electricity cost and energy consumption but in EDE, load is managed by shifting it in off peak hours that reduces the consumption of energy in specific hour. If appliances are not scheduled power consumption is increased which maximizes the electricity cost and peak is generated. Load is scheduled in such a manner that it is shifted from on peak hours to off peak hours.

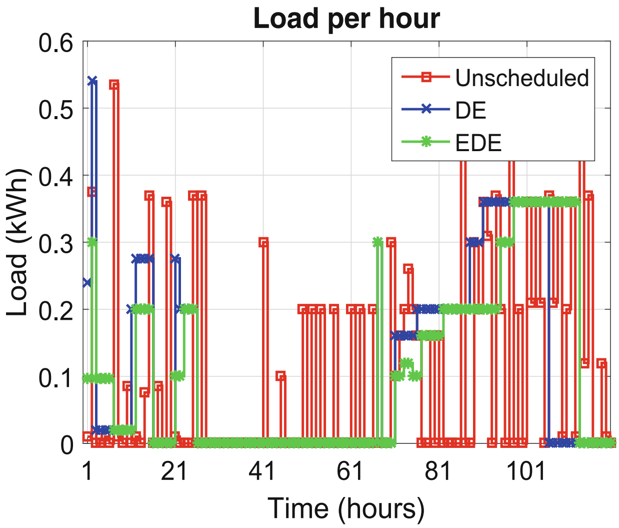

Fig. 5. Load per hour

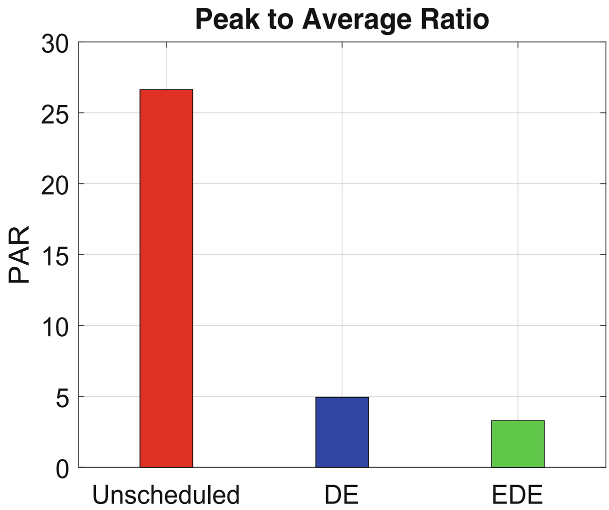

Fig. 6. PAR

PAR is increased in unscheduled load because the maximum load is shifted to a specific hour of a day and creates the peak. In EDE when load is scheduled it reduces the PAR by shifting the load to off peak hours. As shown in Fig. 6 PAR in EDE is minimum as compared to DE and unscheduled. The reduction in PAR provides benefit to both utility and consumer. Waiting time is the delay in operation time of appliances. Fig. 7 shows that by applying EDE, waiting time

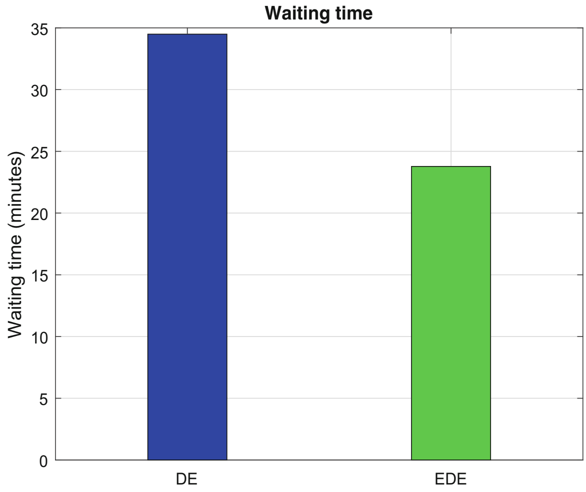

Fig. 7. Waiting time

is reduced, however not as much as electricity cost because there is trade-off between desired lifestyle of user and cost of electricity. User comfort is sacrificed when we reduce the electricity cost of appliances and vice versa. As the cost of electricity is reduced from unscheduled cost so the user comfort is compromised at some level.

6 Conclusion and Future Work

In this paper, we have scheduled appliances on the basis of load management in residential homes. The main objective of the proposed technique is to reduce the consumption cost and maximize the user comfort while considering peak consumption into account. The residential power consumption behavior in time significantly affect the electricity cost. The proposed algorithm optimally distribute the residential load over the time horizon. Simulations results show that there exist a trade-off between electricity cost and user comfort in term of waiting time. The saving in electricity cost depends on how long consumer is willing to face the inconvenience. The overall performance of the proposed technique shows that consumer has achieved a significant reduction in electricity cost with a reasonable waiting time for residential devices. In future work, we can integrate RES in smart grid and implement it in real time scenario.

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Demand Side Optimization in Smart Grid Using Harmony Search Algorithm and Social Spider Algorithm

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Abstract. Electricity is a valuable resource. With the increase of population, this valuable resource is being used inefficiently. To overcome this problem, electricity providers use various techniques like introducing different pricing schemes. In peak hours, when the usage of electricity is high, the utility increases the per unit cost. Therefore, usage of electricity in peak hours result in high electricity bills. The electricity bills can be reduced by efficiently scheduling the home appliances so that few appliances are operated during peak hours. For this purpose many techniques have been proposed. In this paper, we propose a Social Spider Algorithm (SSA) for Demand Side Management (DSM). Harmony Search Algorithm (HSA) has been adapted to evaluate the results of SSA. These algorithms schedules the appliances in such a way that the usage of electricity in peak hours is reduced. This results in reduction of electricity bill and Peak to Average Ratio (PAR).

1 Introduction

Electricity is one of the fundamental needs in the current era. Most of the things we see around us are powered by electricity. The number of devices that use electricity to operate are growing day by day. This is because things are becoming smart and computer-operated. The traditional grid system does not provide any communication system between the utility and consumers. This causes many problems. The users are unaware of the prices and the utility is unaware of the demand of the users. This lack of communication can cause many problems like high electricity bills, high peak hour usage, etc.

Smart Grid (SG) [1] overcomes the drawbacks of the traditional grid system. SG has the ability of monitoring the grid and incase of any failure it can heal itself. In SG, the flow of electricity and communication is bi-directional. The bi-directional communication keeps the users and the utility updated of the usage and demand. The bi-directional flow of electricity is a key element in the SG. In SG, users can generate their own power using solar panels or any other

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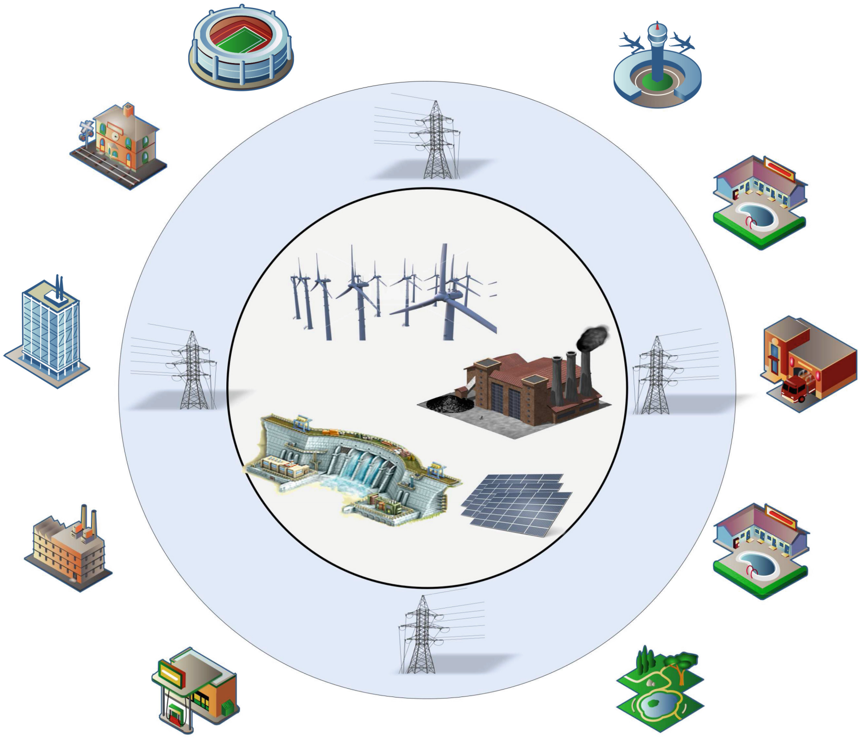

Fig. 1. An overview of Smart Grid

resources like mini-hydropower plants or wind. When the electricity exceeds the user demands, the users can then sell the extra electricity. This can be done by pushing the excess electricity back to the grid. Another advantage of sending electricity back to the grid is to enable the utility to meet high electricity demand (Fig. 1).

High demand of electricity at a specific time creates peak usage at that specific time. This peak is because the demand of electricity is higher than that available. To reduce the high demand, power to some areas is cut from time to time. This is called load shedding. In severe conditions where the demand is very high, the transmission grid might collapse. This might result in blackouts. To ensure reliability of the transmission grid, DSM [2] is used. DSM is the management of the load used by the consumers. DSM motivates users to shift their loads from peak hours to off-peak hours to avoid peak formation. However, inefficiently shifting loads may create peak usage at another time. Therefore, in DSM, efficient shifting of load is necessary. This is achieved by Home Energy Management Systems (HEMS). HEMS schedules the load according to the data received from the utility. Hence, reducing the electricity bill and the PAR.

2 Related Work

With the increase in population, the number of electric appliance required to fulfil the needs of humanity is also increasing. This increasing number of appliances require large amount of electric power. The traditional power grid system is unable to manage such high load requirements. This results in the increase in Peak to Average Ratio (PAR), which in return results in high electricity bills and power blackouts.

For this reason, researchers have proposed many Supply Side Management (SSM) and DSM techniques. These techniques help in reducing the total power consumption, PAR and electricity bills while increasing the user comfort. Some of the proposed techniques are discussed below (Fig. 2).

In [3], Integer Linear Programming (ILP) has been used for DSM. The main objective is to decrease the maximum load by reducing the peak hour usage. Three appliances are taken into consideration, non-shiftable, time-shiftable and power shiftable appliances. Non-Shiftable appliance are supplied with continuous power. The time shiftable appliances require a fixed power for some time slot. The controller can schedule the appliance at any time period but should provide it the fixed power that it requires. The power shiftable appliance can operate with a flexible power. They can be scheduled with a fixed power throughout the day, subject to the condition that they are provided the daily required power. Simulations are carried out for single and multi-home scenarios and the effects are discussed. However, UC and pricing signal have not been taken into consideration. In [4], authors have used heuristics techniques and proposed a hybrid

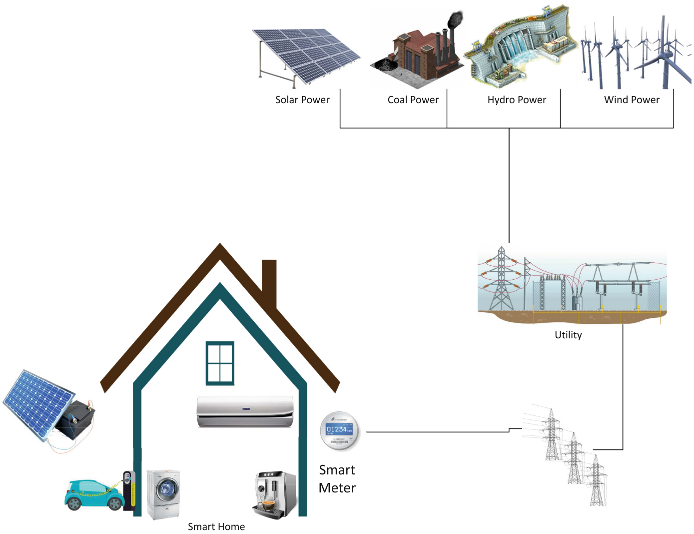

Fig. 2. Home Energy Management System

technique called Genetic Wind Driven (GWD) optimization. Real Time Pricing (RTP) scheme has been used as a pricing scheme. Authors have conducted simulations for single and multiple homes. The main objective is to maximize user comfort while minimizing cost and PAR. However, simulations show that there is a tradeoff between UC and PAR. In most cases, the UC is compromised from 50 to 90% in different techniques. Kai Ma *et al.* [5] have proposed their own optimization technique. Authors have discussed two types of appliances. The first type of appliances have flexible starting time and can be shifted in the scheduling horizon while the second type of appliances have flexible power rating. The electricity cost can be reduced if the starting time of the appliances is delayed to the time where the price is low. However, the user comfort will be affected in this case. If we consider the user comfort the electricity cost will increase. Therefore, the authors have proposed a scheme in which both UC and electricity bill has been considered. PAR has not been considered because there is a tradeoff between PAR and UC.

Samadi *et al.* [6] have discussed the side effects of the RTP Scheme. According to the authors, while using RTP, most of the load will be shifted to the time where the electricity price is comparatively low, thus increasing the PAR in the low cost time. This may result in high demand from the utility and maybe blackouts. Therefore, the authors suggest that a RTP combined with Inclined Block Rate pricing scheme is necessary. For scheduling the appliances the authors use Genetic Algorithm because other optimization techniques like PSO and game theory are non-linear. In [7], Zhuang Zhao *et al.* have discussed the EMS in home area network. The main objective is to reduce the electricity cost for the consumer and the PAR. RTP with IBR has been used as a hybrid pricing scheme. UC has been compromised in an effort to reduce cost and PAR.

In [8], authors proposed a scheme for balancing the user-comfort and electricity price keeping in view the user budget. PAR has been ignored. The main target of the authors is cost per unit satisfaction. Genetic Algorithm (GA) has been used because of its efficiency, convergence speed and flexibility and because GA searches for a globally optimal solution. In [9], authors have discussed the inefficient power consumption in industrial and residential buildings which leads to power blackout. GA techniques has been used and a reduction of 21.91% in PAR has been observed. The authors have not used any pricing scheme. Therefore, electricity cost has not been taken into consideration.

In [10], authors focus on the integration of RES to reduce the use of natural resources. Multi Knapsack Problem has been used using GA, binary particle swarm optimization and ant colony optimization. Authors say that in previous researches the of power consumption and user comfort have been ignored in previous studies. Three types of home appliances have been taken into consideration: fixed, shiftable and elastic. However, the author have ignored the initial installation cost of the RES and the maintenance cost.

In [11], RES with energy storage system has been introduced. The authors have used photovoltaic along with storage batteries. Using this technique, the load from the power grid and PAR has been decreased. But the effect on electricity cost and the cost of RES and energy storage system has not been addressed by the authors. Kanzumba *et al.* [12] have discussed Hydro Kinetic (HKT) system and battery storage system for generation and storage of power respectively. Time of Use (ToU) tariff has been used here. The main purpose here is to minimize the electric cost by maximizing the use of power generated by the HKT system. The HKT system supplies power to the load. If the load is less than the power generated by HKT then the extra power is stored in the batteries or sold to the grid depending on the state of the battery. In case the power supplied to the load is less than that generated by the HKT then the extra power is gained from the battery or the grid. The battery can also be charged from the power grid in off peak hours. Using this strategy, the electricity bill has been reduced. The UC has not been effected in any way, because of continuous power supply either from HKT, battery of the power grid. However, it would have been better if the charging of the battery from the power grid had been considered as it might affect the PAR because the battery is being charged in the off peak hours. If many consumers do so, it might affect the utility negatively. Moreover, the installation and maintenance cost along with the maintenance complexity of the HKT system has not been considered.

3 Problem Statement

The population of the world is increasing day by day. Ultimately, the usage of electricity is also increasing. Maximum usage of electricity by consumers create peaks in the usage of electricity. The time at which these peak are created are called peak hours. Peak hours are a problem for the stability of the utility. A utility can provide a specific amount of electricity per unit time. If the demand increases, blackouts are created. There are two ways to tackle this problem. The first is to increase the power generation. The second is to manage the consumer load in such a way that the demand at a specific time is less than or equal to the distribution. Since increasing the generation is not easy, therefore the utility increases the price of electricity in peak hours. This may result in higher electricity bills. This encourages the consumers to shift their loads to off-peak hours where the prices are comparatively low. Manually managing this load shifting is not easy. An Energy Management Controller (EMC) tackles this difficulty. An EMC schedules the appliances keeping in view the prices throughout the day and the usage constraints of the appliances.

4 Proposed Scheme

4.1 Classification

In SG, an EMC schedules the appliance according to their use. Here, we classify the appliance into two categories: base and shiftable appliances. These type of appliances are explained below.

4.1.1 Base Appliances

These appliances are also known as fixed appliance because their operation time cannot be changed. For example, lights, fans, iron, toaster, microwave oven and coffee maker. The time slots of these appliances cannot be shifted.

4.1.2 Shiftable Appliances

These devices are also known as Interruptible devices because their time slots as well as their length of operation can be modified. Example of these type of devices are air conditioner, refrigerator, water heater and space heater. These devices take part in the scheduling process.

Table 1. Load and time slots of appliances

S.no	Appliance	Category	Power rating	Time slots
1	Air Conditioner	Shiftable	1.44	10
2	Refrigerator		0.73	16
3	Water Heater		4.45	10
4	Space Heater		1.50	11
5	Lightings	Base	1.8	9
6	Fans		0.5	16
7	Clothes Iron		0.8	8
8	Microwave Oven		0.78	8
9	Toaster		3.60	5
10	Coffee Maker		4.40	9

4.2 Pricing Scheme

Different electric providers use different pricing schemes. In this case, we will use RTP pricing scheme. In RTP scheme, the smart meter obtained real time prices from the utility from time. The smart meter is connected to the EMC. The users can view the RTP prices from the EMC and can schedule their appliances accordingly.

4.3 Techniques

In SG, many techniques have been proposed to handle different problems. Many evolutionary algorithm have been used to schedule the appliances to get optimized results. In this paper, we will use HSA and SSO to schedule our appliances. We will compare the results of both the optimization techniques to study their optimization effect.

4.3.1 HSA

Inspired from musicians, HSA [13] has been used in SGs for optimization. Musicians play random notes. These random notes are called Harmony Memory (HM). Now considering this HM, the musician plays another random note. If this note is better than the previous one, the musician replaces it in the HM. Similarly, HSA follows three steps: random HM generation, play based on the HM and finally pitch adjustment.

4.3.2 SSA

SSA is a swarm optimization techniques which was introduced by Cuevas *et al.* [14] in 2013. It has been inspired by the social interaction of the social spiders. In a spider communal web, there are 2 types of spiders: male and female. The females comprise of about 70% of the web. The rest 30% are males. The males with the higher weights are called dominant males. The female spiders show attraction or dislike toward the dominant males based n their weight.

5 Simulations and Results

In this section, the results of the simulation are discussed. Simulations have been carried out to evaluate HSA and SSA. Hourly load, electricity cost, PAR and UC have been evaluated in each case. The simulations have been carried for a single home with 10 appliances [10]. Table 1 shows the appliances, their power ratings and length of operation. RTP pricing scheme has been used for calculating the electricity bill.

The hourly load of the appliances can be seen in Fig. 3. We can see that the unscheduled load create peaks in some places. These peaks result in increased PAR. After applying HSA and SSA techniques, we can see that the peaks have been shifted evenly. This results in reduction in PAR.

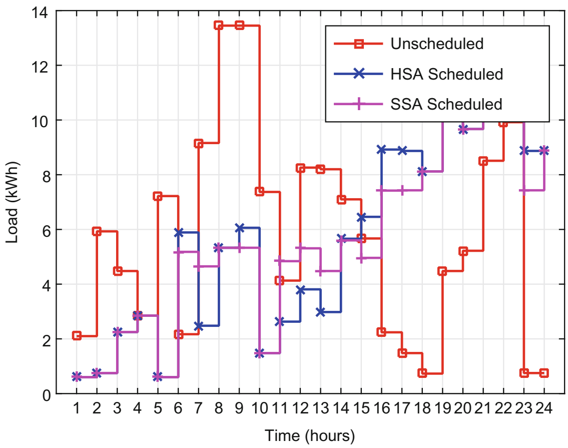

Fig. 3. 24 h Load

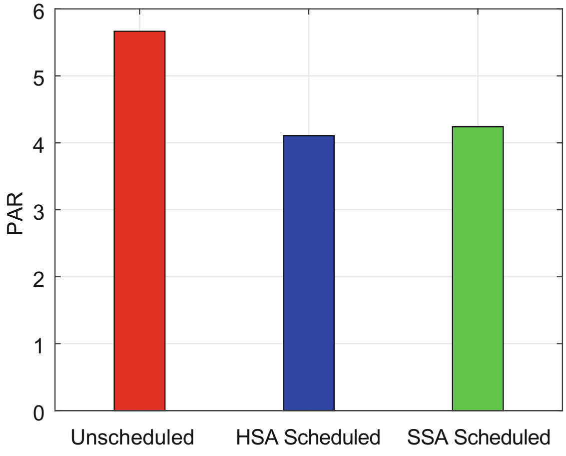

Fig. 4. PAR

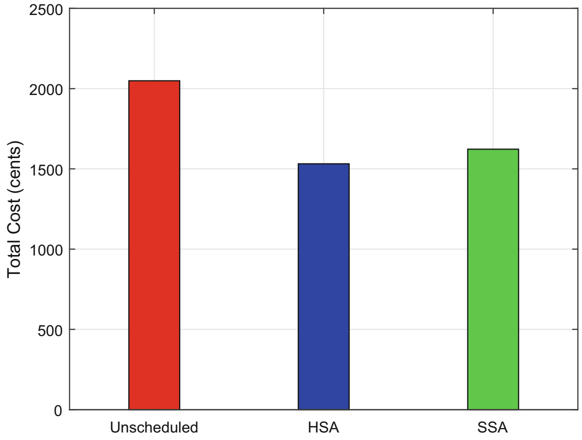

Fig. 5. Total cost

As discussed, after applying HSA and SSA techniques, the load is evenly distributed causing reduction in PAR. Since, we have 6 fixed appliances that cannot be shifted, therefore the PAR is slightly reduced. We can see that with a slight difference, HSA and SSA reduces PAR by 27.52% and 27.011% respectively. This difference can be observed in Fig. 4.

We know that both the algorithms work in such a way to shift the appliances from the peak price slots to the off-peak slots. Therefore, it is obvious that the scheduled cost will decrease from the unscheduled cost. This can be seen in Fig. 5. We can see that HSA reduces the cost by 25.03%, whereas SSA reduces the cost by 22.56%.

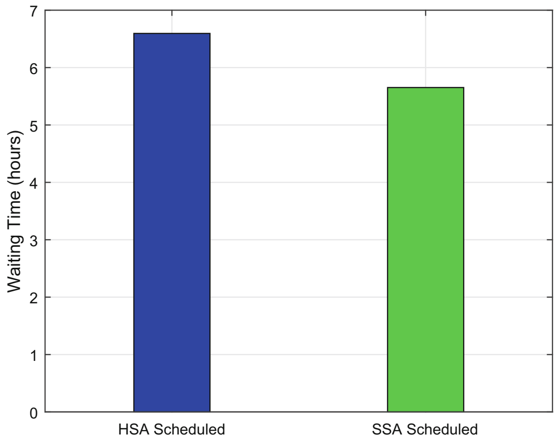

Fig. 6. Waiting time of shiftable appliances

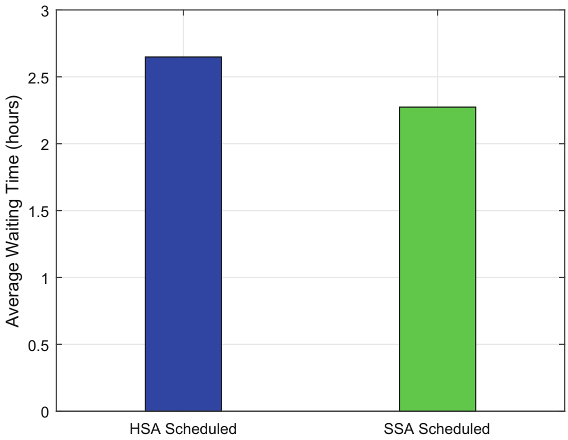

Fig. 7. Average waiting time of HSA and SSO

We know that there is always a tradeoff between electricity cost, PAR and UC. Since our objective is to reduce the electricity cost and PAR, therefore the waiting time will increase. This means that UC will decrease. In Fig. 6, we can see that the average waiting time of HSA is 2.6380 h. While the waiting time is 2.3724 h incase of SSA. This means that SSA does not effect the UC too much. The average waiting time can be seen in Fig. 7, which is 2.31 h incase of SSA.

6 Conclusion

In this paper, we introduced a SSA algorithm for DSM. Simulations have been performed for both SSA and HSA. The results of SSA have been compared with the results of HSA. Simulations show that in our scenario HSA performs slightly better than SSA in terms of reducing electricity cost and PAR. However, the average waiting time of HSA scheduled appliances is higher than that for SSA scheduled appliances. This means that compared to HSA, SSA reduces the cost and PAR without effecting the UC too much. So we can conclude that SSA is able to balance the tradeoff between PAR, electricity cost and UC.

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Home Energy Management Using Social Spider and Bacterial Foraging Algorithm

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Abstract. Electricity is a controllable and convenient form of energy. In this paper we discus about the electricity control. In current years Demand Side Management (DSM) techniques are designed. For residential and commercial sectors. These techniques are very effective to control the load profile of customer in grid area network. In this paper we use two optimization techniques: Harmony Search Algorithm (HSA) and Firefly Algorithm (FA). In our work we categorize smart appliances in three different categories on the basis of their energy consumption. For energy pricing we use Time of Use (ToU)pricing signal. Simulation result verify our adopted approach significantly reduce the cost without compromise the user comfort.

1 Introduction

Now a days increase in population electricity demand increase we need to load balanced for fill the energy demand. In [1] Renewable Energy Resources are used to compensate the electricity demand. The important aspect of smart grid, its a good solution to maintain balance between demand and supply. Demand response is taken by the customer according to the price model. It provide different benefits for consumer and utility. Therefore, the important thing to tackle is demand response [5]. In [4] the authors gives the view of residential load scheduling. Save electricity and cost and also define the cost efficiency. By using the ratio of total consumer consumption of energy and pay total cost of using electricity. Author also define some constant variables to maintain the efficiency cost and residential electricity.

Demand Side Management (DSM) is ones the important key factors of SG for load management. It is used in energy management and helps to reduce peak load. The main goal of DSM is to encourage consumer to use less electricity in peak hours and transfer load to off peak hours. DSM helps to reduce blackout problem. Efficient use of electricity helps to reduce the overall electricity cost. Moreover, harmful effect on the environment reduces by less emission of

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greenhouse gas. It maintains the demand of electricity in such a way that increase reliability and stability of the overall system.

[12] Make a demand response program and also categorize in two different main classes, In first class author define the program for ease of utility, In this program utility give the schedule to the consumer for using the appliances in off peak hour and on peak hours. Other category based on price the consumer reduce their demand according to price signal. Calculating the electricity cost using dynamic pricing rate (Table 1).

Table 1. .

List of abbreviation	
Abbreviation	Definition
EM	Energy Management
HLM	Home Load Management
AOA	Automatically Operated Appliances
RTP	Real time Pricing
AOA	Automatically Operated Appliances
CPP	Critical Peak Pricing
IBR	Inclined Block Rate
ANOVA	Analysis of variation
GHG	Green House Gas
ToU	Time of Use
RES	Genetic Algorithm
GA	Automatically Operated Appliances
BPSO	Binary PSO
DSM	Demand Side Management
ACO	Ant Colony Optimization
UC	User Comfort
HSA	Harmony Search Memory
FA	Firefly Algorithm
MOA	Manually Operated Appliances

In dynamic pricing include time of use (ToU), Critical Peak Pricing (CPP), Inclined Block Rate (IBR), Day Ahead Pricing (DAP) and Real Time Pricing (RTP). Among all the pricing scheme ToU is considered the most efficient pricing scheme for electricity [1]. The common impartial of energy management in SG are to minimize the electricity cost reduce PAR minimize power consumption and maximize the user comfort. Many technique have been proposed in current year to overcome the above deficiency by using different heuristic algorithms [1], [16], [17] and linear programing [7].

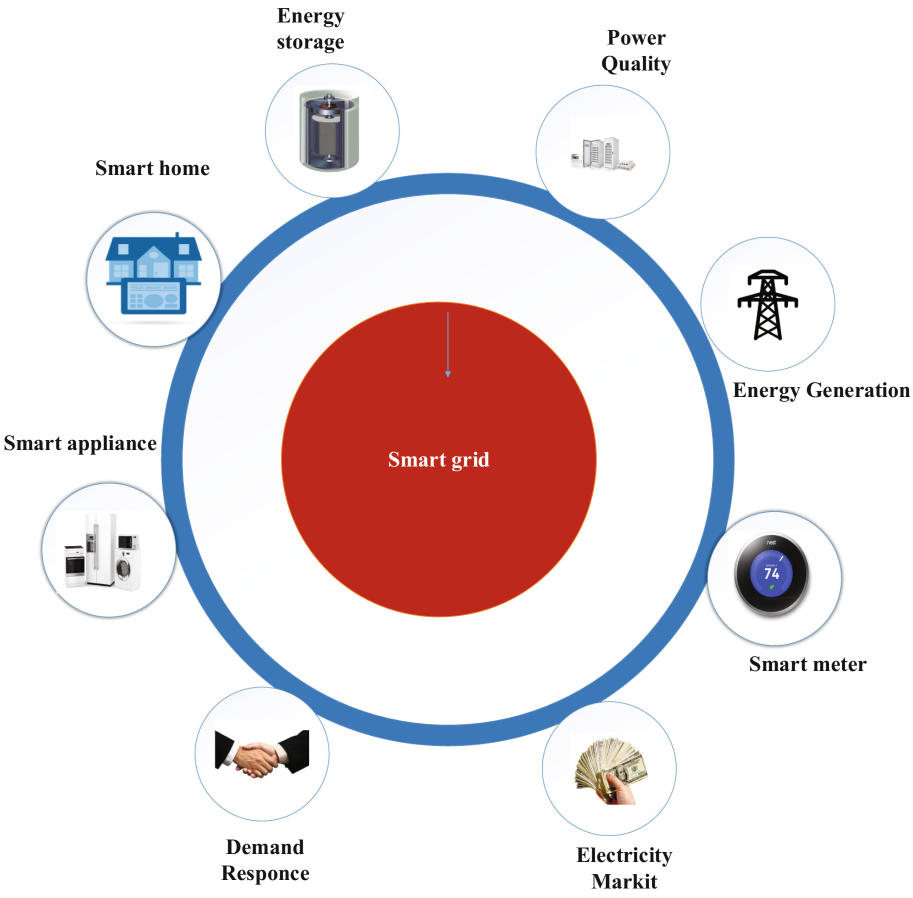

Fig. 1. Smart grid

Our contribution include the scheduling the appliances for single and multiple home. Moreover we used two heuristic algorithm Harmony Search algorithm (HSA) and Firefly Algorithm (FA) to get reasonable solution for our designed model. Result authenticate that our adopted model outperform the existing once. The paper organized as follows: Sect. 2 briefly describe the related work Sect. 3 describe the proposed model Sect. 4 problem formulation and simulation result and then finally paper conclude in the Sects. 5 and 6.

2 Related Work

Different technique has been proposed by the researchers to optimize the energy in DSM. The basic purpose of proposed techniques is to minimize cost, PAR and maximize UC. We discuss different paper below. We classified all papers on different pricing scheme. The measurement of how much cost are involved in the production process in relationship to how much many units are produced.

In [2], the authors proposed decentralized framework for load management in residential area in proposed system, the author main objective is to minimize cost and PAR. In proposed framework, author scheduling home load using two modules. In first module, author focus on load management and in second module minimizes the electricity cost. In proposed framework, the author efficiently minimizes the cost and PAR on the other hand, author ignores UC. Zhu et al., in [6], balance the load using demand response technique. The main objective of author is to schedule the home appliance to reduce the electricity cost. For this purpose the author divide the home appliances into two groups: first appliance run with flexible time and second run with flexible power. The author used RTP for electricity cost calculation. The author minimize cost effectively in proposed system, however author ignore UC and PAR.

In [7], the authors proposed DSM system for power scheduling of appliances. In proposed system author ILP technique for scheduling. The objective of the proposed technique is to minimize the PAR for DSM using ILP. The appliances required to schedule in different category. The author categorized appliances into two groups: Non-Interruptible and Interruptible appliances. ILP technique is considered for optimized solution. The pricing scheme used is fixed price at any time i.e. ToU.The proposed technique in [10], is optimize the energy consumption using BPSO technique. In proposed system, author main objective is to reduce the cost by load management of appliances during on peak and off-peak hours. The author effectively minimizes cost up to 18.45%. The author ignores UC and PAR.

Authors in [4], presented load scheduling framework based on cost efficiency. RTP scheme and fractional programming approach is used. Distributed energy resources are integrated in smart homes. Author addressed the problem of cost of energy consumption. Residential user takes different scheduling method to manage their power consumption. These scheduling methods either increase or decrease the consumption cost. To solve this problem the residential user takes the cost efficiency as a metric to manage its consumption. By using this proposed approach author achieve cost efficiency and efficiently managed the energy consumption on the other hand this approach not consider user comfort. Another efficient DSM controller in residential area is proposed in [8]. The objective of the author is minimizing cost, PAR and compromise the UC. Non-renewable energy resources are used to provide electricity. They are so expensive and cause carbon emission. To solve this problem author proposed the approach of heuristic algorithm based on DSM. This approach helps to schedule the load according to user demand. The authors proposed a hybrid wind driven algorithm, and also used ANOVA test for statistical analysis for measuring the variation in algorithms performance metrics. Appliances are classified in to two categories i.e., (i) non shift able appliances and (ii) shift able appliances. RTP pricing scheme is used.

In [9], the authors objectives is to balance the load during on peak and off-peak hours and addressed power trading problem in his proposed system RES.

In this paper authors used game theoretic technique. For scheduling the appliances dynamic programing approach is used. Objective of this paper is reduce the electricity cost and utilization of RESs. For this purpose the researchers use demand response as a pricing scheme. The proposed technique in [10], is optimizing the energy consumption. The authors scheduled the power usage of smart appliances on the bases of ToU pricing scheme. In this work author used BPSO technique to minimize electricity cost in residential area. The author minimize efficiently electricity cost up to 20%. The authors ignore PAR and UC.

When we combine two techniques for batter results is known as hybrid technique. The objective of [1], paper is reducing the electricity cost and maximize UC by scheduling home appliances in one day of 24 h. With optimal solution for using power from grid and reduce waiting time. Optimal integration, RESs to reduce greenhouse gas (GHG) emission. Authors consider three heuristic technique GA, BPSO and ACO to achieve the objectives as compared their result. Authors presented EMC model in residential area to minimize electricity cost and PAR by energy management according to user usage pattern. The authors combine the ToU scheme with IBR price scheme to calculate electricity cost. However, Neglected power consumption management, RES Integration cost. In [5], the author proposed Energy Management System (EMS) using DR in residential area. Home gateway connects smart appliances to home area network. Author addressed the problem of PAR and electricity cost due to real time pricing scheme. If only RTP pricing scheme is used then load of most of the appliances is shifted in low price hour due to which peak is generated. By combining RTP with IBR pricing scheme PAR ratio and electricity cost is reduced. Genetic algorithm is used to get more optimal solution. Appliances are classified in to two categories: automatically operated appliances (AOA) and manually operated appliances (MOA). AOA are further divided into shift able and non-shift able appliances. Automatically operated appliances are considered. One hour is divided in to five time slots so in one day one hundred and twenty slots are considered. By using this proposed scheme author achieved reduction in PAR and electricity cost and stable whole electricity system. By combining two pricing schemes a benefit is provided to both utility companies and resident. In proposed system, the author reduce cost, however, author ignore UC.

3 Problem Statement

The main objective of DSM is to efficiently schedule energy consumption so that reduction in electricity bill is achieved with maximum user comfort. There are following problems that need to be addressed in smart grid Reduce total power consumption Minimize electricity bill Reduce PAR Maximize user comfort level Provide an optimize schedule of appliances. Many techniques have been adopted in [5–8] to tackle the said issues, however there is tradeoff between user comfort level and electricity bill. To gain our objective function heuristic optimization techniques are used (Table 2).

Table 2. Appliances with length of operation

Group	Appliances	Power rating (kWh)	LOT
Fixed load appliances	Lighting	0.6	9
	Fans	0.75	16
	Clothes iron	1.5	8
	Microwave oven	1.18	8
	Toaster	0.5	5
	Coffee Maker	0.8	9
Shiftable appliances	Washing machine	0.78	5
	Dish washer	3.60	5
	Clothes dyer	4.40	5
Interruptible appliances	Air conditioner	1.44	10
	Refrigerator	0.77	16
	Water heater	4.45	10

4 System Model

Smart Grid include different number of operations and energy measurement including smart meter used in smart home for smart appliances. Smart meter allows two way communications between user and utility. It helps the consumer to consume maximum energy in off peak hours. Recently, different optimization techniques are used for optimize the energy consumption and to maximize the user comfort. In this work, we use a single home with sixteen appliances. Appliances are dividing into three different categories: fixed appliances, shift able appliances and elastic appliances. All section of smart grid are shown below in Fig. 1. In fixed appliances includes lighting, fans, clothes iron, microwave oven, toaster and coffee maker. The second category is shift able appliances which includes washing machine, dishwasher and clothes dryer. In third category of elastic appliances include air conditioner, refrigerator, water heater and space heater. We use ToU as pricing scheme for electricity price calculation. In this work, our main focus is to shift the load from on peak hour to off peak hour for the reduction of the cost and to maintain the user comfort (Fig. 2).

4.1 Harmony Search Algorithm

Harmony Search Algorithm was proposed by GEM [13]. HSA works on the basis of musicians behavior. It is a population based algorithm. The basic steps of HSA are as follows. Initialize the harmony memory that consist of randomly generation of populations after initialization generate a harmony vector. Generating the new harmony it depends on two main parameters first one is harmony memory consideration rate and the second one is pitch adjustment ratio. When we generate harmony memory according to pitch adjustment rate then new vector generated. New generated vector compare it with existing vector in harmony

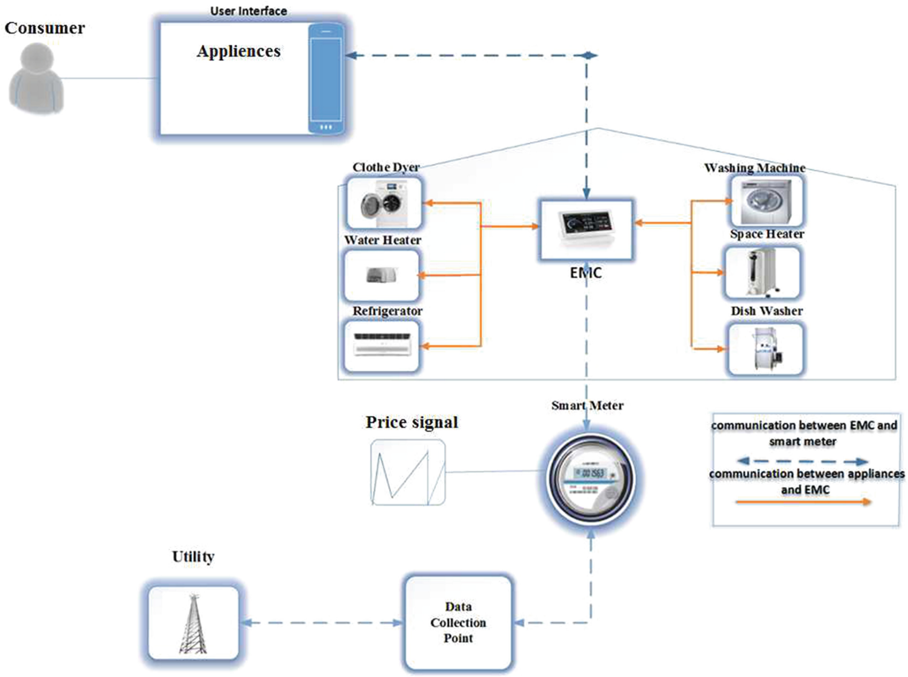

Fig. 2. The architecture of home energy management system

memory. After comparison select the best one and worst discard from the harmony memory. In [14] define the basic steps and pseudo code of HSA.

4.2 Firefly Algorithm

Fire fly algorithm was developed in 2007 by Xin-she- young [14]. FA is deterministic algorithm. Deterministic algorithms are more efficient for finding efficient optimal solution in local search. In FA the two basic variables are: light emitting and attractiveness. In FA three basic step are as follows: In first step firefly attract towards the most attractive firefly at the same time it moves randomly in second step attractiveness is proportional to the flashing light and in last step control the light intensity by using coefficient value. Fire fly attracted in the direction of other fire fly that has brighter flash light than itself. In [15] define pseudo code of FA and also define the value of light intensity, initialization of light intensity, absorption constant of light and the distance value between two fireflies.

5 Simulations and Discussions

Load of our adopted scheme FA with respect to HSA in scheduled and unscheduled are shown in Fig. 1. This figure show that the value of load in FA is

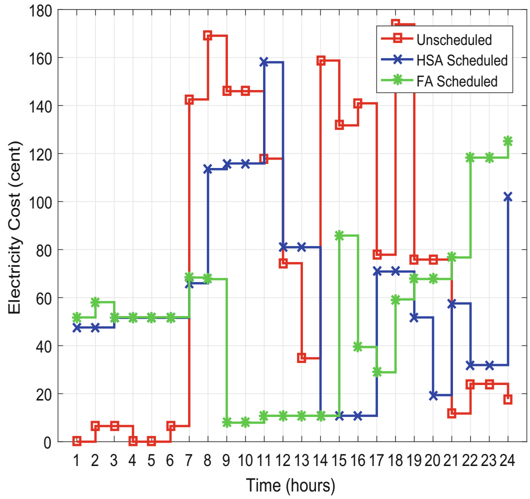

Fig. 3. Cost in 24 h

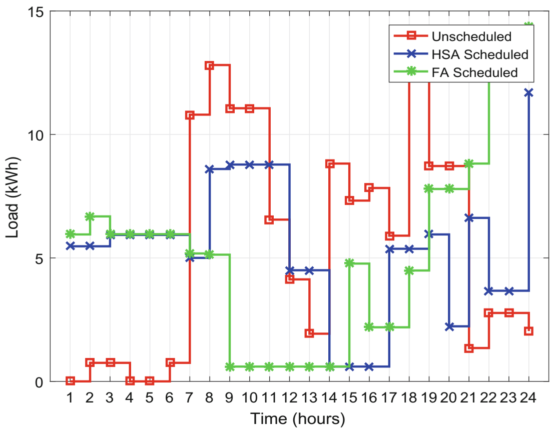

Fig. 4. Load during the day

comparatively better than that of unscheduled and HSA. The maximum value of load in FA is 11 kWh while in HSA its maximum value is 12 kwh. The energy consumption in FA is low while its value is high in HSA and unscheduled. By using FA load is balanced in OPHs as compared to HSA as shown figure. Results show that our purposed technique tackles the load better as compared to HSA and scheduled. In Unscheduled load, load is increased during peak hours that increased the electric cost and Energy consumption but in our proposed scheme load is managed by shifting the load in to OFF peak hours that reduce the energy consumption of specific hour. In Unscheduled, power consumption is increased, the electricity cost is also increased due to peak curve but in my scheme FA

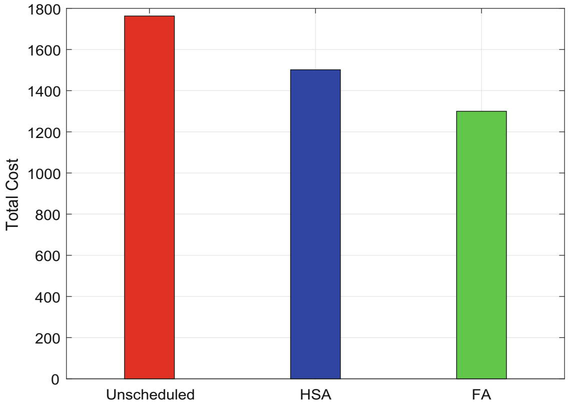

Fig. 5. Total electricity cost

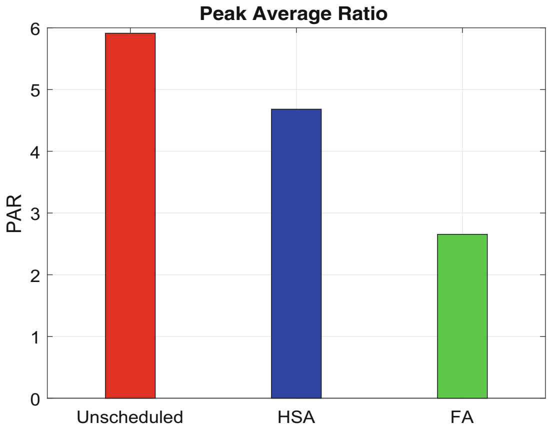

Fig. 6. PAR

peak curve is not generated so power consumption is reduced during peak hour by using ToU cost minimization achieved. In Schedule Load, Load is schedule in such a manner that load shifted from ON Peak hour to OFF peak hour. Maximum energy consumption values are limited. Electricity bill reduction. It is verified that our designed model achieved significant results (Figs. 4, 5, 6 and 7).

PAR is increased in unscheduled load because the max load is shifted to a specific hour of a day and creates the peak. So PAR is increases due to unscheduled load. In FA when load is schedule it reduces the PAR by shifting the load to OFF peak hour. PAR in our scheme FA is minimum. As shown in figure the PAR is slightly reduced as compared to HSA scheduled and greatly reduced as compared to unscheduled. PAR and cost will affect each other. In FA PARs value is 2 while in unscheduled its value is 5.2 and in HSA its value is 2.3. It shows that peak load is expressively reduced in FA according to the comparison of

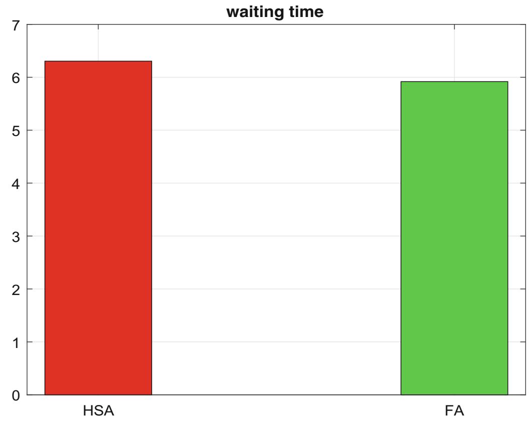

Fig. 7. Waiting time of all appliances

unscheduled and HSA. So PAR is increases due to unscheduled load. In FA when load is schedule the reduction of PAR by shifting the load to OFF peak hour. PAR in my scheme HSA is minimum. Reduction of peak load result shown in Fig. 3. According to the result, peak load is expressively reduce. Results prove that our proposed model effectively tackle the peak formation problem. As shown in figure.

In FA electric cost is reduced because load is balanced. We use ToU pricing scheme for the calculation of electricity bill. In ToU hours are divide into blocks that helps to balance load between on peak hours and off peak hours. In case of unscheduled the maximum value of total cost is 150 cents and in HSA its value is 65 cents while in FA its maximum cost is 60 cents. There is trade off between cost and user comfort. According to our purposed technique FA electricity cost reduced because balance the hours of a day. Electric Cost is increased for unscheduled load because unscheduled load create the peak formation and increased the total cost. Electric cost is increased in unscheduled because price is increases in emergency situation according to price signal ToU. It is verified that our desired model achieved better results.

Waiting time is increased because we reduce the PAR by shift the load from ON peak hour to OFF Peak hour. User comfort also sacrifice when we reduce the electricity cost of appliance. So there is tradeoff between waiting time with cost and PAR. FA waiting time is 4.1 while is HSA its value is 5.4. As there is a tradeoff between waiting time and User comfort so our purposed technique reduce waiting time to gain user comfort. User comfort is linked to both electricity cost and waiting time of appliances. Waiting time is increased because we reduce the PAR by shift the load from ON peak hour to OFF Peak hour. User comfort also sacrifice when we reduce the electricity cost of appliance. When we reduce the waiting time it increases the electric cost and PAR.

6 Conclusion

In this paper we have presented the schedule of appliances for residential energy management. Our emphasis is to avoid peak formation while focusing on consumer electricity bill reduction by conserving the user comfort within acceptable manners. Our designed objective function evaluation based on two heuristic algorithm (HSA and FA) for briefly analysis. In this proposed technique we used ToU as pricing signal for calculating the electricity cost. In future work we will focus on different optimization technique to resolve frustration cost and improve the security and privacy issue between utility and consumer.

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Optimization of Home Energy Management System Through Application of Tabu Search

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Abstract. In the past few years, a number of optimization techniques have been designed for Home Energy Management System (HEMS). In this paper, we evaluated the performance of two heuristic algorithms, i.e., Harmony Search Algorithm (HSA) and Tabu Search (TS) for optimization in residential area. These algorithms are used for efficient scheduling of Smart Appliances (SA) in Smart Homes (SH). Evaluated results show that TS performed better than HSA in achieving our defined goals of cost reduction, improving User Comfort (UC) level and minimization of Peak to Average Ratio (PAR). However, there remains a trade-off between electricity cost and waiting time.

Keywords: Smart grid · Demand side management · Heuristic techniques · Tabu search · Harmony search algorithm

1 Introduction

The world is getting more and more advanced with the emergence of new technologies and their innovative use. Electricity is an important and necessary need in todays world. Everyone tend to prefer their comfort, still no one wants to pay higher cost for it. For the purpose of efficient use of energy with minimum cost and maximum User Comfort (UC), home energy management is done. Electricity is generated in power grid stations and distributed through different utility companies. Traditional grids are unable to meet todays electricity demand in an efficient way. For this purpose, Smart Grids (SG) are introduced. SG is a system that introduces a physical power system which integrates information control and communication technologies to form a customer satisfied platform [3]. Electricity can be generated through variety of ways like hydro power, solar energy, biogas, wind energy etc. This simple architecture for SG is shown in Fig. 1. Through SG consumers can easily manage their electricity usage pattern and reduce their electricity bills. Consumption of electricity can be reduced by controlling the demand of electricity efficiently. One of the major aspect of SG is Demand Side Management (DSM) that maintains a balance between demand

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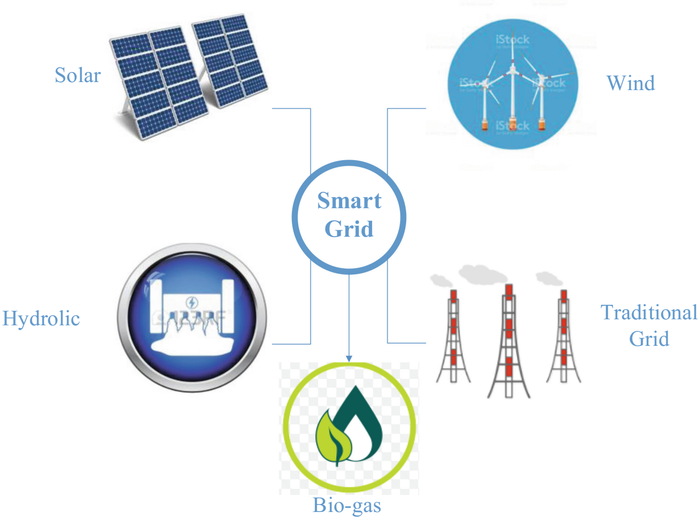

Fig. 1. Architecture of SG

and supply. DSM has two functions, i.e., Demand Response (DR) and load management. Load management results in reduced cost and minimum Peak to Average Ratio (PAR), whereas DR describes the response by the consumers against some announced pricing scheme.

As authors in research work [14], proposed a general DSM model for residential users based on the same objectives for cost reduction, PAR reduction and enhancing UC level. Genetic Algorithm (GA) is used with Real Time Pricing (RTP) tariff. Results show that UC is achieved to some level in terms of waiting time. Two types of price signals are used in Home Energy Management System (HEMS), dynamic and static. DSM is mostly affected by dynamic price signal as they change from time to time. Main goal of DSM is to achieve maximum UC with minimum cost. In this regard, many DSM techniques were introduced in previous years. As in article [13], Wind Driven Optimization (WDO) technique is used along with the Time of Use (ToU) price tariff. The purpose was to achieve minimum cost and maximum UC. In paper [15], a review of different DR schemes is presented. These DR schemes are classified into different categories. Various models for optimal control of DR strategies have also been presented. In [8], the authors propose cost efficient solution for load scheduling. Fractional Programming (FP) approach is used along with day ahead and RTP pricing tariff. With the goal to reduce cost, user can manage their electricity consumption pattern. Simulation results prove that the proposed technique significantly achieve the cost-effective energy consumption pattern. However, cost minimization is still somehow compromised, UC and PAR are not discussed in this paper.

Our contribution is the efficient management of load by reducing PAR, minimizing cost and enhancing UC in terms of reduced waiting time. For this purpose, we used two heuristic algorithms Tabu Search (TS) and Harmony Search Algorithm (HSA) along with RTP pricing tariff. Results prove that TS performed better than HSA and unscheduled in terms of cost and PAR. Also, there is a trade-off between UC and cost.

Rest of the paper is organized as follows. Section 2 comprises of brief related work. Section 3 describes proposed system model. Simulation results and analysis is given in Sect. 4 and the paper is concluded in Sect. 5.

2 Related Work

Around the globe, many researchers are working to optimally schedule the smart appliances in HEMS. In this regard, some of the papers reviewed are discussed as follow.

The authors in paper [1–3], proposed different optimization techniques to efficiently reduce cost and enhance UC level with reduced PAR. In paper [1], three meta heuristic techniques are used i.e., GA, Binary Particle Swarm Optimization (BPSO) and Ant Colony Optimization (ACO). ToU is used with combination of Inclined Block Rates (IBR). Also, there was integration of Renewable Energy Sources (RESs) to enhance the performance and reduce cost. Results show that proposed models achieve the stated objectives of minimizing cost, PAR and maximizing UC. However, GA based Energy Management Controller (EMC) performed better than BPSO and ACO. In [2], DSM controller is designed by using five heuristic algorithms i.e., GA, BPSO, WDO, Bacterial Foraging Optimization Algorithm (BFOA) and the proposed hybrid algorithm as Genetic Wind Driven (GWD). Simulations are performed to compare the results according to cost reduction, energy consumed, PAR reduction and UC. RTP tariff model is used for bill calculation. Results proved that proposed hybrid technique performed better than the other techniques. However, the UC level is compromised in scheduled case upto 50%. Authors in paper [3], presented a GA based DSM model to reduce the cost and avoid peak formation. GA based technique is used for optimization of this non-linear problem. RTP with the combination of IBR is used as a pricing model. Simulation results proved that the presented model achieved the efficiency levels to reduce PAR and cost. However, congestion problem and UC level are ignored.

In papers [4–6], authors used Integer Linear Programming (ILP) to achieve the objectives of cost reduction with maximum UC. In paper [4], authors describes the scheduling problems of the residential areas. Two types of appliances are assumed. Starting time of first type can be adjusted and the power consumption of second type can be reduced, which will cause discomfort to the user. So, day ahead price signal is used along with ILP to achieve tradeoff between payments and discomfort. For simulations, it is assumed that the price signals are announced day ahead of time. User can select between minimum discomfort with maximum cost, its vice versa or tradeoff between both. Though PAR is not efficiently managed. In article [5], there are two main objectives, i.e., to reduce the daily energy cost and also CO_2 emissions created through energy consumption. Both of the objectives conflict with each other. A model is designed to schedule the energy consumption using Mixed Integer Linear Programming (MILP). For simulations, three different price signals are used, i.e., RTP, Critical Peak Price (CPP) from Canada and CPP from US. Results obtained are quiet optimum, however, still there is a tradeoff between cost and emission. Management of UC and PAR is also neglected. The authors of paper [6], proposed a scheduling technique for SG to manage the load through ILP. The objective is to reduce load per hour to achieve balanced load schedule for daily. The designed technique is able to schedule the power consumption as well as Operational Time Interval (OTI) for shiftable appliances, according to the power consumption patterns of all the individual appliances. When the simulations are done, there is a load reduction in per hour. Its drawback is that reduced PAR and UC is not achieved.

Research paper [7,10,11] are evaluated on the basis of dynamic programming. In paper [7], the main purpose was to schedule the load and deal with power trading issues. RESs are also integrated into the system. Interaction between users when they exchange excessive energy locally within themselves is discussed in this paper. For this purpose, a dynamic approach is used for optimization. Simulation results prove that the proposed technique minimizes the energy cost. Also, it proves that using the extra energy locally is quite beneficial as compared to sending it back to the utility companies. In [10], a demand queuing-based Energy Management Scheme (EMS) is presented. Simulations are done by taking the data from residential areas. For energy optimization, a centralized algorithm is presented. Results show that cost minimization and delay reduction are achieved. However, a tradeoff is noticed between delay and energy consumption. Another methodology is proposed by using dynamic pricing scheme for minimizing the energy price. In paper [11], RTP tariff model is used to avoid Peak Hours (PHs) and adjust maximum load in Off Peak Hours (OPHs). The purpose is to achieve the tradeoff between electricity bill and user satisfaction. Results show that there is reduction in electricity cost and maximization of UC level, although PAR is neglected.

As stated in article [9], the authors here are discussing about the user privacy while scheduling of appliances. The drawback of distributed DSM protocols is that they involve every user to communicate and share their energy usage patterns. which may leak the personal information. Distributed privacy friendly DSM is presented by Cristina *et* al. which maintains privacy by integrating data aggregation and perturbation. Simulation result show that there is electricity bill minimization and PAR reduction along with the maintained user privacy. However, the total bill reduction is neglected. As in paper [12], a heuristic approach is proposed for scheduling of appliances in a residential area. Comparison of heuristic algorithm is done with an exact algorithm in terms of computational time and cost. Different energy pricing tariffs are used. Results show that the cost achieved is within 5% of the cost achieved from exact algorithm. However, UC level is neglected.

3 Proposed System

In this section, proposed scheme for power and load scheduling is discussed. RTP pricing tariff is used for getting optimum results by applying HSA and TS on a set of data from residential area. The main objectives are to reduce cost, minimize PAR and to maximize UC level. For this purpose, two heuristic algorithm are used. In the subsection below, HSA and TS are discussed in detail

3.1 HSA

Harmony search is a population based algorithm which is proposed by GEEM et al. in 2001. This algorithm depicts musicians behaviour. HSA follows a number of steps to provide the optimum solution. These steps are given as follows:

1. Initialize Harmony Search Memory (HSM) by random generation.
2. Improvise new harmony.
3. Update harmony memory (HM) by comparing the new solution from the step 2 with the worst number in the HM.
4. Repeat step 3 and 4 until termination criteria is satisfied.

3.2 TS

TS is basically global optimization algorithm that uses local or neighbourhood search methods. TS steps are given as follows:

1. Generate neighbourhood solution from current solution.
2. Generate Tabu List (TL) that records forbidden moves.
3. Set Aspiration Criteria (AC).
4. Perform TS.
5. Update TL after each iteration.
6. If not in TL, update in AC.
7. Check stopping criteria to terminate.

3.3 Electricity Consumption Pattern

Electricity is generated in SG and further distributed to the residential area via different utility companies. Each home is considered to be a smart home having smart meters and smart appliances. For achieving the level of UC, user has to set the Length of Operational Time (LOT) and OTI for each appliance, mentioning the starting time and ending time. This pattern is set on the smart appliance controller connected to the smart meters and send to the utility company. The proposed system is shown in Fig. 2.

Algorithm 1. HSA

```
Initialize all parammeters
for all appliances aϵA
for all time slots tϵT
Generate new population
for j = 1:MaxItr
PA ← (PAmax − PAmin)/(MaxItr) ∗ j + PAmin
    for pp = 1:NVAR
        BW(pp) ← bwmax ∗ exp(coef ∗ j)
    end for
Improvise new harmony
    for i=1:NVAR
        if (ran < HMCR)then
          Do memory consideration
              if (ran < PA)then
               Do pitch adjustment
                 if (pvbRan1 < 0.5)then
                 result ← result + rand(1) ∗ BW(i)
                     else
                     result ← result − rand(1) ∗ BW(i)
                 end if
              end if
           else
          NCHV(i) ← xl + rand(1) ∗ (xu − xl)
        end if
    end for
Update harmony
    for i=1:NVAR
        if new > 0.5
        new ← 1
        else
       new ← 0
        end if
    end for
Termination criteria
    while criteria not satisfied
       repeat step 3 and 4
 end for
```

3.4 Proposed System

For simulations, a single SH is considered having SM and SA. Let T denotes the total time interval for a single day such that $t_i \in T = 1\,\mathrm{h}$ then:

$$T = \{t_1, t_2, t_3......t_n\} \tag{1}$$

SM is considered having 9 appliances divided into three sub-categories [1]. Fixed appliances are those appliances whose LOT and OTI cannot be modified like

Algorithm 2. TS

Initialize all parameter
x'=best solution among trails
S(x) sample of neighborhood $S(x)\epsilon N(x)$
Current solution $x'\epsilon X$
Set tabu list TL=150
Set aspiration criteria AC=0
Set iteration counter K = 0
Randomly generate initial solution
Randomly generate trail solutions $S(x)\epsilon N(x)$ and sort them in ascending order to obtain SS(X).
Let x' be the best trail solution in SS(X)
  if $x' > x$
    $X'' = x$
  else
    X"=x'
  end **while** k¡= number of iterations
    For i=1:TL
      Perform tabu search
      If $X'' > X'$
Update X" in tabu list
Else X" not present in tabu list
update X" in aspiration criteria
end **end** **end**
  If stopping criteria is satisfied
perform termination
else k=k+1
end

fans, toaster, lights etc. Let F denotes the set of fixed appliances and $f_i \in F$ for each appliance. Let P_f be the total power consumption of each appliance:

$$P_f = \{P_f^{(1)}, P_f^{(2)}, P_f^{(3)}..........P_f^{(24)}\} \tag{2}$$

Shiftable appliances are those appliances whose LOT can be shifted without having an effect on their OTI like washing machine, dish washer etc. Let S denotes the set of shiftable appliances and $s_i \in S$ for each appliance. If each shiftable appliance s has a power consumption P_s, then it is denoted as:

$$P_s = \{P_s^{(1)}, P_s^{(2)}, P_s^{(3)}..........P_s^{(24)}\} \tag{3}$$

Base appliances are those appliances whose LOT and OTI both are manageable and can be interrupted or shifted like air conditioner, refrigerators, water heater etc. Let B denotes the set of base appliances and $b \in B$ for each appliance. Let P_b be the total power consumption of each appliance for 24 h then:

$$P_b = \{P_b^{(1)}, P_b^{(2)}, P_b^{(3)}..........P_b^{(24)}\} \tag{4}$$

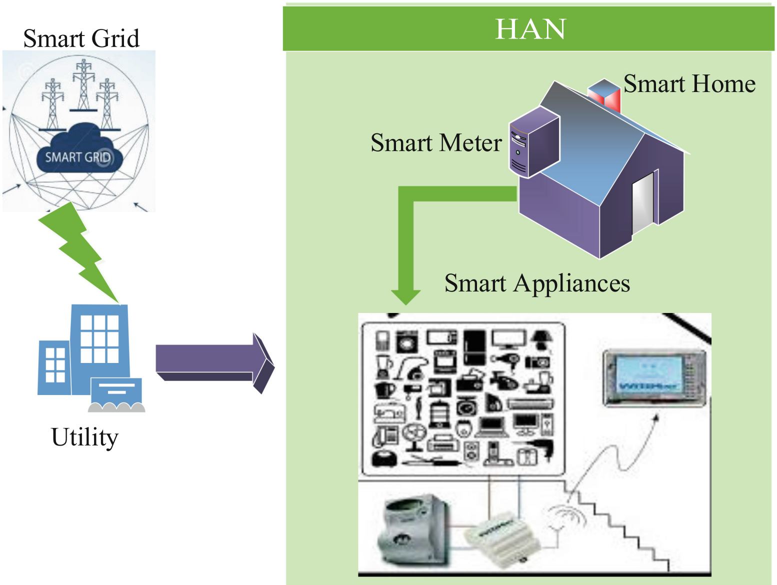

Fig. 2. Proposed system model

4 Performance Evaluation and Analysis

In this section, the simulations results are presented to evaluate the better performance of our proposed scheme TS in comparison with HSA and unscheduled. The algorithms are compared on the basis of stated objectives of cost

Table 1. Parameters used in simulation process

Appliances	Power (kWh)	LOT	OTI	Category
Lights	0.6	12	18:00–08:00	Fixed
Fans	0.75	16	14:00–06:00	Fixed
Clothes iron	1.5	06	14:00–23:00	Fixed
Oven	1.18	07	06:00–22:00	Fixed
Toaster	0.5	02	06:00–10:00	Fixed
Coffee maker	0.8	02	06:00–22:00	Fixed
Washing machine	0.78	05	08:00–16:00	Shiftable
Cloth dryer	4.40	04	06:00–18:00	Shiftable
Dish washer	3.60	03	07:00–12:00	Shiftable
AC	1.44	15	06:00–24:00	Elastic
Refrigerator	0.73	14	06:00–24:00	Elastic
Water heater	4.45	10	06:00–24:00	Elastic
Space heater	1.50	12	06:00–24:00	Elastic

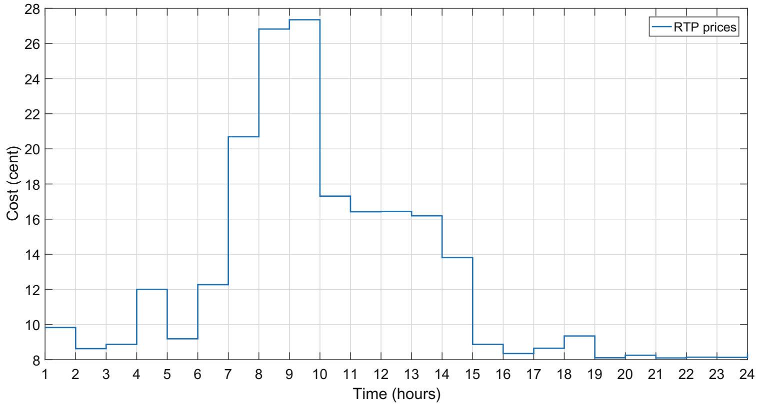

Fig. 3. RTP price signal

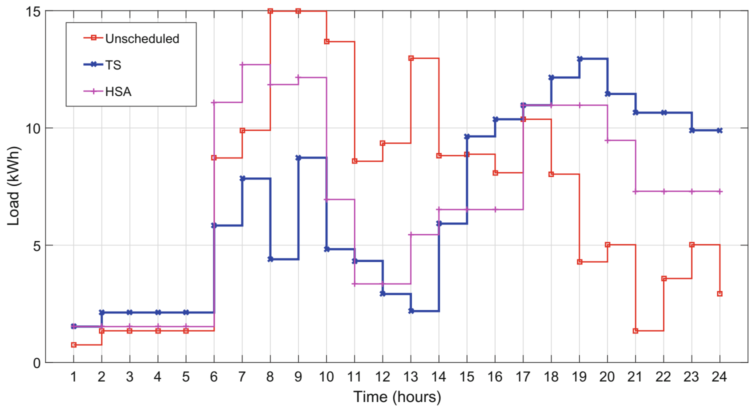

Fig. 4. Load

reduction, minimization of PAR, enhanced UC level and to observe the electricity usage pattern among the PHs and OPHs. A single home is considered having 13 appliances divided into three sub-categories [1], i.e., fixed, shiftable and base appliances. This categorization is shown in Table 1. RTP tariff model is used for the bill calculation.

As depicted in Fig. 3, there is a peak formation due to high electricity prices from 7 AM to 11 AM approximately and the prices are low from 2 PM to 12 AM. Load consumption for each hour before and after scheduling is shown in Fig. 4. As shown in the figure that there is a comparison between load pattern among scheduled and unscheduled appliances. Maximum load after optimization, is shifted to the OPHs due to which the cost and PAR are also reduced. The maximum load of unscheduled during the peak hour is approximtely 15.001 kWh. After applying optimization techniques, total load during the PHs is reduced upto 16.27%

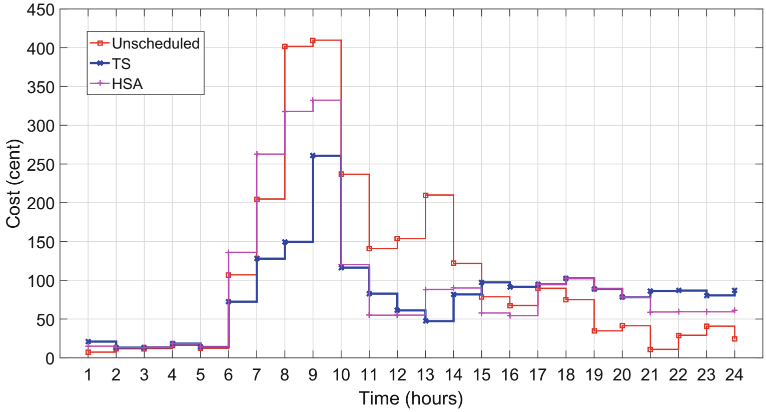

Fig. 5. Cost

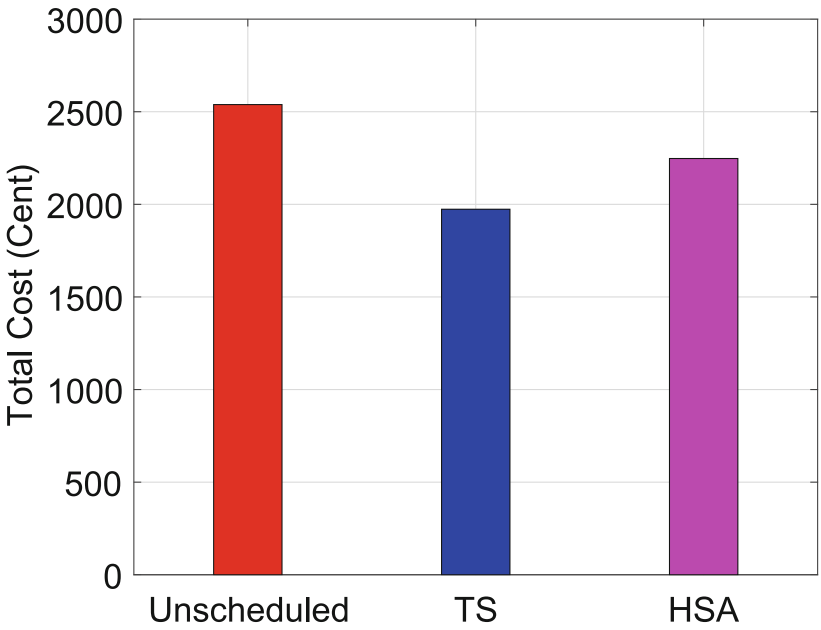

Fig. 6. Total cost

incase of HSA and upto 45.2% incase of TS. This is because the maximum load is shifted to the OPHs.

The comparison of electric cost for per hour is shown in Fig. 5. Here it is clearly illustrated that TS achieved the stated goal of reducing cost as compared to the unscheduled and HSA. This is because the cost during PHs is reduced on a certain level because the maximum amount of load is shifted to the OPHs.

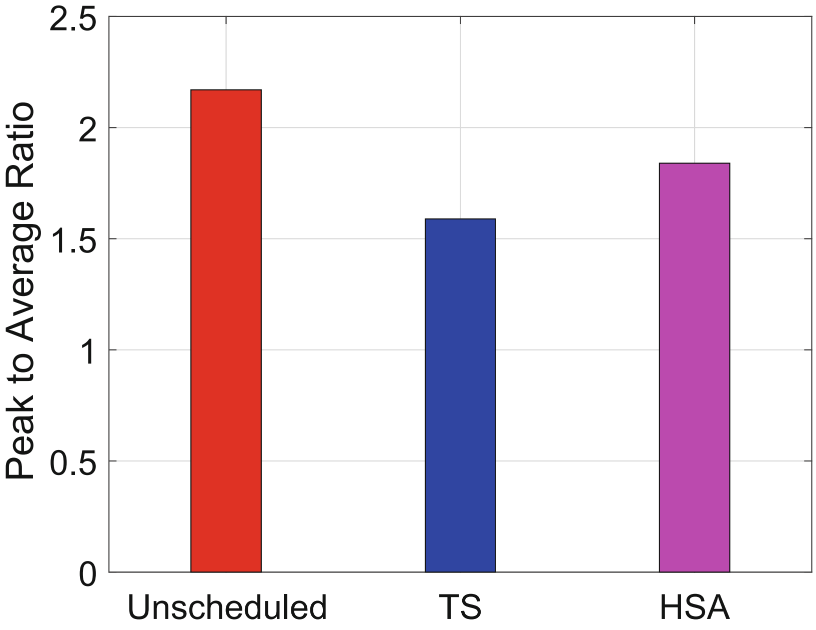

Fig. 7. PAR.

The cost of HSA during PHs is reduced upto 15.5% as compared to unscheduled, whereas, total cost of TS during the PHs is reduced upto 25% as compared to unscheduled. This is because the trial matrix in TS does not allow the maximum value to be saved than it already has. Figure 6, shows the difference of cost among unscheduled, HSA and TS. As depicted in the figure, TS achieves minimum cost as compared to unsceduled and HSA.

Figure 7, illustrates the comparison of achieved PAR between unscheduled, HSA and TS. Our results show that PAR is reduced in case of TS. PAR is the reduction of the peak formation during 24 h. It is not only beneficial for customers but also to the utility companies as it causes load shedding and high cost for the users. Here the TS algorithm efficiently reduces PAR by avoiding peak creation through equal distribution of load.

Figure 8, shows the waiting time in terms of UC as this is the time user has to wait for an appliance to be in working state. Our simulation results show that the waiting time for TS is increased as compared to HSA, still it is quite acceptable. Because there exists a tradeoff between waiting time and electricity cost. The waiting time is increased due to the reason that the price signals are getting low towards the end of the day, so scheduler shifts most of the load to the OPHs. Though the waiting time is increased, still appliances are working well within their defined OTI.

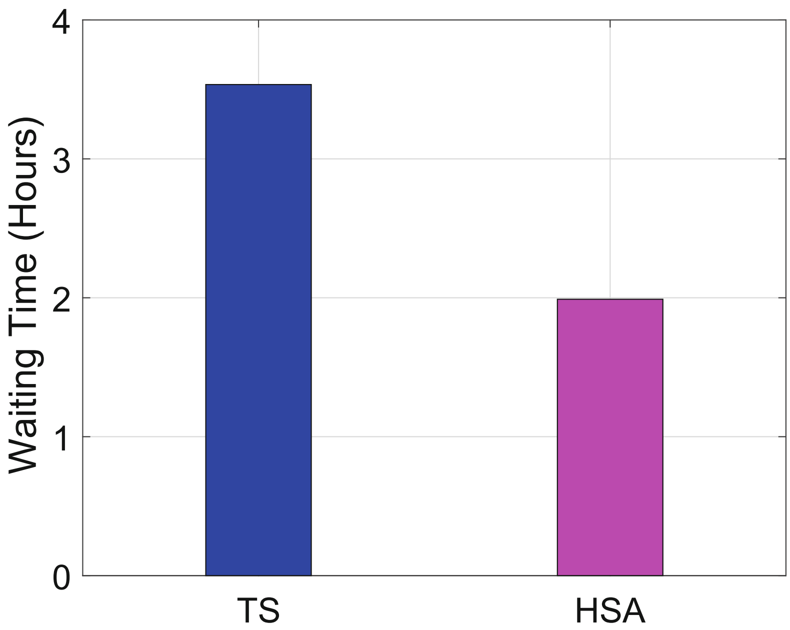

Fig. 8. User comfort

5 Conclusion and Future Work

In this paper, we present an optimization technique for load management and power scheduling of residential area. The purpose was to achieve a solution with minimum cost and reduced PAR. We evaluated our results by conducting simulation on different categories of appliances, i.e., fixed, shiftable and elastic appliances. RTP pricing tariff was used and the efficiency of two heuristic techniques (HSA and TS) was analysed. Results of our proposed system proved that TS outperformed HSA in terms of cost and PAR. Load is efficiently shifted from PHs to OPHs due to which cost is reduced. Though, there exists a trade-off between waiting time and electricity cost. In future, we will work on other optimization techniques for better results with less computational time and reduced complexity.

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Load Scheduling in Home Energy Management System Using Meta-Heuristic Techniques and Critical Peak Pricing Tariff

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Abstract. In this modern world, the demand of energy rises exponentially, that makes it a valuable resource. New techniques and methods are being developed to solve the problem of energy crisis in residential areas. The strategy to handle this problem is by integrating the demand side management (DSM) with smart grid (SG). DSM enables the consumer to schedule their load profile effectively in order to reduce electricity cost and power peak creation, referred as peak-to-average ratio (PAR). This paper evaluates the performance of home energy management system (HEMS) using meta-heuristic techniques; harmony search algorithm (HSA) and flower pollination algorithm (FPA). In this regard, a single home is considered with smart appliances classified as automatically operated appliances (AOAs) and manually operated appliances (MOAs). Moreover, critical peak pricing (CPP) is used as a price signal. In this paper, emphasis is placed on the cost minimization and load scheduling by shifting the load between off-peak and on-peak hours, while considering the user comfort. Simulation results shows that the performance of FPA is better in terms of cost and PAR reduction, whereas there exists a trade-offs between electricity cost and user comfort level.

Keywords: Demand response · Optimization · Smart grid · User comfort · Load scheduling · Demand side management

1 Introduction

The increase use of energy in the existing system produces a significant challenges in terms of utility management, reliability and environmental issues. Thus, a reliable infrastructure is required to make next generation power grid more reliable, green and intelligent systems, which is generally known as smart grid (SG). However, another problem of peak load is created during some hours of the day, when there is an increased demand of energy. This situation can be handled by controlling the load profile of the consumers in an efficient way, which can be

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achieved by demand side management (DSM). In short, SG efficiently manages the energy consumption in such a way that it beneficial for both consumers and utilities. The generic architecture of SG is shown in Fig. 1.

DSM is one the important aspects of SG that controls the demand side activities of the end-users and maintains a balance between demand and supply of energy. Two main functions of DSM includes demand response (DR) and load management. Load management placed a strategic focus on the efficient energy management by shifting the load between off-peak and on- peak hours. It includes the benefit of electricity bill reduction, reduced number of peak formation and improved reliability of the power grid [3]. DR is defined as the responsive action taken by the consumer against the dynamic pricing schemes [4]. It allow consumers to set references to operate smart appliances, considering the price rates. In addition, it also provides the integrity to the power grid infrastructure by managing the load optimally.

The above discussion concludes that DSM can be integrated with SG in order to reduce peak load. Different incentive based pricing schemes have been used by utilities to provide an information about the price rate changes during off-peaks and on-peak hours. Some standard dynamic pricing models includes time of use (TOU), real time pricing (RTP), critical peak pricing (CPP), inclined block rate (IBR) and day ahead pricing (DAP). In order to achieve best out of these incentives, many optimization techniques such as, binary particle swarm optimization (BPSO), genetic algorithm(GA), ant colony optimization (ACO), enhanced differential equation (EDE) and bacteria foraging algorithm(BFA) have been proposed to schedule the load optimally in residential and industrial areas. In this paper, home energy management (HEM) system is considered in order to reduce the peak-to-average ratio (PAR) by shifting the load and cost minimization, while maximizing the user preferences.

Rest of the paper is organized as follow: Section 2 discussed the state-of-the-art work, Sect. 3 describes the proposed system model, and Sect. 4 contains the simulations and results. Finally, paper is concluded in Sect. 5.

2 Related Work

Various load scheduling techniques in SG for DSM been proposed in recent years. In this regard, some of the state-of-the-art work are discussed as follow.

In [5], authors presented a hybrid approach based on GA and wind driven optimization (WDO) for DSM in smart grids. A heuristic algorithm based DSM controller is designed and price tracking frame for RTP is used along with proposed genetic wind drive (GWD) algorithm. The system performed the priority load scheduling between off-peak and on-peak hours. Results indicate that GWD significantly reduced both PAR and cost while maximizing user comfort (UC). However, installation and maintenance cost is neglected while designing DSM controller. Authors in [6], designed the general architecture of the DSM to efficiently utilize energy with renewable energy sources. Load is classified into three categories; fixed, shift able and elastic appliances and problem is formulated

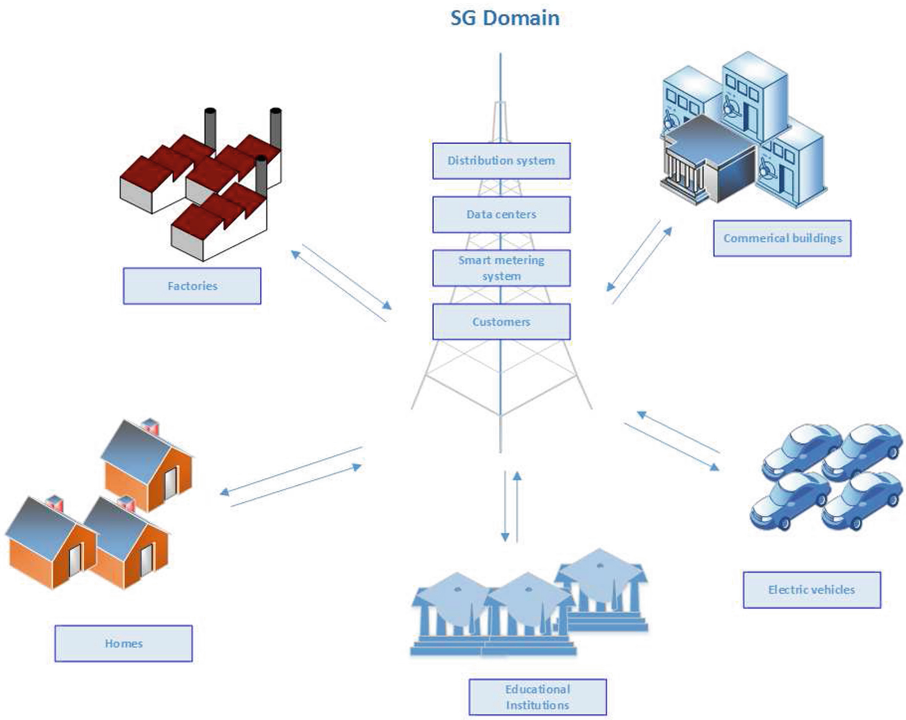

Fig. 1. Smart grid infrastructure

as multi knapsack problem (MKP). TOU with IBR is taken as price signal. Formulated problem is optimized using three heuristic algorithms (GA, BPSO, and ACO) and evaluated their results. Simulations results shows that GA outperformed other approaches and reduced the electricity cost and PAR while considering user comfort. However, this paper does not consider the uncertainty in renewable resources and randomness in user behaviors.

In [7], authors proposed control algorithm to schedules the critical and non-critical load depending on the requirements of the consumer and voltage/power levels. Two load centers; main grid interconnection and two renewable sources are considered to check the robustness of A.C electric springs. Results are assessed on different case studies based on the level of voltages, the energy conserved from the implementation of electric springs varies 4 to 15% for the different cases. However, the proposed architecture is completely subjective and depend highly on the values of voltage applied to non-critical loads. Additionally, the proposed system lacks the type of communication infrastructure used.

Authors in [8] presented a two-leveled stochastic model for energy resource scheduling in smart grids, considering the demand response and uncertainty in renewable energy resources. Problem is formulated as a mixed integer linear programming. Day-ahead pricing scheme is taken into account for making an optimal decision at first level and uncertainty of wind, solar power and electric vehicles at the second level. The proposed stochastic model aims to reduce the operational cost over the scheduling horizon. Results shows that the designed significantly achieved the targeted result, reducing the operational cost by 4% compared to deterministic approach. However, this model has limited flexibility in the absence of DR.

Authors in [9] developed an online energy management strategy (EMS) for real-time operation of micro grids based on Lyapunov optimization. EMS takes into consideration the power distribution network and system constraints. Results reveals that the proposed system performed better that greedy algorithm and is close to an offline optimization algorithm. The proposed system does not allow the control parameters to fall in timecoupled constraints due to the convergence rate of Lyapunov optimization increases. Moreover, this system lacks the statistical analysis to take into account the random behavior.

In [10], authors introduced sparse coding for scheduling the individual household electricity loads. Proposed model is evaluated on 5000 households. Results shows that the sparse code features effectively reduced the forecasting errors. Another paper [11], presented an efficient approach to handle the congestion problems in smart grids through demand response. The proposed scheme used fuzzy logic and ACO to select the most feasible solution. However, both systems lacks the integration of renewable energy resources(RES).

Authors in [12], an energy consumption management approach is proposed for scheduling. Two types of demands are considered: (i) essential and (ii) flexible. A new centralized algorithm is presented to optimize energy for both delay-tolerant and delay-sensitive demands. This scheme also obtained optimal energy decisions to minimize the total cost and delay of the flexible demands. In [13], authors presented the decentralized DR framework to minimize the cost and maximize the user comfort and privacy. Smart meters are integrated in the management system to exchange information to find an accurate load profile. This exchange of information takes place until no improvement can be made in the optimized solution.

Authors in [14], used a game theoretic approach to model the interaction between consumers with excess power generation for power trading. Proposed system adopt dynamic problem to schedule the load of fixed and controllable appliances. Competing users choose their output generation and offered price to maximize revenue. The problem of choosing offered price is formulated as a mixed-integer linear program. Simulated results shows that proposed algorithm reduces the cost burden of users by trading power among competing users. Moreover, proposed system facilitates the integration of renewable resources. However, the initial and maintenance cost of renewable resources is ignored.

3 Proposed System Model

In this section, an optimal approach for load scheduling is proposed based on the CPP scheme.

3.1 System Description

In residential areas, every smart home is connected to smart meters having energy management controller (EMC) to build a bi-directional communication between consumer and the utility. User inputs their power consumption plan via user interface which is connected to the one side of smart meter. On the other side, smart meter is linked with all the home appliances to control their energy consumption and scheduling of all individual appliances. EMC gathers the information of the home appliances connected through HAN and send this information to SG domain via WAN. Figure 2 depicts the DSM setup in residential domain. In this paper, we consider a single smart home having 'm' smart appliances integrated with smart meters. Incentive-based pricing, CPP, is used to calculate the electricity price against the power consumption cost.

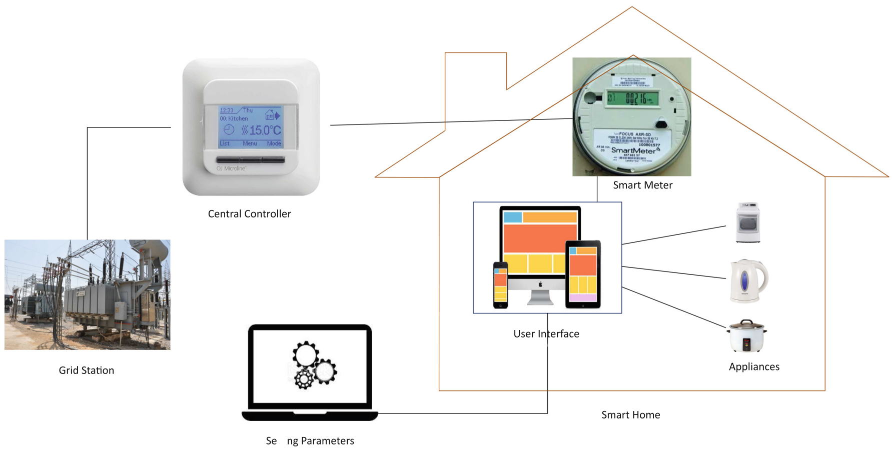

Fig. 2. System model

3.2 Energy Consumption Model

In the proposed model, a single smart home consists of 'm' number of appliances, such that $\mathrm{A} = \{\mathrm{a}_1, \mathrm{a}_2, \mathrm{a}_3, ..., \mathrm{a}_\mathrm{m}\}$ and single day is divided into 120 time slots 't', each having a time resolution of 12-minutes, such that $\mathrm{t} \in \mathrm{T} = \{\mathrm{t}_1, \mathrm{t}_2, \mathrm{t}_3, ..., \mathrm{t}_{120}\}$, then the hourly power consumption demand of an appliance is given as:

$$E_{\mathrm{a}}(t) = \{E_{\mathrm{a,t_1}}, E_{\mathrm{a,t_2}}, ..., E_{\mathrm{a,t_{120}}}\} \tag{1}$$

where $E_{a,t_1}, t_{a,t_2}, ..., t_{a,t_{120}}$ denotes the energy consumption of each appliance in the corresponding time slots. The equation for total energy consumption demand per day for all appliances is calculated as follow [6]:

$$E_T = \sum_{t=1}^{120} \sum_{i=1}^{m} E_{(a_i,t_i)} \tag{2}$$

In the proposed model, 'm' appliances are classified into two categories according to the points mentioned in the next section.

3.3 Classification of Appliances

Considering the length of operational time (LOT), user preferences and operational time interval (OTI), appliances are classified into two categories; namely AOAs and MOAs. AOAs are usually referred to as non-interruptible and interruptible appliances, whereas MOAs operate only if residents are using them manually. The home appliances that could be scheduled are only AOAs, because MOAs would be operate manually. In addition, AOAs considered are assumed to be smart home appliances. Consumers set the starting and ending time of each AOA appliances, denoted by OTI. Operational time length of the smart appliances should be strictly controlled; that is, it should denote the integer multiples of 12 greater or nearest to the actual LOTs of the appliances. For example, if

Table 1. Parameters of classified appliances

AOA	OTI	LOT	Power (kWh)
Air conditioner	41–60	5	1
Air conditioner	61–85	5	1
Air conditioner	86–120	10	1
Electric radiator	1–30	5	1.8
Electric radiator	91–115	10	1.8
Rice cooker	1–25	2	0.5
Rice cooker	41–60	2	0.5
Rice cooker	71–90	2	0.5
Water heater	86–105	3	1.5
Dishwasher	101–120	2	0.6
Washing machine	1–60	5	0.38
Electric kettle	1–25	1	1.5
Electric kettle	66–85	1	1.5
Humidifier	1–30	10	0.05
Humidifier	91–120	10	0.05
Cloth dryer	71–91	4	0.8

the actual operation time of rice cooker is 22 min, then the LOT should be set to 2 (24 min). In final results of appliance scheduling, there must be some errors of few minutes that can be ignored. The details of all AOAs is shown in Table 1.

3.4 Pricing Scheme Model

CPP is taken as price signal for the proposed optimization problem. When utilities observe critical peak days, they substantially raised the price of electricity. Notifications are being sent to consumers a day ahead with significant higher charges during on-peak hours. This will provide consumer with signal to respond either by paying the critical peak rates or reducing their consumption. Customers that reduce their demand on critical peak days benefits from the low electricity consumption charges.

3.5 Problem Formulation

The aims of the load scheduling are: to reduce the electricity bill of the consumer by shifting the load between on-peak and off-peak hours, to maximize the user comfort and to reduce the PAR by maintaining the balance between demand and supply. We assume m number of appliances in a smart home. User input the starting time α_{a} and β_{a} of each AOA appliance, such that it fulfill the constraint($\alpha_{\mathrm{a}} < \beta_{\mathrm{a}}$)and energy consumption per hour $\mathrm{E_a, t_i}$.

3.5.1 Waiting Time

Usually consumer demand to complete their work as soon as possible without delaying. This can be achieved by reducing the waiting time and electricity price. However, there exist a trade-off between waiting time and cost. If we reduce the waiting time, consumer have to pay huge price. Waiting time [6] is represented mathematically as $\varnothing$ and is given as:

$$\varnothing_a = \frac{\eta_a - \alpha_a}{(\beta_a - \tau_a) - \alpha_a} \tag{3}$$

3.5.2 PAR

PAR is defined as the ratio of maximum load to the average load in a given time slot. It is beneficial to reduce PAR to maintain the balance between energy production and consumption and it ensures that grid is not over stressed. It is represented mathematically [6] as ϕ and is given as:

$$\phi = \frac{max(\Delta(t))}{\frac{1}{T}(\sum_{t=1}^{T} \Delta(t))} \tag{4}$$

where T denotes the total number of time slots, i.e. 120. The optimized problem of load scheduling is solved using HSA and FPA and results are compared with the parameters of the unscheduled load. The brief explanation of HSA and FPA are discussed below.

3.6 HSA

HSA imitates the musicians behavior, proposed by GEM [15]. The main steps of HSA includes; random generation harmony memory, harmony memory improvisation and update of worst consideration. Harmony memory improvisation step consists of two control parameters; pitch adjustment ratio (PA) and harmony memory consideration rate (HMCR). A random number is generated, which is compared with these two parameter. If the generated random number is less than HMCR rate, a value is chosen from existing HM for the new harmony memory otherwise value is generated randomly. This new element is further modified according to the pitch adjustment ratio. The equation for harmony memory

Algorithm 1. Scheduling Algorithm : FPA

Initialize all parameters (α_a,β_a,τ_a)
Set lower and upper bounds
for all the appliances a$\in$ A
for all time slots tin T

```
for i = 1 → popsize do
    for j = 1 → appliances do
        Generate random population
        Calculate F=fitness function
        if F()¡F(i-1) && load (t)<unscheduled load (t) then
            F(i)=F(i)
            if (∅_a using (4) && (η_a <, τ_a) then
                appliance is ON
            else
                wait until off-peak hours
            end if
        else
            F(i)=F(i-1)
        end if
    end for
end for
for k = 1 → MaxItr do
    Generate random flowers (population)
    for m = 1 → appliances do
        if rand>ProbabilitySwitch then
            use levy flight to update solution
        else
            select random population
            check simplebounds
        end if
    end forEvaluate new solution
    if F_new<F_old then
        update the solution using new fitness values
    end ifupdate the global best
end forReturn best solution
```

Table 2. FPA terms in correspondence to HEM

FPA parameters	HEM parameters
Flowers	Array of AOAs in binary
Number of flowers	Number of appliances
Cross-pollination	Global optimum
Abiotic pollination	Local optimum
Pollinators	Solution in search space
Probability switch	Appliance states

consideration and pitch adjustment ratio [16] is given as:

$$v_i, j = \{x_r andj, randb \leq HMCR, l_j + randb.(U_j - l_j), else\} \quad (5)$$

$$v_i, j = \{v_i, j + randb.bwj, randb \leq PA,\ v_i, j, else\} \quad (6)$$

3.7 FPA

FPA is inspired by the pollination process of flowers [15], as shown in Algorithm 1. There are four main steps involved in the algorithm. Self-pollination and abiotic pollination are used for local pollination. For global pollination, cross-pollination is considered and pollinators move in a way that obeys Levy flights. Pollinators develop flower constancy, which involved the similarity of two flowers. The switching between local and global pollination is controlled by a switch probability p∈ [0,1]. Equation for fitness function is as follow:

$$z = \{((1 - u(1)^2) + 100 * (u(2) - u(1)^2)^2 + 100 * (u(3) - u(2)^2)^2\} \quad (7)$$

In our proposed system, status (ON/OFF) of AOA appliances are initialized randomly and initial fitness function based on minimum cost and load is calculated. Improvise new population using levy function and probability switch in order to update global best and if the new fitness function is less than old fitness function, update the solution using new fitness function. The overlapping of FPA terms in correspondence to HEM is shown in Table 2.

4 Simulations and Results

Simulations are conducted in MATLAB R2013a to analyze the performance of proposed techniques. Results are then compared, considering the performance metrics such as PAR, electricity cost and waiting time. In this paper, we consider 6 h of evening (5 pm to 11 pm) and 5 h of morning (7 am to 11 am) as peak hours. These hours are selected as peak hours because energy demand is high during these hours.

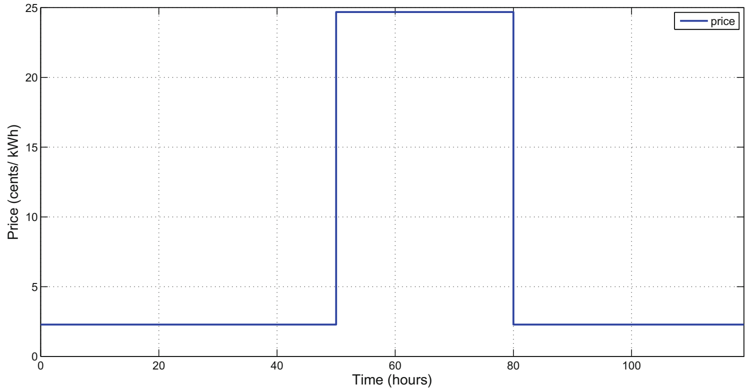

Fig. 3. CPP price signal

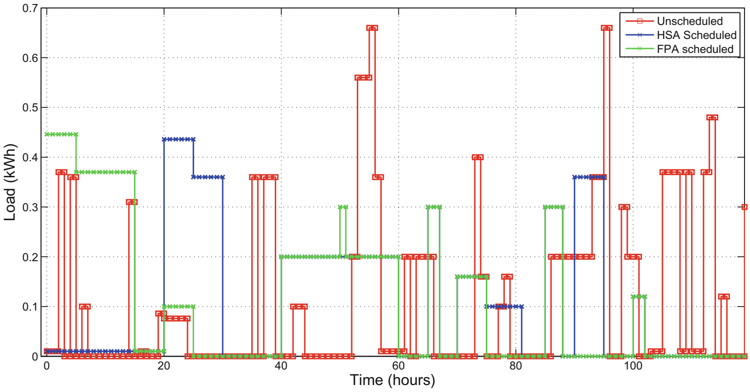

Fig. 4. Load distribution

For simulations, we design a model, considering a single smart home consisting of multiple smart appliances. These smart appliances are further classified into MOAs and AOAs. However, only nine AOAs are participated in load scheduling. The 24 h time period is divided into 120 slots; each slot with a time resolution of 12 min. This division of time slots reduce the wastage of electricity and also it is much convenient to solve the optimization problem. HSA and FPA using CPP pricing scheme, are implemented to schedule the load of designed home model. Figure 3 shows the CPP pricing rates of each hour in a day. Performance of both optimization techniques are discussed and compared in next few paragraphs.

Figure 4 shows the distribution of unscheduled, HSA optimized and FPA optimized load. The graphs shows that load is optimally distribute between on-peak and off-peak hours using HSA and FPA techniques. The purpose of using optimization techniques is to schedule the load in order to achieve the reduction

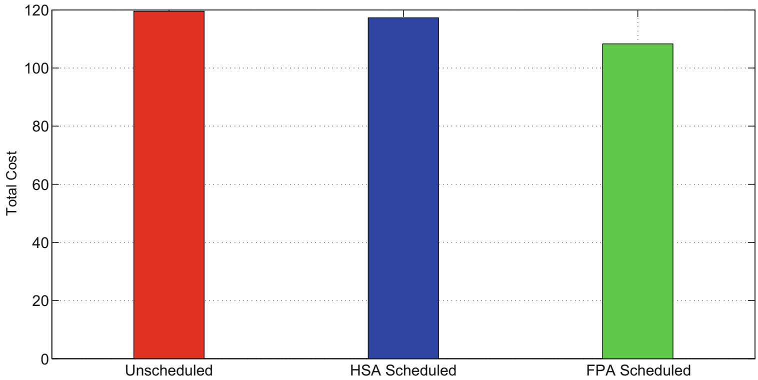

Fig. 5. Total cost comparison

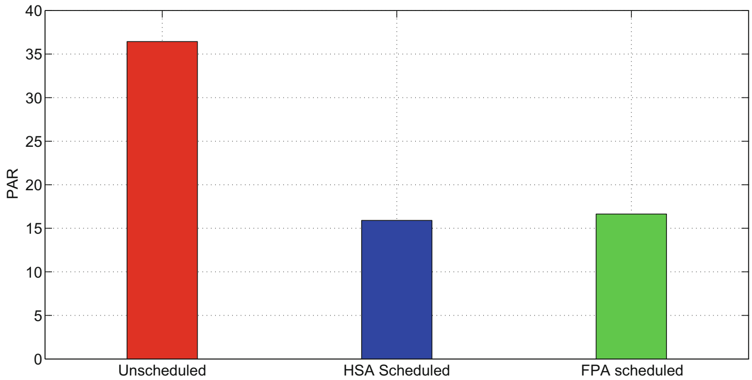

Fig. 6. PAR comparison

of electricity cost and PAR, while considering the demand and requirements of consumers.

Figure 5 shows the total cost for unscheduled, HSA scheduled, FPA scheduled. It can be noticed that price is quite high for the unscheduled case. The reason being that CPP pricing model elevate the price rate during critical usage of energy consumption, as shown by Fig. 4. However, applying the optimization techniques, cost reduced by 2% in case of HSA scheduling and 11% for FPA scheduling.

One of the main goal of load optimization is to maintain a balance between demand and supply to avoid the distress of grids. This can be achieved by reducing the PAR. Figure 5 shows the comparison of PAR among unscheduled, HAS scheduled and FPA scheduled. This can be obvious that PAR of unscheduled load is high, as load is accumulated during on-peak hours. The comparison shows that HSA and FPA optimization techniques significantly reduce the PAR by 21% and 23%, respectively.

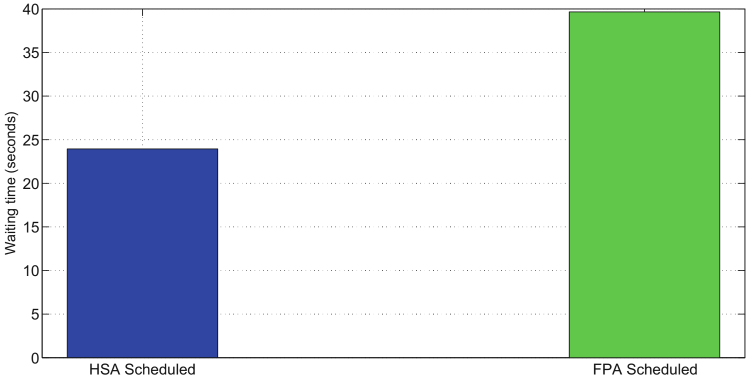

Fig. 7. Waiting time comparison

There exists a trade-off between cost reduction and user comfort or waiting time, shown in Fig. 7. The load shifting between on-peak and off-peak hours confined the user to delay their appliance operations. So, consumer has to compromise preferences in order to achieve the electricity bill reduction. In case of unscheduled load, consumer does not have wait or to compromise comfort. They are free to operate any appliance at any time, therefore waiting time is zero. Figure 6 depicts the graph bar of waiting time for HSA scheduled and FPA scheduled. It can be seen that waiting time for FPA is higher than HAS scheduled. As we have seen in previous graphs, FPA scheduled reduced the cost comparatively more than HSA scheduled. That is why FPA has high bar graph than HSA scheduled.

5 Conclusion

In this paper, we first propose the system model of smart home in residential area for energy management system, and then perform the load scheduling using CPP pricing scheme. The beneficial features of the proposed system is the reduction of electricity cost while minimizing the waiting time of the appliances. Benefit reward for the utility companies is the stability of smart grid system achieved by reducing the ratio of PAR. Results shows that our proposed model works best with the FPA optimization technique by reducing the cost and PAR; unscheduled $>$ HSA scheduled $>$ FPA scheduled. In future, we will extend our work for multiple smart homes and combined price tariffs. We will also work on the hybrid optimization approaches to achieve more accurate results within less execution time and computational complexity.

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Energy Efficiency Using Genetic and Crow Search Algorithms in Smart Grid

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Abstract. Demand Side Management (DSM) is an efficient and robust strategy for energy management, Peak to Average Ratio (PAR) reduction and cost minimization. Many DSM techniques have been proposed for industrial, residential and commercial areas in last years. In this paper, we have design Home Energy Management Scheduler (HEMS) using two algorithms Genetic Algorithm (GA) and Crow Search Algorithm (CSA) for electricity cost and PAR minimization. Real Time Pricing (RTP) signals are used for electricity bill calculation. Simulation results demonstrate that our proposed scheme efficiently achieved our targeted objectives. However, GA performs superior than CSA due to high convergence rate. Furthermore, a trade-off exists between electricity cost and user waiting time; when electricity cost is low, user waiting time is high and vice versa.

1 Introduction

Traditional Power System (TPS) has lot of challenges to face for example lack of consistency, sustainability and reliability. TPS has to manage, produce electricity for the consumers and distant area transmission, which causes line loses, load shading, blackout and increases the rate of electricity bill. To overcome these challenges TPS is now upgraded in Smart Grid (SG). This will help to decreases the line loses, load shading and decrease the rate of electricity bill. Smart grid are referred as Information Communications Technology (ICT) embedded traditional grids. In smart grid the flow of electricity is bi directional between utility and consumers that helps the consumer to manage their bill. In this SG consumers can sell extra electricity to the utility [1]. One of the important module of SG is Demand Side Management (DSM) and Demand Response (DR) that helps consumer to reduce their energy consumption and electricity bill by shifting load from on peak hours to off peak hours. It also helps to avoid blackout and manage electricity load in commercial areas by adapting clipping of load and load shifting strategy [2]. In this paper, two metaheuristic algorithms GA and CSA with RTP pricing signals are used to achieve targeted objects such as cost minimization, reduction of PAR and increase in UC level (Fig. 1).

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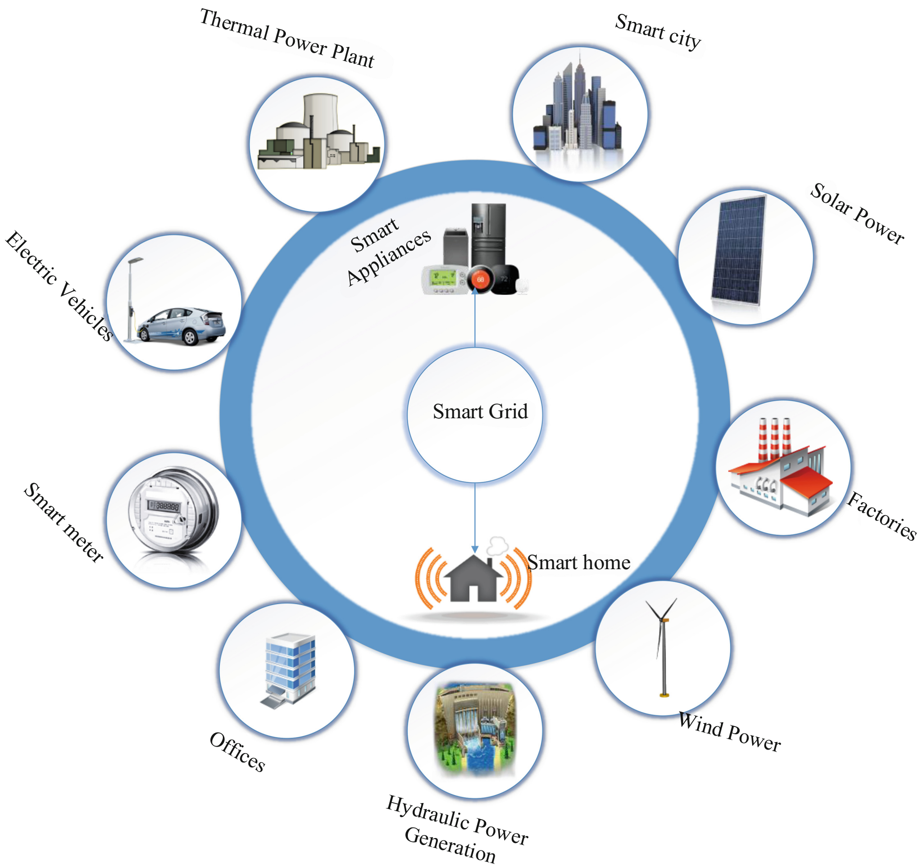

Fig. 1. Smart grid

2 Related Work

In [1], authors discussed five heuristic algorithms Genetic Algorithm (GA), Binary Particle Swarm Optimization (BPSO), Bacterial Foraging Optimization Algorithm (BFOA), and Wind Driven Optimization Algorithm (WDO). Moreover, they proposed hybrid Genetic Wind Driven Algorithm (GWD) and compare with each algorithm for smart grid. The issues that addressed in this paper are neglecting of User Comfort (UC), and inconsideration of PAR. To overcome these issues author used DSM techniques that has been discussed above, by using these authors achieves reduction in PAR, every technique has different ratio to reduce the PAR. However UC is compromised with great ratio almost in every technique and these techniques have been implemented for single home excluding of multiple homes.

The authors addressed in [2], the problem of optimization technique that is designed for DSM, authors describe that convex optimization technique is for individual appliances however it is not suitable for every appliance because of some appliances has fixed power consumption pattern. Once the appliance is started it cannot be stopped until the job is finished, this things produces effect somehow on consumers comfort. To overcome this problem only starting time of appliances is considered under the control optimizer and author proposed a DSM model. After scheduling the fixed or shift able appliance authors achieves the user satisfaction level by scheduling the appliances according to the requirements when it is done properly the peak load are also decreases automatically. This system or technique is only for single households and also for the residential area and authors also neglected the electricity bill cost in the system.

The authors discussed in [3], about the Energy Management Controller (EMC) that is used in Home Area Network (HAN) depends on the smart grid and its purpose is to scheduling the method for home usage is efficiently. The home gateway (HG) receives the demand response (DR) information and Real Time Pricing signals (RTP) is used to transfer with the DR, EMC achieves scheme that operates the appliances automatically in this system but the problem is that it destroys all the entire system due to high PAR and only because RTP pricing signal scheme is used or some appliances may not work due to this reason it is the non linear problem. To make this problem linear and make the entire system efficient, the author used RTP with the Inclining Block Rate (IBR) to reduce the electricity cost and PAR. The upper defined combination of scheme is used with GA to solve the problem. By using this technique the electricity cost is decreases and PAR is also decreases some how. However user cannot on all appliances in the same day that are automatically operate by the system.

In [4], authors investigates the problems that are present in traditional gird and Smart grid system by using different techniques. The issues, authors arises in these systems are that user comfort or integration of RESs is totally ignored in these techniques, their aim is only to reduces electricity bill cost in any case so there is trade-off between user comfort and electricity cost, these problems are the common issues of the residential users. To overcome these issue authors proposed a system know as EMC with Renewable Energy Resources (RESs) by using three heuristic techniques Genetic Algorithm (GA), Bacterial Particles Swarm Optimization (BPSO) and Ant Colony Optimization (ACO) and using the pricing signals RTP and IBR. By applying these techniques and schemes in system authors achieved 50% of the total demand through RES. The electricity bill cost and PAR is effectively reduced in this system and user comfort is also maximized.

The authors focused in [5], on the problem of load scheduling and power selling in system with higher penetration of RESs. To overcome these issues authors adopted the technique of dynamic programming to schedule the different appliances operational time that helps the user to sell their excess power generation to other users and to the utility company. In this paper the author proposed a model named as Game Theoretic approach (GAT), the purpose of this model is that each user aims that to get higher share of the market to maximize the revenue and offered the cost according to the user requirements and also sells extra generation of electric power to other users. By adopting these technique expenses of user for the electric bill is managed, it achieves the integration of renewable energy resource (RES), and minimization of user energy cost. However an initial expense of this model is neglected and may be somehow user comfort is also neglected.

In [6], authors addresses the problem that is trade off between payment and user comfort, these problems occur when user used the appliances which have flexible starting time and uses fixed power to work continuously, in this case the payment is increase. On the other hand if user uses appliances which have flexible power in already defined working hour, in this case user comfort is compromised. To fix these problems author proposed Power scheduling strategy for the residential consumers to achieve the better results between this trade off. Author implements power scheduling strategy on appliances that decrease power consumption during on-peak hours. By applying this technique the author effectively minimized cost through power consumption strategy. PAR is ignored by author in proposed power scheduling strategy.

The authors addresses in [6], the problems that are Energy management in micro grids these problem mostly formulated as an off line optimization problems for day ahead scheduling. To solve these problems the author proposed an on line Energy Management Strategy (EMS) for real time operations of micro grids. These systems check the problem on line and implement the solution of those problems in real world. This system uses two DG models which are i. renewable DG and ii. Is conventional DG one is used for battery storage system and second is used for dispatch able resources. By using EMS technique author achieves better results than off line greedy algorithm that minimization of average total cost. On the other hand if networks not works properly this system cannot give the accurate results.

In [7], authors addresses the problem that Energy management in micro grids is formulated as a non-linear optimization problem, in this system assumes that all generations and loads are connected with one common bus and ignores the on line network system and the operational constraints of the system. Thus solution given by these systems are not considerable and implementable in real life practice. To solve this problem author have focused on the design of a distributed EMS for the micro grids to achieve better results. To propose the distributed EMS where MGCC and the local controller are joined with each other for best solution that is based on IEC 61850. By using this technique authors wants to minimize the cost of generation, minimize the classification of customer in DSM and also wants to minimize the energy losses. By applying this system and techniques author achieves fastest algorithm. However this technique is not used in real life scenario.

The authors describes in [8], that in smart grid, residential consumer adopts different techniques to manage their power consumption with specific objectives, on the other hand conventional load scheduling methods wants to maximize the consumption payoff or minimize the consumption cost. To overcome this issue authors introduced a novel concept of cost efficiency t based on residential load scheduling frame work that is used to improve the economical efficiency of the residential electricity consumption. To achieve the user reflects behavior effectively and achieves the optimal energy consumption, authors proposed cost efficient load scheduling algorithm. Author also considered the effects of service of the system in practical practice. The authors purposed cost efficient load scheduling algorithm is for the demand sides and using day ahead binding process and real time pricing scheme by using a fractional programming approach. By using these techniques and approaches author achieves the reduction of cost and increases the cost consumption of electricity and have better economical results in residential areas. However this system is only to achieve residential area, commercial areas efficiency cost is not included.

In [9], authors describes that power companies are unable to meet the requirements of the consumers due to the increase in population day by day, industries and buildings. The usage of electric appliances is automatically increased in daily based activities. So it is difficult to maintain the balance between consumption and the consumer demands. As a result it produces impact on user comfort level because user shifts the load from on peak to off peak hours to reduce the electricity bill. On the other side if all users want to use the maximum number of appliances in off peak hours the consumption of electricity is automatically increased. So service provider need to load balancing mechanism to avoid the extra utilization of the power grid because when there is extra consumption the electricity bill is automatically increased instead of consumer used electricity power in off peak hours. To avoid this problem the author purposed to implement multi objective evolutionary algorithm to reduce the cost and energy usage, this technique also minimize the electricity bill and the execution waiting time of the appliances. However minimization of PAR is not discussed.

The authors in [10], describes that smart grid is that concept which is more flexible, controllable and environment friendly. Home energy management (HSM) system is an important component of smart grid that gives the number of the benefits to the users and saving the electricity bill, reduction of the peak demand and DR and Time of Use (TOU) that provides reduction to users during the time of peak demands. The authors proposes an energy efficient optimization model that is based on the technique BPSO, this technique is proposed for residential electric consumers. The aim of author is to minimize the electricity cost, efficiently shifts the appliances operation time from high to low peak average ratio and saves the electricity bill cost. The BPSO technique also used to schedule the appliances. By using this technique the authors achieves 295 reduction in energy consumption cost, minimization of daily usage cost, and also bill is reduces 19.6%. On the other hand peak average time is neglected.

In [11], authors describe about the universal inspired Crow Search Algorithm (CSA) recently proposed in year 2016. The motivation of this algorithm came from crow search method that is used for hiding the food. CSA also go through with the low convergence rate like other algorithms. To overcome this issue new algorithm Chaotic Crow Search Algorithm (CCSA) is proposed. CCSA is improved form of CSA. To check the performance of CCSA, this algorithm is compared with other algorithm for 20 appliances. After the Comparison result it shows that clearly that this technique is suitable for 20 appliances, and this technique has best fitness value and Convergence speed than others. However, this algorithm is only for simple techniques.

The authors describe in [12], about the Support Vector Regression (SVR) and Auto Regressive Integrated Moving Average (ARIMA) based hybrid method to evaluate the speed and direction of the tidal current. To check the problem globally new recently developed Crow Search Algorithm (CSA) is used. After implementation and comparing the results with different algorithm its shows that it provides better predictions than other. And by using this technique SV-Masco is deduced. This hybrid technique provides better results in speed and direction of the direction of the Tidal current.

3 Problem Statement

In TPS, there were lot of challenges and issues that users had to face i.e., load shading, blackout and user has to pay maximum electricity bill. To over come these challenges and problems HEMS was introduces in SG by using metaheuristic techniques GA and CSA. In this work, 15 number of smart appliances are considered under RTP signals, these appliances are further categorize in three categorizes that are fixed, Shiftable, and elastic appliances that are shown in Table 1. In SG flow of information is bi directional, consumer and utility can

Table 1. Appliances with their LOT

Group	Appliances	Power rating (KW)	Lot
Fixed appliances	Refrigerator	0.125	3
	Lightening	0.5	8
	Electric stove	1.5	8
Shiftable appliances	Dishwasher	1	9
	PC	0.25	16
	Cloth dryer	0.5	8
	Electric vehicle	2.5	8
	Water heater	1.5	17
	Pool pump	2	9
Elastic appliances	Hair dryer	1	8
	TV	0.25	9
	AC	1	10
	Heater	1.5	12
	Ironing appliances	1	10
	Vacuum cleaner	1	9

easily communicate with each other. This system also secure in terms of line losses, electricity theft as compare to TPS. DSM is an important factor of SG, through DSM consumers can manage energy in a efficient way because it is also known as efficient strategy to control and handle energy.

4 Proposed Scheme

In smart grid DSM facilitates many useful, efficient and reliable operations [9]. The main aim of this strategy is to handle the load management for multiple categories of homes in residential area. It is also helpful to reduce the load from on peak hours to off peak hours. To connect the multiple homes together smart meter is used. Smart meter is internet using device that is used to calculate the energy consumption of homes and buildings. Traditional meter calculates only total consumptions of the energy, on the other hand smart meter tells that how much energy is consumed by which device. That is helpful to reduce the load in on peak hours. After the load management, it also provides help to avoid the black out. There are three type of appliances that are used in multiple categories of home. (i) Fixed Appliances, (ii) Shift able Appliances, (iii) Elastic Appliances. These types are explained further below. The proposed metaheuristic techniques are also discussed below in this section.

4.1 Categorization of Appliances

4.1.1 Fixed Appliances

The appliances that must run on regular basis in any case for example Refrigerator, Lightening, Electric Stove, Fan etc.

4.1.2 Shiftable Appliances

These appliances are known as non-interruptible appliances. These appliances can be scheduled any time throughout the day. Ones these appliances started cannot be interrupted for example Dishwasher, PC, Cloth Dryer, Electric Vehicle, Water Heater, Pool Pump.

4.1.3 Elastic Appliances

These appliances are known as interruptible appliances. These appliances can be interrupted for example Hair Dryer, Tv, AC, Heater, Ironing Appliances and Vacuum Cleaner.

4.2 Techniques

Meta heuristic are the techniques that are inspired by the nature, and gives the solution of optimization problem. The solution given by these techniques are near to the optimal solution. These techniques are used with different searching algorithms like GA, BFA, CSA, etc. In this paper two Meta heuristic algorithms are used.

4.2.1 Genetic Algorithm (GA)

GA is nature inspired algorithm and used to evaluate the population and biological problems. It is use to give better optimal solution than other algorithms but this solution is not the exactly solution of the population. In this paper GA is used to evaluate the results of 15 appliances for 24 h, using RTP signals. The steps of GA algorithm that is use to evaluate the results are, (i) Initialization of Population, (ii) Selection of Parents, (iii) Cross over and Mutation, (iv) Terminate the population.

4.2.2 Crow Search Algorithm (CSA)

CSA is population based algorithm. That defines the behavior of crow that how they live and act in groups. Earlier in 2016, this algorithm is implemented in real life and compare with other population based algorithms to evaluates different results. In this paper, this algorithm is implemented using 15 appliances with RTP price signal. CSA cumulatively compares its performance with GA to check that which algorithms achieves best optimal results. The steps CSA follow to evaluate the results are, (i) Initialize the population, (ii) Initialize the

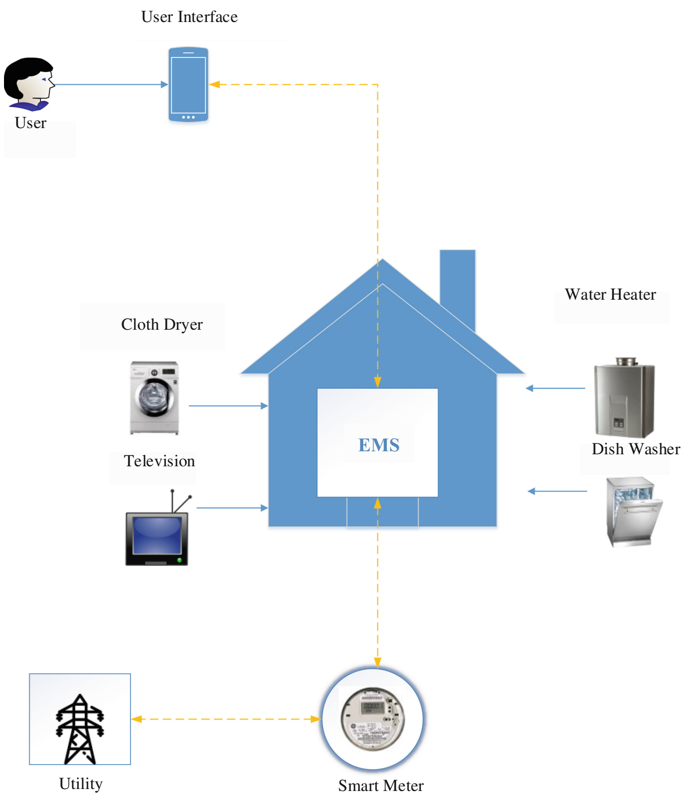

Fig. 2. System architecture

Algorithm 1. CSA

Randomly initialize the position of a flock of C crows in the search space
Evaluate the position of the crows
Initialize the memory of each crow
while $iter \leq iter^{max}$ **do**
  for $i = 1C(forallCcrows)$ **do**
    randomly get a crow j to follow i
    Define awareness probability
    if $r^j \geq AP^{j,iter}$ **then**
      $x^{i,iter_1} = x^{i,iter} + r^i X(m^{j,iter} - x^{i,iter})$
    else
      $x^{i,iter+1} = arandompositionofsearchspace$
    end if
  end for
  Check the feasibility of new positions
  Evaluate the new position of the crows
  Update the memory of crows
end while

position and memory of the crow, (iii) Evaluate fitness function, (iv) Generate new Position, (V) Check the Feasibility, (vi) Evaluate, (vii) Update the memory of the crow.

4.3 Pricing Scheme

In this paper RTP pricing signals are used for 15 appliances. RTP is tariff based pricing signals and used to calculate the results of the consumption of the electricity (Fig. 2).

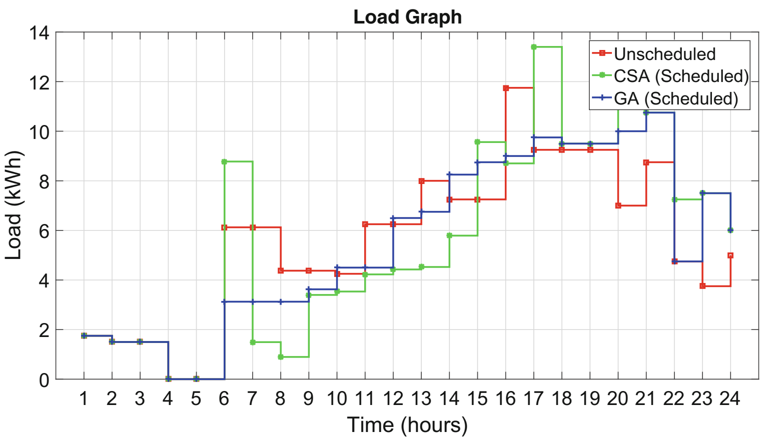

Fig. 3. Load graph

5 Results and Simulations

In this section, meta-heuristic techniques GA and CSA are evaluated. In order to evaluate the performance of GA and CSA we considered a single home having 15 appliances for 24-1 hour time slot. We use RTP pricing scheme to evaluate the result of appliances which we divided in three categories such as fixed, Shiftable, elastic appliances. The main objective is to evaluate performance of proposed meta-heuristic algorithms GA and CSA on the basis of PAR reduction, cost minimization, and increase in user comfort. We had run code almost 3/4 time than average result is taken to show the performance result. After optimizing the load we evaluate following results that are clearly shown in the graphs. In Fig. 4, PAR of unscheduled, CSA, and GA is shown, it is depicted that PAR of CSA is reduced from 4.4 to 2.3 that is 62.68% and the PAR of GA is reduced

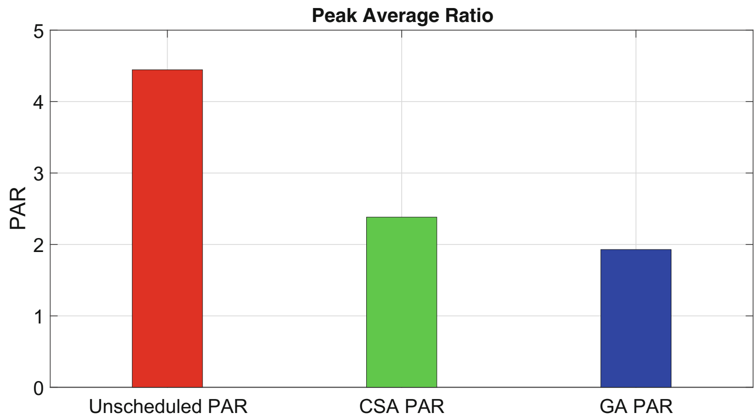

Fig. 4. Peak to average ratio

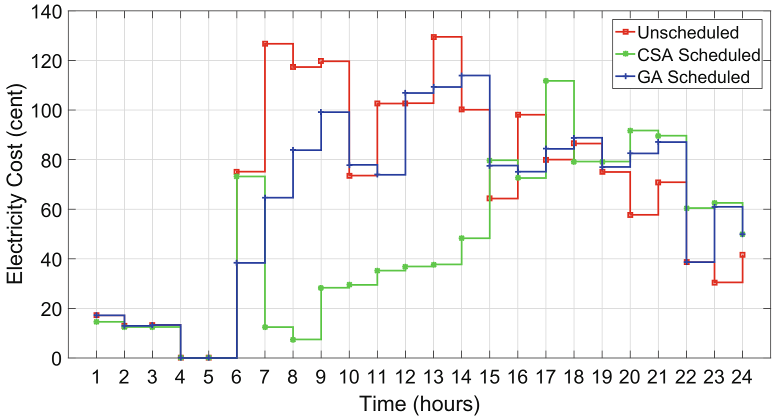

Fig. 5. Electricity cost in 24 h

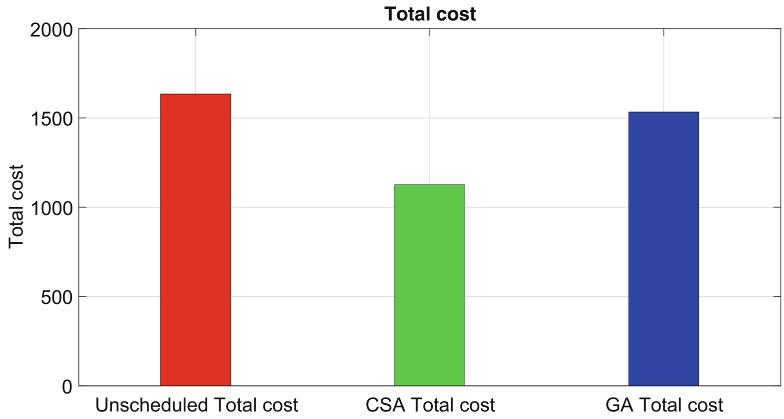

Fig. 6. Total cost

Fig. 7. Waiting time

from 4.4 to 1.9 that is 79.36%. In Fig. 5 electricity cost of unscheduled, CSA, and GA is shown, in this graph it is clearly shown that CSA and GA has less electricity cost than unscheduled that is 17.57% and 16.66%. In Fig. 6 total cost of unscheduled, CSA, and GA is shown, it is clearly shown that CSA and GA has less total cost than unscheduled that is 28.28% and 5.76%. In Fig. 7 waiting time of CSA and GA is shown, that is 2.9 and 2.55, it is clearly shown that GA has less waiting time than CSA, and by using GA user comfort is increased. In Fig. 3 load graph of unscheduled, CSA, and GA is shown, it is shown that the load of CSA, and GA is 15.62% and 7.92%. Load of unscheduled and algorithms always remains balanced and equal. In this figures it is clearly shown that our proposed techniques have clearly reduced the results, such as reduction in PAR, cost minimization, and desirable user comfort.

6 Conclusion and Future Work

In this paper, we investigated and evaluated energy efficiency of meta-heuristic techniques in SG. We implement our proposed scheme in residential area; comprising of 15 smart appliances, in terms of cost, PAR minimization with desirable waiting time. We achieved the minimum electricity cost through appliances scheduling from on-peak to off-peak hours. The finding of our proposed scheme are; (i) PAR is reduced via CSA and GA is 62.68% and 79.36% respectively, (ii) Electricity cost reduction through CSA and GA is 17.57% and 16.66% respectively that is less than unscheduled electricity cost, (iii) waiting time by implementing CSA and GA is 2.9 and 2.55 respectively, that shows desirable waiting time. On the other hand, a tradeoff exists between total electricity cost reduction and user waiting time. After whole simulation and evaluation of our proposed scheme, it clearly shows that in term of cost CSA outperforms GA and in term of PAR reduction and desirable waiting time GA out performs CSA. This result clearly shows that overall GA has better performance then CSA. In future, a hybrid technique of CSA and GA will proposed for electricity cost and PAR minimization.

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Residential Demand Side Management in Smart Grid Using Meta-Heuristic Techniques

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Abstract. The rise of energy demand is an alarming situation for mankind as it can lead towards a crisis. This problem can be easily tackled by assimilating Demand Side Management (DSM) with traditional grid by means of bi-directional communication between utility companies and consumers. This study evaluates the performance of Home Energy Management System (HEMS) using meta-heuristic optimization techniques: Genetic Algorithm (GA) and Crow Search Algorithm (CSA). The appliances are classified in three sets on the basis of their electrical energy consumption pattern. Moreover, the Real Time Pricing (RTP) scheme is used for power bill control. The core aims of this paper are to minimize electrical energy cost and consumption by scheduling of appliances, decline in peak to average ratio, while getting the best out of user comfort. Besides, simulation results illustrate that there is a trade-off between waiting time and electricity cost. The outcomes also indicate that CSA perform better as compared to GA in relation to cost.

Keywords: Demand response · Home energy management · Optimization · Smart grid · User comfort

1 Introduction

In the modern day world and with growing technology, electricity has become the basic necessity of all individuals. Moreover, the demand of electrical energy is also greater than before with the progress of population. It can result in distress as providing electricity to such masses has become a challenging problem in the current world. Besides, the customary power system is insufficient to tackle issues of power grid like consistency, immovability, and sturdiness [1]. As a consequence, a different setup is desired that is capable enough to tackle the challenges. In this regard, the novel technology of smart grid has been introduced in the literature which excels in the exciting features like communication expertise, computational facilities, control schemes and different measuring devices

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with present grid. Furthermore, smart grid qualifies bidirectional course of information concerning utility and consumers as presented in Fig. 1. In addition, smart grid has blessed the users to now become prosumers. The modern users are proficient enough to retail their produced electrical energy to the utility companies. It has been observed that utility is attracted in revenue percentage increase with the decline in Peak to Average Ratio (PAR).

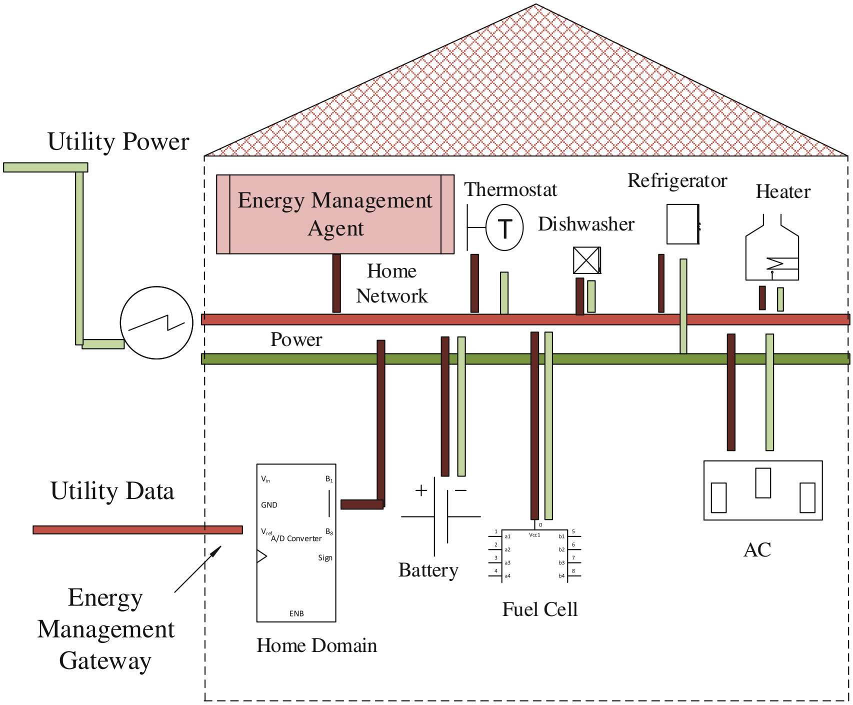

Fig. 1. Smart grid

Demand Side Management (DSM) is considered one of the significant features of a smart grid. DSM is regarded as the preeminent elucidation in order to sustain equilibrium between demand and supply. Moreover, administration of load and Demand Response (DR) is core utilities of DSM. On the subject of load administration, it is beneficial in lessening of peak power plants, effective consumption of power and decline in electricity cost of the smart grid in terms of dependability and tractability [2]. Nonetheless, DR is an approachable accomplishment in use by dint of a consumer, contrary to dynamic pricing schemes. The extremely instable nature of the load may perhaps creep up the reliability of the grid in a trice. Consequently, DR [3] is supposed to be significant in order to handle the qualms such as it is responsible for litheness at comparatively low tariffs. Generally, DR is alienated in two classifications: incentive DR program and price DR program.

The association of supply and demand are further precisely imitated by dynamic pricing schemes rather than flat rate pricing schemes. Time of Use (ToU), Inclined Block Rate (IBR), Critical Peak Pricing (CPP), Day Ahead Pricing (DAP), Real Time Pricing (RTP) and others are some of the dynamic estimating prices. These tariffs reassure the consumers to transfer high power load to off-peak hours as it will reduce the PAR and cost. RTP is deliberated as an utmost proficient pricing scheme for power fairs [4] and offers buyers statistics about the real price of electrical energy at any specified time.

The paper discusses Home Energy Management System (HEMS) in order to diminish the PAR by shifting of peak load from on-peak hours to off-peak hours to moderate the cost. One of the motivation for this study is all-encompassing usage of electrical energy in local and residential region. According to a recent survey, 21% of entire energy is being expended by domestic erections [5] which is accumulative each year promptly. The study has been a hot debate topic in literature from recent years as consumption of energy and its efficient management has become a goal for scholars. The paper presents the literature review and depicts the mechanism of smart grid optimization in Sect. 2. Consequent to this, Sect. 3 highlights the associated problem concerning the on-peak hours and its significances on the grid and user and Sect. 4 integrates the proposed elucidation of emphasizing complications with a complete depiction of formerly used methodologies GA and CSA. Moreover, the outcomes are demonstrated and substantiated on the base of simulation in Sect. 5. Section 6 accomplishes the study with future work.

2 Related Work

The accumulative need for electrical energy in the grid and the request to handle the electrical energy consumption efficiently has been premeditated in a number of mechanisms in the literature. A lot of methodologies have been recommended and executed in order to cope with power consumption and lessen the cost. This paper presents some significant papers that address this specific issue associated with this work.

2.1 Hybrid Techniques

The authors in [6,7] achieved the instability of the load during on-peak and off-peak hours. Besides, the goals of reduction of PAR, lessened cost plus increased User Comfort (UC) were also succeeded using hybrid techniques. The methods of Hybrid Genetic Wind Driven (HGWD), knapsack and multi-knapsack problem, Wind Driven Optimization (WDO), Binary Particle Swarm Optimization (BPSO) Bacterial Foraging Optimization Algorithm (BFOA) and Genetic Algorithm (GA) were used as proposed techniques in these papers.

An optimum load scheduling was the main objective between the appliance and cost effectiveness in [8] by means of BPSO with the pricing signal of ToU. In this scenario, the users were characterized on the basis of setting up the specified criteria of the appliances. Furthermore, conventional consumers were devoid of HEMS and assumed to be carefree of utility cost. Conversely, smart users were supposed to be well acknowledged with the HEMS design while the smart prosumers yield some energy from Renewable Energy Sources (RES) other than consumption. In this paper, HEMS was specified as the mark and reduction of cost was done. Nonetheless, UC and RES were found middle ground.

A Realistic Scheduling Mechanism (RSM) was proposed by [9] to condense user distress of a customer in the pricing scheme. This was attained by categorization of the appliances which had highest priorities and further lower ones. The classification recommended was activity dependent appliance, occupancy dependent and independent appliances and the set of rules significantly to their working intervals.

2.2 Dynamic Programming Techniques

Power transaction as well as scheduling of load with the incorporation of RES was achieved by [10] by means of Dynamic Programming (DP). A load control procedure for DSM was proposed for this scenario and DP was used to set up the functioning time of various categories of appliances. Besides, game hypothetical methodology was used to model the superfluous power generation which assists the user to sell their extra generated electrical power. Moreover, they could further offer it to domestic consumers at a subordinate value as compared to the buying price enforced by the electric company. That possibly will buoy up the usage of RES and thus consumers can consume the surplus power locally, which reduces the reverse power flow problem. Though, the original installation cost of RES was not considered.

2.3 Evolutionary Techniques

The aim of reduction in cost and taking full advantage of UC was accomplished by [11,12] by means of GA. They also scheduled appliances in different categories. In this regard, authors anticipated an instantaneous HEMS using scheduler, which used a GA in the company of RTP with IBR to control the uncertainty of classification or power failure. The projected pricing scheme arrangement accomplished better results and gratified all profits for both domestic and utility corporations. On the contrary, a relative examination of GA, BPSO and Ant Colony Optimization (ACO) techniques also took into account. Moreover, the outline of scheduling scheme with GA and other concerns of RES and Battery Storage System (BSS) was motivated as well. This particular objective was intended to decrease the electricity bill charges and get the most out of the UC. It was observed that RES reduced the load on the utility and offered the prospect for end users to accumulate their formed electricity for further usage when needed. In this scenario, BSS was not an operational idea for the real world as it has high installation and conservation charges.

2.4 Linear and Fractional Programming Techniques

The scheduling of appliances on different time slots and power rates was done by [13]. Load scheduling was accomplished in DSM for 24 h using the integer linear programming technique. Besides, branch and bound method put into practice so that UC can be scheduled. The anticipated solution can be functional in the domestic environment and local area. The scheduling of appliances was done by HEMS in built-up environment. Moreover, the proposed mechanism progresses the performance of the power grid by decreasing the PAR. Conversely, the UC and RES were not deliberated.

The authors in [14], mostly laid emphasis on electricity consumption. The Distributed Energy Resources (DER) were combined with smart house that delivered the substantial influence on the cost efficiency. The consumer can enhance the consumption scheduling and a new load scheduling algorithm was also developed to enhance the cost efficiency by using the innovative fractional programming tool. The DER were also combined with algorithm design and optimization was achieved. The cost efficiency was enhanced by optimal scheduling ever since the indicator of previous consumption behavior was delivered. Nonetheless, cost minimization was not measured by simulation.

2.5 Other Techniques

The authors in [15] put forward the concept of a weighted graph. The system could distinguish the requirement of energy for users that is much closer to the optimal need. The performance of the anticipated structure was assessed by way of different performance metrics which took account of peak-demand, demand variation, energy cost and the utility of the customers. Moreover, the simulations illustrated that the dynamic scheduling scheme, i.e., Dynamic Demand Scheduling (D2S), conceded enhanced performance in contradiction of the existing ones.

The regionalized structure was proposed by [16] in which the DR mechanisms for the inhabited operators were focused in order to minimize electrical energy bills and maximize the UC. In this context, customers Smart Meters (SM) integrated Home Load Management (HLM) modules to interchange the load allied data. Fast convergence rate and optimal arrangement were accomplished deprived of giving in waiting time as well as cost. The projected methodology congregated after scarce instants self-sufficiency of given size. The power effectiveness of smart grid and Smart Home Security (SHS) was discussed by [17]. It was a case study that designated the petition of electrical energy in the countryside of Colombia. The compromise was observed between the demand of electricity limit and UC.

3 Proposed System Model

The DSM facilitates more proficient and consistent grid processes in a smart grid. The two central utilities of DSM take account of demand side control activities and energy management for end consumers. Likewise, the DSM reassures the customers to put away a maximum of their energy requirements for the period of off-peak hours. Moreover, the smart meters consents bi-directional communication between utility companies and the purchaser as shown in Fig. 4. The users are capable to notify the utility on the subject of their power consumption configuration by means of smart meters. A number of optimization methods have been put into practice in this decade to elucidate the optimization problem in smart grid. In this paper, a single home is taken as an experimental model with six pieces of equipment. In this regard, the appliances are categorized into three sets: set A, set B and set C as illustrated in Fig. 2. The set A comprises of the interruptible appliances which consist of lights only. The appliances in this set can be turned on all through the day and any time. Besides, the set B encompasses base appliances like refrigerator and AC. The set C of appliances includes non-interruptible equipment's such as toaster, kettle and cloth washer.

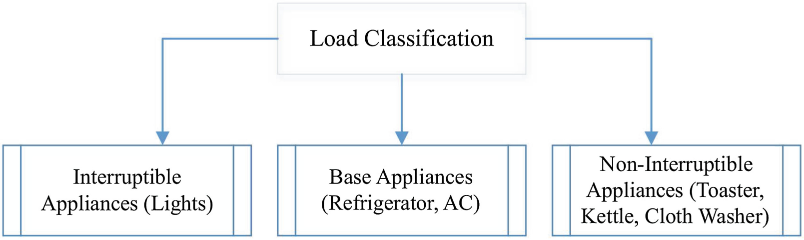

Fig. 2. Load classification

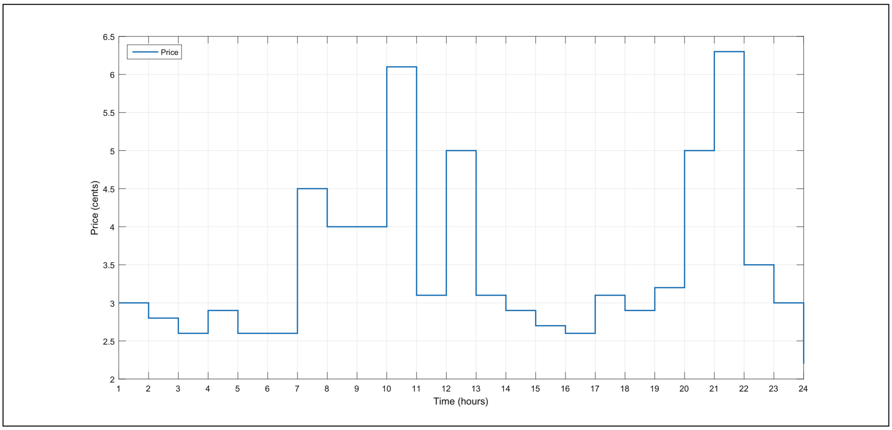

Fig. 3. RTP signal

The RTP pricing scheme is used for calculation of the electrical energy bill in this paper as shown in Fig. 3. In addition, the power consumption of every machine is assessed in kilo Watt hour (kWh). The categorization and power consumption of each appliance is specified in Table 1. The main aim of this research is the decline of PAR and reduce the consumption of power in order to lessen the rate of energy. Furthermore, the paper lay emphasis on the decline of total cost with reduction of peak load. The total cost, load and PAR are premeditated in Eqs. 1, 2 and 3 respectively.

$$TotalCost = \sum_{h=1}^{24} t_i(E|_1^h * \int_1^6 P) \tag{1}$$

$$TotalLoad = \int_1^6 P * A(\forall appliances \in A) \tag{2}$$

$$PAR = \lim_{x \to \infty} Avg(TotalLoad)^{-1} * \max(TotalLoad) \tag{3}$$

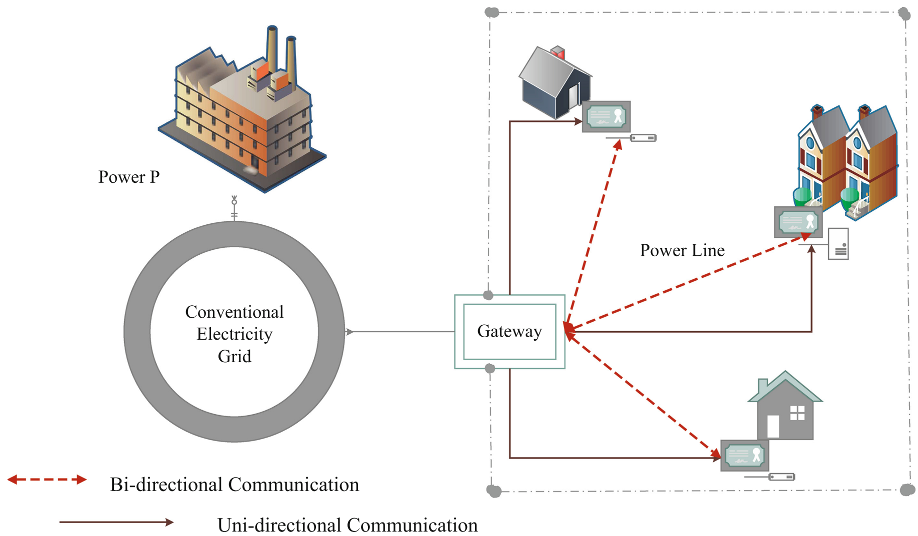

Fig. 4. Autonomous DSM in smart grid

4 Proposed Methodology

Lots of optimization methods have been premeditated in literature to tackle the smart grid associated complications. Likewise, numerous methodologies of artificial intelligence have been used to improve a capable system to find the solution near to optimal. GA is supposed to be the common approach among others as it is accustomed to find the paramount optimal elucidation from the group of specified chromosomes. The Crow Search Algorithm (CSA) is a population centered method which indicates that crow stock their leftover foodstuff in smacking places and recover it when the sustenance is desired. The paper scrutinizes the GA and CSA and evaluates which of the technique performs efficiently and gives better optimal results in the classification.

4.1 Genetic Algorithm

The Genetic Algorithm is an accepted selection procedure which is centered on the human heredities. It uses the unsystematic search heuristic methodology to resolve the constrained and unconstrained optimization complications. Generally, the practices surveyed in GA follow the standard "survival of the fittest" specified by Charles Darwin [18]. Moreover, GA is mostly appropriate for intricate non-linear models where the position of the inclusive most favorable solution is a challenging task. Nevertheless, GA does not assure optimality even though when it influences the solution owed to the prospect nature for expansion of result.

Table 1. Classification of appliances

Group	Appliances	Power rating (kWh)	Daily usage (Hours)
Interruptible base load	Lights	0.5	10
Base load item	Refrigerator	0.2	14
	AC	1.4	12
Non-interruptible base load	Toaster	1.14	1
	Kettle	1.2	3
	Cloth washer	0.7	2

The instigation of GA starts with the chromosomes populace and latterly new population is carefully chosen on the base of suitability value. The key segments of GA take in the following [19]: selection, crossover and mutation. In selection procedure, the fitness significance is assigned by calculating the procedure with genomes. The finer one is acknowledged by their fitness significance. Subsequently, two individuals are nominated from the selection procedure in crossover method. The selected one is in the form of bits, which then go through phases of crossover. However, the crossed bits are supposed to be the enhanced elucidation instead of the optimal solution. Furthermore, the ration of the new individuals will have more or less of their bits flicked or turnover with an approximately low prospect in mutation phase.

Algorithm 1. Genetic Algorithm

Initialize all parameters (α_a,β_a,τ_a)
Set bounds
for all the appliances **do**
  Generate an initial random population
  while $itr<maxItr$ **do**
    itr=itr+1
    calculate fitness function of each individual
    select individual according to fitness function
    choose pair for crossover according to roulette
    perform crossover with prospect P_c
    perform mutation with prospect P_m
  end while
end for

4.2 Crow Search Algorithm

The CSA is a population based meta-heuristic algorithm [20]. The major ideologies of CSA include some aspects which include: crows live in the group, crows commit to memory the location of their hiding spaces, crows follow each other for purposes of pilfering and crows defend their accumulations from being stolen by a possibility. The strengthening and modification in CSA is mostly measured by the constraint of Awareness Probability (AP). CSA has a tendency to demeanor the hunt on a limited area where a recent good way out is instituted by reduction of the AP value. Contrariwise, the prospect of examining the locality of recent good results declines and CSA lean towards the search space on an inclusive measure (randomization) by the escalation of the AP. Consequently, the usage of large values of AP upsurges divergence [21]. In the initialization of the problem, the decision variables are demarcated. Successively, the adaptable parameters of CSA like flock size (n), maximum iterations (maxiter), length of flight (fl) and the AP are esteemed. The flock size is then randomly located in a N-dimensional search space as shown in Eq. 4.

$$Crows = \begin{pmatrix} C_{1^1} & C_{2^1} & \cdots & C_{N^1} \\ C_{1^2} & C_{2^2} & \cdots & C_{N^2} \\ \vdots & \vdots & \ddots & \vdots \\ C_{1^n} & C_{2^n} & \cdots & C_{N^n} \end{pmatrix} \tag{4}$$

Here every crow signifies a viable clarification of the problem respectively. The memory for each crow is primed as depicted in Eq. 5. The memory for each crow is primed.

$$Memory = \begin{pmatrix} M_{1^1} & M_{2^1} & \cdots & M_{N^1} \\ M_{1^2} & M_{2^2} & \cdots & M_{N^2} \\ \vdots & \vdots & \ddots & \vdots \\ M_{1^n} & M_{2^n} & \cdots & M_{N^n} \end{pmatrix} \tag{5}$$

Algorithm 2. Crow Search Algorithm

Randomly initialize the position of flock of N crows (α_a,β_a,τ_a)
Evaluate the position of the crow
Initialize the memory of each crow
while $itr \leq iter^{max}$ **do**
  for $i = 1 \rightarrow N$ **do**
    randomly get the crow j to follow i
    Define awareness probability
    if $r^j \geq AP^{j,iter}$ **then**
      $x^{i,iter_1} = x^{i_iter} + rix(m^{j,iter} - x^{i,iter})$
    else
      $x^{i,iter} = arandompositionofsearchspace$
    end if
  end for
  Check the feasibility of new position
  Evaluate the new position of the crows
  Update the memory of crows
end while

The superiority of location is calculated for each crow by dint of introducing the values of decision variable hooked on the objective function. Then new population is generated and the feasibility of new positions is checked for each crow. Moreover, the fitness function of new positions is evaluated and memory is updated until the termination criteria is reached.

5 Results and Discussion

This section provides a brief description of simulation results. The experimentations and simulations were conducted in MATLAB in order to calculate the performance of the GA and CSA. The algorithms were assessed on the basis of electrical energy cost, power consumption, PAR and waiting time. The RTP tariff scheme is used for energy bill calculation as shown in Fig. 3 and discussed in Sect. 3.

The Fig. 5 expresses the variance of the entire cost among unscheduled and scheduled patterns. It can be evidently noticed that CSA succeeds having minimum cost as compared to GA. Besides, the Fig. 6 exemplifies the power cost for each hour for the GA and CSA. The consequences indicate that price compensated for the duration of on-peak hours is truncated in contradiction to unscheduled load since load for the period of on-peak hour has been budged to off-peak times. Moreover, 75% and 85% maximum load during on-peak hours is abridged in CSA and GA respectively. It is clear that CSA disturbed the load optimally and beats the GA scheduling by 5% approximately.

In addition, the waiting time is premeditated in terms of user comfort. There exists a trade-off concerning power cost and waiting time. The paper describes the waiting time as the period when a customer time lags for an appliance to turn ON. Similarly, off-peak hour or low price hour should be favored by end users to decrease power bills. Conversely, if luxury is chosen, then the customers will not delay for their processes to be executed. Thus, consumers have to find the middle ground for cost. The Fig. 7 presents user comfort of the consumer for techniques of CSA and GA. The records display the inverse association between cost and waiting time in cooperation.

The decrement of PAR supports to maintain the steadiness of the grid and it progresses the capability and adeptness of the grid as well. The performance of CSA and GA is illustrated in Fig. 8 for PAR. It can be noticed that the PAR of CSA is approximately 9% lower contrary to GA. Furthermore, the PAR of CSA and GA both are less as compared to unscheduled one. Nonetheless, the Fig. 9 shows the total load. The Fig. 10 signifies the consumption of power for each

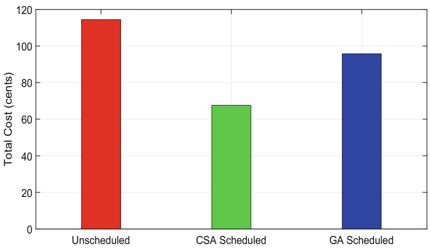

Fig. 5. Total cost

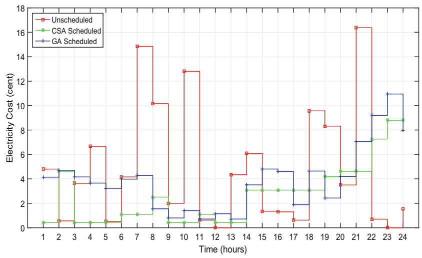

Fig. 6. Electricity cost per hour

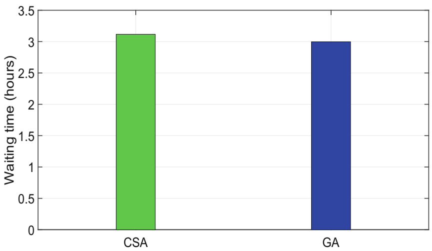

Fig. 7. Average waiting time

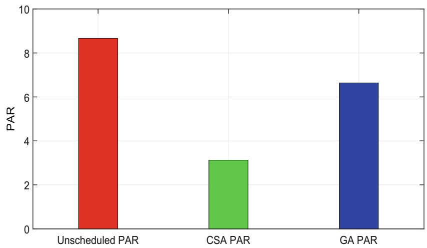

Fig. 8. Peak to average ratio

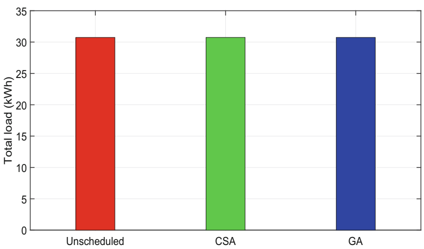

Fig. 9. Total load

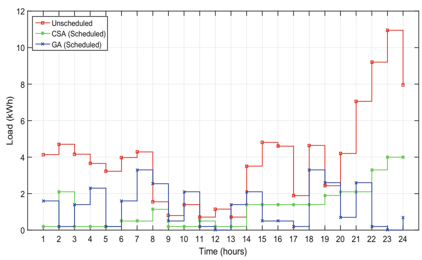

Fig. 10. Hourly energy consumption

hour afore and prior to scheduling. Moreover, the inclusive power consumption in scheduling case is fairly optimum and comparatively low.

6 Conclusion and Future Work

The paper estimates the challenge of domestic load management for different categories of appliances. In this regard, the piece of equipment's was arranged on the basis of their energy consumption pattern. Moreover, the performance of the meta-heuristic algorithms was calculated on the basis of cost decline, energy consumption, user comfort and PAR reduction. Besides, there was a trade-off between waiting time (UC) and electricity cost as illustrated from simulations. CSA demonstrated the efficiency in terms of cost as compared to GA with RTP pricing scheme. Likewise, the concentrated power consumption was abridged as well during on-peak hours in contradiction to unscheduled one. The load was also well-adjusted as per mandate and shifted towards off-peak hours shorn of generating the ultimate load. For the future, the integration of RES will be considered in smart grid for further decline in cost.

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A Machine Learning Approach for Ranking in Question Answering

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Abstract. Question Answering is a challenging topic and is gaining growing attention in last years being an interesting interdisciplinary research area and having practical application. In this paper we focus on the answer selection, a step of Question Answers that selects answers to the questions from among the answer candidates based on the result of question analysis. This process can be very challenging, as it often entails identifying correct answers amongst many incorrect ones. In particular, we focus on the ranking of the answers based on Italian language and referring to a dataset that is closed-domain, containing questions about cultural heritage with successive True or false answers. In this paper we demonstrate that, using an approach based on classification, we can reach a very high accuracy that is better than the accuracy reached with other approaches based on fuzzy logic.

Keywords: Machine learning · Question answering · Hypothesis generation · Smart health

1 Introduction

Question answering (QA) is a challenging topic due to its central role in digital assistants like Siri, Google Assistant, Alexa, and Cortana, and in cognitive systems like Watson [14]. Research in the field of Question Answering attempts to address an heterogeneous and varied type of questions: facts, lists, definitions, hypotheses, etc. Question Answering systems use knowledge bases or corpora documents from which they extract information to try to find answers to questions posed. The size of these collections can range from small corpora to the entire world wide web. Literature has usually split the Question Answering into two sub-domains:

- Closed domain: questions, and consequently their answers, typically belong to a single domain. In QA Close Domain, the knowledge base can be composed of a small number of documents. It is also possible to use ontologies or domain language resources;

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– Open domain: questions can address any topic and if one can not exploit domain language resources on the other hand the available collections contain a huge amount of data from which to extract the information.

Another classification is based on typology of question that can be classified in:

– Reality questions (factoid): Questions about the world's general culture with successive True or false answers.
– Questions on subjective belief: with "irrelevant/unacceptable" or "relevant/acceptable" responses.

Traditional question answering (QA) systems typically employ a pipeline approach, consisting roughly of question analysis, document/passage retrieval, and answer selection [5]. In this paper we focus on answer selection, that selects answers to the question from among the answer candidates based on the result of question analysis. This process can be very challenging, as it often entails identifying correct answer(s) amongst many incorrect ones [13]. In particular, we focus on the ranking of the answers, that is the last step of a pipeline implemented and described in [7]. The developed approach for QA is based on Italian language and refer to a dataset that is closed-domain, with questions about cultural heritage with successive True or false answers.

In this paper we demonstrate that, using an approach based on classification, we can reach a better accuracy than the one described in [14], that is related to the same pipeline and the same dataset used in this paper, but is based on fuzzy logic.

2 Related Work

Research in the field of Question Answering attempts to address an heterogeneous and varied type of questions: facts, lists, definitions, hypotheses, etc. Question Answering systems use knowledge bases or corpora documents from which they extract information to try to find answers to questions. The size of these collections can range from small corpora to the entire world wide web. In literature, it is common to divide the Question Answering into two sub-domains: the closed domain, where questions, and consequently the answers, typically belong to a single domain. In QA Close Domain, the knowledge base can be composed of a small number of documents and it is also possible to use ontologies or domain language resources. Open domain can address any topic and the available collections contain a huge amount of data from which to extract the information. Question Answering was born within the research field of Artificial Intelligence and from this has drawn many techniques especially aimed at analysing and understanding the language. One of the main areas covered by Artificial Intelligence is automatic learning, known in literature as Machine Learning. The aim pursued by this field of the AI is the design and implementation of systems capable of synthesizing new knowledge, starting from the observation of a set of sample data. In general here is a great deal of interest both in Machine Learning [11] and Question Answering in several domains [10] and also in applying

Machine Learning techniques for Question Answering. In [2], authors consider the problem of ranking a set of instances and demonstrates proving a theorem and a number of lemmas, that the ranking problem can be reduces to a classification problem. Moreover authors show that there is a robust mechanism for translating any binary classifier learning algorithm into a ranking algorithm.

Many existing approaches to ranking take advantage of the fact that ranking may be reduced to classification [9]. In particular, in [9] using this reduction, authors propose a framework designed in the DeepQA system and the capabilities it provides for applying machine learning techniques discussing how capabilities of that framework can address the challenges in this domain and showing an experimental evaluation that demonstrates the improvements in system accuracy. In [6] authors propose a learning to rank (L2R) approach for ranking answers in Q&A forums approach based on Random Forests performing a set of experiments using a Q&A test collection extracted from Stack Overflow. Authors also perform a comparative analysis between different machine learning methods in the task of ranking answers. In [16] authors evaluate a number of machine learning techniques for the task of ranking answers to why-questions obtaining he optimum score by Support Vector Regression for the pairwise representation, and reasonable results with SVM and Genetic Algorithm (GA). Logistic Regression Models are used in [15] and in [9] where researchers experimented with a number of different machine learning techniques, but settled on regularized logistic regression which consistently performed better.

3 General Approach

To classify documents, you need to decide which parts to consider features of the document before you begin. In other words you have to find the ones that are the constituent elements of the text in question. This set takes on the feature set name. Clearly choosing the type and number of features to consider during the learning will affect the whole analysis and, consequently, the results. In the face of such motivations, it is evident that the ultimate purpose of the analysis is clear in order to make an accurate choice of the features. Features that can be used in learning are different and you can always find new ones according to your specific needs. In Question Answering, as well as in Information Retrieval, having the need to analyse texts written in natural language, fractured reference to feature types whose analysis has now become very affirmed in the literature of these two fields.

In Question Answering what is most often required of such techniques is the ability to learn a labeling feature that can then be used to predict the values of a finite class of attributes. More formally we can say that for the learning phase, we use a set of data records described by a set of attributes

$$A = A_1, A_2, ...A_{|A|}$$

where

$$|A|$$

denotes the number of attributes, that is, the size of A.

This dataset also contains a special set of classes

$$C = c_1, c_2, .., c_{|C|}$$

With

$$|C| > 2.$$

The training set can then be seen as a table of Relationship between classes and attributes in which each record in the table describes A part of past experience, that is, a basis for learning (Fig. 1).

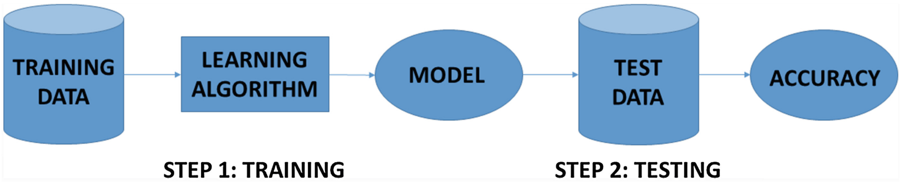

Fig. 1. General approach

Given a data set D, the learning objective is the production of a predictive classification function. Learning takes place on the training set. By learning a model, using a learning algorithm, this is evaluated with the help of a testing dataset that is designed to evaluate the accuracy of the system, as shown in Fig. 4. The accuracy of the system is calculated as:

$$Accuracy = \frac{Number\ of\ Correct\ Classifications}{Total\ Number\ of\ Test}$$

Different learning algorithms are reported in the literature as described in Sect. 2. We analysed the performances of the algorithm described in the following sections.

3.1 Random Forest

Random forests [3] is an ensemble classifier that consists of many decision trees and outputs the class that is the mode of the class's output by individual trees. Random Forests are a combination of tree predictors such that each tree depends on the values of a random vector sampled independently and with the same distribution for all trees in the forest [3]. The algorithm operates by constructing a multitude of decision trees at training time and outputting the class that is the mode of the classes (classification) or mean prediction (regression) of the individual trees. The generalization error for forests converges as to a limit as the number of trees in the forest becomes large. The generalization error of a forest of tree classifiers depends on the strength of the individual trees in the forest and the correlation between them [3]. It is one of the most accurate learning algorithms available. For many data sets, it produces a highly accurate classifier.

3.2 Multi-Layer Perceptron (MLP)

The multilayer perceptron consists of a system of simple interconnected neurons, or nodes, which is a model representing a nonlinear mapping between an input vector and an output vector. The nodes are connected by weights and output signals which are a function of the sum of the inputs to the node modified by a simple nonlinear transfer, or activation, function [8]. Layers of different sizes can be chained and the output of each layer is computed using the same mechanism. It is the superposition of many simple nonlinear transfer functions that enables the multilayer perceptron to approximate extremely non-linear functions. If the transfer function was linear then the multilayer perceptron would only be able to model linear functions. Due to its easily computed derivative a commonly used transfer function is the logistic function. The output of a node is scaled by the connecting weight and fed forward to be an input to the nodes in the next layer of the network. This implies a direction of information processing hence the multilayer perceptron is known as a feed-forward neural network.

3.3 Support Vector Machine

In machine learning, support vector machines (SVMs) [4] are supervised learning models with associated learning algorithms that analyse data used for classification and regression analysis. Support vector machines are based on the Structural Risk Minimization principle from computational learning theory. The idea of structural risk minimization is to find a hypothesis H for which we can guarantee the lowest true error. The true error of H is the probability that H will make an error on an unseen and randomly selected test example. An upper bound can be used to connect the true error of an hypothesis H with the error of H on the training set and the complexity of H measured by VC-Dimension, the hypothesis space containing H. Support vector machines find the hypothesis H which approximately minimizes this bound on the true error by effectively and efficiently controlling the VC-Dimension of H. SVMs are very universal learners [12]. In their basic form, SVMs learn linear threshold function. Nevertheless, by a simple plug-in of an appropriate kernel function, they can be used to learn polynomial classifiers, radial basic function RBF networks, and three-layer sigmoid neural nets.

3.4 Logistic Regression

Logistic regression [9] is a statistical method for analysing a dataset in which there are one or more independent variables that determine an outcome. Logistic regression produces a score between 0 and 1 according to the formula:

$$f(x) = \frac{1}{1 + e^{-\beta_0 - \sum_{m=1}^{M} \beta_m x_m}}$$

where m ranges over the M features for instance x and β_0 is the bias. An instance x is a vector of numerical feature values, corresponding to one single occurrence of whatever the logistic regression is intended to classify. Output f(x) may be used like a probability, and learned parameters β_m may be interpreted as the contribution of each feature.

3.5 Experimental Results

For the experimental phase have acquired a collection of questions under the Cultural Heritage domain, using a manually annotated gold-standard dataset containing 907 questions and the related answer's features described in [7].

The software that has been utilized for machine learning in the experimental phase is KNIME Analytics Platform (Konstanz Information Miner)[1], an open source software issued under the GNU General Public License. KNIME has a modular data pipelining concept that integrates various components for machine learning and data mining. A graphical user interface allows assembly of nodes

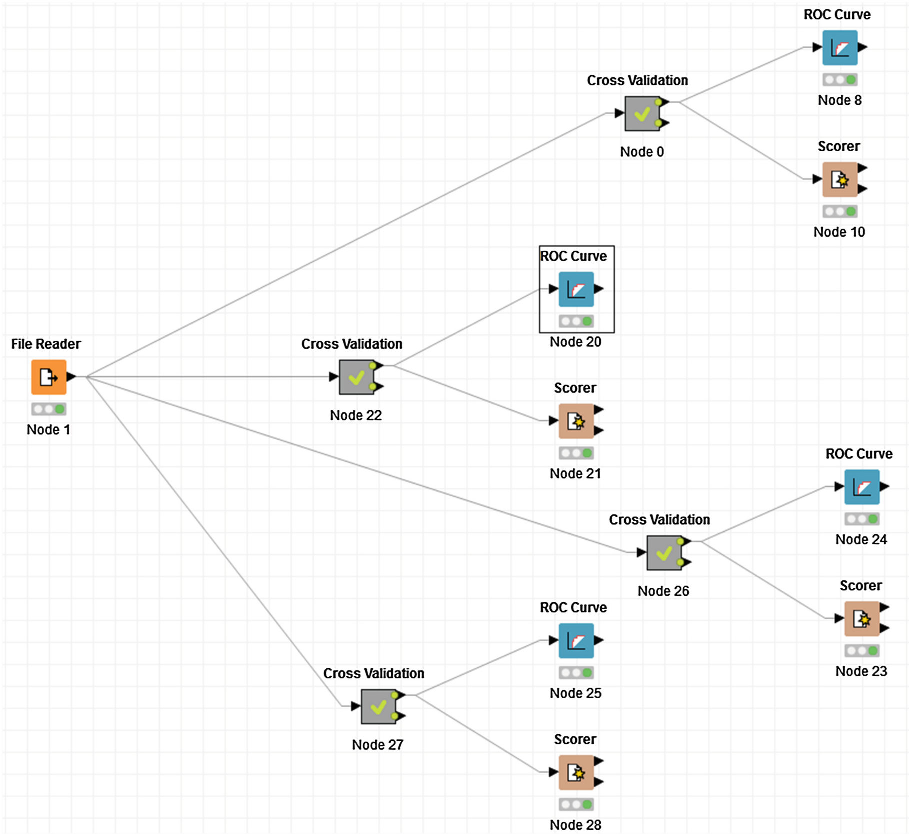

Fig. 2. Knime flow

[1] https://www.knime.org/.

for data pre-processing, classification, regression, clustering, association rules, and visualization. Moreover tools for data mining and machine learning schemes are provided (Fig. 2).

We create a training test and a test set containing 80% and 20% of the dataset, respectively randomly selected.

We create four parallel execution using the Weka implementation of the four algorithm described in the previous section. The decision of utilize Weka algorithm is due to the fact that, according to several papers that propose an evaluation of several of the most popular Open Source and Free Data Mining Tools [1,17] WEKA outperforms the highest accuracy level and subsequently the best performance.

The Random Forest (RF) algorithm setting was: number of trees to build = 100.

An analysis of the internal and external performances of the selected models has been provided by calculating several parameter such as the sensitivity (true-positive rate), specificity (true-negative rate) and accuracy (overall

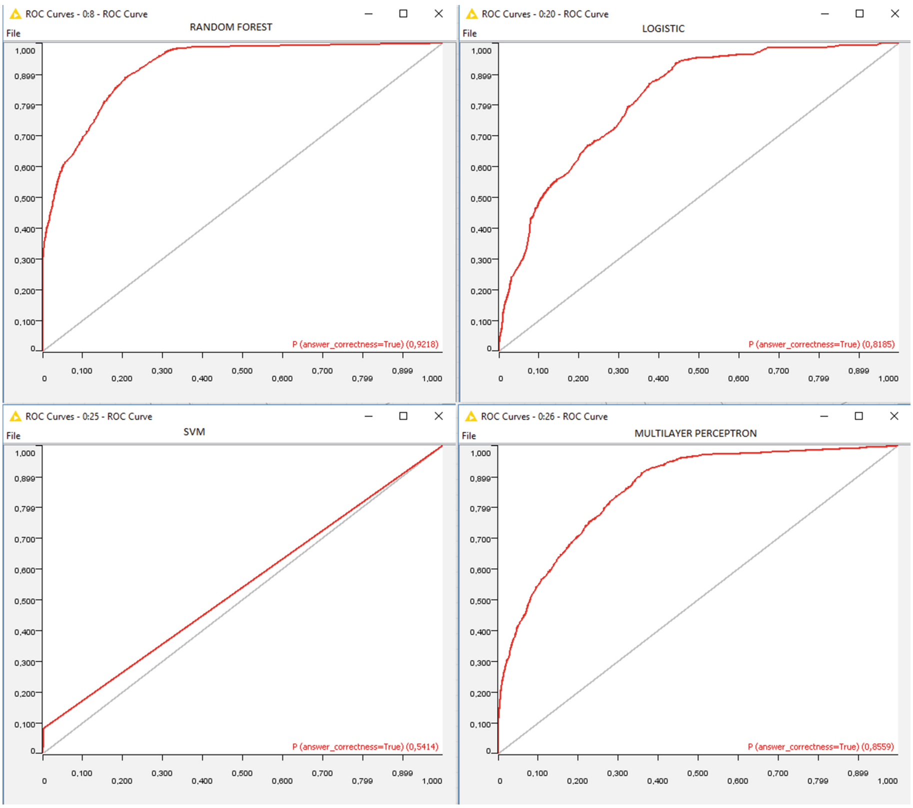

Fig. 3. ROC curves

predictability). In addition, the areas under receiver operating characteristic (ROC) curves were employed to describe true performance with more clarity then accuracy. The plotted ROC curves show the true-positive rate, either versus the false-positive rates or versus the sensitivity as shown in Fig. 3.

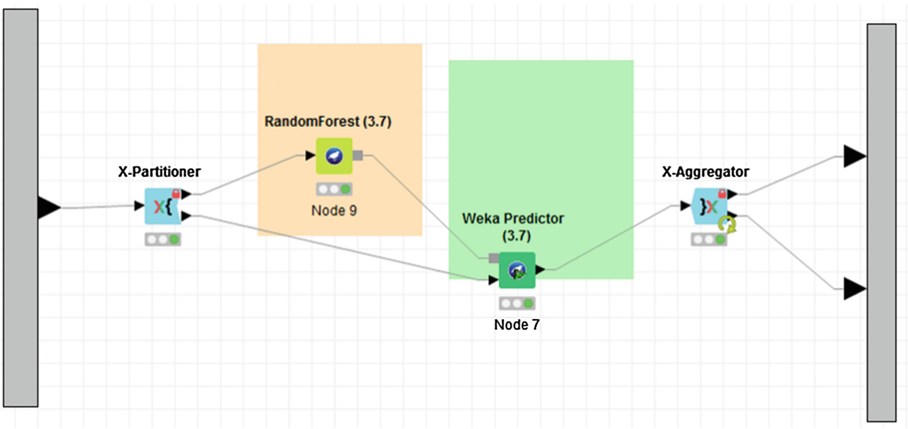

Fig. 4. Cross validation

For internal validation, we employed a k-fold cross-validation, with k = 10. It consists of randomly partition of the original sample into 10 equal sized subsamples. A single subsample of the 10 subsamples was retained as the validation data for testing the model while the remaining k − 1 subsamples were used as training data. The cross-validation process was then repeated 10 times (that constitutes the folds), using each of the 10 subsamples exactly once as the validation data. In order to produce a single estimation, the 10 results from the folds were then averaged. The advantage of this method, over repeated random sub-sampling, is that all observations are used for both training and validation, and each observation is used for validation exactly once (Fig. 2).

As shown in Table 1 all the algorithm reached a better accuracy than the fuzzy approach proposed in [14] and the best accuracy was reached using the Random Forest.

Table 1. Accuracy

Algorithm	Accuracy
Random forest	0.9309662888429071
Multilayer	0.9140283093149731
SVM	0.9070333815531669
Logistic	0.9012286901906209

The approach using Random Forests (RF) has been shown consistently effective in this experimentation. Among its advantages, we cite its insensitivity to parameter choices, its resilience to overfitting, and its high degree of parallelization.

The dataset that we used for the experimental phase is a small one so we do not investigate scalability issues, in terms of time and space complexity. Nevertheless, in the case of huge dataset or Open Domain QA it is necessary to parallelize the processes designating specific nodes to be run on separate machines in order to support scalability.

4 Conclusions

Question answering is a challenging topic that is gaining attention in recent years. In this paper a machine learning approach was proposed for ranking answers in QA. The proposed approach is applied using and comparing several algorithm of machine learning on an original dataset based on Italian language. Evaluation results show that Random forest as a classifier proved to outperform the other techniques. Ongoing work is focused on addressing similar problems in Open-domain question answering. In this case, the idea is to designate specific nodes to be run on separate machines, allowing parallelization of the processes in KNIME thanks to its modular architecture. In this way it is possible to improve scalability performance.

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Detecting Malware Based on Opcode N-Gram and Machine Learning

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Abstract. Due to its seriously damage to computer and network, malware (short for malicious software) has caught the attention of both anti-malware companies and researchers for decades. Although signature-based detection is the most significant method used in commercial anti-malware, it fails to recognize new and unseen malware. To solve this problem, n-gram of the Opcodes, generated by disassembling the executables, is used to be the features for the classification process. However, many researches in the past set n small such as 1 or 2. In this paper, firstly, we use various n-gram size from 1 to 15. Then we compare different feature select methods. Lastly, we perform experiments with different MFP, short for malicious files percentage to demonstrate which setting is better.

1 Introduction

The term malware (e.g., virus, worm), short for malicious software, is created to damage or destruct modern computer and network without owners' authorization. Malwares are classified into several categories: worms, viruses, Trojans, backdoors and so on. The rapid development of information technology has led to an increase in the creation of new malwares for various purposes which are based on political, economic, terrorist or criminal motives. Some of these malwares are used to steal sensitive information such as password and some are deployed to threaten the hosts and services. Due to the enormous loss and adverse effect cause by malware, malware detection has been one of the network security issues.

In order to protect legitimate users from the attacks, the most significant way to defense against malware is anti-malware, which mainly use signature-based method to detect malware. This method relies on identification of unique strings in the binary code. While signature-based method is fast to identify known malware precisely, it fails to recognize unknown malicious code and it is a tough work which requires a great deal of time, funds and expertise. In fact, such signature-based method can be easily bypassed by simple obfuscation techniques. Due to the economic benefits, the growth of creating malware is at a high speed.

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To solve the problems existed in the signature-based method, heuristic-based method, which utilizes machine learning as well as data mining, is proposed to detect unknown characteristic features for both malicious samples and benign software. Then these extracted features are used to build classification tools, which can predict the software in the test set. For example, Schultz et al. [1] were first to introduce the idea of applying data-mining methods to detect different malware based on their respective PE files. Application Programming Interface calls, system calls, byte codes and opcodes are usually selected to be features in the training phase.

In this paper, we use a representation based on opcodes (i.e., operational codes in machine language). To select the suitable features which will be used to train the classification, we use Information Gain and Categorical Proportional Difference, which are widely used in text categorization. At last, we use the trained model to detect sample in the test set. The main contributions of this paper can be summarized as follows:

Well represented feature for malware detection: opcode sequences are extracted from the PE (Portable Executable) files as the preliminary feature, from which the top features are selected using information gain and categorical proportional difference. Such kind of features can be easily used to represent the PE files.

Extensive factors in this paper: Not only we extend the opcode n-gram size which is ranging from 1 to 15, but also extend the malicious files percentage between 30% and 70%.

Comprehensive experimental studies: We conduct a series of experiments to evaluate each part of our framework and the whole system is based on real sample collection, which includes both malicious and benign PE files.

The remainder of this paper is organized as follows: Sect. 2 introduce the related work. In Sect. 3, an overview of our framework is presented. Section 4 describe the process of extraction and feature selection, we present the concept of IG (Information Gain) and CPD (Categorical Proportional Difference). Section 5 describes the classification algorithm: SVM (Support Vector Machine). Section 6 presents the evaluation method. Experimental results are presented in Sect. 7. Finally, Sect. 8 concludes.

2 Related Work

This research is an investigation into malware detection using opcode n-gram. So a summary of the related research is given here to aid the discussion within this paper. Signature-based method is widely used in anti-malware industry to detect malware [2]. An example of a signature is a sequence of bytes that is always present within a malicious executable and within the files already infected by that malware. However, this classic method always fails to detect variants of known malware or previously unseen malware, due to the fact that the signatures can be easily bypassed [3]. Malwares writer always use code obfuscation techniques [4] to hide the actual behavior of their malicious creations. The obfuscation algorithms include variable renaming, which replaces a variable identifier with another one; code reordering, which changes the order of program instructions and garbage insertion, which adds sequences that do not modify the behavior of the program. Another technique is polymorphism [5]. Polymorphic malware uses encryption to change parts of the malware which is controlled by a decryption key which is changed when the malware is executed.

To solve the problem mentioned above, two approaches have been proposed: anomaly detectors and data-mining-based detectors. Anomaly detectors use information extracted from the benign software to build a benign behavior profiles. Then this profile is qualified as suspicious as noon as a significant deviation appears. To detect malware, Cai et al. [6] used byte sequence frequencies as the information extracted only from benign software to measure the deviations. However, their method has a high false positive ratio. Data-mining-based approaches rely on datasets which include several characteristic features for both benign software and malware. Then these features are used to build classification tools that can predict unknown sample. For instance, Schultz et al. [7] introduce the idea of applying data-mining to detect different malware based on their respective PE files. They extracted three different types of features which are byte sequences, constant strings and system resource information from the files. Later these features are used as inputs for Naive Bayes, Multi-Naive Bayes and Ripper to classify benign and malicious files. Actually, the performance of the data-mining-based methods mainly relies on the features extracted from the PE files.

Over the past few years, API calls [8], machine instructions [9], byte code, system calls are widely used features. Besides these, there also exists several studies depending on other features such as data flow graph, Dynamic Link Libraries. To detect variants of known malware families, Santos et al. [10] proposed a method based on the frequency of appearance of opcode sequences. Furthermore, they describe a method to mine the relevance of each opcode and thereby, weigh each opcode sequence frequency. Fan et al. [9] used the instruction sequences extracted from the sample files as the feature which is used in the proposed sequence mining algorithm. Later, they used the malicious sequential pattern to build the All-Nearest-Neighbor (ANN) classifier. Robert et al. [11] proposed the use of (Operation Code) Opcodes, generated by disassembling the executables. They use n-grams of the Opcodes as features for the classification process. They present a full methodology for the detection of unknown malicious code, based on text categorization conceptions. Our research relies on the opcode n-gram which has been used in previous study. However, most of these researches extracted n-grams with small n such as 1, 2, 3. In this paper, not only we extend the opcode n-gram size which is ranging from 1 to 15, but also extend the malicious files percentage between 30% and 70%. At the same time, we conduct an experiment to figure out that how the sum of train set influences the classification.

3 System Architecture

Figure 1 shows the system architecture of the malware detection framework, which consists of two major components: one is opcode extractor and feature selection, another is the classifier for malware prediction. We briefly describe each component below.

1. Opcode extractor and feature selection: In this module, we used the IDA Pro to obtain the assembly files. Using the generated assembly files, we extract the opcode and

build the preliminary vocabulary. Later, we use IG and CPD to compute each opcode in the vocabulary. Then we selected the top 100 opcodes as the feature.

2. SVM classifier: In this module, the input executables (including the training samples and the testing samples) are transformed into vectors based on the feature obtained from the module above. Then the SVM is used to conduct malware prediction.

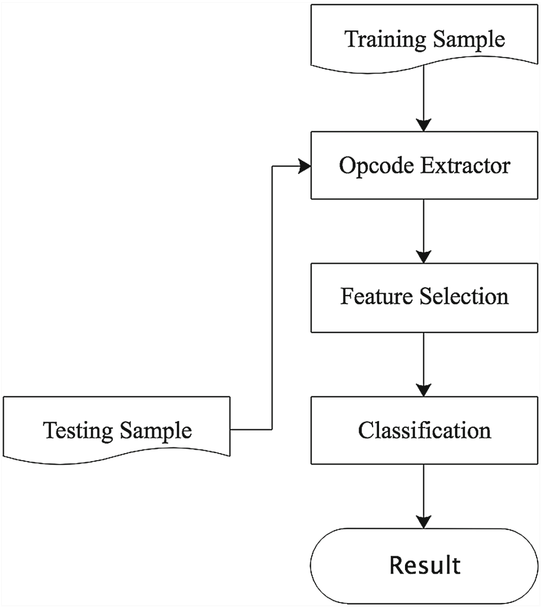

Fig. 1. The framework of detection system

The detail processes will be presented in the following two sections.

4 Opcode N-Gram Extraction and Feature Selection

In this section, we describe the method used to extract opcode n-gram from training sample set. Then we describe the feature selection method based on IG and CPD.

4.1 Representing Executables Using Opcode

An Opcode (short for operational code) is the portion of a machine language instruction which can specify the operation to be performed [12]. A complete machine language instruction consists of an Opcode and the specification of one or more operands. There are several operations of an Opcode which include program control, logical operations, data manipulation and arithmetic.

The first step is designed to represent each PE files in a long symbol sequence, where each symbol corresponds to an opcode appearing in the executable. This is accomplished by disassembling the PE files followed by parsing the opcodes, as follows:

Disassembling: A third party disassembler IDA Pro [13] is used to disassemble each sample, creating an assembly representation for the sample. Figure 2 shows an example, which is a fragment of the disassembly for the malware named Virus.Win32.Hezhi.

```
lea     ecx, [esi+3ch]
push    [ebp+var_4]
call    sub_4016F4
push    [ebp+var_4]
call    ebx
mov     ecx, esi
call    sub_401404
```

Fig. 2. A fragment of the output of disassembled Virus.Win32.Hezhi

Parsing: Based on the assembly instructions generated in the first step, a compact representation in obtained for the samples, making using of the opcodes but ignoring the operands. This is because it is the opcode which stands for the behavior of an instruction. Moreover, the machine instructions may vary across different malware variants, however, their opcodes usually remain the same. So we developed a parser in JAVA to translate the sample to a sequence of opcodes discarding the operands, encoding each opcode with a unique number (say ID). For example, the Virus.Win32.Hezhi shown in Fig. 2 now is represented in 100 103 55 22 251, with 100 and 103 being the ID of lea, push, respectively.

The second step is to create vocabulary/words corresponding to the selected n-gram size. For example, from the opcode sequence in Fig. 2, we can get opcode 1-gram: lea, push, call, mov and opcode 2-gram lea push, push call, call mov.

4.2 Feature Selection

An important task when preparing the data set is to reduce the data set complexity while maintaining or improving performance of the classification model. For this purpose, the most common approach is to apply a feature selection algorithm. The objective of feature selection is basically to apply a feature quality measure to prioritize the available features and then keep only the best features from the prioritized list. In the information retrieval domain, the bag-of-words model (in which the logical order of words has no importance) performs better than other models in representing text documents.

Different feature selection measures, such as Document Frequency, and Fisher Score, are commonly used for obtaining reduced data sets. Information Gain and Categorical Proportional Difference are relatively new additions in the feature selection algorithm family for text classification tasks. In this step, we compare the two methods

Mutual information is a measure that indicates how statistically dependent two variables are. In the context of machine learning, the term information gain is sometimes used synonymously with mutual information. The definition of mutual information is presented as follow:

$$I(X;Y) = \sum_{y \in Y} \sum_{x \in X} p(x,y) \log\left(\frac{p(x,y)}{p(x) \cdot p(y)}\right) \tag{1}$$

In our particular case, we define the two variables as each opcode frequency and whether the instance is malware. In this way, X is the sample number including the opcode and Y is the class of the file (i.e. malware or benign software), p(x, y) is the joint probability distribution function of X and Y, p(x) and p(y) are the marginal probability distribution functions of X and Y.

CPD (Categorical Proportional Difference) represents a measure of the degree to which a word contributes to differentiating a specific class from others [9]. The possible value of CPD is within the interval of −1 and 1. A CPD value close to −1 indicates that a word to large extent occurs in an equal number of instances in all classes and a value in proximity of 1 indicates that a word occurs only in one class. Given that A is the number of times word w and class c occur together and B is the number of times word w occurs without class c, then we may define CPD for a particular word w and class c as follows:

$$\mathrm{CPD}(\mathrm{w}, \mathrm{c}) = \frac{\mathrm{A} - \mathrm{B}}{\mathrm{A} + \mathrm{B}} \tag{2}$$

Furthermore, once we compute the mutual information or CPD between each opcode and the executable class (malware or benign software), we sorted them in a file. Then the top 100 opcodes help us to achieve a more accurate detection of malware variations.

5 SVM Classifier for Malware Prediction

Due to the increasing growth of malware, offering protection from unknown malware is an important challenge in malware detection. Data mining approaches usually depend on machine-learning algorithms that use both malicious and benign software to detect malware in the wild.

Machine learning is a discipline in Artificial Intelligence (AI) concerned with the design and development of algorithms that allow computers to reason and make decisions based on data. Generally, machine-learning algorithms can be classified into three different types: unsupervised learning, supervised learning and semi-supervised learning algorithms. First, unsupervised machine-learning algorithms, or clustering algorithms, try to assess how data are organized into different groups called clusters. In this type of machine-learning, data do not need to be labelled. Second, supervised machine-learning algorithms, or classifying algorithms, require the training dataset to be properly labelled (in our case, knowing whether an instance is malware). Finally, semi-supervised machine-learning algorithms use a mixture of both labelled and unlabeled data in order to build models, thus improving the accuracy of unsupervised methods. Since in our case malware can be properly labelled, we use the supervised machine-learning method - Supported Vector Machine. The n-dimensional-space-based representation of the data is divided by the hyperplane constructed by the SVM into two regions (shown in Fig. 5). The hyperplane maximizes the margin between the two regions or classes (in our case, malware or benign software).The optimal hyperplane is represented by a vector w and a scalar b in a way that the inner products of w with vectors $\phi(X_i)$ from two class are divided by an interval between −1 and +1 subject to b:

$$\left(w, \phi\left(X_i\right)\right) - b \geq +1 \tag{3}$$

for every Xi that belongs to the first class (in our case malware) and

$$\left(w, \phi\left(X_i\right)\right) - b \leq -1 \tag{4}$$

for every Xi that belongs to the first class (in our case benign software).

There are several kernels used in SVM, such as polynomial, radial, or sigmoid kernel which can optimize the problem that involves finding w and b. In this paper, will use the LIBSVM [14] - A Library for Support Vector Machines.

6 Evaluation

6.1 Research Questions

We want to evaluate the framework for detection of unknown malicious software through three experiments, by answering:

1. which dimension of n-gram is the best: small (say 1, 2, 3, 4, 5), medium (e.g. 6, 7, 8, 9, 10), or big such as 14 and 15?
2. Which feature selection method is better: IG or CPD?
3. What is the best MFP in the training set in our situation?

6.2 Evaluation Measures

For evaluation purposes, the following evaluate measures are used in the results:

True Positive Ratio (TPR): The number of malware instances correctly detected divided by the total number of malwares files (shown in Eq. 5):

$$TPR = \frac{TP}{TP + FN} \tag{5}$$

Where TP is the number of malware instances correctly classified (true positives) and FN is the number of malware cases misclassified as benign software (false negatives).

False Positive Ratio (FPR): The number of benign executables misclassified as malware, divided by the total number of benign files (shown in Eq. 6):

$$FPR = \frac{FP}{FP + TN} \tag{6}$$

Where FP is the number of benign software cases incorrectly detected as malware and TN is the number of legitimate executables correctly classified.

Furthermore, we measured accuracy: the total number of the classifier's hits divided by the number of instances in the whole dataset (shown in Eq. 7)

$$\text{Accuracy} = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{TN} + \text{FP} + \text{FN}} \tag{7}$$

7 Experimental Result and Analysis

To answer the three questions presented earlier, we implement most components of the framework under Java Development Kit environment and then design a wide and comprehensive set of evaluation runs. We collect 3000 malicious instances and 1000 benign instances. Malware are downloaded from http://vxheaven.org/, while the benign file are system programs coming from a newly installed Windows XP system. Because a PE file is may be compressed or encrypted, we use PEiD to detect packers, cryptors and compilers. Finally, we sample 1000 records from our dataset, which includes 500 records of malicious executables and 500 records of benign executables. All the experimental studies are conducted under the environment of Windows 10 operating system plus Intel i5-4200 M 2.50 GHz and 4 GB of RAM.

7.1 Opcode N-Gram Size

When the n is small, the result of the framework is obviously excellent which will be demonstrated in the experiments later.

7.2 Feature Selection

In this experiment, we compare two feature selection methods: IG and CPD.

Figures 3 and 5 present the accuracy and TPR of IG are generally higher than CPD. Figure 4 presents that the FPR is similar when opcode n-gram size is small. Consequently, the better feature selection method is IG, which will be used in next experiment. Another fact can be presented in figures above that when the size of n-gram is small, the accuracy is high, while the large size decreases the accuracy.

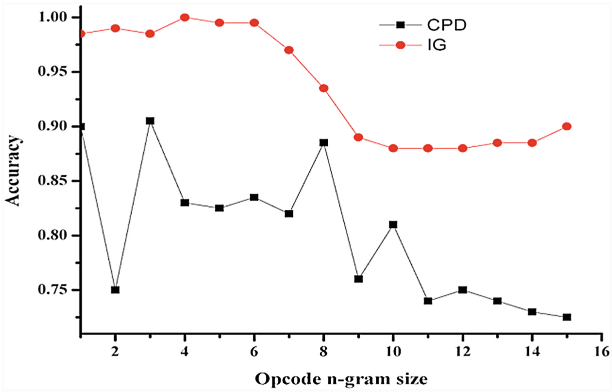

Fig. 3. The accuracy of CPD and IG

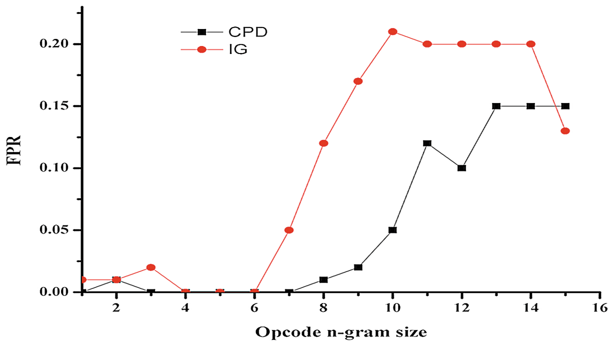

Fig. 4. The FPR of CPD and IG

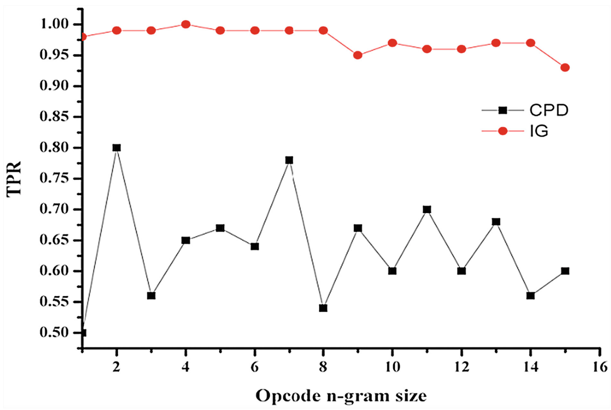

Fig. 5. The TPR of CPD and IG

7.3 Malicious Files Percentage

In this experiment, we use different MFPs from 30% to 70%, while the benign records remain constant.

Figure 6 presents that the accuracy of MFP-50% and MFP-60% are similar, both are higher than others. Figure 8 presents that the TPR of MFP-50%, MFP-60% and MFP-70% are similar which are higher than MFP-30% and MFP-40%. Figure 7 presents that the FPR of different MFPs except MFP-70% are similar. Consequently, MFP-50% is the best one in this experiments.

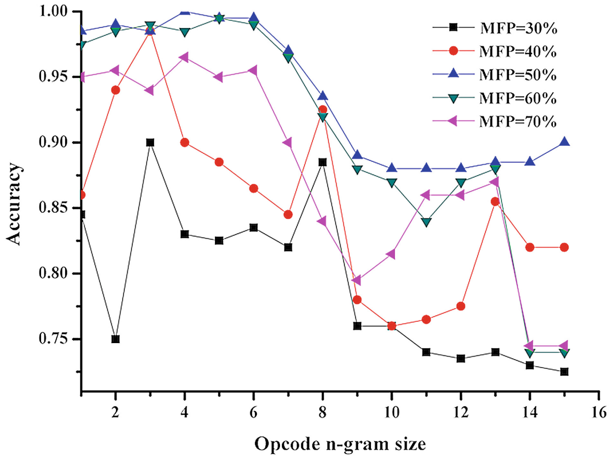

Fig. 6. The accuracy of different MFP

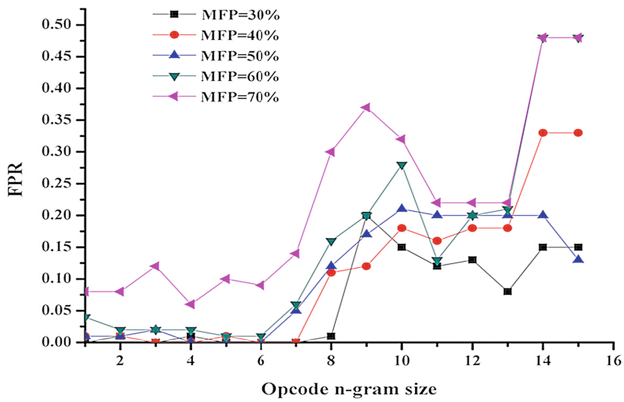

Fig. 7. The FPR of different MFP

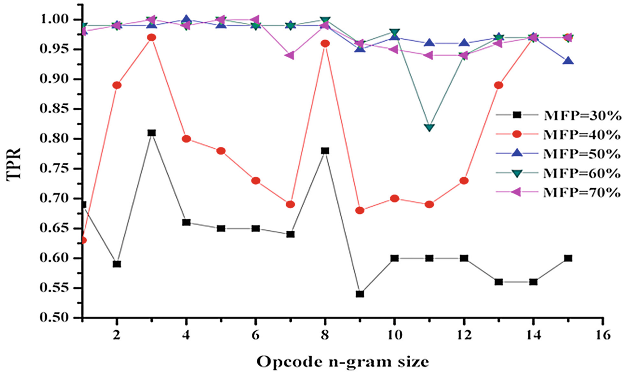

Fig. 8. The TPR of different MFP

8 Conclusion and Future Work

In this paper, we extend the method for malware detection. We conduct a set of experiments with a widely range of opcode n-gram size from 1 to 15, which is never used before. First we compare different feature selection method: IG and CPD. Finally, we use different malicious file percentage.

The pivotal elements of outstanding detection system are opcode n-gram size, the MFP. When the n is greater than 7 or 8, the accuracy, TPR and FPR decrease. After our study, we found that there are no n-gram such as 14-gram among most of the malicious files. So these n-gram with greater n cannot represent these malwares very well.

The future development of this malware detection system will be concentrated in three main research areas. First, we will expand the size of training set. Second, we will focus on the packed executables using hybrid dynamic-static approach. Finally, we will use advanced classifiers to improve our detection system.

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Performance Evaluation of WMNs by WMN-PSOSA Simulation System Considering Constriction and Linearly Decreasing Vmax Methods

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Abstract. Wireless Mesh Networks (WMNs) have many advantages such as low cost and increased high speed wireless Internet connectivity, therefore WMNs are becoming an important networking infrastructure. In our previous work, we implemented a Particle Swarm Optimization (PSO) based simulation system for node placement in WMNs, called WMN-PSO. Also, we implemented a simulation system based on Simulated Annealing (SA) for solving node placement problem in WMNs, called WMN-SA. In this paper, we implement a hybrid simulation system based on PSO and SA, called WMN-PSOSA. We evaluate the performace of WMN-PSOSA by conducting computer simulations considering Constriction Method (CM) and Linearly Decreasing Vmax Method (LDVM). The simulation results show that the LDVM has better performace than CM for this scenario.

1 Introduction

The wireless networks and devises are becoming increasingly popular and they provide users access to information and communication anytime and anywhere [11,12,14–17]. Wireless Mesh Networks (WMNs) are gaining a lot of attention because of their low cost nature that makes them attractive for providing wireless Internet connectivity. A WMN is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among them-selves (creating, in effect, an ad hoc network). This feature brings many advantages to WMNs

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such as low up-front cost, easy network maintenance, robustness and reliable service coverage [1]. Moreover, such infrastructure can be used to deploy community networks, metropolitan area networks, municipal and corporative networks, and to support applications for urban areas, medical, transport and surveillance systems.

Mesh node placement in WMN can be seen as a family of problems, which are shown (through graph theoretic approaches or placement problems, e.g. [8,20]) to be computationally hard to solve for most of the formulations [33]. In fact, the node placement problem considered here is even more challenging due to two additional characteristics:

(a) locations of mesh router nodes are not pre-determined, in other wards, any available position in the considered area can be used for deploying the mesh routers.
(b) routers are assumed to have their own radio coverage area.

Here, we consider the version of the mesh router nodes placement problem in which we are given a grid area where to deploy a number of mesh router nodes and a number of mesh client nodes of fixed positions (of an arbitrary distribution) in the grid area. The objective is to find a location assignment for the mesh routers to the cells of the grid area that maximizes the network connectivity and client coverage. Node placement problems are known to be computationally hard to solve [18,19,34]. In some previous works, intelligent algorithms have been recently investigated [2–4,6,7,9,10,21,23,25–27,35].

In our previous work, we implemented a Particle Swarm Optimization (PSO) based simulation system, called WMN-PSO [28]. Also, we implemented a simulation system based on Simulated Annealing (SA) for solving node placement problem in WMNs, called WMN-SA [24].

In this paper, we implement a hybrid simulation system based on PSO and SA. We call this system WMN-PSOSA. We evaluate the performance of hybrid WMN-PSOSA system considering Constriction Method (CM) and Linearly Decreasing Vmax Method (LDVM).

The rest of the paper is organized as follows. The mesh router nodes placement problem is defined in Sect. 2. We present our designed and implemented hybrid simulation system in Sect. 3. The simulation results are given in Sect. 4. Finally, we give conclusions and future work in Sect. 5.

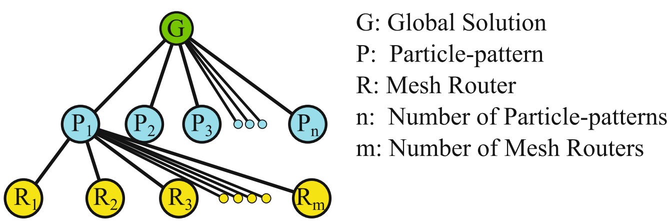


Fig. 1. Relationship among global solution, particle-patterns and mesh routers.

2 Node Placement Problem in WMNs

For this problem, we have a grid area arranged in cells we want to find where to distribute a number of mesh router nodes and a number of mesh client nodes of fixed positions (of an arbitrary distribution) in the considered area. The objective is to find a location assignment for the mesh routers to the area that maximizes the network connectivity and client coverage. Network connectivity is measured by Size of Giant Component (SGC) of the resulting WMN graph, while the user coverage is simply the number of mesh client nodes that fall within the radio coverage of at least one mesh router node and is measured by Number of Covered Mesh Clients (NCMC).

An instance of the problem consists as follows.

- N mesh router nodes, each having its own radio coverage, defining thus a vector of routers.
- An area $W \times H$ where to distribute N mesh routers. Positions of mesh routers are not pre-determined and are to be computed.
- M client mesh nodes located in arbitrary points of the considered area, defining a matrix of clients.

It should be noted that network connectivity and user coverage are among most important metrics in WMNs and directly affect the network performance.

In this work, we have considered a bi-objective optimization in which we first maximize the network connectivity of the WMN (through the maximization of the SGC) and then, the maximization of the NCMC.

In fact, we can formalize an instance of the problem by constructing an adjacency matrix of the WMN graph, whose nodes are router nodes and client nodes and whose edges are links between nodes in the mesh network. Each mesh node in the graph is a triple $\boldsymbol{v} = < x, y, r >$ representing the 2D location point and r is the radius of the transmission range. There is an arc between two nodes $\boldsymbol{u}$ and $\boldsymbol{v}$, if $\boldsymbol{v}$ is within the transmission circular area of $\boldsymbol{u}$.

3 Proposed and Implemented Simulation System

3.1 PSO Algorithm

In PSO a number of simple entities (the particles) are placed in the search space of some problem or function and each evaluates the objective function at its current location. The objective function is often minimized and the exploration of the search space is not through evolution [22]. However, following a widespread practice of borrowing from the evolutionary computation field, in this work, we consider the bi-objective function and fitness function interchangeably. Each particle then determines its movement through the search space by combining some aspect of the history of its own current and best (best-fitness) locations with those of one or more members of the swarm, with some random perturbations. The next iteration takes place after all particles have been moved. Eventually the swarm as a whole, like a flock of birds collectively foraging for food, is likely to move close to an optimum of the fitness function.

Each individual in the particle swarm is composed of three $\mathcal{D}$-dimensional vectors, where $\mathcal{D}$ is the dimensionality of the search space. These are the current position $\mathbf{x}_i$, the previous best position $\mathbf{p}_i$ and the velocity $\mathbf{v}_i$.

The particle swarm is more than just a collection of particles. A particle by itself has almost no power to solve any problem; progress occurs only when the particles interact. Problem solving is a population-wide phenomenon, emerging from the individual behaviors of the particles through their interactions. In any case, populations are organized according to some sort of communication structure or topology, often thought of as a social network. The topology typically consists of bidirectional edges connecting pairs of particles, so that if j is in i's neighborhood, i is also in j's. Each particle communicates with some other particles and is affected by the best point found by any member of its topological neighborhood. This is just the vector $\mathbf{p}_i$ for that best neighbor, which we will denote with $\mathbf{p}_g$. The potential kinds of population "social networks" are hugely varied, but in practice certain types have been used more frequently.

In the PSO process, the velocity of each particle is iteratively adjusted so that the particle stochastically oscillates around $\mathbf{p}_i$ and $\mathbf{p}_g$ locations.

Initialization

Our proposed system starts by generating an initial solution randomly, by *ad hoc* methods [35]. We decide the velocity of particles by a random process considering the area size. For instance, when the area size is $W \times H$, the velocity is decided randomly from $-\sqrt{W^2+H^2}$ to $\sqrt{W^2+H^2}$.

Particle-pattern

A particle is a mesh router. A fitness value of a particle-pattern is computed by combination of mesh routers and mesh clients positions. In other words, each particle-pattern is a solution as shown is Fig. 1. Therefore, the number of particle-patterns is a number of solutions.

Fitness function

One of most important thing in PSO algorithm is to decide the determination of an appropriate objective function and its encoding. In our case, each particle-pattern has an own fitness value and compares other particle-pattern's fitness value in order to share information of global solution. The fitness function follows a hierarchical approach in which the main objective is to maximize the SGC in WMN. Thus, the fitness function of this scenario is defined as

$$\text{Fitness} = 0.7 \times \text{SGC}(\boldsymbol{x}_{ij}, \boldsymbol{y}_{ij}) + 0.3 \times \text{NCMC}(\boldsymbol{x}_{ij}, \boldsymbol{y}_{ij}).$$

Routers replacement methods

A mesh router has x, y positions and velocity. Mesh routers are moved based on velocities. There are many moving methods in PSO field, such as:

Constriction Method (CM)

CM is a method which PSO parameters are set to a week stable region ($\omega = 0.729$, $C_1 = C2 = 1.4955$) based on analysis of PSO by M. Clerc et al. [5,31].

Random Inertia Weight Method (RIWM)

In RIWM, the ω parameter is changing randomly from 0.5 to 1.0. The C_1 and C_2 are kept 2.0. The ω can be estimated by the week stable region. The average of ω is 0.75 [31].

Linearly Decreasing Inertia Weight Method (LDIWM)

In LDIWM, C_1 and C_2 are set to 2.0, constantly. On the other hand, the ω parameter is changed linearly from unstable region ($\omega = 0.9$) to stable region ($\omega = 0.4$) with increasing of iterations of computations [31,32].

Linearly Decreasing Vmax Method (LDVM)

In LDVM, PSO parameters are set to unstable region ($\omega = 0.9$, $C_1 = C_2 = 2.0$). A value of V_{max} which is maximum velocity of particles is considered. With increasing of iteration of computations, the V_{max} is kept decreasing linearly [30].

Rational Decrement of Vmax Method (RDVM)

In RDVM, PSO parameters are set to unstable region ($\omega = 0.9$, $C_1 = C_2 = 2.0$). The V_{max} is kept decreasing with the increasing of iterations as

$$V_{max}(x) = \sqrt{W^2 + H^2} \times \frac{T - x}{x}.$$

Where, W and H are the width and the height of the considered area, respectively. Also, T and x are the total number of iterations and a current number of iteration, respectively [29].

3.2 Simulated Annealing

3.2.1 Description of Simulated Annealing

SA algorithm [13] is a generalization of the metropolis heuristic. Indeed, SA consists of a sequence of executions of metropolis with a progressive decrement of the temperature starting from a rather high temperature, where almost any move is accepted, to a low temperature, where the search resembles Hill Climbing. In fact, it can be seen as a hill-climber with an internal mechanism to escape local optima. In SA, the solution s' is accepted as the new current solution if $\delta \leq 0$ holds, where $\delta = f(s') - f(s)$. To allow escaping from a local optimum, the movements that increase the energy function are accepted with a decreasing probability $\exp(-\delta/T)$ if $\delta > 0$, where T is a parameter called the "temperature". The decreasing values of T are controlled by a *cooling schedule*, which specifies the temperature values at each stage of the algorithm, what represents an important decision for its application (a typical option is to use a proportional method, like $T_k = \alpha \cdot T_{k-1}$). SA usually gives better results in practice, but uses to be very slow. The most striking difficulty in applying SA is to choose and tune its parameters such as initial and final temperature, decrements of the temperature (cooling schedule), equilibrium and detection.

In our system, cooling schedule (α) will be calculated as

$$\alpha = \left(\frac{SA\ Ending\ temperature}{SA\ Starting\ temperature} \right)^{1.0/Total\ iterations}.$$

Algorithm 1. Pseudo code of PSO-SA.

/* Generate the initial solutions and parameters */
Computation maxtime:= T_{max}, $t := 0$;
Number of particle-patterns:= m, $2 \leq m \in \boldsymbol{N}^1$;
Starting SA temperature:= $Temp$;
Decreasing speed of SA temperature:= T_d;
Particle-patterns initial solution:= $\boldsymbol{P}_i^0$;
Global initial solution:= $\boldsymbol{G}^0$;
Particle-patterns initial position:= $\boldsymbol{x}_{ij}^0$;
Particles initial velocity:= $\boldsymbol{v}_{ij}^0$;
PSO parameter:= ω, $0 < \omega \in \boldsymbol{R}^1$;
PSO parameter:= C_1, $0 < C_1 \in \boldsymbol{R}^1$;
PSO parameter:= C_2, $0 < C_2 \in \boldsymbol{R}^1$;
/* Start PSO-SA */
Evaluate($\boldsymbol{G}^0$,$\boldsymbol{P}^0$);
while $t < T_{max}$ **do**
  /* Update velocities and positions */
  $\boldsymbol{v}_{ij}^{t+1} = \omega \cdot \boldsymbol{v}_{ij}^t$
    $+C_1 \cdot \text{rand}() \cdot (best(P_{ij}^t) - x_{ij}^t)$
    $+C_2 \cdot \text{rand}() \cdot (best(G^t) - x_{ij}^t)$;
  $\boldsymbol{x}_{ij}^{t+1} = \boldsymbol{x}_{ij}^t + \boldsymbol{v}_{ij}^{t+1}$;
  /* if fitness value is increased, a new solution will be accepted. */
  if Evaluate($\boldsymbol{G}^{(t+1)}$,$\boldsymbol{P}^{(t+1)}$) >= Evaluate($\boldsymbol{G}^{(t)}$,$\boldsymbol{P}^{(t)}$) **then**
    Update_Solutions($\boldsymbol{G}^t$,$\boldsymbol{P}^t$);
    Evaluate($\boldsymbol{G}^{(t+1)}$,$\boldsymbol{P}^{(t+1)}$);
  else
    /* a new solution will be accepted, if condition is true. */
    if Random() $> e^{\left(\frac{Evaluate(\boldsymbol{G}^{(t+1)},\boldsymbol{P}^{(t+1)})-Evaluate(\boldsymbol{G}^{(t)},\boldsymbol{P}^{(t)})}{Temp}\right)}$ **then**
      /* "Reupdate_Solutions" makes particle back to previous position */
      Reupdate_Solutions($\boldsymbol{G}^{t+1}$,$\boldsymbol{P}^{t+1}$);
    end if
  end if
  $Temp = Temp \times t_d$;
  $t = t + 1$;
end while
Update_Solutions($\boldsymbol{G}^t$,$\boldsymbol{P}^t$);
return Best found pattern of particles as solution;

3.2.2 Acceptability Criteria

The acceptability criteria for newly generated solution is based on the definition of a threshold value (accepting threshold) as follows. We consider a succession t_k such that $t_k > t_{k+1}$, $t_k > 0$ and t_k tends to 0 as k tends to infinity. Then, for any two solutions s_i and s_j, if $fitness(s_j) - fitness(s_i) < t_k$, then accept solution s_j.

For the SA, t_k values are taken as accepting threshold but the criterion for acceptance is probabilistic:

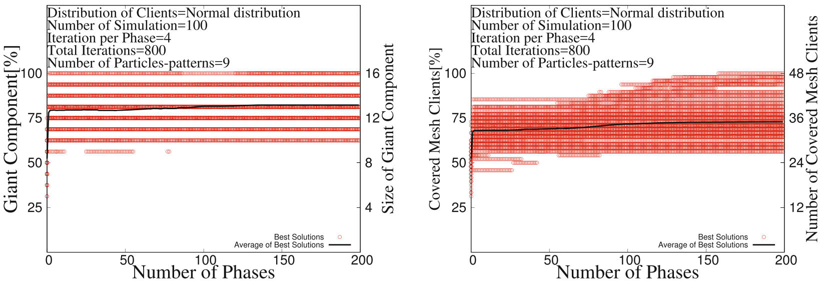
- If $fitness(s_j) - fitness(s_i) \leq 0$ then s_j is accepted.
- If $fitness(s_j) - fitness(s_i) > 0$ then s_j is accepted with probability $\exp[(fitness(s_j) - fitness(s_i))/t_k]$ (at iteration k the algorithm generates a random number $R \in (0,1)$ and s_j is accepted if $R < \exp[(fitness(s_j) - fitness(s_i))/t_k]$).

In this case, each neighbour of a solution has a positive probability of replacing the current solution. The t_k values are chosen in way that solutions with large increase in the cost of the solutions are less likely to be accepted (but there is still a positive probability of accepting them).

4 Simulation Results

In this section, we show simulation results using WMN-PSOSA system. In this work, We consider normal distribution of mesh clients. The number of mesh routers is considered 16 and the number of mesh clients 48, respectively. The total number of iterations is considered 800 and the iterations per phase is considered 4. We consider the number of particle-patterns 9. We conducted simulations 100 times, in order to avoid the effect of randomness and create a general view of results. We show the parameter setting for WMN-PSOSA in Table 1.

We show the simulation results from Figs. 2, 3 and 4. In Fig. 2, we see that solutions converge before 100 phases and NCMC does not reach maximum (100%) when the replacement method is CM. Figure 3 show that the SGC increases gradually and all solution reaches maximum value. Comparing CM and LDVM, the LDVM has better performance than CM. We show the visualized results for WMN-PSOSA in Fig. 4. We see that all mesh routers are connected when we use LDVM.

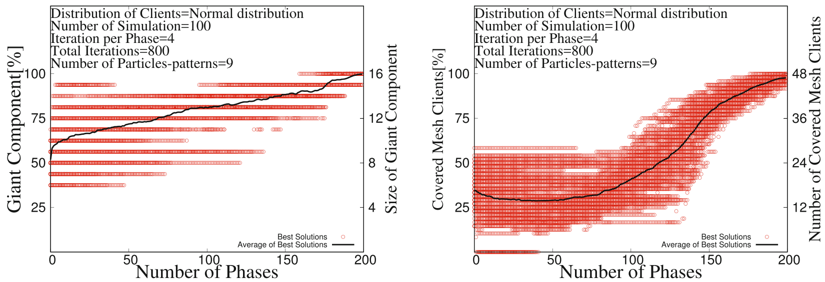


(a) SGC (b) NCMC

Fig. 2. Simulation results of WMN-PSOSA considering CM.

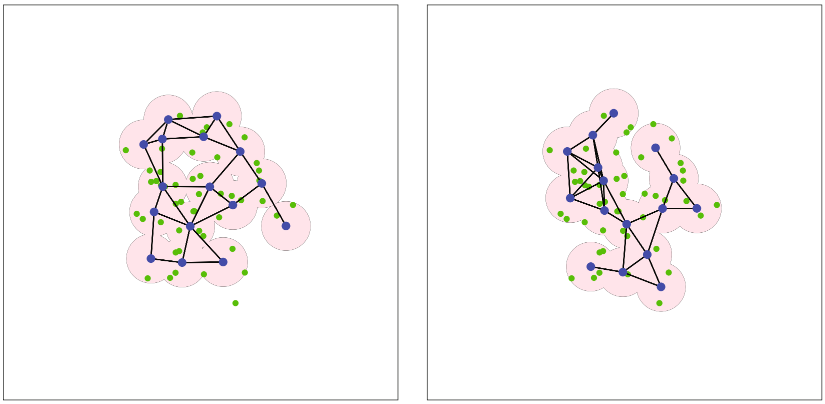
Table 1. WMN-PSOSA parameters.

Parameters	Values
Clients distribution	Normal distribution
Area size	32.0×32.0
Number of mesh routers	16
Number of mesh clients	48
Total iterations	800
Iteration per phase	4
Number of particle-patterns	9
Radius of a mesh router	2.0
SA starting temperature value	10.0
SA ending temperature value	0.1
Temperature decreasing speed (α)	0.99426
Replacement method	CM, LDVM



(a) SGC (b) NCMC

Fig. 3. Simulation results of WMN-PSOSA considering LDVM.



(a) CM (b) LDVM

Fig. 4. Visualized image of simulation results for different replacement methods.

5 Conclusions

In this work, we evaluated the performance of a hybrid simulation system based on PSO and SA (called WMN-PSOSA) considering Constriction Method (CM) and Linearly Decreasing Vmax Method (LDVM). Simulation results show that the LDVM has better performace than CM for this scenario.

In our future work, we would like to evaluate the performance of the proposed system for different parameters and patterns.

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Characterizing User Influence Within Twitter

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Abstract. This paper explores whether influence can be quantified from public Twitter data. Compared to other social media applications, Twitter is content-centered, rather than relationship-centered. There is no indication of mutual relationships for the user within the application, making it difficult to gauge influence. By analyzing the data that already had mutual relationships, we identify the characteristics that created the boundaries of a community, and influence within it. We looked at Twitter user data, as well as Tweet data to find ways to characterize user influence among them. We measure type of users based on factors such as: those that they follow and how active they are. The Expert members are mutually agreed upon, as evidenced by their large followings, and the large number of followers who have added them to a list. They are most likely to post replies and original tweets, and are unlikely to re-tweet. Active members keep the conversation going, as evidenced by their strong followings. They are more likely than the other types to re-tweet. Passive members, the largest group, participate by liking (Favorite) tweets that they consume, encouraging experts and active members to continue their actions, and sustaining the boundaries of the group.

1 Introduction

In recent years, there have been a variety of social media platforms that have attracted their share of attention. From Myspace [10] to Facebook [5], to Twitter [15] and Instagram [8] to Snapchat [14], etc., there has been also a consistent requirement for companies to provide more social platforms for their customers to use and interact with each other. These social networks have been credited positively, such as allowing minority voices to be heard, enabling cross-cultural interactions, and simply allowing more people connect with their friends with these recently introduced mechanisms. The enthusiasm about these platforms has generated some controversy, since opposing voices have been allowed to be heard [1]. Complaints about harassment, bigotry and cybercrime are only a few of the problems that these networks have suffered from, leading many to question both the ethical viability of these platforms, as well as the financial stability of even some of the larger networks such as Twitter.

With all of the uncertainties about Twitter and other social networks, the question of how influence is gained inside these networks becomes extremely important. Understanding how particular users gain popularity would allow Twitter and other entities

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the chance to interact with Twitter audiences far more effectively. Advertisers would be able to target more influential people, entertainers and others who use Twitter as a marketing tool would be able to engage their audience far more effectively, and Twitter itself would be able to limit some of the more undesirable sources of influence on their network. The dynamic distributed structure of social networks is one of the reasons that it appeals to its users. It offers users the unique ability to freely explore the network and connect to people near and far without limits. From the view of online social network analysis, the social environment can be expressed as patterns or regularities in relationships among interacting units. The unit of analysis in online social networks is not the individual but an entity consisting of a collection of individuals and the linkages among them [16]. The concept of a network emphasizes the fact that each individual has ties to other individuals, each of whom in turn is tied to a few or many others. According to [13], social influence is defined as change in an individual's thoughts, feelings, attitudes, or behaviors that results from interaction with another individual or a group of people. Influence has long been actively studied in marketing, sociology, communication and political sciences.

Seemingly, users with the most followers should have the most influence, as they would have the greatest potential reach. However, we observed that those who had many followers were not necessarily the most active. Their potential influence went unrealized. However, there were other users whose actions succeeded in keeping the conversations going across a group of users. Since Twitter's presentation is centered around the life cycle of Tweets, rather than the relationships among the users, can relative influence among a group of users be measured?

2 Related Work

One of the well known questions about Twitter is that unlike many traditional sources of media, there are no appointed watchdogs or gatekeepers screening the flow of information in the network and the cost of "publishing" anything on Twitter is incredibly low, therefore, Twitter might invalidate model based and more traditional forms of mass media. There is also a lack of enforced boundaries or groups, like on Facebook, which allows a much wider distribution of information, but also tends to complicate the situation more that ever, when it comes to discussing how groups of people participate in online discussions. These situations are important motivations for defining a rational measurement of influence in Twitter's network and a variety of measurements that might eventually be used as a scientific method to influence a part of the network.

Measuring influence and social networking potential on Twitter has been discussed in several papers [2,17]. One approach is measuring influence not only with taking followers and interactions into account, but also by analyzing similarities with the help of a ranking method similar to PageRank [17]. Other approaches define different types of influence on Twitter, such as in-degree and re-tweet [2]. They concluded that each indicator leads to a different ranking of users and that in-degree, i.e. the number of followers a user has, reveals little about the actual influence of a user. Re-tweet influence is strongly content-oriented, whereas a higher degree of influence suggests a high value of the user's name. The closely related topics of tweeting dynamics and the prediction of content popularity and information distribution have also been discussed in [2].

Some research in [4,9] suggests that people are more affected by the opinions of their peers than influentials. Recent studies of online social networks [2] support the hypothesis that influentials exert disproportionate amount of influence. With the numbers of active users on these sites numbering in the millions or even tens of millions, identifying influential users among them becomes an important problem with applications in marketing [2]. Twitter has no way for a user to ask another to follow them. Instead, it suggests that users "gain friends and fans on Twitter" by engaging, following others, reading and posting [15]. During that experience, Twitter gathers information to provide for a user additional content and account suggestions [15]. A separate tweet object is generated when a user tweets, which includes the original creator id, but then additional data is captured as the tweet lives on through likes and re-tweets.

3 Our Proposed Approach

Our hypothesis is that someone attempting to be an influencer on Twitter should try to engage their audience, but there is a definite lack of agreement on how this intend should be achieved. It becomes especially difficult to follow such attempt when one considers the recent work such as [7], which indicates that an individual has a distinct limit on how many actual relationships they can form, maxing out around one to two hundred people. There has to be some sort of strategy an influencer can use to gain viewership without attempting to form individual relationships with thousands of individuals on Twitter. Discovering this strategy will be an important factor in revealing the mechanisms behind influence on Twitter. For the purposes of this paper, there will be four measurements of a user's influence.

A social networking relationship within a smaller "inner" circle, rather than the broader network, would seem to be more influential on social media. Twitter uses an algorithm that pushes content into the user timeline. The first group of tweets in the timeline will be from those the user has chosen to follow. The order of the tweets as they appear in the timeline may correlate to their potential influence, simply because they are more likely to be seen if they appear earlier. Those that appear further down in the Timeline may never been seen at all, as users have many opportunities to click off into other directions as they engage with Tweets. The challenge to identifying influence is to first recognize the inner circle, and then quantify the relative influence of users within it. We sought to find a set of users with a large number of mutual relationships who are all interested in the same professional topic. We identified a subset of users in an online community, with overlap among followers. Next step is to see what usage patterns provide the predictability to sustain a recognizable community, thus creating an inner circle. Then we could isolate the characteristics that correlate to influence. Four primary characteristics for measuring influence emerged from the data:

- *Number of Followers:* The number of followers collected by a user increases by both fame and activity level. A person can be well known outside of Twitter, like a politician or an entertainment figure, and their number reflects a built-in notoriety, regardless of regular activity. Users can also accumulate fame within Twitter by regular engagement. As they tweet and are liked, re-tweeted or followed, Twitter increases the amount of times they are suggested as an account to follow for others, often resulting in a larger number of followings.

A twitter user's influence can be correlated to their number of followers because of the potential reach of their tweets. The tweets of a user with a high number of followers will go out into the timelines of a larger number of other users. However, if they don't engage regularly, their twitter influence is unrealized, so this measure alone is not sufficient to measure influence.

- *Number Listed:* Twitter users may choose to any of the users they follow to a list, usually created to specify a subset of related users. It is a way of prioritizing users, whose content you value, and want to be able to view regularly.

  Users seem willing to casually follow many users, giving them a high following count. However, they seem much more selective when choosing to add one to a list. If a user is "Listed" by a high number of users, it means his content is expressly valued by those users, which is a indication of potential influence.
- *Ratio of Followers/Followings:* The ratio of the number followers (those that follow them) to the number of followings (those they follow) is an indication of the balance of their level of provision and consumption of content. If someone has a significant amount of followers, and relatively few followings, they are likely successfully acting as a provider of content that is being consumed, a sign of influence.
- *Number of Tweets Per Year/Activity Level:* For a twitter user to exercise their influence, they need to appear to use Twitter as a continual source of communication, daily or weekly, not just on a promotional basis. Total number of tweets divided by number of years of use gives a number of tweets per year, a very board indication of activity level.

The above characteristics can be combined to compare influence among related users: (i) The number of followers (N_F), (ii) Ratio of number of followings to number of followers ($\frac{N_{FW}}{N_F}$), (iii) Listed, which is the number of users who specify to see their content in best tweets first (N_{listed}), and (iv) Activity level, which is the average number of tweets per year (N_T). Here α, β, γ and η are weight parameters and f is the influence of each twitter user i:

$$f_i = \alpha * N_F + \beta * \frac{N_{FW}}{N_F} + \gamma * N_{listed} + \eta * N_T \tag{1}$$

By starting with a group of users we knew already had mutual relationships, we observe which usage patterns provide the predictability to sustain a recognizable community, thus creating an inner circle. Then we could isolate the characteristics that correlate to influence.

4 Performance Evaluation

In order to collect the data, a tool developed by a Github contributor named Sferik [6] was used. It allowed lists of the users followers, most recent tweets, and other data to be gathered effectively and compared with one another. We ran few scripts in order to generate an accurate picture of how the users could be measured. The data was mostly

Table 1. Final Results, where "∗" represents too many to count.

	Number of followers	Followers' followers	Ratio of followers to followings	Activity level	Total followers	% of Tweets	Replies	Retweets
Active	11492	28030103	52:1	5350	17.7:1	34	50	16
Active	9897	30410977	55:1	1822	19:1	12	23	64
Active	15763	26842121	35:1	4886	19:1	50	22	28
Active	22680	162295654	17:1	11528	17:1	20	40	40
Active	12024	37788693	19:1	1248	13:1	58	32	10
Active	7350	16071291	44:1	2016	28:1	83	10	7
Active	13905	4671666	732:1	184	56:1	68	3	29
Active	16011	108383768	34:1	7636	12:1	37	48	15
Famous	101343	*	40:1	9360	51:1	39	47	14
Famous	160070	*	538:1	2185	86:1	41	27	32
Famous	122337	*	543:1	5700	40:1	27	60	12
Famous	117994	*	275:1	12711	22:1	40	39	11
Famous	456696	*	630:1	1659	296:1	45	18	37
Passive	1	3	0.13:1	0	0	*	*	*
Passive	203	*	0.48:1	19	0.015	*	*	*
Passive	100	31066	7:1	156	25:1	88	10	2

collected using the *whois()*, *followers()*, and *last1000()* tweets functions. Unfortunately, the followers function did not perform as fast as we expected, due to the extensive amount of parameters passed to the function to perform in sufficient amount of time when targeting the higher levels of the users in the community.

The number of followers could be taken directly from the *whois()*, as well as the date the user joined Twitter and the total number of tweets. Dividing the number of tweets by the number of years leads to the average activity level for the user. The ratio of followings to followers and the ratio of listed to followers could also be taken from the *whois()*. The number of followers' followers was taken by summing the followers column of the results from the *followers()*. The percentages for original tweets, re-tweets and replies were taken from the *last1000tweets()* data. Entries that started with "RT" were considered re-tweets, entries starting with "@" were considered replies, and entries that started with neither were considered to be original tweets. As depicted in Table 1, we categorized users into three different groups. The first category were those users who were considered famous, or highly influential. They were characterized by (i) high numbers of followers, (ii) large ratios of followers compared to their followings or their listed followers, and (iii) followers with large numbers of followers. A second category, with more moderate measures of each of these measurements, could be considered active members of the community, but not nearly as influential as the high level members. Finally, the third category consisted of users with few, if any, followers, very low ratios of listed or followings versus their number of followers, and very few followers with large groups of followers themselves. The relative activity of the users were also measured, as far as their number of tweets in the past year, and the breakdown of their various types of tweets: (i) number of original tweets, (ii) number of re-tweets, and

(iii) replies were also analyzed by comparing the number of each in the users' last thousand to two thousand tweets, in order to better understand the kind of effective behavior that would lead these users to become influential within their group.

Several interesting patterns emerged as this data was analyzed. First, activity level appeared to have little effect on the amount of influence a user had. Users who contributed almost half the number of tweets as other more active users still have comparable or more followers, and much higher ratios of followings/listed to followers. Types of tweets appeared to be much more important than the quantity. The percentage of tweets which were actually re-tweets or replies seemed to have a much greater effect on the size of their audience and the other measurements of popularity, which had been previously defined. Another intriguing observation is that many of these Twitter influencers actually spent the majority of their time talking with each other more than their individual users. The grand majority of their audience is made up of followers who act more like observers than participants in the conversation. Many of them never actually interact with the more active and influential members of the group at all, yet the replies and re-tweets of the community's core members still attract large amounts of attention from the group. In addition, we observed that a successful influencer on Twitter does not attempt to flood the network with original content, or even attempt to engage each individual member of their audience. Instead, they establish mutual relationships with other highly influential individuals, and then have public conversations with those individuals online. The topic doesn't even necessarily have to relate directly to the purpose of the group. Our initial point of contact with this community talked about their webcomic or writing, but most of their re-tweets and conversations ranged across other topics such as travel, politics, or relating everyday personal experiences. Figure 1 compares the years a user had been on twitter versus the level of activity. Of interest is the fact that users with less years seemed to be less active overall. Figure 2 was generated using data from the *last1000tweets()*. Since the dates of each tweet are included in the results of this function, we could find the amount of time needed to generate those thousand tweets, giving us a window of time that we could then compare to the percentages of re-tweets, replies and original tweets. Lower percentages appeared to correlate with larger windows of time, or in other words, lower activity levels on twitter. Figure 3 depicts the total number of audiences as the number of followers and the percentages of re-tweets and replies for the past one thousand tweets increased. In Fig. 4 the number of followers is compared to the number of followers with over nine thousand followers of their own. High levels of high influence followers appeared to correlate with large overall audiences.

Our result show the fact that influencers spent disproportionate amounts of time re-tweeting and replying to other high influence individuals. Taking the data from both the *followers()* function and the *last1000tweets()* function, the sum of the number of re-tweets and replies that mentioned followers with over nine thousand followers of their own was calculates. The percentage of high influence followers was then compared to how often they were mentioned in re-tweets and replies, showing that they received extremely disproportionate amounts of attention from their fellow influencers. We observed when for an approximate number of samples 11492, only 1.9% are influencers and for total re-tweets/replies is 66, there are 22.73% influencers. In order to

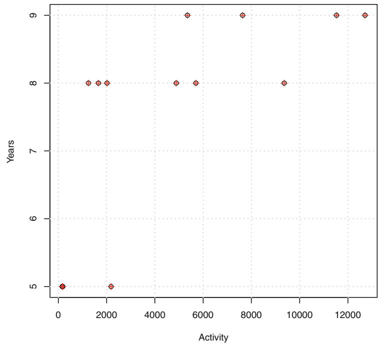

Fig. 1. Years vs Activity

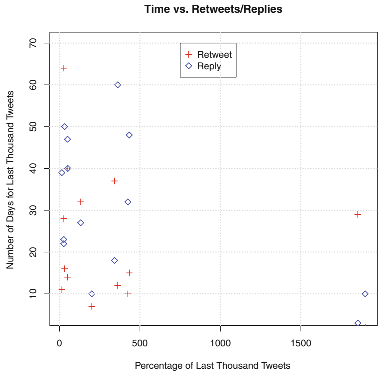

Fig. 2. Time vs Re-tweets/Replies

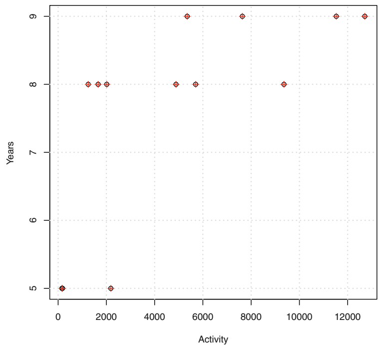

Fig. 3. Percentage of Re-tweets/Replies vs Audience

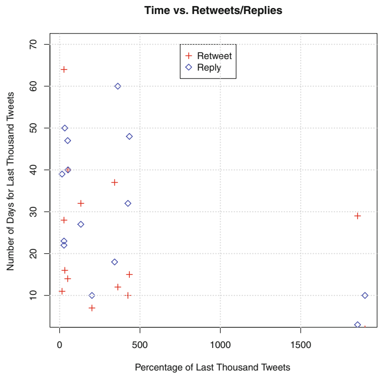

Fig. 4. Audience vs Influence

gain a better understanding of how this mechanism works, we can turn to a popular example in another forms of media: radio talk-shows. People listen to talk-shows without the expectation that the radio hosts will try to engage with them directly; in fact there is likely a very small minority of talk show listeners who bother to call in when given the opportunity. They do, however, expect relatable dialogue, sort of an observational version of the "bikeshedding" rule [11], where people prefer to discuss (or in this case, observe conversations about) subjects with which they are familiar. A similar trend can happen with other digital media such as Youtube videos (particularly videos like Let's Plays of team based games), and podcasts. Twitter can be used in a similar manner, effectively dividing the Twitter network into three pieces: the group that uses Twitter as a sort of performance platform, the group which watches the performance, and the relatively small group that uses it for actual personal relationships and communication. Just like those other forms of entertainment, then, the group of performers may not define themselves as a community by replying and re-tweeting with each other, and discussing the various subjects they find interesting, but the audience who watches them is not particularly bound by any group boundaries. This aspect of Twitter would explain why communities are so hard to define on the network, since the groups performing for the benefit of the others don't actually try to draw hard, exclusive boundaries to their audiences. They want to extend the limits as far as possible, and audiences are fluid between the communities they observe.

In other words, an observer could watch any groups they choose, becoming a member of an audience that doesn't participate in the community any more than someone listening on the radio. Similarly, the performers don't have to try and form thousands of relationships with their audience; they only have to connect to the other performers who can help them have engaging conversations for the benefit of their audience. Twitter provides two public APIs, a streaming API and a REST API, specified in the Twitter developer documentation to provide programmatic access to Twitter function and data [15]. When logged into Twitter, a user can export his own data, or view it on a Dashboard within the developer area of the application. To do so, each user creates its own "Twitter App", associated with its unique Twitter ID. That provides the API with user authentication to perform searches. For example, Twitter uses a user's app to refine all the data that he has access to within the app, and provides that same access outside of the application. The Twitter REST API offers a broad set of capabilities of GET and POST capabilities, which most are functions that users would use as normal usage within Twitter. However, there are some that can be used to extract data to use to characterize interaction within a group of users. Calls to the API are allowed through use of Twitter applications (based on a single user's authentication) from the command line or the Twitter console. The application has a number of functions that would be useful, although they are constrained by Twitter's rate limits.

Although Twitter offers open access to their data, they enforce rate limits on calls using the REST API, in order to manage resources, and to protect them from abuse. As an alternative, they offer streaming APIs that provide real-time streaming of Twitter's data for use in other applications. For our purposes, we needed the REST API to make calls to get historical Twitter data for various users. For each of the user we identified in our community, we could retrieve basic aggregate user information to use to characterize their usage of Twitter. This gave us a starting point for comparing influence across the group of users. The size of the followings of many of the twitter users in our community fell just under the REST API limits, meaning we could also retrieve all of their followers data, up to about 20,000 followers. For a single user, we could also extract data to identify patterns of usage, like frequency and type of tweet. In our effort to try to "predict the next tweet", we first identified an established community of users with extensive mutual relationships. From them, we can observe and characterize the members patterns of interaction. Using user-related data from the Twitter API, we identified a set of three distinct user types (Expert, Active, Passive) that emerged within the group based on the scale of their followings and their average level of activity. Expert users have $N_F > 10000$, $\frac{N_{FW}}{N_F} > 100:1$, $N_{listed} > 1000$, and $N_T > 1$ per day. Active users have $1000 < N_F < 10000$, $\frac{N_{FW}}{N_F} > 10:1$, $N_{listed} > 100$ and $N_T > 1$ per day. Passive users have $N_F < 100$, $\frac{N_{FW}}{N_F} < 0:1$, $N_{listed} > 0$ and $N_T < 1$ per day.

The next piece is to characterize the nature of the Tweets themselves, and use that to try to predict where the next tweet will come from. The Twitter API includes a tweet object containing the original message, time and date it was created, and its creator. The data is prefaced with "RT" in the case of a retweet, and an "@Username" for replies. The Tweet object is updated data during its life-cycle to indicate how many times it has been retweeted or favorited. A look at a user's timeline of recent tweets reveals their rate of activity, as well of the type of tweet. The frequency of their tweets plus the type of tweet tells us how and when they are using Twitter. By looking at the patterns for our user types, we can see how influence is established. Patterns of past activity, plus our measurement of influence gives us information to predict where the next tweets are likely to come from. For our Expert users, their timeline is a collection of tweets, retweets and replies in a short period of time. They engage in constant passing conversation with their counterparts in the community (replies), while being available for immediate response to trending topics (retweets). This sustains their following, so that when they have a professional announcement to make, their audience is already gathered and engaged, and thus more likely to pay attention to it (original tweets). For our Active users, their timeline reveals a slightly different pattern of behavior. They are in the process of building a following, so their activity has more retweets than original tweets or replies. They may be increasing their followings by engaging with trending topics, participating with others who re-tweet messages that catch their attention. Regular patterns of this result in increasing direct engagement with other users available at the same time, who respond to similar messages.

For our Passive users, the timeline has far less activity. Their activity is not daily, but weekly or less. Without the retweet and reply activity, their timeline includes more original tweets, but stretched out over a long period of time. A look at their user data, however, reveals a higher level of favorites, suggesting that they are engaging by reading tweets and favoriting as a means of engagement. Table 2 depicts user data and nature of Tweets on Twitter. After calculating influence for each of the 10,261 users in the set, we assigned the type based on our thresholds, producing the following distribution: 0.68% of users are Expert, 6.21% are Active and 93.11% are Passive. Our thresholds were established to identify patterns of increasing influence through Twitter usage, for professional purposes. As users spend time on Twitter, the natural result is to follow, and be followed by others with similar interest. For users with a more specific purpose, active engagement will result in opportunities for greater influence beyond just a higher number of followers. They are more likely to be added to "Lists", created by other users to identify users whose content they are most interested in viewing. They are also likely to engage more directly with other users, expressed by a higher average number of Tweets, original, retweets and replies. Twitter's algorithm prioritizes the tweets into user feeds by previous "engagement and attention" as it is also described in [12]. The combination of higher levels of those characteristics reflects a pattern of usage that results in gathering influence over a larger following over a period of time.

We expected that users with the highest calculated Influence would also be characterized as Expert based on our thresholds. We looked at the top 1% most influential users in our dataset, and found that only half of them were actually Expert users. The top 1% users in our set have each accumulated a very high number of followers (most have 10,000+), resulting in their relatively higher influence calculation. Some have built their following through deliberate active engagement on Twitter. However, some accounts

Table 2. User data and nature of Tweets on Twitter

	Followers	Following	Followers/ Followings	Listed	Tweets	Avg. Tweets per year
Expert	86870409	63630383	137.8057609	222822	15441	1544.1
Expert	14083103	762	18481.76247	37478	9844	2461
Expert	7181423	51	140812.2157	44450	5304	663
Expert	3663900	165	22205.45455	26177	3316	368.4444444
Expert	118792	429	276.9044289	5275	115749	12861
Active	284417	4227	67.28578188	7438	28810	2881
Active	216700	4012	54.01296112	4214	20918	2614.75
Active	67825	3314	20.46620398	2059	57123	6347
Active	64618	2445	26.42862986	3400	209319	26164.875
Active	48548	795	61.06666667	1262	32964	4120.5
Passive	659	62	10.62903226	65	1807	301.1666667
Passive	646	99	6.525252525	37	5826	832.2857143
Passive	594	203	2.926108374	28	2286	457.2
Passive	574	325	1.766153846	39	7037	1005.285714

have simply run up a high number of followers by fame. Several accounts that could be bots are noticeable, shedding light on the reality that bots could account for 9–15% of all active Twitter accounts as it is also described in [3]. These accounts may have a high number of followers, but they don't engage in the style of engagement that meets our thresholds for Expert users.

5 Conclusion and Future Work

Each type of user seems to play a necessary role to form a recognizable community. The Expert members are mutually agreed upon, as evidenced by their large followings, and the large number of followers who have added them to a list. They are most likely to post replies and original tweets, and are unlikely to re-tweet. Active members keep the conversation going, as evidenced by their strong followings. They are more likely than the other types to re-tweet. Passive members, the largest group, participate by liking (Favorite) tweets that they consume, encouraging experts and active members to continue their actions, and sustaining the boundaries of the group. Interaction with a large number of followers or followings might contribute to user's tendency to engage in behavior they might otherwise avoid. Perhaps there is a number where they begin to feel like they are acting "anonymously". This could be extended to analyze the ways people commonly use Twitter, comparing narrow uses (like micro-blogging) to broader uses (business and promotion), all inside one application.

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Routing in a DTN: Performance Evaluation for Random Waypoint and Steady State Random Waypoint Using NS3 Simulator

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Abstract. In this paper we evaluate the performance of Epidemic, Spray and Wait and their versions with congestion control and Epidemic with TCP for Random Waypoint (RWP) and Steady State Random Waypoint (SSRWP) mobility models. For performance evaluation, we used delivery ratio, hop count, average delay and average buffer occupancy metrics. Simulations are conducted using NS3 simulator. The simulation results show that the network performance is better for SSRWP mobility model.

1 Introduction

Delay Tolerant Networks (DTNs) enable communication where connectivity issues like sparse connectivity, intermittent connectivity, high latency, long delay, high error rates, asymmetric data rate, and no end-to-end connectivity exists. In order to handle disconnections and long delays, DTNs use store-carry-and-forward approach.

In DTNs multiple copy routing protocols are mostly used. Multiple copies can lead to congestion in networks that are typically characterized by scarce resources, so a message deletion policy must be used for multi copy routing schemes. These schemes can use the acknowledgement method to remove the useless bundles from the network, preventing the nodes from the buffer overflow

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problem and avoid transfer of useless message replicas thus relaxing the resources of the nodes.

Combining routing with a congestion control scheme would manage better nodes buffer. In this work, we use the congestion control mechanism for DTNs proposed in [1,2]. This mechanism locally advertises a node's buffer occupancy to adjacent nodes based upon which latter can take local decisions and avoid sending messages to nodes whose buffers are nearly full. Congestion control mechanism enables to maximize resource utilization when resources are available.

In this paper, we investigate and compare the performance of Epidemic, Spray and Wait and their versions with congestion control and Epidemic with TCP when Random Waypoint (RWP) and Steady State Random Waypoint (SSRWP) mobility models are used. The performance evaluation metrics are: delivery ratio, hop count, average delay and average buffer occupancy. For the simulations, we use NS3 simulator [3].

The remainder of this paper is as follows. Section 2 give a short introduction to DTN and routing protocols. The simulation system design is presented in Sect. 3. In Sect. 4 are shown the simulation results. Finally, the conclusions and future work are presented in Sect. 5.

2 DTNs and Routing Protocols

2.1 DTN Overview

DTN are occasionally connected networks, characterized by the absence of a continuous path between the source and destination [4,5]. The data can be transmitted by storing them at nodes and forwarding them later when a link is established. This technique is called message switching. Eventually the data will be relayed to the destination. DTN is the "challenged computer network" approach that is originally designed from the Interplanetary Internet, and the data transmission is based upon the store-carry-and-forward protocol for the sake of carrying data packets under a poor network environment such as space [4]. Different copies of the same bundle can be routed independently to increase security and robustness, thus improving the delivery probability and reducing the delivery delay. However, such approach increases the contention for network resources (e.g., bandwidth and storage), potentially leading to poor overall network performance.

In [6], authors have studied this model and found that it can provide substantial capacity at little cost, and that the use of a DTN model often doubles that capacity compared with a traditional end-to-end model. The main assumption in the Internet that DTNs seek to relax is that an end-to-end path between a source and a destination exists for the entire duration of a communication session. When this is not the case, the normal Internet protocols fails. DTNs get around the lack of end-to-end connectivity with an architecture that is based on message switching. It is also intended to tolerate links with low reliability and large delays. The architecture is specified in RFC 4838 [7].

Bundle protocol has been designed as an implementation of the DTN architecture. A bundle is a basic data unit of the DTN bundle protocol. Each bundle comprises a sequence of two or more blocks of protocol data, which serve for various purposes. In poor conditions, bundle protocol works on the application layer of some number of constituent Internet, forming a store-and-forward overlay network to provide its services. The bundle protocol is specified in RFC 5050. It is responsible for accepting messages from the application and sending them as one or more bundles via store-carry-and-forward operations to the destination DTN node. The bundle protocol runs above the TCP/IP level.

2.2 Routing Protocols

In order to handle disconnections and long delays in sparse network scenarios, DTN uses store-carry-and-forward approach. A network node stores a bundle and waits for a future opportunistic connection. When the connection is established, the bundle is forwarded to an intermediate node, according to a hop-by-hop forwarding/routing scheme. This process is repeated and the bundle will be relayed hop-by-hop until reaching the destination node. A number of different routing protocols have been proposed for DTNs. Most of the routing protocols create multiple copies of the bundle in order to increase the probability of reaching the destination. In [8–16] authors deal with routing in DTNs. In this work, we will use two widely applicable DTN routing protocols Epidemic [17] and Spray and Wait [18].

Epidemic routing protocol: Epidemic [17] is a protocol that is basically a flooding mechanism. Each message spreads like a disease in a population without priority and without limit. When two nodes encounter each other they exchange a list of message IDs and compare those IDs to decide which message is not already in storage in the other node. The next phase is a check of available buffer storage space, with the message being forwarded if the other node has space in its buffer storage. The main goals of this protocol are: maximize the delivery ratio, minimize the latency and minimize the total resources consumed in message delivery. It is especially useful when there is lack of information regarding network topology and nodes mobility patterns.

Spray and Wait routing protocol: Spray and Wait [18], is a routing protocol that attempts to gain the delivery ratio benefits of replication-based routing as well as the low resource utilization benefits of forwarding-based routing. The Spray and Wait protocol is composed of two phases: the spray phase and the wait phase. When a new message is created in the system, a number L is attached to that message indicating the maximum allowable copies of the message in the network. During the spray phase, the source of the message is responsible for "spraying", or delivery, one copy to L distinct "relays". When a relay receives the copy, it enters the wait phase, where the relay simply holds that particular message until the destination is encountered directly.

3 Simulation System Design

3.1 NS3

The detailed simulation model is based on NS-3 (ver-3.26) [3]. The NS3 simulator is developed and distributed completely in the C++ programming language, because it better facilitated the inclusion of C-based implementation code. The NS3 architecture is similar to Linux computers, with internal interface and application interfaces such as network interfaces, device drivers and sockets. The goals of NS3 are set very high: to create a new network simulator aligned with modern research needs and develop it in an open source community. Users of NS3 are free to write their simulation scripts as either C++ main() programs or Python programs. The NS3's low-level API is oriented towards the power-user but more accessible "helper" APIs are overlaid on top of the low-level API.

In order to achieve scalability of a very large number of simulated network elements, the NS3 simulation tools also support distributed simulation. The NS3 support standardized output formats for trace data, such as the pcap format used by network packet analyzing, tools such as TCPdump, and a standardized input format such as importing mobility trace files from NS2 [19].

The NS3 simulator has models for all network elements that comprise a computer network. For example, network devices represent the physical device that connects a node to the communication channel. This might be a simple Ethernet network interface card, or a more complex wireless IEEE 802.11 device.

3.2 Simulated Scenarios

We created two different simulation scenarios: in the first scenario is used RWP mobility model and in the second one SSRWP. In both scenarios the network consist of 100 nodes, the simulation area is 2,5 km $\times$ 2,5 km and the simulation time is 1800 s. Destination nodes generate return receipts to the source node and they are used as antipackets. Antipackets delete the bundle copies in the buffer in order to make free space. Antipackets have a lifetime of 1000 s, a size of 10 Bytes and a 26 bytes header.

For both scenarios we evaluate the performance of Epidemic and Spray and Wait protocols and their versions with congestion control (congestion threshold 0.7) and also use epidemic with TCP. A bundle can be generated only if the node has sufficient amount of free buffer space. DTN nodes advertise their buffer content to each other every 100 ms by sending Hello messages. Moreover, if DTN congestion control is enabled, a bundle can be forwarded only to such intermediate nodes that have enough free buffer space.

RWP model is a commonly used mobility model for simulations of wireless communication networks. Basically, in RWP every node picks up a random destination and a random velocity at certain points called waypoints. This model has been extended in a number of ways in order to take into account more realistic movements.

SSRWP model [20,21] is based on RWP model for case when speed, pause and position are uniformly distributed random variables. The difference is that the initial values of these parameters are not from uniform distribution but from stationary distribution of RWM model.

We use the following performance metrics are used: delivery ratio, hop count, average delay and average buffer occupancy.

- **Delivery ratio** is the ratio of number of delivered messages to that of created messages.
- **Average delay** is the average time elapsed from the creation of the messages at source to their successful delivery to the destination.
- **Hop count** is the average number of hops counts between the source and the destination node of bundles.
- **Average buffer occupancy** is the average amount of bytes stored in the buffer nodes.

4 Simulation Results

The simulation results of delivery ratio for RWP and SSRWP model are shown in Fig. 1. Under the same simulation conditions SSRWP has higher delivery ratio compared with RWP mobility model. This is related with the probabilistic distribution with steady state for the initial node position and speed, because SSRWP uses different distribution from RWP (RWP uses uniform distribution). In SSRWP an initial time for setting them is not needed before the simulations. When SSRWP is used the network created will be more stable, more contacts between nodes can occur and more bundles can be delivered. The decrease of delivery ratio for epidemic with TCP shows that SSRWP is better for one directional communications rather than two directional communication. Congestion control improves the delivery ratio for both protocols because bundles are not generated if the buffers are full.

In Fig. 2 are shown the results of the average delay. Decrease of average delay for SSRWP shows that SSRWP performs better than RWP. For spray and wait and epidemic with and without congestion control the delays are almost the same. For epidemic with TCP, the delay is higher because of acks.

The results for hop count are shown in Fig. 3. Hop count is almost the same for both scenarios because the number of nodes is the same. Epidemic protocol will have higher hop count because it make use of more network resources (intermediate nodes) compared with spray and wait.

In Fig. 4 are shown the results for average buffer occupancy. For SSRWP, we can see a decrease of buffer occupancy for all protocols. If we have a node “a” that have met before node “b” than it has more chances to meet it again compared with RWP. In the encounters after the first time, nodes exchange also antipackets that delete duplicated bundles from the buffers. The importance of

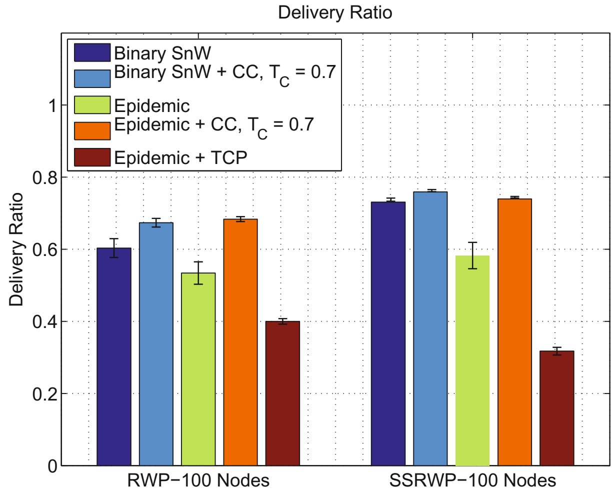

Fig. 1. Simulation results of delivery ratio.

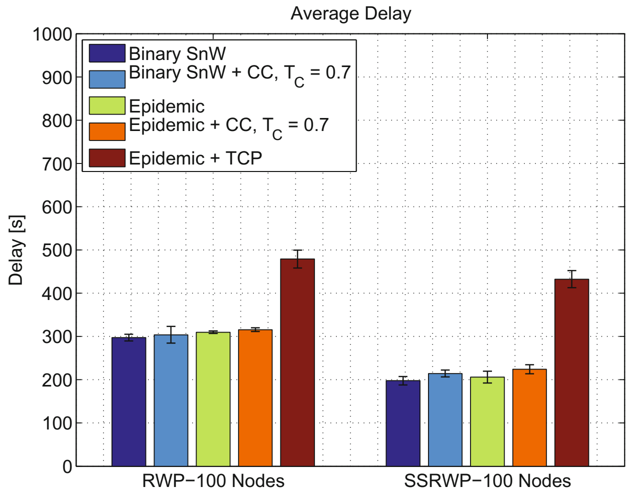

Fig. 2. Simulation results of delay.

congestion control is that it controls the buffers from being full. The usage of congestion control and the good management of buffers helps in better delivery ratio. For epidemic with TCP, the buffer occupancy is higher than spray and wait because more packets are created.

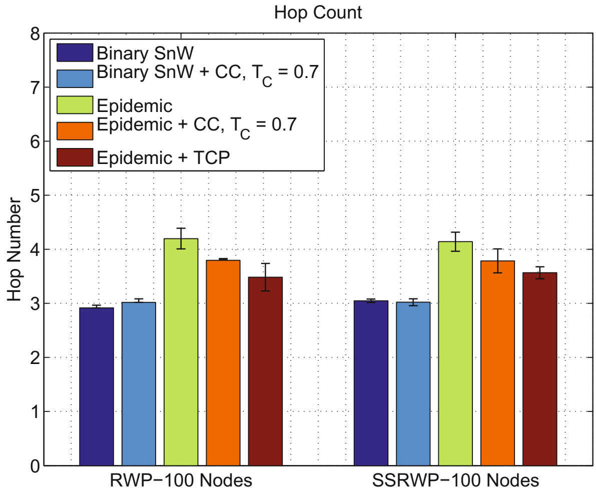

Fig. 3. Simulation results of hop count.

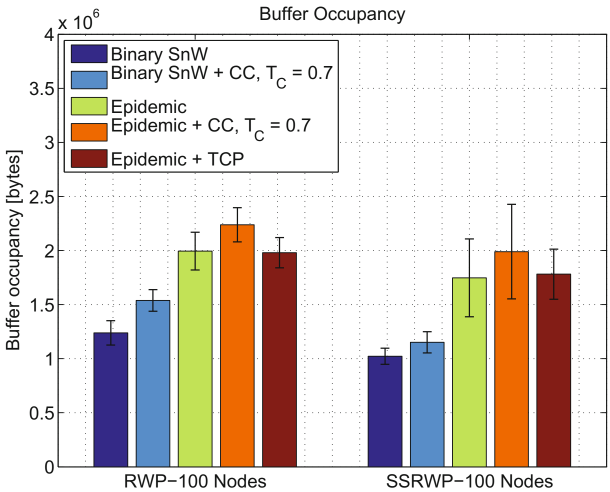

Fig. 4. Simulation results of buffer occupancy.

5 Conclusions

In this paper, we evaluated and compared the performance of SSRWP and RWP mobility models for Epidemic, Spray and Wait and their versions with congestion control and Epidemic with TCP. The performance study showed the following results.

- When SSRWP is used the network will be more stable, more contacts between nodes can occur and more bundles can be delivered compared with RWP.

- Congestion control improves the delivery ratio for both protocols because bundles are not generated if the buffers are full.
- For epidemic with TCP the delay is higher for both scenarios because of acks used.
- The importance of congestion control is that it controls the buffers from being full. The usage of congestion control and the good management of buffers helps in better delivery ratio.

In the future, we would like to make extensive simulations to evaluate the performance of different routing protocols considering different scenarios and parameters.

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Optimal Residential Load Scheduling Under Utility and Rooftop Photovoltaic Units

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Abstract. In the smart grid (SG) users in residential sector adopt various load scheduling methods to manage their consumption behavior with specific objectives. In this paper, we focus on the problem of load scheduling under utility and rooftop photovoltaic (PV) units. We adopt genetic algorithm (GA), binary particle swarm optimization (BPSO), wind driven optimization (WDO), and proposed genetic wind driven optimization (GWDO) algorithm to schedule the operation of interruptible appliances (IA) and non interruptible appliances (Non-IA) in order to reduce electricity cost and peak to average ratio (PAR). For energy pricing combined real time pricing (RTP) and inclined block rate (IBR) is used because in case of only RTP their is possibility of building peaks during off peak hours that may damage the entire power system. The proposed algorithm shift load from peak consumption hours to off peak hours and to hours with high generation from rooftop PV units. For practical consideration, we also take into consideration pricing scheme, rooftop PV units, and ESS in our system model, and analyze their impacts on electricity cost and PAR. Simulation results show that our proposed scheduling algorithm can affectively reflect and affect users consumption behavior and achieve the optimal electricity cost and PAR.

1 Introduction

The energy demand in the world drastically increases day by day and fossil fuels are limited and being exhausted. So smart grid (SG) emerged as a smart solution, that accommodate fossil fuels generation, renewable energy (RE) generation, and hybrid generation. Therefore it is important to increase utilization of RE sources (RESs) because of environmental issues and need to reduce carbon emission. Regulatory body passed renewable portfolio standard to increase production from RESs. Under renewable portfolio standard the utility company and energy providers in the U.S. and the U.K. to serve some the consumers load with RESs [1,2].

Demand side management is the utility program to balance the users stochastic demand with utility generation in order to avoid capital investment on

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more energy generation. In demand side management, various pricing mechanisms and demand response (DR) programs are employed by utility company to efficiently manage consumption behaviour and reshape demand of users. The time of use (ToU) pricing tariff have three pricing tariffs in a day to motivate consumers to shift their load from on peak demand hours to off peak hours. Critical peak pricing (CPP) designated to critical peak hours having high price. Real time pricing (RTP) designated to hourly varying pricing scheme [3].

Residential load scheduling has attracted significant attention, however, an important challenge for residential load scheduling is that users are unable to respond to the price incentives. To handle this problem authors in literature proposed many solution. References [8–16] schedule residential load using optimization techniques in order to reduce the electricity bill. In addition, to load scheduling of consumers in response to fluctuating pricing schemes, the consumers installed rooftop photovoltaic (PV) units and energy storage systems (ESS) in order to efficiently balance load with the generation, reduce carbon emission, and reduce electricity cost.

In this paper, we present energy management of a home that produce and consume electrical energy. The house is equipped with PV units, ESS, and a set of electrical appliances that consume electrical energy from PV units and utility according to user preference. The household optimizes their energy consumption behavior in order to reduce its electricity bill. Moreover, we develop genetic wind driven optimization (GWDO) algorithm for load scheduling under combined RTP and inclined block rate (IBR) environment to reduce electricity cost and peak to average (PAR). Our proposed scheduling algorithm can effectively improve economical efficiency of residential consumption under utility and rooftop PV units and help consumers to save expenditure and reduce PAR.

The rest of the paper is organized as follows. Related work and motivation is presented in Sect. 2. In Sect. 3, system model is introduced. Section 4 includes simulation and discussion, and Sect. 5 concludes the paper.

2 Related Work and Motivation

In order to optimally cope the gape between demand and supply numerus techniques and RESs integration are addressed in literature by authors. Authors in [7], presented demand side energy consumption scheduling in presence of PAR constraint and users preference in order to reduce the cost. Moreover, they introduce multi objective optimization techniques which minimize cost and inconvenience posed to users. They use distributed algorithm for solving initial and multi objective optimization problem. However, RESs integration are not addressed by the authors.

The authors implemented electricity storage and appliances scheduling schemes in [8] for residential sector in order to reduce electricity cost. The storage system allows consumers to purchase electricity at off peak times and satisfy its demand through storage during on peak times. However, the uncoordinated charging and discharging of batteries results discomfort to users. The authors proposed smart home energy management system for joint scheduling of electrical and thermal appliances [9]. The controller receive price information and environment data in order to optimally schedule appliances to reduce cost. However, the authors achieved economical solution at cost of users comfort. The authors used intelligent decision support systems under generic and flexible cost model for load scheduling in [10] to reduce the peaks and enhance the power system efficiency. However, the authors reduced the peaks and cost while user comfort is comprised. The authors in [11], proposed joint access and load scheduling under DR schemes in order to reduce cost. However, PAR is increased while reducing the cost. Authors proposed in [12], residential load control algorithm for demand side management under combined RTP and IBR pricing scheme in order to reduce the electricity bill and PAR. However, the authors reduced peaks in demand while user comfort is minimized. The authors presented prosumers demand side management in order to encourage consumers not only to take part in generation but also in efficient load scheduling [13]. The smart scheduler schedules house hold appliances under utility and distributed generation to reduce electricity cost. However, peaks in consumption are emerged while reducing electricity cost this may damage the entire power system.

The authors proposed optimal scheduling method in [14] for distributed generations, battery ESS, tap transformer, and controllable loads for SG application. They use BPSO technique to solve optimization problem and proved by simulation that total system losses are minimized battery ESS size are considerably reduced. However, the system objectives are achieved at cost system complexity. The authors in [15], proposed two market models in order to cope the gape between demand and supply. In [16], authors proposed novel appliances commitment algorithm to optimally schedules appliances under operational constraints and economical consideration in order to maximize comfort and reduce cost. However, peaks may emerge while reducing cost because most users start operation during off peak timeslots.

3 System Model

We consider a smart power system with a single utility company and serval users. Each user is equipped with RESs, such as rooftop PV units. The energy demand of users are fulfilled by their local RE generation and power imported from utility company. Furthermore, the home energy management control system (HEMCS) comprises of EMCU, appliances, smart meter, and inverter. We assume that each home is equipped with smart meter which is connected to EMCU for load scheduling and adjusting energy consumption. We divided the scheduling time horizon into T_h timeslots, where $T_h = \{1, 2, 3, ..., 120\}$.

We classify the appliances on basis of their operation and demand requirements as, interruptible appliances (IA), non-interruptible appliances (Non-IA), and must run appliances (MR-A). The operation of IA can be delayed or interrupted by EMCU if required. In addition, IA completes its operation in disjoint time interval and the interruption of operation does not impact completion of the task. For Non-IA, cannot be interrupted, shifted, and shutdown during operation until to completion, it is only possible to delay its operation. On the other hand, MR-A are refrigerator, air conditioner, and dispenser, these appliances are price inelastic because refrigerator and dispenser need to be on at all times during the day.

We consider RTP method combined with IBR for electricity pricing because in case of only RTP there is a possibility of building peaks during off peak timeslots.

To take the benefit from solar energy, we integrate rooftop PV units with households to optimally schedule household appliances in order to reduce electricity cost, PAR, and carbon emission. The output power of PV units is calculated as [5]

$$E^{PV}(t) = \eta^{PV}.A^{PV}.I_r(t).(1 - 0.005(T^a(t) - 25)) \quad \forall \ t \tag{1}$$

where η^{PV} is the percentage energy efficiency of PV unit, A^{PV} is the area of PV units in (m^2), $Ir(t)$ is the solar irradiance (kW/m^2) at time t, 0.005 is temperature correction factor [6], the outdoor temperature (°**C**) at time t and 25 is standard room temperature (°**C**).

To cope the gap between the demand and supply, we assume that each user is equipped with PV units and ESS. If the harvested energy is surplus or off peak hours the energy is stored in ESS. If the harvested energy is deficient then all harvested energy is used to serve the load. The energy stored in ESS is calculated by the following formula [5]

$$E^{ESS}(t) = E^{ESS}(t-1) + \kappa \ . \ \eta^{ESS} \ . \ EP^{Ch}(t) - \frac{\kappa \ . \ EP^{Dch}(t)}{\eta^{ESS}} \tag{2}$$

where $E^{ESS}(t)$ is the stored energy at timeslot t while taking into account energy charged, discharged, and self discharging rate. And η^{ESS} is the efficiency of ESS, energy taken from rooftop PV units to charge ESS is $EP^{Ch}(t)$, and $EP^{Dch}(t)$ is the energy discharged from ESS to serve the load at timeslot t.

$$EP^{Ch}(t) \leq EP^{Ch}_{UB} \tag{3}$$

$$EP^{Dch}(t) \leq EP^{Dch}_{LB} \tag{4}$$

$$E^{ESS}(t) \leq E^{ESS\text{-}Ch}_{UB} \tag{5}$$

where EP^{Ch}_{UB} is the upper limit of charging ESS, EP^{Dch}_{LB} is the lower limit of discharge and $E^{ESS\text{-}Ch}_{UB}$ is the upper limit of the stored energy.

4 Simulation Results and Discussion

In this section, simulations results and discussions are presented in order to evaluate the performance of demand side management under the RESs such as

Table 1. Description of appliances

Category	SA	OTS	Power rating (KW)
Must run appliances	Air conditioner	75	1.5
	Water cooler	70	1
	Refrigerator	60	0.5
Interruptible appliances	Washing machine	40	0.7
	Clothes dryer	40	2
	Water motor	36	0.8
Non-interruptible appliances	Electric kettle	20	1.5
	Electric iron	30	1.8
	Oven	25	2

rooftop PV units. In our simulation settings the scheduling time horizon 24 h is divided into 120 timeslots. We compare our proposed algorithm GWDO with other heuristic algorithms such as, GA, BPSO, WDO to validate the effectiveness of our proposed algorithm. We consider a single home in residential sector under utility and rooftop PV units having IA, Non-IA, and MR-A. The description of the appliances are listed in Table 1. For electricity pricing, we adopt RTP method combined IBR. The RTP signal is MISO daily electricity pricing tariff taken from FERC is shown in Fig. 1 and the normalized form of solar irradiance and temperature data obtain from METEONORM 6.1 for Islamabad region of Pakistan is presented in Figs. 2 and 3. The PV units generate electricity, depends on solar irradiance, ambient temperature, efficiency of PV units, and effective area of PV units. When ESS is fully charged, then it is utilized later during on peak hours in order to reduce the electricity cost and PAR.

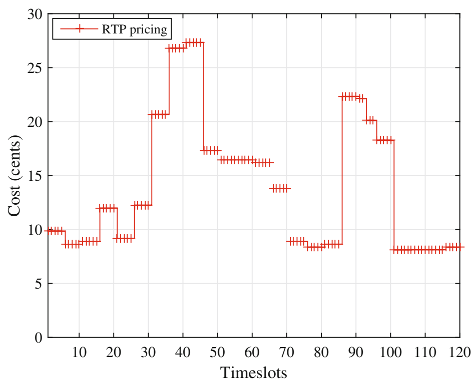

Fig. 1. RTP profile

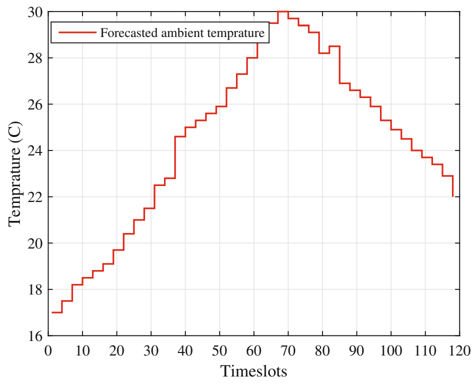

Fig. 2. Forecasted temperature profile

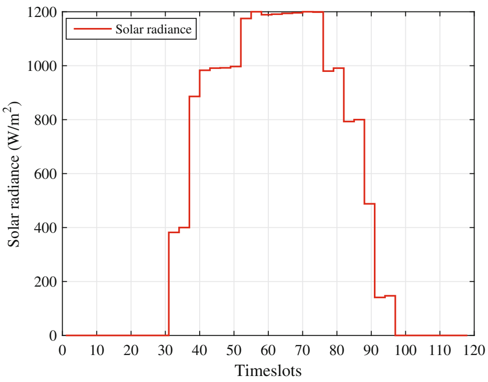

Fig. 3. Solar irradiance profile

4.1 Energy Consumption Behavior of Appliances

The load scheduled based on (GA, BPSO, WDO, GWDO) and unscheduled without RESs and ESS is shown in Fig. 4. The unscheduled load of users without RESs and ESS have consumption peaks of 9.1 KWh at timeslot 90, 8.90 KWh during timeslots 91 to 93, 8 KWh during timeslots 81 to 83, 7.8 KWh during timeslots 94 to 106, and 6 KWh during timeslots 107 to 111. The scheduled load based on GA of users have peak energy consumption of 6.1 KWh at timeslot 1 to 2, 6 KWh at timeslots 11 and 25. The percent decrement of peak power consumption in case of GA as compared to unscheduled is 32.96%. The BPSO based scheduling of users have peak energy consumption of 6.2 KWh at timeslot 42 and 59 and 6.1 KWh at timeslot 40 to 41. The peak energy consumption of BPSO is 31.86% less than as compared to unscheduled case. In case of WDO based scheduling the peak energy consumption of 6.05 KWh at timeslot 59 and 5.8 KWh at timeslot 51 and 85. WDO based scheduling have moderate energy consumption in the remaining timeslots. The percent decrement in peak power consumption in case of WDO is 33.51% as compared to unscheduled.

Our proposed GWDO technique based scheduling peak energy consumption of 5.9 KWh at timeslots 1, 2 and 106. The percent decrement of GWDO is 35.16% as compared to unscheduled. The load scheduled based on (GA, BPSO, WDO) and unscheduled with RESs is shown in Fig. 5. The peak energy consumption of scheduled load based on GA, BPSO, WDO, GWDO, and unscheduled are 6.1 KWh at timeslot 1 to 2, 5.6 KWh at timeslot 28 to 29, 5.5 KWh at timeslots 6 to 7, 5.8 KWh at timeslots 1 and 103, and 8.1 KWh at timeslots 91 to 95, respectively. The percent decrement of heuristic techinques (GA, BPSO, WDO, GWDO,) as compared to unscheduled are 24.69%, 30.86%, 32%, 28.39%, are respectively. Our proposed scheme GWDO over all profile load with RES is better as compared to other heuristic techniques (GA, BPSO, WDO).

The unscheduled load and scheduled load based on (GA, BPSO, WDO, GWDO) with RESs and ESS is shown in Fig. 6. Our proposed scheme GWDO over all load profile with RESs and ESS is best among the other heuristic techniques (GA, BPSO, WDO) and unscheduled as clear from Fig. 6.

4.2 Electricity Cost per Timeslot Analysis

The electricity cost of scheduled load based on (GA, BPSO, WDO, GWDO) and unscheduled load without RESs and ESS is shown in Fig. 7. The maximum electricity cost per timeslot of scheduled load based on GA, BPSO, WDO, GWDO, and unscheduled load are, 0.9 cents/KWh at timeslot 31, 0.6 cents/KWh at timeslot 43 and 58, 0.55 cents/KWh at timeslot 57, .49 cents/KWh at timeslot 1 and 103 and 2.1 cents/KWh at timeslots 88 and 89. As clear from Fig. 7 that our proposed scheme GWDO has most stable and optimal electricity cost profile as compared to other heuristic algorithm and unscheduled.

The electricity cost of scheduled load and unscheduled load with RESs is shown in Fig. 8. The maximum electricity cost of unscheduled load with RESs

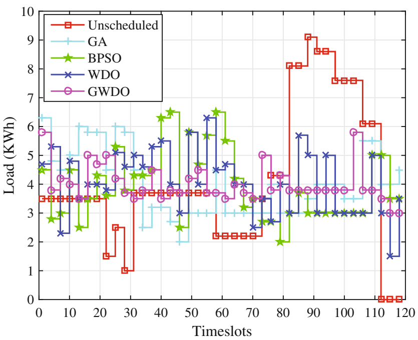

Fig. 4. Energy consumption without RESs and ESS

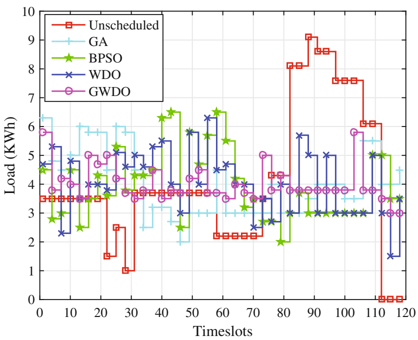

Fig. 5. Energy consumption with RESs

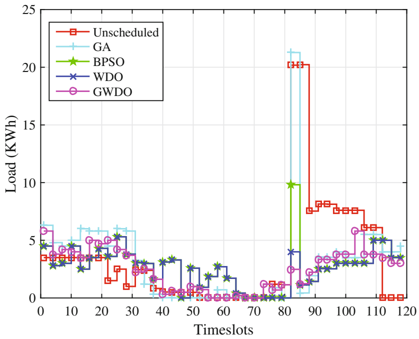

Fig. 6. Energy consumption with RESs and ESS

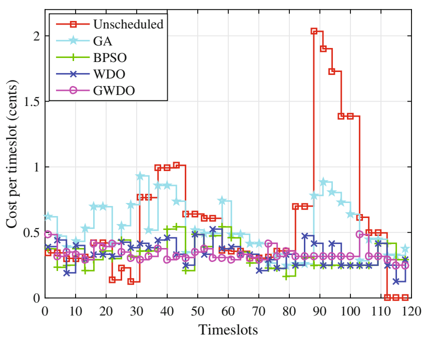

Fig. 7. Electricity cost without RESs and ESS

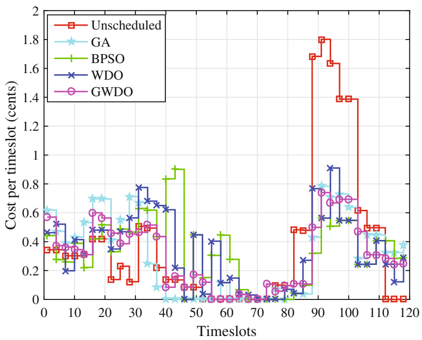

Fig. 8. Electricity cost with RESs

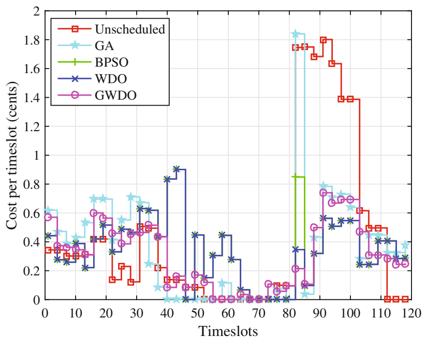

Fig. 9. Electricity cost with RESs and ESS

is 1.8 cents/KWh at timeslot 91 to 93, 1.7 cents/KWh at timeslot 89 to 91, 1.65 cents/KWh at timeslots 97 and 98, and 1.4 cents/KWh at timeslots 99 to 102 because the users do more activities in these timeslots, so therefore, energy consumption in these timeslots is high which results high electricity cost. GA based scheduled load has maximum electricity cost 0.8 cents/KWh at timeslot 91, 0.7 cents/KWh at timeslots 16 to 21 and 29 to 31 because the energy consumption at these timeslots is maximum. The BPSO based scheduled load has maximum electricity cost of 0.9 cents/KWh at timeslot 43, 0.85 cents/KWh at timeslots 41, and 0.7 cents/KWh at timeslots 35 and 36 due to high energy consumption at these timeslots. The WDO based scheduled load has maximum electricity cost of 0.9 cents/KWh at timeslot 93 and 0.75 cents/KWh at timeslots 31, 32, 89, and 90 because in this scenario energy consumption is high in these timeslots. Our proposed scheme GWDO is better than other heuristic techniques (GA, BPSO, WDO) in terms of electricity cost as shown in Fig. 8.

The comparative analysis of scheduled load based on (GA, BPSO, WDO, GWDO) and unscheduled load with RESs and ESS in terms of electricity cost is shown in Fig. 9. The simulation results show that GWDO has most suitable, stable, and optimal profile as compared to unscheduled load and other heuristic techniques (GA, BPSO, WDO) in terms of electricity cost (Figs. 10, 11 and 12).

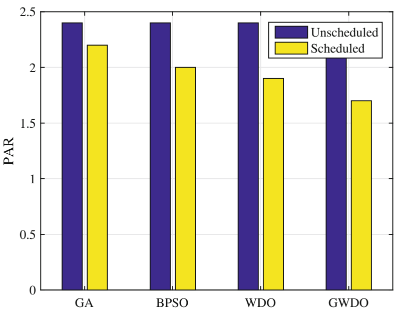

Fig. 10. PAR without RESs and ESS

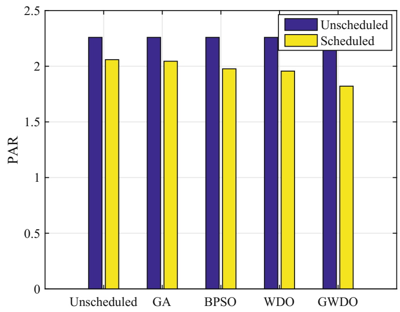

Fig. 11. PAR with RESs

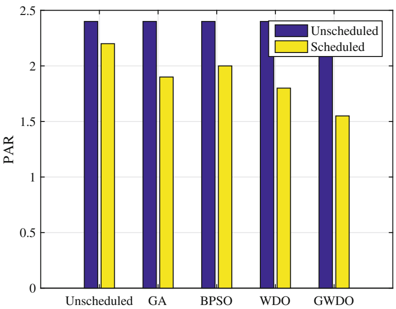

Fig. 12. PAR with RESs and ESS

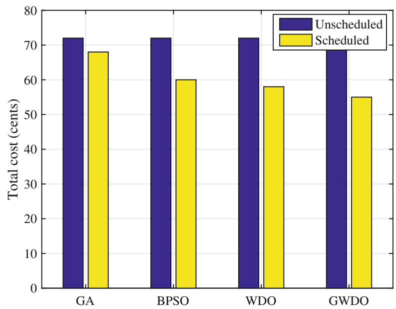

Fig. 13. Total cost without RESs and ESS

4.3 PAR Analysis

The PAR of scheduled load using (GA, BPSO, WDO, GWDO) and unscheduled without RESs and ESS is shown in Fig. 13. The EMCU based on all these algorithms are designed to avoid the peaks which results reduction in the PAR. The GA, BPSO, WDO, and GWDO reduce the PAR as compared to unscheduled case by 8.3%, 16.5%, 20.8%, and 29.1%, respectively. The percent decrement of GWDO is more as compared to the other heuristic techniques which ensures that our proposed scheme outperform than other heuristic techniques. This reduction in PAR provide benefits to utility and consumers interms of power system stability and electricity bill savings, respectively.

The PAR of scheduled load using (GA, BPSO, WDO, GWDO) and unscheduled with RESs is shown in Fig. 14. The simulation results show that with incorporation of RESs our proposed algorithm GWDO reduces the PAR by 30% as compared to unscheduled load case. Moreover, our proposed algorithm tackle the problem of peak formation and optimally shifts the load from on peak timeslots to off peak timeslots.

The PAR of scheduled load based on (GA, BPSO, WDO, GWDO) and unscheduled with RESs is shown in Fig. 15. Results show that the integration of RESs reduces the PAR by 30% and after incorporating the ESS as well, the PAR is reduced by 35.4%. This reduction in PAR not only enhances the stability and reliability of the power system but also reduces the electricity bill of the consumers.

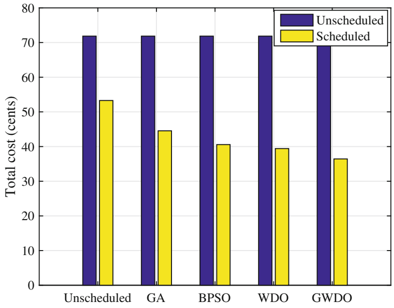

Fig. 14. Total cost PAR with RESs

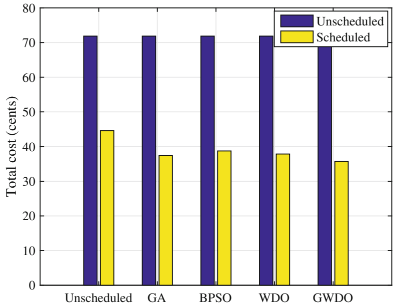

Fig. 15. Total cost with RESs and ESS

4.4 Total Cost Analysis

The aggregated cost analysis of scheduled load without RESs is shown in Fig. 13. The heuristic techniques GA, BPSO, WDO, and our proposed GWDO reduces the electricity cost by 4.2%, 15.49%, 18.3%, and 22.5%, respectively. The percent decrement in case of our proposed GWDO is more as compared to unscheduled and scheduled load using heuristic techniques (GA, BPSO, WDO).

The aggregated cost analysis of scheduled load with RESs is shown in Fig. 14. The percent decrement of our proposed GWDO technique is 47.7% as compared to unscheduled because it employees the crossover and mutation steps of GA on best values rather than on random values. So our scheme outperform as compared to other heuristic techniques such as GA, BPSO, and WDO.

The aggregated cost with RESs and ESS of scheduled load and unscheduled load is shown in Fig. 15. The percent decrement of our proposed scheme with incorporation of RESs and ESS are more as compared to without RESs and with RESs. So our scheme is beneficial for consumers in order to reduce their cost.

5 Conclusion

In this paper, we adopt GA, BPSO, WDO, and proposed GWDO algorithm for residential load scheduling under utility and rooftop PV units. The main idea is to encourage consumers to take part in RE generation and efficient load scheduling in order to reduce electricity cost. We used combined RTP and IBR to avoid building of peaks during off peak hours because that damage the entire power system. The proposed algorithm aimed to reduce the electricity cost and PAR. Simulation results evidenced that our proposed system model for home energy management significantly reduce electricity cost and PAR.

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A Hybrid Genetic Based on Harmony Search Method to Schedule Electric Tasks in Smart Home

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Abstract. In the residential area, high electricity demand of power-consuming household tasks has become a crucial issue. Thus, the key objectives of home energy management system (HEMS) are scheduling power-consuming household tasks to minimize electricity cost and maximize consumer's comfort. The many utilities offer residential demand response (DR) program to shift residential customer electricity consumption during the peak time period to match demand and supply. In this paper, we propose optimal load scheduling algorithm a hybrid genetic based on harmony search (HGHS) for HEMS to schedule power-consuming household tasks. The new optimal load scheduling algorithm HGHS gives optimal solution to schedule power-consuming household tasks based on real time pricing (RTP) electricity tariff within electricity task time window during the day in order to minimize electricity cost, reduce peak-to-average ratio (PAR) and maximize user comfort. The proposed model implemented in a single smart home and simulation results of proposed HGHS algorithm are compared with genetic algorithm (GA) and harmony search algorithm (HAS) and it provides better results in reducing the daily electricity cost and PAR by reducing load at peak hours. Simulation results shown that the trade-off between electricity cost reduction and user comfort exist in two conflicting objectives.

1 Introduction

In electricity grid power outages occasionally arise because of increased number of power-consuming household tasks and over demand of electricity from residential in the period of peak hours. To meet the required high electricity demand from customer, electricity suppliers are imposed to enhance the generation of electricity by establishing extra electric power plants. However, this solution is not feasible due to unsustainability and increased CO_2 emissions that contribute to climate change [1].

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The alternative solution, demand response (DR) program that implemented in demand side management (DSM) has been investigated to reduce electricity consumption in household tasks during period of peak hours and enhance the power plant utilization in the United Kingdom and many other countries since 1970s [2]. The DR program plays a key role improving overall operational efficiency and reliability of smart grid (SG) and is expected to offer economic benefits to consumer. The original model of SG introduced with the idea of advanced metering infrastructure (AMI). The ultimate objectives of AMI are to improve DSM, efficient energy utilization, making self-healing reliable power grid security and protection against spiteful damages and natural failures and disasters [3]. Using a DSM approach electricity consumption can be minimized with the help of changing residents' living behavior to better match in demand and supply by controlling the operation of household tasks from the user side [3]. The most significant feature of SG technology is interactive relationship between utilities, power grid operators, smart energy meters and smart homes that allows them functioning together. The emerging feature of DSM system DR program exploits the smart energy meters that can offer two-way communication among end users and utilities, which help the end user to make decision and schedule power-consuming household tasks based on electricity price signal. Therefore, a properly designed DR program offers features that help consumers to schedule power-consuming household tasks so that, they can reduce electricity cost and improve the level of their comfort based on their preference and demand profile [4].

In literature, DR programs based on their features and functionalities are broadly classified into incentive-based programs (IBP) and price-based programs (PBP). In IBP, the utility can direct access and control power-consuming household tasks to reduce electricity demand in the period of peak hours by providing financial benefits to participating end user. In PBP, end users gladly schedule the power-consuming household tasks in their houses based on time-based and real time electricity tariffs such as time-of-use (TOU) pricing, real time pricing (RTP) and critical peak pricing (CPP) [5]. A smart home facilitated with price-based DR approaches is generally operational with home energy management system (HEMS) that allows residential consumers to control and schedule their power-consuming household tasks associated with smart power meter [6]. By using HEMS at domestic sector, the household electricity load entirely controlled and automated using information communication technology (ICT) and enabling DR programs. In last decade, many optimization approaches has been proposed to facilitate residential consumer reducing electricity cost with changes energy usage pattern by implementing an optimal HEMS based on various dynamic pricing tariffs.

In [7], authors proposed GA based an efficient scheduling method for home power usage by introducing DR program based a general architecture of energy management system (EMS) in home area network (HAN). By adopting combined pricing model of RTP and IBR, proposed method effectively reduce the electricity cost and PAR. Roh et al. [8], introduced residential DR program to schedule appliances of various categories. Authors proposed an electricity load scheduling algorithm using low computational complexity model based on generalized Benders decomposition approach, adapting TOU pricing model in order to reduce electricity cost and obtain the optimal scheduling of power-consuming appliances. Rastegar et al. [9], proposed a price-based HEM framework to incorporate the operational priority of different appliances in optimal model of an energy management system. The value of lost load (VOLL) of each appliance is defined to indicate the operational priority of appliances from the customer perspective. The proposed price-based DR program considered VOLL, operation constrains of appliance and electricity tariff model to schedule household appliances, so that energy and reliability cost reduction for next day can be achieved.

However, in last decade mainly researchers paying attention on reducing electricity consumption and electricity cost and ignored user comfort factor to design DR program based HEMS. Thus, to optimally schedule and supervise power-consuming household tasks there must be considered all promising parameters, such as user comfort level, peak-to-average load demand limit and pricing tariff. In this paper, we propose optimal load scheduling algorithm a hybrid genetic based on harmony search (HGHS) for HEMS to schedule power-consuming household tasks. The new optimal load scheduling algorithm HGHS gives optimal solution to schedule power-consuming household tasks based on real time pricing (RTP) electricity tariff within electricity task time window in order to minimize electricity cost, reduce peak-to-average ratio (PAR) and maximize user comfort. The remainder of this paper is organized as follows: in Sect. 2, the related work is described briefly with relevant approaches, techniques and algorithms. In Sect. 3, proposed system model is briefly described. In Sect. 4, proposed algorithm is briefly explained. In Sect. 5, the simulation results are discussed and finally, concluding remarks are given in Sect. 6.

2 Related Work

In literature, many researchers proposed optimal solutions based on price-based DR signal to optimally schedule household smart appliances. In this regard, we briefly discussed a few recent journal publications.

In [10], authors proposed binary backtracking search algorithm (BBSA) based schedule controller for HEMS to manage the energy consumption and to verify the accuracy of developed scheduler experimental results are compared with binary Particle swarm optimization (BPSO) schedule controller. The BBSA real time optimal schedule controller provides better optimal schedule for household appliances. The priority and resident comfort constrains are applied to reduce energy consumption and total electricity bill and to save electricity at peak hours. In [11], a novel method to design HEMS based on efficient energy scheduling Dijkstra algorithm for an autonomous energy management-based cost reduction solution is proposed to reduce the total cost under maximum available energy constrains as well as household appliances constrains. A low complexity method is also proposed to reduce the computational efforts. To encounter the peak demand by minimizing the overall cost, the complexity of scheduling algorithm, help in reducing power consumption by HEMS. Shirazi et al. [12], proposed a smart home energy management model using mixed integer linear programming (MILP) to jointly control and schedule electrical and thermal household appliances with aims to reduce electricity cost. To design the smart home energy management model discomfort index has been considered with controllable integration of RESs and ESS to avoid peak hours and reduce electricity cost under RTP tariff model.

In [13], a novel residential energy management system (REMS) is designed using mixed integer nonlinear programming (MINLP) model to improve the efficiency of energy consumption in a typical smart micro-grid (SM-G). The competitive objectives are minimum electricity cost and maximum user comfortable level. The integration of RESs, ESS and thermo-electrical features of the house help to improve efficiency of energy consumption in residential SM-G. The different tariff model like RTP, TOU and flat rate (FLR) model are used to measure the efficiency of proposed model. Gudi et al. [14] implement heuristic optimization algorithm BPSO to design a DSM based simulation tool with GUI support to control distributed energy resources, optimally schedule the operation of household appliances and an estimate for home electricity consumption to reduce customer's cost in a hybrid renewable energy system (HRES). In [15], authors proposed a smart-grid strategy based on optimization approach GA combine with a two-point estimate method in order to reduce cost and enhance hybrid system efficiency for matching the controllable HVAC load with ESS and hybrid-renewable energy generation. The proposed strategy applied on a residential sector and simulation results show that the efficiency of hybrid system increase by combining the GA with a two-point estimation method.

In [16], a MILP model has been proposed to optimally schedule the DER operation and energy-consuming household tasks in order to reduce a one-day forecasted smart homes' energy consumption cost in microgrid. Authors in [17] proposed a novel cost efficiency-based framework for scheduling of residential load using Fractional Programming (FP) approach to enhance the economical efficiency of energy-consuming household tasks. By integrating the DER in framework, the simulation results show that proposed framework is greatly effective in enhancing the economical efficiency of energy-consuming household tasks. In [18], GA based energy management model is designed to schedule household appliance according to predefined time window to achieve the objective function, reduce electricity bill and avoid peak formation. Authors in [19], modeled a new algorithm based on MILP and a heuristic algorithm for a HEM system to schedule high power-consuming household appliances. In this study, each high power-consuming household appliance properly modeled to achieve objectives to reduce energy consumption and maximize user comfort. Logenthiran et al. [20] proposed heuristic based evolutionary algorithm (EA) for scheduling power-consuming appliances to reduce electricity cost for domestic, industrial and commercial user. Based on objective curve received from utility the DSM schedule electricity load close to objective curve.

3 Proposed System Model

In the proposed model, we assume smart home that mainly comprises advance metering infrastructure (AMI), home gateway (HG), smart meter, home appliances and in-home display devices and communication occur between them with the help of wireless home area network (HAN). The key features of AMI are collecting the energy consumption data from smart meters and transmitting it to the utility as well as communicating a DR signal for pricing tariff and peak hours from the utility to the smart meters. The smart home pursues its own electricity demand curve, total electricity demand depending on household available power-consuming appliances and living habits. The household power-consuming appliance tasks are classified into two categories flexible tasks and inflexible tasks. The flexible tasks, this kind of household task can be scheduled automatically in smart home using proposed model for HEMS. The inflexible tasks, in literature these tasks referred as base line load or real time appliances.

It is assumed that AMI communicating a DR signal for RTP pricing tariff from the utility to the smart meter one day in advance. The one day divided into 48 time slots of half hour each. The power-consuming available household 12 electrical appliances are scheduled according to define operation time window and their respective operating times and power rating are based on [23]. The detail about operation time window, constant power rates listed in Table 1.

Table 1. Electricity consumption task [23].

	Task	Power rating (kWh)	Earliest Start time (h)	Latest finish time (h)	Time window length (h)	Duration (h)
1	Dish washer	1	9	17	8	2
2	Washing machine	1	9	12	3	2
3	Spin dryer	2.5	13	18	5	1
4	Laptop	0.1	18	24	6	2
5	Desktop	0.3	18	24	6	3
6	Vacuum cleaner	1.2	9	17	8	1
7	Electrical cars	3.5	18	8	14	3
8	Cooker hob	3	8	9	1	1
9	Cooker oven	5	18	19	1	1
10	Microwave	1.7	8	9	1	1
11	Fridge	0.3	0	24	24	24
12	Interior lighting	0.84	18	24	6	6

4 Proposed Scheduling Algorithm

In this paper, proposed optimal load scheduling algorithm HGHS combined GA and HSA and results show that the new algorithm is feasible and effective. In coming subsection, we described GA, HSA and HGHS.

4.1 Genetic Algorithm

Genetic algorithm inspired by the genetic process of living organisms, a universal heuristic optimization technique in which an evolutionary programming approach is adopted. To solve the optimization problem, it depends upon few constrain parameters and less computation resources as compared to traditional mathematical approaches but can only guarantee a local optimal solution. At present, GA application exists in numerous fields including function optimization, pattern recognition, image disposal, machine leaning, combinatorial optimization, optimization controller and scheduler and so on. The GA is effectively influenced by crossover operator and mutation operator to find out optimal solution from search space. The crossover operator should be applied on those chromosomes (strings [0, 1]) which are proficient to generate better offspring. Generally, one-point crossover operator is applied in which an arbitrary bit position in binary string is selected as crossover point and then swapped binary substrings of the two parents to generate offspring (child). Mutation operator play role to preserve the genetic diversity of population from one generation to the next generation. Mutation operator arbitrarily turns over some bits in a chromosome (binary string) and can occur in a binary string at every bit position with very small probability.

However, GA has limitations such as low convergence speed, high calculation time and prematurity. In recent research, it observed that the combining random searching algorithms with GA significantly improve the performance of GA [22].

4.2 Harmony Search Algorithm

A newly emerging algorithm comes from an artificial phenomenon, musical harmony of music creation is called harmony search algorithm (HSA). It was proposed by Zong Woo Geem and Joong Hoon Kim [21]. To improve the local optimization performance of HSA the fine tuning technique is adopted. HSA is an evolutionary algorithm that based on behavior of musician such as experience-based play, random play and pitch adjusted play. To get the initial right state of harmony in HSA three main operations are considered such as pitch adjustment, random selection and memory-based play and the initially generated harmony search (HM) consists of a harmony memory size (HMS) number of randomly produced solutions for the under consideration optimization problem. There exist a uniform distribution of random number in between upper and lower bounds of the problem in each part of a harmony in HM at initial stage [21]. The searching space provides base to randomly generate the elements of new harmony as follows:

$$x_{i,j} = l_i + rand().(u_j - l_j) \tag{1}$$

where $x_{i,j}$ is the jth element of harmony x_i, and harmony memory HM = $\{x_1, x_2, ..., x_N\}$; l_j and u_j are the lower and upper bounds of the ith searching dimension; rand() generates a real random number uniformly distributed in [0, 1].

In next step after generation of initial HM, improvisation process started and new harmony generated based on two control parameters – harmony memory consideration rate (HMCR) and pitch adjustment rate. The random selection technique is applied to choose elements of new harmony by considering HMCR value and pitch adjustment ratio of each generation of HSA as follows.

$$v_{i,j} = \begin{cases} x_{rnd,j} & rand() < HMCR \\ l_j + rand().(u_j - l_j) & else \end{cases} \tag{2}$$

where $x_{rnd,j}$ is the jth element of the randomly selected harmony x_{rnd}.

After that, the obtained elements in the memory concern operation are changed to their neighbors based on the pitch adjusting rate as follows.

$$v_{i,j} = \begin{cases} v_{i,j} \pm rand().bw_j & rand() < HMCR \\ v_{i,j} & else \end{cases} \tag{3}$$

where bw_j is the random distance bandwidth for the jth element.

The newly generated harmony is compared with minimum (worst) harmony in HM and if the new harmony is better, in that case existing old minimum harmony is replaced with new harmony in HM.

4.3 A Hybrid Genetic Based on Harmony Search

We propose optimal load scheduling algorithm for household appliances a hybrid genetic based on harmony search (HGHS). The harmony and HM in HSA and chromosome and population in GA have dissimilar terminologies for feasible solution. Based on them, it is interesting to hybridize HS with a GA in order to obtain some possible improvement. So a new hybrid algorithm HGHS is put forward by appropriately integrating harmony and chromosomes as well as harmony memory and population for optimal scheduling of household appliance. The main procedure of the new algorithm is that to begin with initiate parameters including the population size, harmony memory size (HMS) and the probability of mutate HM, the generations, the probability of crossover, HMCR, pitch adjustment ratio, number of iteration (NI) and disturbance bandwidth (BW). The two basic parameters HMCR and pitch adjustment ratio of HS algorithm significantly control the performance as well as the speed of the convergence of the solution. The HMCR is utilized to set the probability of preceding information stored in the HM and then adjust pitch adjustment ratio accordingly.

As describe in Algorithm 1, in next step the fitness value of each individual in the population is calculated. After that, using selection, crossover and mutation features of GA the next population is generated. The next population generated by GA considered as harmony memory and chromosome considered as harmony. In next step, new harmony is generated by HS and the fitness value of each individual in the harmony (population) is calculated again.

Algorithm 1. Hybrid Genetic Based on Harmony Search

Initialize the algorithm parameters HMS, Pitch Adjustment Ratio (PAR), HMCR, and Bandwidth (bw) distance, problem dimension (D);
`/* Initialize the HM */`
for *i=1:HMS* **do**
    for *d=1:D* **do**
        $HM_{i,d} = l_i + rand(1).(u_j - l_j)$;
    end
end
for *i=1:HMS* **do**
    Evaluate the fitness for each individual in HM;
end
Applied crossover operator on HM;
Applied mutation operator on HM;
while *the halting criteria is not satisfied* **do**
    for *d=1:D* **do**
        `/* memory consideration */`
        if $rand() < HMCR$ **then**
            $x_{new}(d) = x_a(d),\ where\ \ a \in (1, 2, ..., HMS)$;
            `/* pitch adjustment */`
            if $rand() < PAR$ **then**
                $x_{new}(d) = x_{old}(d) + bw \cdot (2 \cdot rand - 1)$;
            end
        else
            `/* random selection */`
            $x_{new}(d) = x_{min,d} + rand \cdot (x_{max,d}, x_{min,d})$;
        end
    end
    Update the HM as $x_w = x_{new}$;
    if $f(x_{new}) < f(x_w)$ **then**
        Include x_{new} to the HM;
        Exclude x_w from the HM;
    end
end

5 Simulations and Discussions

In this section, we present the simulation results and thorough comparison between unscheduled load and scheduled load using GA, HSA and proposed optimal load scheduling algorithm HGHS. First we present the system settings; the proposed operation cycle for system is 24 h and is divided into 48 timeslots of half hour each and electricity pricing signal for 48 timeslots based on RTP tariff taken from FERC as shown in Fig. 2. The objective of using RTP model is to enable consumers to make decision that can be beneficial for them in terms both of electricity bill reduction and comfort level. In residential sector, a single home equipped with 12 basic household electrical tasks is considered that takes electricity from utility. The household appliances or tasks are further classified into flexible tasks and inflexible tasks. All power-consuming household tasks are available to be scheduled according to their given power rating, operation time window and length of operational time is based on [23] and power-consuming household tasks for the scheduling listed in Table 1. The simulations results are obtained from executing MATLAB R2015b in a computer with Intel Core-i5 CPU and 4 GB memory.

Energy consumption pattern of unscheduled load and scheduled load using GA, HSA and proposed optimal load scheduling algorithm HGHS is shown in Fig. 1 It is shown that maximum energy consumption value are limited to 5.02 kWh, 3.27 kWh, 3.52 kWh and 3.07 kWh for unscheduled, GA, HSA and HGHS respectively. The maximum value of electricity bill in unscheduled model is 1699 cents as shown in Fig. 3. It is reduced to 1401.4 cents, 1364.3 cents and 1302.8 cents in the case of GA, HSA and HGHS respectively. The electricity bill reduced 17.519%, 19.701% and 23.317% using algorithms GA, HSA and HGHS respectively per day of a single home. This shows that hybrid technique is more cost-efficient than GA and HSA.

Electricity load curves/ power consumption pattern for GA, HSA and HGHS described that appliances are optimally distributed in given time window without

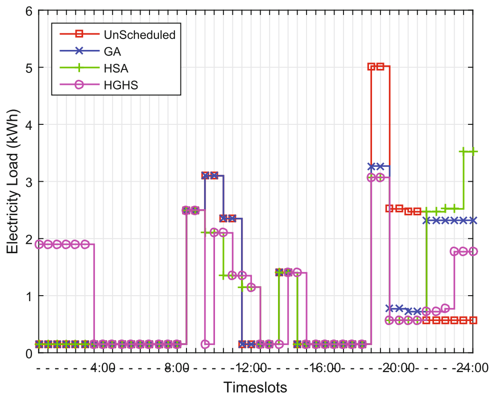

Fig. 1. Energy consumption pattern

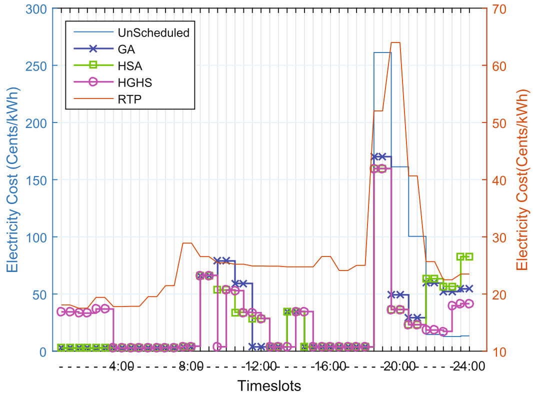

Fig. 2. Electricity price signal

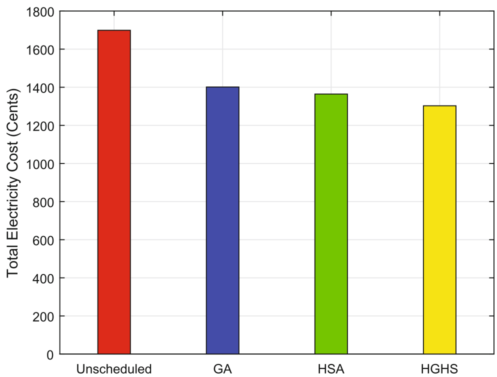

Fig. 3. Total electricity bill

creating peak in peak hours of a day. Peak-to-Average Ratio (PAR) of unscheduled and using GA, HSA and proposed optimal load scheduling algorithm HGHS is shown in Fig. 4. It shows that PAR is significantly reduced for GA, HSA and HGHS as compared to unscheduled case. There is no peak formation in any hour of a day and PAR is maximum reduced in case of and proposed optimal load scheduling algorithm HGHS. It is shown in Fig. 4 that PAR values are limited to 3.3871, 3.6461 and 3.18 for GA, HSA and HGHS optimization technique respectively.

User comfort is related to both electricity bill reduction and less waiting time for a task to start. In order to achieve lower electricity bills, smart users must operate their flexible appliances according to optimal schedule. During scheduling of flexible appliances, operational time is not fixed due to price variation in dynamic RTP tariff model. Generally, it is observed that tradeoff exist in electricity cost reduction and waiting time. The purpose of scheduling algorithm to delay the operation of any flexible appliance is to optimize the system according

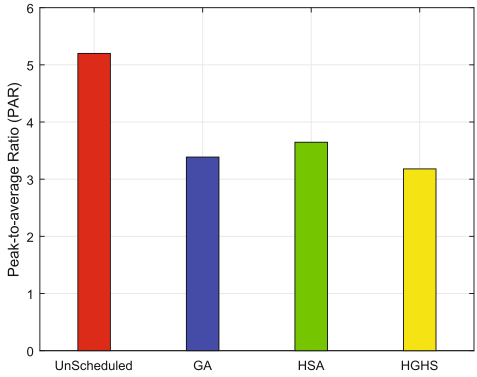

Fig. 4. Peak-to-average ratio (PAR)

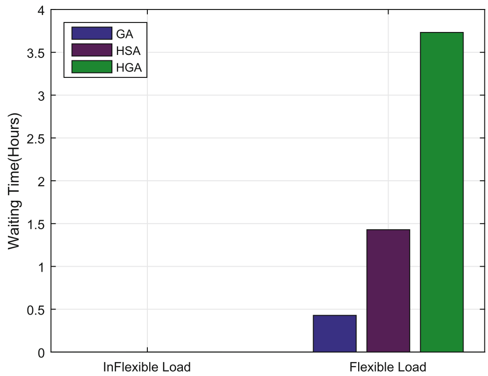

Fig. 5. Waiting time (Hours)

to the designed objective function. When energy consumption of an appliance is more than the power capacity of a particular hour or during high peak hour, appliance scheduler shifts the appliance to another time slot. By ignoring waiting time factor, optimized scheduling cannot be achieved. The waiting time for inflexible load and flexible load is shown in Fig. 5.

6 Conclusion

The new proposed optimal load scheduling HGHS algorithm gives optimal solution to schedule household tasks operation. The scheduling is based on RTP electricity tariff at each time interval and subject to the constraints at specific electricity task time window, the earliest starting time and latest ending time for each appliance defined by consumers in order to minimize electricity cost, PAR and maximize user comfort. The proposed model implemented in a single smart home to schedule household tasks and simulation results of proposed

HGHS algorithm efficiently reduce the electricity cost and PAR by reducing electricity load in peak hours. Although, the trade-off exist between the electricity cost reduction and user comfort, simulation results shown that new algorithm is feasible and effective. The proposed algorithm performance may significantly increase by integrating the renewable energy sources (RESs) and energy storage system (ESS) features and hybridized GA and HSA more effectively.

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An Efficient Home Energy Management Scheme Using Cuckoo Search

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Abstract. Smart grid plays a significant role in decreasing of electricity consumption cost through Demand Side Management (DSM). Smart homes, a part of smart grid contributes a lot in minimizing electricity consumption cost via scheduling home appliances. However, user waiting time increases due to scheduling of home appliances. This scheduling problem is considered as an optimization problem. Meta-heuristic algorithms have attracted increasing attention in last few years for solving optimization problems. Hence, in this study we propose an efficient scheme in Home Energy Management System (HEMS) using Genetic Algorithm (GA) and Cuckoo search algorithm to solve optimization problem. The proposed scheme is implemented on a single smart home and a smart building; comprising of thirty smart homes. Real Time Pricing (RTP) signals are used in term of electricity cost estimation for both single smart home and a smart building. Experimental results demonstrate the extremely effectiveness of our proposed scheme for single and multiple smart homes in terms of electricity cost and Peak to Average Ratio (PAR) minimization. Moreover, our proposed scheme obtains the desired tradeoff between electricity cost and user waiting time.

Keywords: Cuckoo search · Genetic Algorithm · Smart grid · Demand response

1 Introduction

Electricity cost and pollution minimization are two worldwide growing problems [1]. Currently, energy supply systems are dependent on few large electricity producing plants by using conventional fossil fuels. Later on, the electricity which is produced by the traditional power plants spread to the electricity consumers with the help of distribution and transmission networks. According to [2], during electricity production, transmission and distribution, more than 65% of the electricity produced is wasted.

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With the evolution of smart grid, we have good opportunity to save maximum energy. Smart grid is an efficient power system that includes control system, communication technologies and intelligent information system. In smart grid, we can save electricity by Demand Side Management (DSM) or Supply Side Management (SSM). SSM involves all those activities, which are performed for electricity production, transmission and distribution of electricity. In DSM, the end users alleviate the electricity cost and minimize the Peak to Average Ratio (PAR) by scheduling their home appliances from high price hours to low price hours or by integrating Renewable Energy Sources (RES). The two main functionalities of DSM are load management and Demand Response (DR) [3]. In this work, load management means very intelligent management of the load. Residents can enjoy minimum electricity expenditure and reduce PAR through proper management of load.

An opportunity is offered by DR programs for consumers to play an important role in the operation of the smart grid by minimizing or transferring their electricity consumption from peak hours to off-peak hours in response to time-based electricity rates or may be any other forms of financial motivation for end consumers [4]. The DR programs have two types: The first one is the incentive-based DR programs [5], where the home appliances are wirelessly shifts to OFF state by utility with a short notice when peak is created in any time interval. Price-based DR programs are another type of DR programs where the electricity provider motivates the consumer to manage their home appliances in efficient way for cost reduction, minimization of electricity consumption and PAR [6]. Due to advancement in computing and communication technologies, smart homes and smart grid play very important role for reducing energy consumption in buildings. Electricity consumer can reduce electricity cost, PAR and electricity consumption via interactive relationship between the smart homes and the utility [7].

Furthermore, when smart homes are connected to the smart grid, 10–30% electricity can be saved by scheduling of home appliances via DSM approach [8]. According to [9], different dynamic pricing schemes are proposed for consumer motivation to reduce load in peak hours. Dynamic pricing schemes includes Time of Use (ToU), Real Time Pricing (RTP), Critical Peak Pricing (CPP), Inclined Block Rate (IBR) and Critical Peak Rebate (CPR). However, when consumers shift the electricity consumption from peak hours to off-peak hours, PAR goes to unfeasible. Many researchers proposed different techniques to solve this problem.

In this paper, we have proposed DSM approach for residential consumers, which is based on scheduling techniques. The main focus of our work is to decline the electricity cost, PAR minimization and to obtain desirable user waiting time. We consider single smart home and a smart building consisting of thirty smart homes for implementation. Two meta-heuristic techniques GA and Cuckoo search have been implemented along with RTP signals. Simulation results show the effectiveness of the proposed system.

The rest of the paper is organized as follows: in Sect. 2, we discuss the related work. Section 3 explains the system model. Section 4 consists of proposed scheme. Computational results are highlighted in Sect. 5. Finally, paper findings are presented in Sect. 6.

2 Related Work

Scheduling smart home appliances optimally for cost minimization and load neutralization is a challenging research issue targeted by the research community. In the last few years, many techniques have been proposed for cost minimization, PAR reduction and user comfort maximization.

In [10], the authors proposed a scheduling technique to minimize total electricity expenses and balance the load using Mixed Integer Linear Programming (MILP) for residential consumers. The proposed scheme efficiently reduce the electricity expenses and PAR. However, user comfort is not considered in their work. The same method was extended by Agnetis *et al.* in [11], by using heuristic approach for household energy consumption, climate comfort level and timeliness. Authors in [12], further incorporated scheme using GA, Particle Swarm Optimization (PSO) and Multiple Knapsack Problem (MKP) under three different pricing signals RTP, ToU and CPP. Simulation results demonstrate the effectiveness of their proposed scheme. Cost minimization in smart grid was targeted in [13], by using GA with RES and other storage devices i.e., batteries. The stored electricity is used in specific time interval when the electricity price or demand is high. Charging and discharging limits of the batteries are given by the authors. However, the authors ignore the installation cost and maintenance expenses of RES and storage devices. Authors in [14], proposed a technique for balancing load in industry, commercial and residential areas. The comprehensive simulation results show that the proposed strategy GA-DSM achieved the objective; reduction in electricity consumption which is 21.91% during peak hours. However, the authors did not discuss about PAR and user comfort.

In [15], the authors proposed a model for residential area for cost minimization by using Mixed Integer Non-Linear Programming (MINLP) under ToU pricing scheme. Their proposed scheme reduced 25% electricity cost, however, PAR is not addressed in their work. Another cost minimization scheme is proposed by Pedram Samadi *et al.* [16], dynamic programming was used for shifting the appliances in different time intervals and to interact the user with extra electricity production, game theory is adopted. According to this work residents produce electricity from RES for their home usage and extra produced electricity sell to the neighbors or utility. The authors ignored the installation and maintenance cost of RES. In [17], the novel scheduling model is proposed for cost minimization and reduction in PAR in residential area using heuristic techniques. GA and BPSO are used for optimization and simulation results elaborate the effectiveness of proposed model.

3 System Model

Efficient and reliable operations in smart grid are empowered by DSM. DSM key parameters are energy management and demand side control activities for end consumers. We assume a system model having a power system with single utility and N number of end consumers. In order to compute hourly power consumption, smart meters are installed at every residence. Smart meters are used

Table 1. Appliances parameters

Appliance class	Appliance name	Power rating (kW)	Earliest starting time (h)	Finishing time (h)	LOT (h)
Base load appliances	Cooker hub	3	8	10	1
	Cooker oven	5	18	20	1
	Microwave	1.7	8	10	1
	Laptop	0.1	18	24	2
	Desktop	0.3	18	24	3
	Vacuum cleaner	1.2	9	17	1
	Electrical car	3.5	18	8	3
Deferrable appliances	Dish washer	1.5	9	17	2
	Washing machine	1.5	9	12	2
	Spin dryer	2.5	13	18	1
Non-deferrable appliances	Interior lighting	0.84	18	24	6
	Refrigerator	0.3	1	24	24

to communicate the extracted information of user demand to the utility. It also communicates price information from the utility to the end consumer. A set of appliances is considered $\mathrm{A}_n = \{\mathrm{A}_1, \mathrm{A}_2, ... \mathrm{A}_n\}$, along with an assumption that each appliance is capable to communicate with Energy Management Controller (EMC), which schedule the appliances depending upon the availability of the time slot. Each appliance must complete its execution between earliest starting time and least finishing time. The earliest starting time and least finishing time for each appliance is defined by end consumer explained in Table 1. The whole day is divided into 24 time slots, each time slot consists of 1 h.

Furthermore, we categorize the home appliances in next section which we consider in our proposed work.

3.1 Assortment of Load

To evaluate the objective function of our proposed scheme for single and multiple smart homes, we considered two scenarios in our work. First, we implement on single smart home and then we investigate the performance of our proposed scheme on multiple homes. Each home has n number of appliances. For simplicity, we partitioned the appliances in three categories named deferrable, non-deferrable and base load appliances. For every home, let $\mathrm{A}_n = \mathrm{a}_d + \mathrm{a}_{nd} + \mathrm{a}_b$, demonstrate three classes of the appliances, where a_d, a_{nd}, a_b be the cumulative of deferrable, non-deferrable and base load appliances respectively. These appliances are scheduled in 24 h time horizon, explained below:

$$t \in T, \forall, T = \{t_1,\, t_2,\, t_3,\, t_4,\, ...t_{24}\}$$

For our scheduling problem, we consider twelve different basic appliances for all homes, normally every home consists of these basic appliances. Every smart home in a building have different living habits such that power rating and Length of Operational Time (LOT). All the appliances with their power rating, earliest starting time, least ending time and LOT for a day are explained in the Table 1.

3.1.1 Deferrable Appliances

In this work, we define deferrable appliances that can be interrupted or shifted in any of given time slots in a day depending upon their necessity. Dish washer, washing machine and spin dryer are included in this class. Let a$_d$ be the combination of deferrable appliances and $A_d \in a_d$ demonstrates every appliance in this class as deferrable appliance. Here λ_d shows the power rating of every appliance in this class. The total electricity utilization of deferrable appliances in a day ε_d is shown by the following mathematical formula:

$$\varepsilon_d = \sum_{a_d \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_d \times \alpha_d(t) \right) \tag{1}$$

The total cost of one day which is paid by the consumer to the utility against all deferrable appliances is given by:

$$\delta_{a_d}^{Total} = \sum_{a_d \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_d \times \rho(t) \times \alpha_d(t) \right) \tag{2}$$

Similarly, the total electricity consumption cost for multiple smart homes against deferrable appliances in a day is calculated by the Eq. 3 respectively.

$$\varphi_{a_d}^{Total} = \sum_{Home=1}^{30} \left(\sum_{a_d \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_d \times \rho(t) \times \alpha_d(t) \right) \right) \tag{3}$$

Here $\alpha_d(t)$ represents the ON/OFF status of deferrable appliances in the form of 1 or 0.

3.1.2 Non-deferrable Appliances

We consider an appliance non-deferrable, which cannot be shifted or interrupted while executing. These appliances need time slot right for the completion of their execution. We assume refrigerator and interior lighting as non-deferrable appliances. Let $A_{nd} \in a_{nd}$, represents each appliance in the class of non-deferrable appliances. The power rating of each appliance is λ_{nd} and total energy utilization ε_{nd} per day is shown by the following mathematical formula:

$$\varepsilon_{nd} = \sum_{a_{nd} \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_{nd} \times \alpha_{nd}(t) \right) \tag{4}$$

Due to un-interruptible behaviour, end users pay maximum cost because in demanded slot, utility has higher prices. The reason behind high prices is increase in PAR. In order to maintain balance between generation and consumption, the utility charges higher prices. The cost of each day for all appliances in non-deferrable class can be computed using Eq. 5.

$$\delta_{a_{nd}}^{Total} = \sum_{a_{nd} \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_{nd} \times \rho(t) \times \alpha_{nd}(t) \right) \tag{5}$$

The total electricity consumption cost of 30 homes against non-deferrable appliances for individual day is calculated by the Eq. 6 respectively.

$$\varphi_{a_{nd}}^{Total} = \sum_{Home=1}^{30} \left(\sum_{a_{nd} \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_{nd} \times \rho(t) \times \alpha_{nd}(t) \right) \right) \tag{6}$$

Here $\alpha_{nd}(t)$ represents the ON/OFF status of non-deferrable appliances in the form of 1 or 0.

3.1.3 Base Load Appliances

The third class of appliances is known as base load appliances and these appliances consist of base load for every smart home, their operational time cannot be modified. However, the scheduler has to schedule base appliances between user defined starting and ending time. Let $A_b \epsilon a_b$, represents all appliances in this class. The power rating and energy consumption of these appliances can be demonstrated by λ_b and ε_b, respectively. Per day energy consumption is given by:

$$\varepsilon_b = \sum_{a_b \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_b \times \alpha_b(t) \right) \tag{7}$$

The total electricity cost against 24 h for single smart home is paid by consumers can be calculated by Eq. 8.

$$\delta_{a_b}^{Total} = \sum_{a_b \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_b \times \rho(t) \times \alpha_b(t) \right) \tag{8}$$

The total electricity consumption cost which is paid against base load appliances for multiple homes in 24 h explained in Eq. 9.

$$\varphi_{a_b}^{Total} = \sum_{Home=1}^{30} \left(\sum_{a_b \epsilon A_n} \left(\sum_{t=1}^{24} \lambda_b \times \rho(t) \times \alpha_b(t) \right) \right) \tag{9}$$

Here $\alpha_b(t)$ represents the ON/OFF status of base load appliances in the form of 1 or 0.

4 Proposed Schemes

In smart grid, every smart home is connected with a smart meter and smart meter is further connected with an EMC. Smart meters and EMC permit the mutual two-way communication between electricity consumers and the utility. It inspires the consumer for load shifting from peak hours to off-peak hours for cost minimization. However, load shifting in off-peak hours may cause for generation of peaks in off-peak hours. This problem is considered as an optimization problem and in the last few years many techniques have been used to solve the optimization problem. For this optimization problem, two meta-heuristic techniques GA and Cuckoo search are used. In the next section, a brief introduction of GA and Cuckoo search is presented, and then procedures of GA and Cuckoo search in our work are uncovered.

4.1 GA

GA is well known algorithm from the Meta-heuristic algorithms which is also called as global search algorithm. Due to the high convergence rate, GA find very optimized solution for any computing problem. GA was explained in [18], that works on the basis of genetic population like chromosomes. GA is actually used to solve the optimization problem in computing and the solution is obtained in binary form (0, 1), however other encodings are also used for solution. The first step is to initialize population randomly, evaluation of fitness function is next step and the last step of GA is reproduction of new population. Three main tasks; selection, crossover and mutation are performed for reproduction step. The new population (or solution set) is reproduced iteratively using crossover and mutation operators. In crossover, two parents are selected on the basis of fitness values and new offsprings are generated. The crossover probability of GA is explained below.

$$P_c = 0.9$$

The mutation operator is used to bring changes in the new population by changing one or more bits. Mutation probability is very low in natural genetic process, so best mutation probability is explained below.

$$P_m = 1 - P_c$$

The parameters of GA are explained in Table 2.

Table 2. GA parameters

Parameters	Values
Population size	200
Number of iteration	500
Crossover rate	0.90%
Mutation rate	0.10%
n	12

Table 3. Cuckoo search parameters

Parameters	Values
Number of host nests	50
Number of iteration	500
Discovery rate	0.225
n	12

4.2 Cuckoo Search

Cuckoo search is a meta-heuristic nature inspired algorithm which is used to find optimal solution of any computing problem. Cuckoo search is based on the reproduction behavior of some special type of cuckoo species and features of lèvy flights of some birds explain in [19]. Some cuckoos dump their eggs in the other birds nests, called host nests. Host birds discover the eggs that are laid by other cuckoos for reproduction. The number of host nests are fixed and the discovering probability of the host is $P\alpha = [0, 1]$. Cuckoo search algorithm provides optimal solution through adopting following three basic rules.

- Every cuckoo put only one egg at a one moment in one nest which is randomly selected by cuckoos.
- Only the nests, containing superior quality of eggs are selected for next production.
- The quantity of host nests is constant and the host birds discovered the eggs, which are laid by cuckoos.

For reproduction step, only the nests containing best quality of eggs (best local solutions) are selected. To find out global best solution Lèvy flights are performed for generating new solutions $X^{(t+1)}$ for a Cuckoo$_i$, [19].

$$X_i^{(t+1)} = X_i^{(t)} + \alpha \oplus Levy(\lambda), \tag{10}$$

The parameters of Cuckoo search are explained in Table 3.

5 Simulations and Discussions

For showing legitimacy and productiveness of our proposed work. We have conducted simulations, in order to show an optimal scheduling for both single and multiple smart homes. The randomization is one of the key factors in heuristic techniques, therefore we have taken results of the average of 10 runs. We design a model for both single home and smart building; comprising of 30 smart homes each one has 12 smart appliances with same living patterns (i.e. length of operation, power rating).

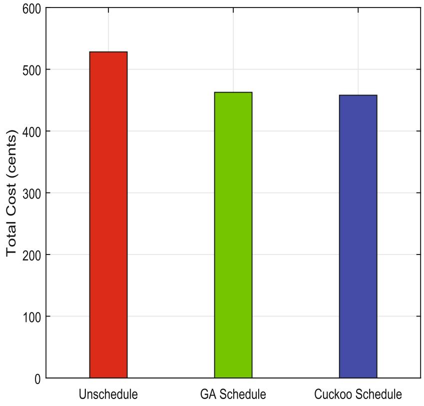

Fig. 1. Total cost for single home

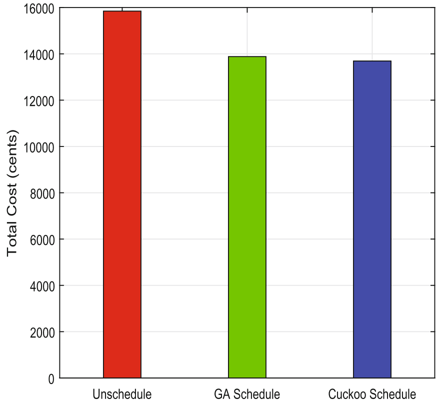

Fig. 2. Total cost for 30 homes

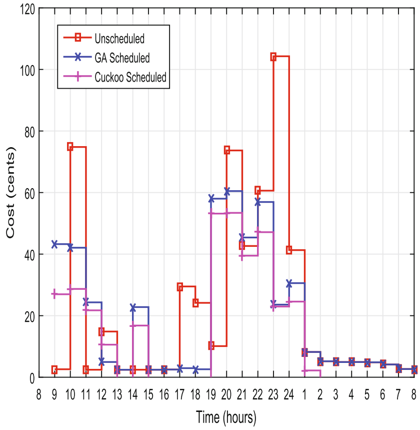

Fig. 3. Hourly cost for single home

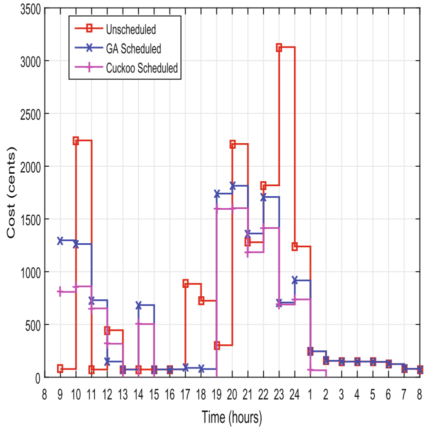

Fig. 4. Hourly cost for 30 homes

All the appliances with their parametric values that are used in our simulations are shown in Table 1. Non-deferrable appliances do not play any significant role for managing load because these are not scheduled and must perform operation in time. The time horizon is composed of 24 time slots in a day, starting from 8 am to 8 am next day. Per hour electricity consumption for single and multiple homes shown in Figs. 7 and 8 respectively. This shows that our proposed schemes perform superior for load transferring without interrupting the overall electricity consumption.

RTP signals are used for electricity cost estimation, per hour electricity cost with RTP signals for unscheduled load and scheduled load through Cuckoo search, GA for single smart home and multiple smart homes in a building is shown in Figs. 3 and 4 respectively. We minimize per hour electricity cost and as a result total per day electricity cost is reduced which is represented for sin-

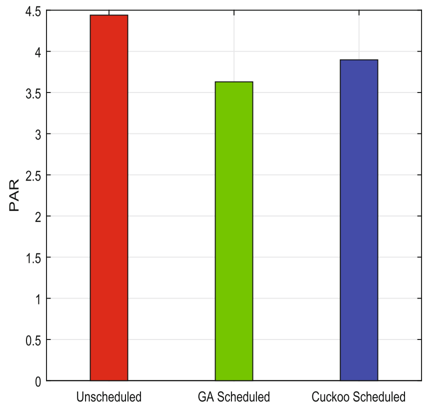

Fig. 5. Peak to average ratio

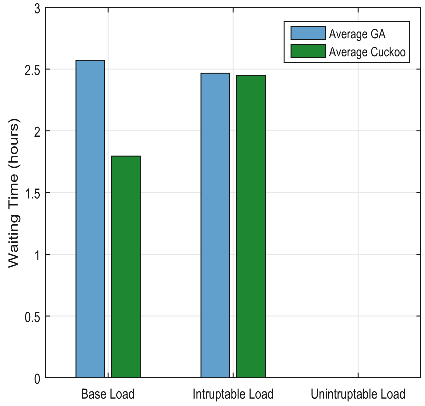

Fig. 6. Appliances waiting time

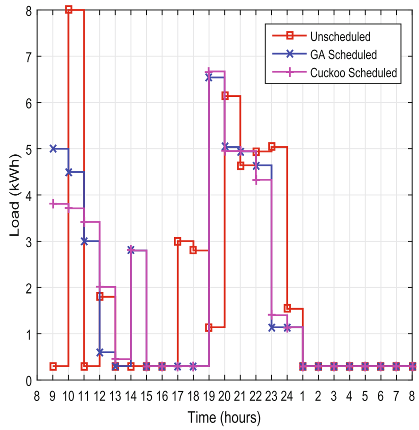

Fig. 7. Hourly load for single home

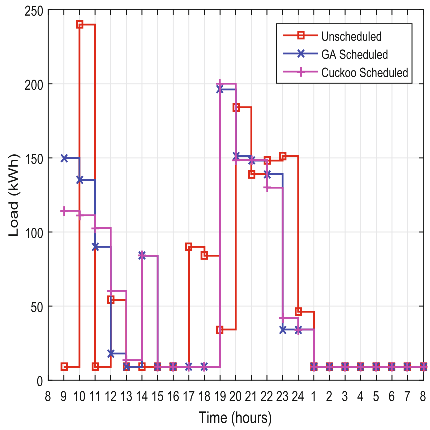

Fig. 8. Hourly load for 30 homes

gle and multiple smart homes in Figs. 1 and 2 respectively. The results show that electricity cost is low using Cuckoo search, GA and CSA as compared to unscheduled electricity consumption. Using RTP signals, GA and Cuckoo search reduce the electricity cost by 12.64% and 13.96% for single and multiple smart homes.

PAR results using RTP signals are shown in Fig. 5, which distinctly shows that our proposed schemes minimize the PAR as compared to unscheduled PAR. Furthermore, PAR reduction using GA and Cuckoo search is 17.41% and 12.94% for single and multiple smart homes. The above discussions show that Cuckoo search shifts load in more efficient manners as compared to other counter parts.

While decreasing the cost and PAR, the waiting time increases which is shown in Fig. 6. It shows that the tradeoff between electricity cost and user waiting time, when electricity cost is high waiting time is low and vice versa.

However, our proposed scheme achieves the desirable tradeoff between electricity cost and user waiting time. The waiting time of non-deferrable appliances is zero because these appliances may not be interrupted or shifted.

6 Conclusion

In this paper, meta-heuristic based scheduling scheme has been proposed using GA and Cuckoo search under RTP signals for HEMS in DSM. The main targets of our work are to minimize electricity cost, PAR reduction with desirable user waiting time for single and multiple smart homes. Results illustrate that the scheduling algorithm GA reduces the electricity cost 12.64% for single and multiple smart homes and also minimizes the PAR by 17.41%. On the other hand, Cuckoo search minimizes the cost by 13.96% for single and multiple smart homes and also minimizes the PAR by 12.94%. The minimization in PAR maximize the stability of electric grid and ensure the stable and reliable grid operations. Furthermore, our proposed scheme achieved the affordable user waiting time. It is concluded on the behalf of above discussion, our proposed scheme using Cuckoo search shows supremacy in terms of cost minimization while desirable user waiting time and GA performs superior in term of PAR reduction. The performance of Cuckoo search is superior than GA because Cuckoo search spent maximum time on global search instead of local search and there are lesser parameters to be fine-tuned than GA.

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Phonetics-Based Parallel Privacy Preserving Record Linkage

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Abstract. We live in an era characterized by the abundance of data, often conveying personal information. Linking this kind of data is useful for a variety of applications, raising, however privacy concerns. To address this issue, privacy preserving record linkage has emerged, with techniques aiming at revealing to the matching parties only the actually matching records. Since the linking process usually involves large volumes of data, it is evident that such procedures could benefit from outsourcing computation to cloud infrastructures taking advantage of parallel computing platforms, such as Apache Spark. In this paper, we extend a phonetic codes based method for privacy preserving string matching, by designing a new protocol specifically tailored to operate in parallel in the cloud, employing the map reduce model. We theoretically analyze its characteristics and empirically assess its performance, comparing it with the corresponding sequential algorithm.

1 Introduction

In the last years, we are experiencing an unprecedented increase in data production and availability. These data, often originating from heterogeneous sources when processed and combined may offer valuable information for applications such as data integration, business intelligence, web mining and recommendation systems. However, since a large portion of these data regards human activity, privacy issues arise, opening up a new research domain, known as *Privacy Preserving Record Linkage* (PPRL). In PPRL two or more dataholders attempt to identify common entities stored in their records, without revealing to each other any additional information.

Let us consider a medical researcher who wants to investigate the possible side effects of a new medicine. The researcher needs access to data across different hospitals, doctors and pharmacies to identify patients that were prescribed the medicine and the symptoms or treatments these individuals may have received afterwards. However, revealing all such information about patients to the researcher compromises their privacy. Ideally, she would only need to know the symptoms patients that were prescribed the medicine exhibited and no other

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information about them or other patients. Therefore, the goal of privacy preserving record linkage is to link records across multiple data sources without allowing the revelation of any other information to the sources or to any external party involved in the linkage process, besides the common (linked) records.

Since data sources are heterogeneous, holding different schemas and no common unique identifiers, linking methods need to exploit fields that are common to all data sources to identify common entities. Thus, the core process of PPRL is *privacy preserving matching*, which is the focus of this paper. Besides heterogeneous, data is also usually dirty complicating the linkage process further. Considering the large volumes of available data, record linkage is rendered a very resource demanding task [6]. As the volume of available data increases, requirements for processing power also increase, leading organizations to outsource their computational tasks to Infrastructure as a Service (IaaS) cloud providers. Consequently, the recent evolution of big data processing engines, such as Apache Spark [17], opens new directions for exploiting their capacity for parallel processing.

To this end, we propose a parallel, cost-effective protocol for performing privacy-preserving approximate string matching, in order to exploit novel big data processing capabilities. This protocol is based on phonetic codes, extending current work in the field [9]. A phonetic code is a hash of a string based on its pronunciation. Phonetic codes are used on names for almost a century [13] for duplicate detection and record linkage due to their inherent information suppression properties, which make them tolerant to spelling errors. This protocol also features noise generation to prevent frequency attacks and encryption of both actual and fake data to enable processing by an untrusted party. In the proposed extended protocol, all these operations execute in parallel exploiting the capabilities of Spark's framework.

We assume that dataholders outsource their data to trusted, in terms of storage, IaaS providers, who will also take up the data processing task. In case these providers make use of federated services, the consent of dataholders for outsourcing such data is required. Also, we use a third, cloud-based party which is not necessarily required to be trustworthy as no private information is leaked. We implement our protocol using Apache Spark and provide empirical evidence regarding its performance, showing its suitability for a cloud-based parallel environment, compared to the baseline sequential algorithm.

The rest of the paper is organized as follows. Section 2 summarizes works related to ours. In Sect. 3, we formulate the problem we address and briefly present the basic components of our approach. Section 4 details the proposed technique, while Sect. 5 contains our empirical evaluation. Finally, Sect. 6 sums up with conclusions and some thoughts for future work.

2 Related Work

Numerous efforts address the privacy preserving matching problem. We propose a parallel approach extending [9], where phonetic codes are used for privacy preserving matching. Alternatively, Schnell et al. [15] used a bit vector based encoding, namely Bloom filters, combined with n-grams to take advantage of their approximate matching properties. However, as indicated in [12], under certain conditions, this method is susceptible to constraint satisfaction cryptanalysis. Homomorphic encryption [10] may be also used for private matching but for numerical fields [7], while our work focuses on strings. Privacy preserving data integration is not limited to record linkage. Data-mashup [2] is another area where data access should take place under constraints. At the same time, significant efforts have been made towards using Hadoop for record linkage [11], while our approach utilizes Spark. Given the fact that Spark offers many advantages against Hadoop [16], it is evident that utilizing Spark comprises a new promising research direction.

3 Problem Formulation and Background

In this section, we formally define the problem we are solving and present the details of the building blocks that comprise our solution.

3.1 Problem Formulation

Without loss of generality, let us consider two data sources, called Alice (A) and Bob (B), who respectively hold r^A and r^B records each. We denote as r_i^A and r_i^B the i-th record of Alice and Bob, respectively. We represent the j-th attribute of these records as $r_i^A.j$ and $r_i^B.j$.

Privacy preserving record linkage is the problem of identifying (linking) all pairs of r^A and r^B records that refer to the same real world entity, so that no more information is disclosed to either A, B or any third party involved in the process besides the identifiers of the linked r^As and r^Bs.

Alice and Bob will most probably use different schemas in their databases. As such, they will have different attributes. Let R^A be Alice's schema and R^B be Bob's schema and let us assume that in these schemas m of the attributes are common between the two sources forming a composite key. These attributes might be names, surnames, addresses, birth dates. As such, none of these on its own may comprise a unique identifier that can be used to identify a record. We refer to these attributes as *matching attributes* or *matching fields*. The composite key is used to determine when two records *match*, i.e., when they refer to the same entity. To determine when two records match, the respective attributes forming the composite key need to be compared. Considering that our data is often dirty, matching should rely on a similarity or distance function.

Let us consider a similarity function $sim_j() \rightarrow [0..1]$ and a threshold $t_j > 0$. Given the records r_i^A and r_i^B with matching attributes $r_i.1 \ldots r_i.m$ for both Alice and Bob, we define the following matching function $M \rightarrow \{0, 1\}$:

$$M(r_i^A, r_i^B) = \begin{cases} 1, & \text{iff } sim_j(r_i^A.j, r_i^B.j) \geq t_j, \forall j \in [1, m] \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

If $M(r_i^A, r_i^B) = 1$, then the pair (r_i^A, r_i^B) is a match.

This process is the *matching process*. To preserve privacy, i.e., ensure *privacy preserving matching* (PPM), after the completion of this process, the only information revealed is the identifiers of the matched records.

3.2 Phonetic Algorithms for Matching

A phonetic algorithm is an algorithm which maps a word to its pronunciation. Such methods have been broadly used in the past for record matching performed on names. The main feature of phonetic algorithms is their fault tolerance against typographical errors. While our method is applicable to any phonetic algorithm, for illustration purposes in this work we use Soundex [13].

Soundex [3], based on English language pronunciation, is the oldest (patented in 1918 [13]) and best known phonetic encoding algorithm. Each word is encoded by applying certain rules of grouping similar sounds. In particular, Soundex keeps the first letter of a string and converts the rest into numbers according to Table 1. All zeros (vowels and ‘h’, ‘w’ and ‘y’) are then removed and sequences of the same number are merged to a single one (e.g. ‘333’ is replaced with ‘3’). The final code is the original first letter and three numbers (longer codes are stripped-off, and shorter codes are padded with zeros). For example, the Soundex code for ‘Alexandros’ is ‘A425’, while the code for ‘Karakasidis’ is ‘K622’. A drawback of Soundex is that it maintains the first letter of the encoded word intact, thus any error or variation at the beginning of a name will result in a different Soundex code. To overcome this problem, a common solution is to reverse the words and use Soundex on the resulting strings.

Table 1. Soundex conversion table.

$a,\ e,\ h,\ i,\ o,\ u,\ w,\ y$	$\rightarrow$	0
$b,\ f,\ p,\ v$	$\rightarrow$	1
$c,\ g,\ j,\ k,\ q,\ s,\ x,\ z$	$\rightarrow$	2
$d,\ t$	$\rightarrow$	3
l	$\rightarrow$	4
$m,\ n$	$\rightarrow$	5
r	$\rightarrow$	6

As we previously showed, matching in the privacy preserving paradigm can be formalized using Eq. 1. When using phonetic algorithms for matching, the similarity function sim_j used in the formula has as input two phonetic codes and examines their absolute similarity, returning 1 when the two codes are identical and 0 otherwise. As such, the matching threshold t_j is set to 1, so that the two codes compared are considered as matches only when they are identical.

3.3 Apache Spark

Apache Spark [17] is an open source, memory based data processing framework, suitable for big data. It is considered as the next generation big data processing engine, overtaking Hadoop MapReduce. Spark extends MapReduce in many ways [16]: it is faster, easier to program, and it goes far beyond batch applications to support a variety of computationally intensive tasks. Its main data abstraction Resilient Distributed Dataset (RDD), offers the ability of lazy processing in parallel across a cluster. Users create RDDs by applying transformations (such as map, filter, and groupBy) to their data. Spark's lazy evaluation of RDDs allows it to find an efficient computation plan. Transformations return a new RDD object representing the result of a computation but do not immediately compute it. When an action is called, Spark looks at the whole graph of transformations, allowing users to build up programs modularly without losing performance, with RDDs providing explicit support for data sharing among computations. A typical Spark cluster setup consists of a master machine directing tasks of program to be executed, referred to as driver, to worker machines.

4 A Parallel Privacy Preserving Phonetics Matching Protocol

In this section, we describe a protocol for performing privacy preserving matching on textual data. This protocol relies on phonetic codes and it is based on a series of properties phonetic codes and phonetic encoding algorithms exhibit. Information suppression is one of such properties. A phonetic code comprises a lossy representation of the input string. As such, phonetic encoding algorithms may be considered as non one-to-one functions.

The fact that phonetic codes are not one-to-one mappings is the key feature for both ensuring privacy preservation and performing approximate string matching. Since these codes are generalized versions of the original strings, words with similar spellings or misspellings map to the same phonetic code. This way, accurately matching phonetic codes leads to approximate matching of the original strings. As the use of phonetic codes reduces the problem of approximate string matching to exact string matching, traditional database indexes over these codes can be exploited to speed up the matching process. Moreover, the non one-to-one mapping ensures privacy, as the same code may map to several different original words. Finally, considering the low complexity of phonetic algorithms, it is evident that their blend of properties is ideal for performing privacy preserving record linkage.

To further enhance the inherent private characteristics of phonetic algorithms, we employ noise injection, so that information is hidden by the uncertainty produced for the entire dataset. The procedure described thereafter may be used with other privacy preserving matching methods. However, for reasons of demonstration and without loss of generality, we assume that the Soundex algorithm is used to perform matching operations.

In our protocol, we consider two parties, Alice and Bob, holding their own data and a third party, Carol, who performs the join operation between the data of the two sources, using the phonetic codes produced by Alice and Bob. We also consider that all three participants have a Spark cluster at their disposal, thus performing computations in parallel.

4.1 Protocol Operation

At the beginning of the linkage process, it is sufficient for Alice and Bob to agree on a set of common fields appearing in both their data, that are to be used as matching fields. Alice and Bob's data do not have to conform to the exact same schema and usually exhibit heterogeneity. No prior knowledge is required by either party, and appropriate privacy preserving schema matching algorithms [4,14] may be deployed to determine these matching attributes without compromising the privacy of either party.

Next, each party prepares separately its own data for matching following Algorithm 1. First, using a *Map* operation, each of the matching fields is converted to its Soundex equivalent (line 1). Afterwards, random fake Soundex codes using a *Parallelize* operation are generated (line 2). Then, these two volumes of data are merged using a *Union* operation (line 3). Next, all codes are encrypted through a secure hash function e.g. SHA256 using again a *Map* operation (line 4). Finally, the entire dataset is randomly sorted to ensure that Carol cannot infer which Soundex codes refer to actual real world entities (line 5). We further clarify the preparations at Alice and Bob using an example.

Algorithm 1. Actions taken by Alice and Bob to encode their data.

Input:
- r: Plaintext dataset
Output:
- d: Deideintified dataset

1 $d_1 \leftarrow$`Map` (`Soundex` (r));
2 $d_2 \leftarrow$`Parallelize` (`RandomSoundex` ());
3 $d_3 \leftarrow$`Union` (d_1, d_2);
4 $d_4 \leftarrow$`Map` (`SHA256` (d_3));
5 $d \leftarrow d_4$.`orderBy` (`rand` ());
6 `Collect` (d)

Example 1. As illustrated in Fig. 1, let us assume that Alice holds two rows in her database and that she has agreed to privately match them with Bob's data using the phonetic-based privacy preserving matching method we propose using the 'Surname' field as the single matching field.

1. Alice generates the Soundex encoding for the matching field in each of her two records (Fig. 1(1)). As such, 'Johnson' is transformed into 'J525' and 'Miller' into 'M460'.

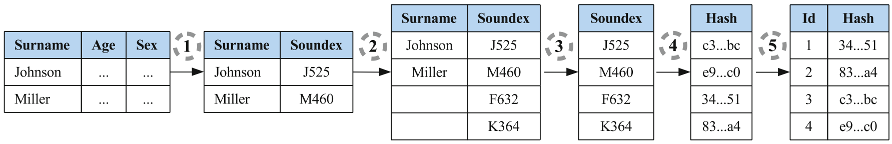


Fig. 1. Data preparations by Alice.

2. Then, she generates a number of random fake Soundex codes which, in our example, are two: 'F632' and 'K364' (Fig. 1(2)).
3. All codes are encrypted through a secure hash function, i.e., SHA-256 (Fig. 1(3)).
4. The created table is randomly sorted to ensure that Carol cannot infer which cipher codes refer to actual records (Fig. 1(4)).
5. A unique identifier in the domain [1..4] is assigned to both actual and fake encoded fields. At this point, each source maintains a table where each row consists of two fields: the unique identifier and the cipher (Fig. 1(5)).

The protocol proceeds by with the data exchanges between parties and matching, which is carried out by Carol, as illustrated in Fig. 2.

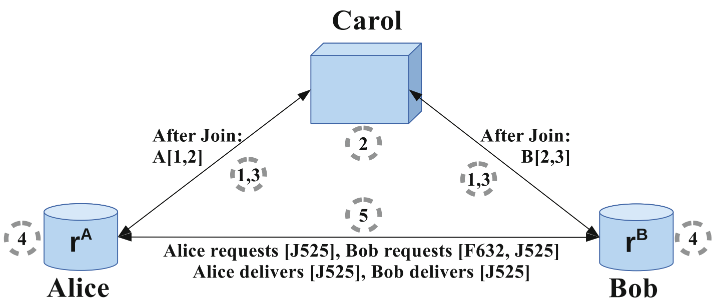


Fig. 2. Overview of the phonetic matching protocol.

1. Alice and Bob send their encrypted data through a secure channel to Carol.
2. Carol performs the join operation on the encrypted Soundex codes each party has send. Carol's role is important in this setup, since it refrains either Alice or Bob from acquiring information from each other's dataset. Neither of the two dataholders is aware of the others dataset size nor of the data transmitted to Carol. On the other hand, neither Carol has full access to information, since she only collects and joins encrypted Soundex codes.
3. Carol returns the source's identifiers for the encrypted Soundex codes which succeeded at the matching operation, through a secure channel.

4. Each source determines which of these identifiers belong to its own set of actual records. This is an important step, because a party omits from the results the codes which reflect to fake records and those which are highly distinctive.
5. Sources contact directly each other asking for rows the fields of which have the resulting identifiers. Finally, each source delivers to the other the rows that are not tagged as descriptive and that exist in their actual datasets.

4.2 Privacy Discussion

In this protocol, we assume that all participants exhibit an Honest But Curious behavior. This means that they do not try to deviate from the protocol, but they try to learn as much as possible based on the information they gather following the protocol's steps. Using a third party, each source is unable to determine data held by other sources. It is only aware of its own private data. Carol is neither aware of the actual data nor of the amount of data residing in each source, thus, becoming unable to perform a frequency attack on these data. This is due to three reasons. First, data reaching Carol are encrypted. Second, even if Carol decrypts the data, she would acquire a set of Soundex codes, and due to Soundex 's inherent information suppression properties, they would contain fuzziness. Finally, not all data represent actual records in the source due to the fake Soundex records injected. The additional records inserted may burden the transmission channel and the participating parties. However, since our aim is to provide privacy, the additional resources required are not considered as significant. The comparison of the encrypted Soundex codes takes place at Carol in order to prevent either source from inferring information upon the size of the dataset of the other party. Furthermore, no information may be leaked from intermediate data, since no such data are generated.

Example 2. Let us continue Example 1. Based on their data, each of Alice and Bob, creates a table which consists of the matching attribute and its Soundex code. The procedure for Alice is illustrated in Fig. 1, while Table 2 illustrates Bob's data. Bob wishes to match data with ids 2, 3 and 4, since the rest of the rows hold fake Soundex codes. According to our protocol, Bob and Alice send to Carol columns 'Id' and 'Hash' of their datasets. Carol receives the tables from both sources and joins them. If Carol attempted to disclose some information, she would fail, since she would not know which records reflect real world entities and which are fake. Thus, she would not be able to infer the size of either party's record set. Even in the case she assumed that all entities were real, she would not be able to infer the actual data either due to both the secure encryption used and also the inherent information suppression properties of Soundex.

After Carol performs a JOIN operation over the encrypted Soundex codes, she returns the ids of the matching codes to their corresponding owners, i.e. A[1, 2] for Alice and B[2, 3] for Bob, as shown in Fig. 2. Bob recognizes ids B[2, 3] as correct matches, while Alice recognizes A[2] as a correct match and A[1] as a false positive, since its Soundex code resulted from fake data.

Then, both Alice and Bob ask each other for the data represented by the matching codes. At this point, Bob asks Alice for data represented by the hash ‘c3...bc’ and ‘e9...c0’, which correspond to Soundex codes ‘F632’ and ‘J525’, respectively. Similarly, Alice only asks for ‘e9...c0’ that corresponds to ‘J525’. Finally, the two sources exchange the records based on the intersection of common hash codes, which in this case is ‘e9...c0’, i.e. records ‘Johnson’ of Alice and ‘Johnsen’ of Bob.

Table 2. Bob’s data.

Id	Soundex	Surname	Hash
1	A100		bb...12
2	F632	Fortson	c3...bc
3	J525	Johnsen	e9...c0
4	M346	Modler	2f...e5
5	R325		34...1c

5 Empirical Evaluation

In this section, we present the experimental evaluation of our approach. Our aim is to compare the time consumed to perform the same tasks using both the original sequential algorithm and our parallelized approach.

5.1 Experimental Setup

We have implemented simulations of both the parallel approach we propose and the original sequential algorithm using Anaconda Python 4.3. We tested both implementations using the Okeanos IaaS academic service.[1] Our infrastructure comprises of four virtual machines, each of them having two cores. For the parallel algorithm we use one machine, having 6 GBs of RAM, as the Spark cluster master. The three other machines operate as workers. These are identical, featuring 4 GBs of RAM, but we deploy the default setup that allocates only 1 GB per worker. We tested 3 different Spark clusters, with 1, 2 and all 3 worker machines. In all parallel setups, data are read directly from the file system and no indexes are used. For the sequential version, we use one of the worker machines we equipped with MariaDB for holding and joining data, which are indexed to further increase performance.

We use a dataset originating from the North Carolina voters database.[2] The attributes: ‘last name’, ‘first name’, ‘middle name’, ‘city of residence’ and

[1] https://okeanos.grnet.gr/home/.
[2] http://dl.ncsbe.gov/index.html?prefix=data/.

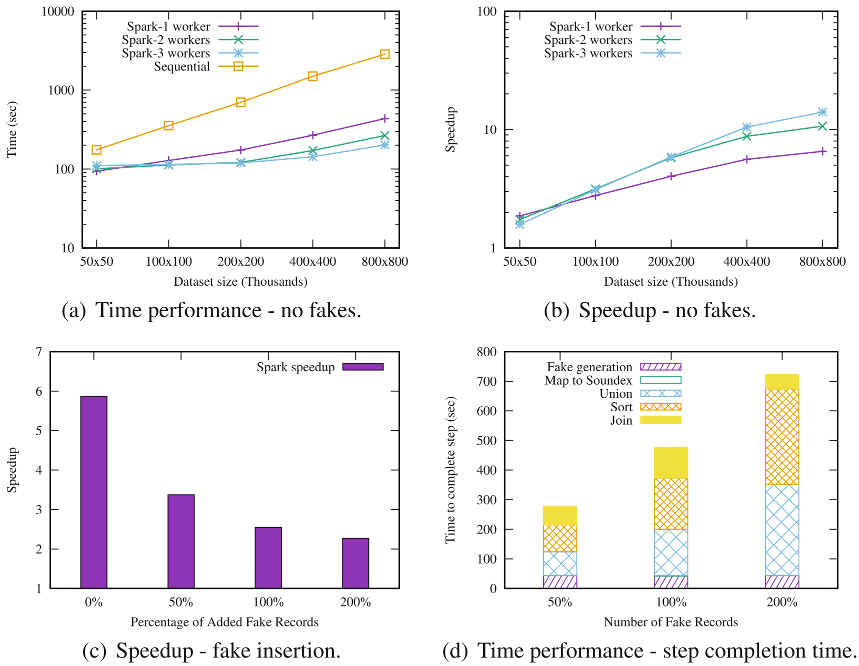
'precinct description' were chosen as matching attributes. We assume that the attributes chosen comprise a candidate key, and deduplicate the dataset using the respective attribute combination. After deduplication, we generated samples, forming two databases so that 25% of their records is common.

We assume that the first generated database of each pair belongs to Alice, while the second one to Bob. Our samples resulted in databases comprising of 50, 100, 200, 400 and 800 thousand records each. Since we are interested in linking low quality data, we corrupted Bob's common records [1]. The corrupted records contain one error per attribute, as it is rather unusual for a word to contain more than one to two typographical errors [5]. With equal probability, the error may be either a character insertion, deletion or substitution.

5.2 Experimental Results

We only measure performance with respect to time, as with respect to accuracy both parallel and sequential algorithms have identical behavior, i.e., parallelization does not compromise the quality of the private matching method.

In the first set of experiments, we measure the performance of the private matching method with respect to different dataset sizes, while excluding the overhead of generating the infused fake records. We measure execution time (Fig. 3(a)) and the speedup achieved by each parallel setup, defined as the ratio of



(a) Time performance - no fakes.

(b) Speedup - no fakes.

(c) Speedup - fake insertion.

(d) Time performance - step completion time.

Fig. 3. Time performance of the sequential and parallel algorithms.

sequential execution time to the parallel execution time (Fig. 3(b)). In both cases, the vertical axis is logarithmically scaled. The sequential algorithm exhibits a quadratic behavior with respect to execution time as shown in Fig. 3(a). Using Spark however significantly improves performance. While using more workers for smaller datasets does not improve performance, even being slower for the 50×50 dataset due to the setup and communications overhead, as the size of the datasets increases using more workers achieves better results. In particular, for the 800×800 dataset, the speedup is above 14 as depicted in Fig. 3(b). This translates in 2845 s for the sequential version as opposed to 202 s that the 3-worker spark version. The speedup is significant even when only one worker with the two cores is used.

In the next set of experiments, we study the behavior of the parallel algorithm when fake records are injected. For illustration purposes, Fig. 3(c) includes the results for the 200×200 dataset and all 3 workers. Again, the vertical axis represents speedup, but is linearly scaled. The horizontal axis stands for the percentage of fake records generated with respect to the dataset size. The parallel algorithm outperforms the sequential one in this case as well. However, we can also see that speedup decreases as the amount of fake records inserted increases. Nevertheless, the parallel approach is still more than two times faster in the worst case when tripling the dataset size.

The observed speedup reduction lead us to perform a third set of experiments to further investigate the behavior of each of our parallel method's steps by assessing the time required to complete each step. We used the same setup as in the second set of experiments reporting execution time for each of the method's steps with respect to the percentage of fake records injected. To measure the time required for each step as the steps are executed transparently at different machines by the Spark cluster, we measured first the time required to complete the first step of our algorithm, i.e. fake generation. Then, at each subsequent experiment, we added the next step of our method and after its completion measured the time difference with the execution time of the previous steps as computed by the directly preceding experiment. Figure 3(d) shows that the time required both to generate fake records and map the dataset to Soundex codes is minimal and almost stable compared to the total time consumed. The steps that overwhelm execution time are the concatenation of the original with the generated data and sorting the additional data. Particularly, these steps increase execution time linearly to the size of generated data. Finally, join operations amount to only a small part of the total execution time.

6 Conclusions and Future Work

In this paper, we have proposed a parallel algorithm based on phonetic encoding for performing privacy preserving matching. As we have experimentally shown, the proposed algorithm outperforms its sequential counterpart for large datasets. As next steps, we aim at parallelizing a privacy preserving blocking method [8] for pruning unlikely to match candidate record pairs, so as to further improve linkage time.

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Improved Ant Colony RBF Spatial Interpolation of Ore Body Visualization Software Development

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Abstract. With ore body space interpolation and the three dimensional simulation visualization, has been for the internal structure of the ore body is too complex and the effect not beautiful. Using nonlinear improved ant colony radial basis neural network method for ore grade for interpolation, in contrast to the traditional inverse distance square interpolation method to improve the precision of more. With Vc++ and OpenGL environment developed ore body visualization software, and ore body grade distribution visualization, facilitate further research.

1 Introduction

It is difficult to describe complicated and diversified non-layered ore bodies with regular geometries. Compared with foreign software limited by application and promotion such as Mincomine and GOCAD [1], most domestic related researches are conducted based on the facial model of ore bodies, ignoring the internal distribution condition of the ore body attribute data, which are more important. Considering the distribution of ore body attribute data can embody the external reasons for formation of ore bodies, this article lays the emphasis on the three-dimensional simulation on the law of ore body internal data based on block model. In which the research on the spatial interpolation of grades of different blocks in ore bodies plays a significant role in predicting the whole mine and establishing the visual model. This article introduces the radial basis neural network with the advantage in spatial scattered point interpolation as the basic model for spatial interpolation. At the same time, aiming at the disadvantages of neural network training in global convergence and rate of convergence, it optimizes it by adopting the improved ant colony algorithm, so as to realize the construction of the brand new spatial interpolation model.

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The imported raw data consists of the wellhead data and the drilling sampling and grade data shown in the following Tables 1 and 2:

Table 1. The wellhead data.

Exploration number	Drilling number	X	Y	Z
47	CK1103	3330832.62	38590265.74	16.31
47	CK1303	3330802.04	38590325.93	18.33
47	CK1503	3330777.01	38590370.45	19.30
51	CK1502	3330865.65	38590405.63	16.44
5	ZK501-1	3329670.33	38590292.87	43.93
5	CK206	3329709.48	38590193.29	37.33
5	5CK216	3329693.90	38590231.86	40.66
13	ZK1301	3329890.18	38590286.01	31.72
15	ZK1504	3329917.32	38590348.17	39.48
16	ZK1601	3329319.02	38589689.74	16.65
16	ZK1603	3329338.45	38589641.74	35.44

Table 2. The drilling sampling and grade data.

Drilling number	Sampling number	Depth (from)	Depth (to)	Cu-pct
CK1103	2	255.22	256.22	0.45
CK1103	3	256.22	257.22	0.56
CK1103	4	257.22	258.22	0.54
CK1103	5	258.22	259.22	0.59
CK1103	6	259.22	260.22	0.48
CK1103	7	260.22	261.22	0.53
CK1103	8	261.22	262.22	0.51
CK1103	9	262.22	263.72	0.52
CK1103	11	289.4	290.4	0.12
CK1103	12	290.4	291.4	0.21
CK1103	13	291.4	292.72	0.11
CK1303	1	366.15	367.15	1.4
CK1303	2	367.15	368.15	1.05
CK1303	3	368.15	369.15	1.09
CK1303	4	369.15	370.15	1.43
CK1303	5	370.15	371.15	0.61
CK1303	6	371.15	372.15	2.39
CK1303	7	372.15	373.15	2.34
CK1303	8	373.15	374.15	1.63
CK1303	9	374.15	375.15	1.87
CK1303	10	375.15	376.15	2.18
CK1303	11	376.15	377.15	1.59

2 Methodology

2.1 RBF

Compared with the whole interpolation algorithm, the radial basis function neural network interpolation is a local interpolation algorithm in the realization process [2–6] For spatial interpolation, the local interpolation algorithm is more valuable because the complexity of the non-layered orebody is much higher than that of the local. The radial basis function network is used to cluster the sample data by first determining the initial center, which is equivalent to dividing the whole of the spatial data, and then further network training for each local area divided into [7–9]. Through this localized processing, the complexity of the spatial interpolation problem is reduced, and the feasibility of the problem solving is also increased.

The radial basis function neural network is a three-layer forward network, which is divided into the input layer, hidden layer and output layer, the basic structure is shown in the following Fig. 1:

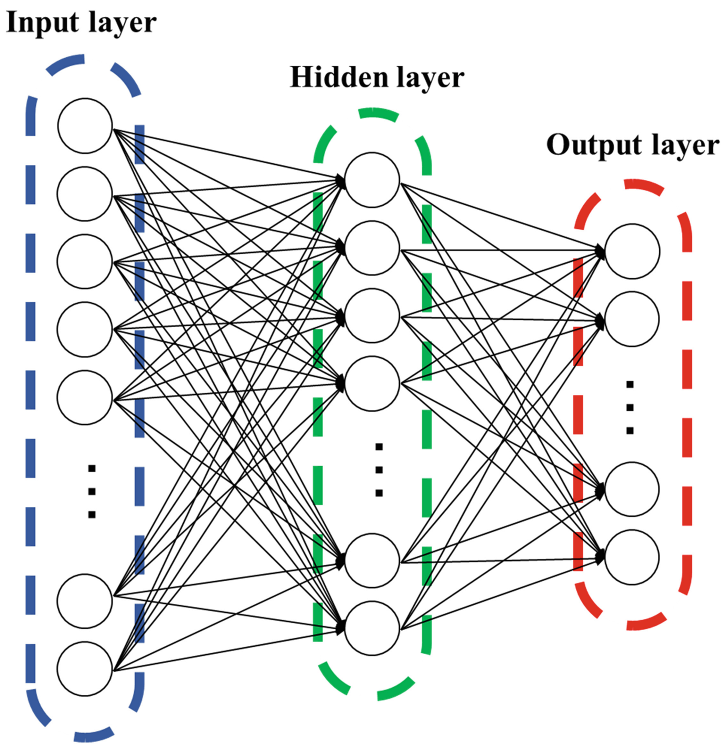

Fig. 1. The structure of the RBF.

2.2 Improved Ant Colony Radial Basis Model

Considering that radial basis has disadvantages such as instable overall convergence and difficulty in initial center determination [10–13], this article selects optimal initial center for the radial basis in combination of the global optimization feature of the ant colony algorithm, which is an effective solution [14–16]. Aiming at problems such as stagnation due to insufficient optimization dynamic in positive feedback based ant colony algorithm, this article proposes the scheme of mutual regulation between the self-adaptive pheromone volatility coefficient and the quantity of the self-adaptive ant colony, so as to improve the optimization dynamic during stagnation of ant colony, which makes up for deficiencies of the ant colony algorithm.

The main thought for improving ant colony is described as follows:

Record the n parameters composed by the weight and the threshold values in the RBF hidden layer as $q_i(1 <= i <= n)$. Set the value of each parameter q_i as m random nonzero values, to constitute the set I_{qi}. It is equivalent to the condition that there are n cities in the TSP problem, with m paths to be selected in each city. Each ant in the ant colony traverses each set I_{qi}, equivalent to traversing the n cities. Each ant selects an element in each I_{qi} as per the selection probability controlled by the information amount of the element; i.e., it sets a path in each city. An ant traverses selects a parameter when traversing each set I_{qi}; i.e., it selects the parameters of a group of RBF hidden layer. It is only needed to change the information amounts of the elements, until the ants are conducted with convergence to the same group or several groups of parameters, to acquire the optimal parameter combination, i.e., the optimal initial center. However, the ants may be stagnated at a group or several groups of solutions, and cannot achieve the target. In this condition, firstly, it is necessary to reduce the too much influence of the generated information amount on the selection probability, to provide the ants with more free space during path selection, which increases the initiative of the ants to certain extent. Secondly, the quantity of ant colony restrains the optimization capacity of the ant colony, and the increased amount of the ant colony during stagnation can improve local conditions. At the same time, it is necessary to set a upper limit for the maximum ant colony quantity for restraint, in order to avoid slow rate caused by too large quantity on ant colony.

The specific procedures are listed as follows:

(1) Set the quantity of the ant colony as Num and the initial value as a constant h. Set the upper limit of the quantity of the any colony as $8h$ and the maximum target output error of the optimal parameter to the training samples as $goal = 0.01$; the initial cycle number N_c as 0. Set the pheromone which is used to control the density of the selection probability of each element j in the set I_{qi} as $T_j(I_{qi}) = 1$, and make the variation amount of the pheromone as $\Delta T_j(I_{qi}) = 0$.

(2) Make all the ants traverse the n sets, and select an element in each set. The probability for the kth ant to select the jth element in the ith set is:

$$p(T_j^k(I_{qi})) = \frac{T_j^k(I_{qi})}{\sum_{g=1}^{m} T_g(I_{qi})} \tag{1}$$

Finally, make $N_c = N_c + 1$.

(3) Calculate the output error of the network parameter selected by each ant on the sample training, and calculate the total quantity of all the selected solutions of all the ants as N_I. Calculate the optimal solution of the selected parameter as $y_{\max}(N_c + 1)$. Calculate the maximum output error of the training sample corresponding to the optimal solution as $E_{\max}(N_c + 1)$.

$$T_j(I_{qi})(N_c + 1) = (1 - \rho)T_j(I_{qi})(N_c) + \Delta T_j(I_{qi}) \tag{2}$$

where $\Delta T_j(I_{qi}) = \sum_{k=1}^{Num} \Delta T_j^k(I_{qi})$ represents for the pheromone left by the k[th] ant.

$$\Delta T_j^k(I_{qi}) = \begin{cases} 1/\max_{n=1}^{S}(O_n - O_q) & \text{the k}^{\text{th}}\text{ ant selects the element} \\ \quad\text{others} & \end{cases} \tag{3}$$

where S is the number of samples; O_n is the actual output; O_q is the expected output. $\max_{n=1}^{S}(O_n - O_q)$ is the parameter selected by the k[th] ant, i.e., the maximum output error to various training samples. ρ is the pheromone volatility coefficient, $\rho \in [0, 1]$.

$$\rho = \begin{cases} 0.05 + 0.95\frac{Num}{8h} & N_I\ (N_c) = N_I(N_c + 1)\ \text{and}\, E_{\max}(N_c) = E_{\max}(N_c + 1) > goal \\ 0 & \text{others} \end{cases} \tag{4}$$

$$\text{Num} = \begin{cases} \text{Num} & \rho = 0 \\ 2\text{Num} & \rho \neq 0\,\text{and}\, Num \neq 8h \\ 8\text{h} & \rho \neq 0\,\text{and}\, Num = 8h \end{cases} \tag{5}$$

When N_c achieves the maximum training number $N_{c\max}$ or $N_I\ (N_c) = N_I(N_c + 1)$ and $E_{\max}(N_c) = E_{\max}(N_c + 1) <$ goal, it outputs the optimal solution; or turn to Step Two.

(4) After the determination of the initial center, calculate the value of σ according to $\sigma = d/\sqrt{2M}$ (d is the maximum distance of all the types, and M is the number of the determined initial centers), and then train the weight of the network output layer through the conjugate gradient.

3 Empirical Results

Firstly, conduct algorithm verification through parts of samples. Conduct data discretization by adopting the survey data on the delafossite of Tonglushan in Hubei, to acquire 301 groups of spatially dispersed data of the copper mine, which are taken as the verification samples.

Then conduct normalization processing to the sample data, and select 296 groups of data as the training samples and the other 5 groups as the test samples. The interpolation is conducted by utilizing the inverse distance method, to acquire the result. Then the interpolation of the new algorithm is conducted to determine the network structure of RBF in combination of the improved ant colony algorithm. Considering that the model is used for spatial interpolation, the number of the nerve cell nodes of the input layer is 3, and the initial setting of the hidden layer is 296, and the nerve cell of the output layer is 1. The number of the new centers of clustering is 11 based on the clustering with the improved ant colony algorithm, and re-regulate the number of the nodes of the hidden layer to 11. Then select the conjugate gradient method to train the weight of the output layer through sample training. Finally, acquire the interpolation result as per the interpolation of the test samples. The statistical magnitudes of the accuracy of prediction A_p and the error of mean square are adopted in this article as standards for inspecting the interpolation effect of the two interpolation methods. The statistical significance of A_p refers to the degree of closeness between the predicted value and the actual value, and M_{se} refers to the fluctuation degree of the deviation between the predicted value and the actual one. It is obvious that larger A_p and smaller M_{se} lead to more favorable interpolation effect. Because it means the closeness between the predicted value and the actual one, as well as small range of fluctuations in deviation. Their formulas are listed as follows, respectively:

$$A_p = (1 - \sum_{k=1}^{s} (T_k - \widehat{T_k})^2 \Big/ \sum_{k=1}^{s} (T_k - \overline{T})^2) \times 100\% \tag{6}$$

$$M_{se} = \frac{1}{s} \sum_{k=1}^{s} (T_k - \widehat{T_k})^2 \tag{7}$$

In which T_k refers to the actual value of the kth sampling data point; $\widehat{T_k}$ represents for the predicted value on the kth sampling point with the inverse distance method or the new model method; $\overline{T}$ represents for the average value of the verified actual values of the sampling data points. Based on formula (6) and (7), A_p is larger and M_{se} is smaller when the predicted value is close to the actual value.

The statistics of the test results acquired from the new model and the inverse distance method are as shown in Table 3:

Based on the above table, compared with the inverse distance method, the accuracy

Table 3. Comparison on statistics of test results.

A_p/%		M_{se}	
Inverse-distance method	The new model	Inverse-distance method	The new model
42.06	65.89	3.59	2.17

of the new model method is significantly improved during interpolation to the grades of ore bodies. After the input of the same variable (x, y, z), the accuracy of prediction of the new model is increased by 56.66% and the error of mean square is decreased by 39.55%. The increase in the accuracy of prediction and the significant reduction on the error of mean square indicate that the interpolation effect of the new model method is significantly improved than that of the inverse distance method.

4 Conclusions

The article conducts interpolation on grades of spatially dispersed non-layered ore bodies with the improved ant colony radial basis algorithm, and conducts comparative verification with the inverse distance method. It is proved that the spatial interpolation based on the new algorithm is improved in accuracy. On this basis, it constructs a new spatial interpolation model to develop and realize the model based visual software for non-layered ore bodies by utilizing VC ++ and OpenGL environment, so as to facilitate further research on the correlation between the spatial distribution regulation and the internal characteristics related to grades of ore bodies.

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RBF Model Based on the KECDBN

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Abstract. For the dilemma in determining the structure and shortage of supervision in learning process of the deep learning feature extraction algorithm CDBN, this paper proposes a method to improve this situation by adopting KECA to extract features more deeply and effectively and then we take the extracted features as the input of RBF. We use foreign exchange series to conduct the em-pirical study which shows that the accuracy of the KECDBN-RBF model is obviously improved compared to single RBF.

1 Introduction

As a nonlinear feature extraction method, the continuous restricted Boltzmann machine (CRBM) is a type of symmetric restricted diffusion network (RDN) [1] including the visual layer and the single hidden layer. CRBM has strong capacities on nonlinear high dimensional data simulation and nonlinear feature extraction [2], which has been applied to fields such as fingerprint identification [3], geochemical anomaly identification [4] and financial research. By adopting the nonlinear function as the activation function, it conducts nonlinear transformation to original features, to deconstruct the high order nonlinear relationship implicated among original features, so as to acquire the features with strong discrimination [5, 6].

However, CRBM is an unsupervised learning algorithm, with learning effect restricted by learning degree. CRBM cannot explore the deep abstract features in condition of insufficient learning degree, leading to unsatisfactory whole learning effect. On the contrary, the over learning may lead to the covering of the explored deep abstract features, giving rise to adverse influence on the whole learning effect. Therefore, it is the key element for the deep learning effect to determine the learning degree of CRBM; i.e., supervise the learning process. This article supervises the learning process by utilizing the kernel entropy information in the KECA algorithm to further construct the KECDBN network so as to explore the sample features in a deep and effective way.

2 CDBN and KECDBN

2.1 CDBN

The CRBM algorithm can be utilized to handle with continuous actual values [7]. And the basic structure of the CDBN is shown in the following Fig. 1.

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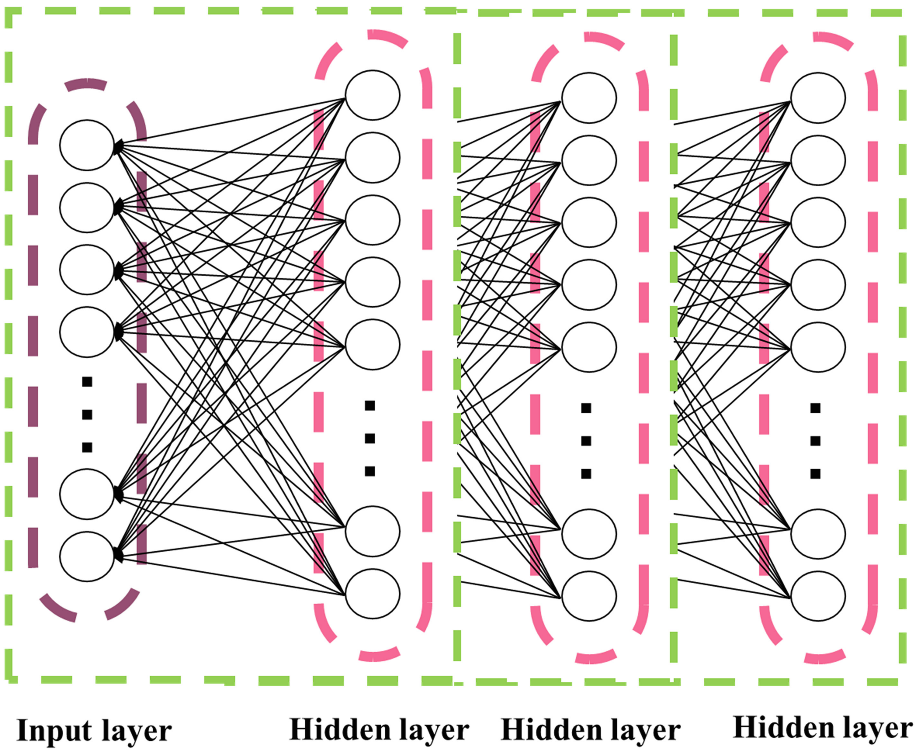

Fig. 1. The structure of CDBN.

The CDBN algorithm composed by multilayer CRBM has the following procedures:

(1) Initialization; $\{S_i\}$ represents for the state of the nodes of the visual layer, and $\{S_j\}$ represents for the state of the nodes of the hidden layer; initialize the weight and the parameters of various layers α_j and b_i randomly.
(2) Select and apply a group of training samples to the network randomly, and update $\{S_j\}$, the state of various nodes of the first hidden layer is determined by the Eq. (1):

$$S_j = \varphi_j(\sum_i W_{ij}S_i + \sigma N_j(0,1)) \tag{1}$$

(3) Update $\{S_i\}$, the state of the nodes of the visual layer, as per $\{S_j\}$, the state of the nodes of the hidden layer of the previous step, to acquire the updated state as follows:

$$S_i' = \varphi_i(\sum_j W_{ij}S_j + \sigma N_i(0,1)) \tag{2}$$

(4) Update $\{S_j\}$, the nodes of the hidden layer, again as per $\{S_i^{'}\}$, the nodes of the visual layer of the previous step, to acquire the updated state as follows:

$$S_i^{'} = \varphi_i(\sum_j W_{ij} S_i^{'} + \sigma N_i(0,1)) \tag{3}$$

(5) Select the next training sample randomly, and turn to Step 2. In condition that the last sample in the training samples has been selected, calculate the weight and the variation quantities of the parameters of the visual layer and the hidden layer, respectively, so as to update the weight and the parameters by the following Eq. (4) to Eq. (9):

$$\Delta W_{ij} = \eta_w(< S_i, S_j > - < S_i^{'}, S_j^{'} >) \tag{4}$$

$$\Delta a_j = \frac{\eta_a}{a_j^2}(< S_j^2 > - < S_j^{'2} >) \tag{5}$$

$$\Delta b_i = \frac{\eta_b}{b_j^2}(< S_i^2 > - < S_i^{'2} >) \tag{6}$$

$$W_{ij}(k+1) = W_{ij}(k) + \Delta W_{ij} \tag{7}$$

$$a_j(k+1) = a_j(k) + \Delta a_j \tag{8}$$

$$b_i(k+1) = b_i(k) + \Delta b_i \tag{9}$$

(6) Turn to Step 2 again, and start the first training. Stop training in condition that the number of trainings achieves the set maximum value or the updated variation quantity of the weight matrix is much too small, to end the learning of the CRBM of the layer.
(7) Take the output result of the previous layer of the CRBM network as the input of the next layer of the CRBM network, and repeat the training process of Step 1-6 to train a new layer of CRBM network; the training to the whole CDBN is finished after the end of the training for all layers of the CRBM network.

However, CRBM is an unsupervised learning algorithm, and insufficient or over learning degree leads to adverse influence on the exploration of deep abstract features. Therefore, it is critical to supervise the learning process of CRBM. It is proposed in this article to supervise the learning process by utilizing the kernel entropy information in the KECA algorithm, so as to further construct the KECDBN network.

2.2 KECDBN

In combination of the idea of kernel entropy component analytical algorithm, this article maps the input dataset of the continuous limited Boltzmann machine and the output dataset acquired from each learning to the high dimensional kernel space, respectively. It then constructs the kernel matrix by utilizing the Parzen window function and estimates the Renyi information entropy of various datasets by utilizing the kernel matrix; in addition, it measures the learning degree of CRBM by utilizing the difference on the Renyi information entropy. The improved KECDBN has the following procedures:

(1) Conduct the first round of sample training, and calculate the weight as well as the variation quantities of parameters of the visual layer and the hidden layer. Set the initial learning step and the initial pheromone volatility coefficient ρ = 1. Then update the weight and parameters of various layers, and modify the updating formula as the following Eqs. (10) to (12):

$$W_{ij}(k+1) = \rho \times W_{ij}(k) + (2-\rho) \times step \times \Delta W_{ij} \tag{10}$$

$$a_j(k+1) = \rho \times a_j(k) + (2-\rho) \times step \times \Delta a_j \tag{11}$$

$$b_i(k+1) = \rho \times b_j(k) + (2-\rho) \times step \times \Delta b_i \tag{12}$$

Set the step length control threshold η and the volatility control threshold ε. Calculate the output of the hidden layer of all the original input data at the first weight and after parameter updating. Calculate the Renyi entropy of the original input dataset, which is recorded as $R_{in}{}^{(1)}$, and the Renyi entropy of the input dataset of the hidden layer, which is recorded as $R_{out}{}^{(1)}$; make the minimum information loss $Lost_{min}$ and information loss Lost(1) meet the following relation:

$$Lost(1) = Lost_{\min} = \left| R_{in}^{(1)} - R_{out}^{(1)} \right| \tag{13}$$

At the same time, make:

$$W_{out} = W, a_{out} = a, b_{out} = b \tag{14}$$

(2) Continue the training of the next round, and calculate the weight as well as the variation quantities of the parameters of the visual layer and the hidden layer. Calculate the output of the hidden layer of all the original input data at this round of weight as well as after parameter updating. In addition, calculate the information loss amount as per the method in Step (1):

$$Lost(k) = \left| R_{in}^{(k)} - R_{out}^{(k)} \right| \tag{15}$$

(a) If $Lost(k) < Lost_{\min}$, $Lost_{\min} = Lost(k)$ and $W_{out} = W, a_{out} = a, b_{out} = b$;
(b) If $Lost(k) > Lost(k-1)$, make step = 0.5step and ρ=0.5ρ;

(c) If $Lost(k) > Lost(k-1)$ and $Lost(k) < \varepsilon$, judge the continuity of such conditions; if the occurrence number achieves 5, make ρ=0.1ρ; or ρ=1;
(d) If $Lost(k) \leq Lost(k-1)$, make ρ=1;
(e) If $Lost(k) \leq Lost(k-1)$ and $\frac{1-Lost(k)}{Lost(k)} < \eta$, make step = 2step;
(f) If $Lost(k) \leq Lost(k-1)$ and $Lost(k) < \varepsilon$, and this condition occurs for continuous 5 times, make ρ=0.1ρ; or ρ=1.
(3) If $Lost(k)$ is less than the termination threshold or achieves the maximum number, make $W = W_{out}, a = a_{out}, b = b_{out}$, and ends it.

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2.3 The Radial Basis Function Neural Network

RBF is a locally connected three-layer feedforward neural network [8–10] which consists of the input layer, hidden layer and the output layer, among which the hidden layer is also called the radial basis layer whose nodes generate a localized response to the input data and will generate non-zero response when the input data is in the specified area. i.e. map the input data to a new radial base space, and the output layer nodes finish the linear addition in the new space.

And the base function used in the hidden layer for RBF is a Gaussian function which is shown in the following Eq. (16):

$$R_i(X) = \exp\left[-\|X - C_i\|^2 / (2\sigma_i^2)\right], \text{ i} = 1, 2, \ldots, \text{N}. \tag{16}$$

where N denotes the number of the hidden layer' nodes, X represents the input vector whose dimension is N, Ri (X) represents the output of the ith hidden layer node, and Ci and σi represent the center and width of the base function of the ith hidden layer node, respectively. It can be seen that the most important part of the RBF network is to determine the center Ci and the width σi of the base function, which determines the performance of the network. The choice of the center Ci and the width σi for the basis function is determined using the HCM algorithm in this study [11].

3 The Empirical Study

This article selects the data of three foreign exchanges of GBP/USD, USD/JPY and AUD/USD as the research objects during June 30, 2010 – June 30, 2015, with totally 1302 valid trading days. In addition, it selects the first 1200 data as the training set and latter 102 data as the test set. The data are acquired from CCER China's Financial and Economic Database. Example of a Computer Program from Jensen K., Wirth N. (1991) Pascal user manual and report. Springer, New York.

3.1 The Determination of the Structure of KECDBN

In this paper, the network layer is set to 1 to 10 of the 10 possible options, and also set the number of nodes per layer to 1 to 10 of the 10 possible options. Corresponding to the 10 selected network structures, each selected learning output is taken as the input of the RBF network with the best structure determined, and then the output of the optimal structure RBF network is used as the prediction result of the selection method. Select the number of nodes with the smallest average absolute error to determine the number of nodes in the first layer, and then select the output of the first layer network of the node as the input of the next layer network according to the previous method to the next layer of network nodes.

3.2 The Empirical Results

The mean absolute error (MAE) index [12, 16] is adopted in this article to evaluate the prediction effects of the three models:

$$MAE = \frac{\sum_{i=1}^{T} \left| y_i - y_i' \right|}{T} \tag{17}$$

where $Y = (y_1, y_2, \ldots, y_T)^T$ is the actual exchange rate; $Y' = (y_1', y_2', \ldots, y_T')^T$ is the exchange rate predicted by the model; T is the number of the samples in the test set. Based on the expression, smaller error value embodies more favorable prediction effect of the model. Please refer to Table 1 for the results of comparisons between the RBF model and the KECDBN-based RBF model on the predictions to the test sets of the three types of foreign exchange data.

According to the prediction results of the three exchange rates as per sequences in Table 1, the KECDBN-based RBF prediction model has higher prediction accuracy when compared with the single RBF prediction model. Therefore, KECDBN can effectively extract the distributed features of data.

Table 1. The evaluation results of the two models.

MAE	RBF	KECDBN + RBF
GBP/USD	0.0361	0.0330
USD/JPY	0.0094	0.0081
AUD/USD	0.0082	0.0073

4 Conclusions

This article solves the deficiencies of the CDBN deep learning method by utilizing the kernel entropy component analytical method. As for the single RBF model, the deep learning method KECDBN can extract the distributed features of limited sample data, with effective deep feature extraction capacity, which further improves the prediction accuracy of the RBF model, with certain practical significance. Further research can be conducted on KECDBN in the future.

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Design of a S-box for SMS4 Based on Threshold Implementation

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Abstract. TI(threshold implementation) is a new masking method that is based on secret sharing and multi-party computation, which can resist the first-order DPA attacks provably and effectively. In this paper, we propose a new S-box scheme on SMS4 which is based on TI. The new S-box scheme uses a secret sharing method to group the input and output of S-box, which can effectively improve the safety of S-box, next, in order to reduce the computational difficulty, converting input to composite field inside the S-box. After analysis and verification, the new S-box scheme can effectively resist first-order DPA attack, and has lower power consumption and less realized area.

1 Introduction

In January 2006, The Office of State Commercial Cipher Administration of China (OSCCA) released the specification of SMS4. No long after the public, SMS4 was applied to the Wireless Authentication and Privacy Infrastructure (WAPI) standard [1], which is a Chinese mandatory national standard dedicated to protecting data packets in wireless network. However, since the SMS4 algorithm adopts the same Feistel structure with the AES algorithm, both of them are vulnerable to resist the Side-channel attack. Similarly, the AES approaches for resisting the channel attack are also applicable to the SMS4 algorithm.

In 2006, Nikova et al. put forward the idea of TI based on secret sharing to resist DPA attack for the first time [2], and proved the security of this scheme against the DPA attack through Strict proof. In 2011, Mora-di et al. intuoduced a very compact S-box and a Threshold Implementation of AES, which applied the secret sharing theory to the AES S-box [3], improving the resistance of TI to first-order DPA attacks for AES.2013. Bilgin et al. designed the implementation scheme of Keccak algorithm based on TI and verified the security by experiments [4]. The next year, Bilgin et al. designed a implementation scheme of S-box based on TI. However, as a block cipher algorithms similar to the AES algorithm, little research has been done about how to prevent DPA attacks on SMS4 algorithm [5]. In 2007, Fen Liu et al. gave a detailed analysis of SMS4, and investigated and explained the origin of the S-box employed by the cipher [6], laying the foundation for the next research. In 2008, Xuefei Bai presented a differential power analysis attack method on every byte of round keys [7], bying doing the attack, they obtained the round keys of the last four rounds of SMS4 and then found out the 128-bit encryption key. In the same year, they proposed a secure

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masking scheme which adopted the a new inversion method based on composite field and realized it by VLSI. In 2015, Hao Liang et al. proposed a masking scheme [8], and proved its effectiveness by theoretical analysis and simulated CPA.In this paper, we proposed a new S-box of SMS4 algorithm based on TI, which is secure theoretically against first order DPA attack.

The paper is organized as follow, the Sect. 2 introduces the SMS4 algorithm. In Sect. 2.2, the DPA attack method is described briefly. In Sect. 3.1, the principles about TI is briefly introduced. In Sect. 3.2, we introduce the AES scheme of Bilgin and our SMS4 scheme. The conclusion of this work is presented in Sect. 4.

2 Preliminaries

In this section, we will introduce the S-box of SMS4 algorithm, and the basic principle of TI.

2.1 SMS4 Block Cipher

Since the SMS4 algorithm was published, the research on its security has been concerned by many cryptography experts. As the only nonlinear part of the SMS4 algorithm, the S-box is the key part to evaluate the security of the SMS4 algorithm. In 2007, Fen Liu et al. studied and analysised the S-box of SMS4 algorithm, finding out that the 8bit data of input in S-box needs to go through three steps, the first affine transformation, inverse, and the second affine transformation, and gets the output result in the final [6]. After the research, Fen Liu et al. successfully obtained a set of algebraic expressions, and gave the s pecific values of the relevant parameters. It was proved by experiments that the expressions and related parameter values can satisfy all the S-box values.

The algebraic expressions for the s S-box are as follow

$$S(x) = I(x \cdot A_1 + C_1) \cdot A_2 + C_2 \tag{1}$$

Where I means inversion over the field $GF(2^8)$, the matrices $A_1, A_2 \in GL(8,2)$, and the vectors $C_1, C_2 \in GF(2^8)$. and the row vectors in the algebraic expression are

$$C_1 = C_2 = \begin{pmatrix} 1 & 1 & 0 & 0 & 1 & 0 & 1 & 1 \end{pmatrix} \tag{2}$$

The cyclic matrices A_1, A_2 are as follows

$$A_1 = A_2 = \begin{pmatrix} 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 0 & 1 & 1 & 1 \\ 1 & 1 & 0 & 0 & 1 & 0 & 1 & 1 \end{pmatrix} \tag{3}$$

The irreducible polynomial is

$$M(x) = x^8 + x^7 + x^6 + x^5 + x^4 + x^2 + 1 \tag{4}$$

Here we introduce the inversion method of S-box based on composite field in AES algorithm, the method is also applicable to S-box of SMS4 algorithm, the process is shown in the following figure (Fig. 1).

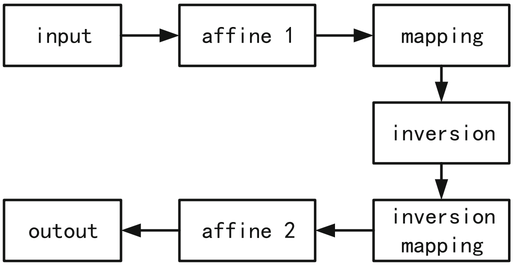

Fig. 1. This picture simply shows what has gone through for the data of S-box from input to output.

2.2 DPA

DPA(differential power analysis) is one of the most representative side channel attacks, and one of the most popular power analysis attacks, whose basic principle is to make use of the connection between the instantaneous energy of cryptographic equipment and the data and operations being performed. By using special electronic measuring instruments and mathematical statistical techniques [9], the power consumption of the CMOS chip can be detected and analyzed when different instructions are executed, next wo can obtain important information related to the key in the chip. The goal of the DPA is to record lots of power consumption tracks when cryptographic device performs encryption and decryption operations for a large number of different data, and analyze the fixed time energy consumption of equipment by using these trajectories, and then regard the energy consumption as a function of the data being processed to recover the password for the key equipment. The greatest advantage for a attacker is that he does not have to know the specific information of a cryptographic devicee [10]. A complete DPA usually include the following 4 steps

(a) select an intermediate value of the algorithm executed by the cryptographic device, and construct a differential function D, where m is known and k is the sub key to be guessed.
(b) input a large number of different data for the cryptographic device, and record the energy consumption trajectory m_i and t_i.
(c) guess the sub key k, calculate the assuming middle value, use the energy consumption take place of the middle value according to the selected mathematical model, classify the energy consumption trajectory t_i, and compare with the actual

energy traces, the average power trajectory is calculated and the differential trajectory is computedthe actual energy trace comparison, calculate the average power trace t and do differential calculation with the classified energy consumption trajectory, the formula is as follows

$$\Delta_D(j) = \frac{\sum_{i=1}^{n} D(m_i, k_i) \times t_i(j)}{\sum_{i=1}^{n} D(m_i, k_i)} - \frac{\sum_{i=1}^{n} (1 - D(m_i, k_i)) \times t_i(j)}{\sum_{i=1}^{n} (1 - D(m_i, k_i))} \tag{5}$$

Analysis the differential results, if there is an obvious spike, the guessed value is correct, otherwise, repeat (c).

(d) By repeating the three steps mentioned above, all the subkeys can be obtained, and the key of the device will be recovered.

3 Threshold Implementation of the SMS4 S-Box

In this section, we will introduce the basic principle of TI, and the design scheme of SMS4 S-box based on TI.

3.1 TI Resists DPA Attack Principle

Shamir proposed the concept of secret sharing in 1979, and gave the (k, n) threshold scheme. The basic idea is to divide a complete secret into several parts and assign every part to each different participant, and the secret can not be reconstructed unless the number of the participant reaches k or more, where k is called the threshold value of the scheme [11]. The programme must be fulfilled:

(a) arbitrary participant whose number is k or more can reconstruct the secret.
(b) arbitrary participant whose number is less than k can not be reconstruct the secret.

The scheme is usually implemented by Lagrange interpolation. Firstly, a polynomial needs to be constructed that its power is $k-1$, the constant term is used to keep secret, and then the secret is divided into n parts so as to assign randomly to n participant. When the secret needs to be restored, the complete secret can be recovered if unless the number of the participants reaches k or more, otherwise, any information can not be acquired about the secret.

We define $\oplus$ as the addition operation over the field $GF(2^m)$ (XOR), $\sum$ as the addition of real numbers, and $\bar{x}$ represents the vector $(x_1, x_2, \ldots, x_n)$, $\bar{x}_i$ represents the vector $(x_1, x_2, \ldots, x_{i-1}, x_{i+1}, \ldots, x_n)$ which missing x_i, the probability when $t(x) = T$ is represented by $\Pr(t(\overline{x}) = T)$. Inspired by the idea of secret sharing and threshold scheme, we split x into n parts, If the following formula is established:

$$x = \bigoplus_{i=1}^{n} x_i \tag{6}$$

Using a secret sharing scheme, in order to uniquely determine x, we need all the n parts. In a perfect secret sharing scheme as (n, n), even a attacker get $n-1$ parts of the secret, he can not get any information about the secret. In a ramp scheme (k, t, n), the secret can be restored at least t or more honest participant to be involved, but when the number of malicious participant reaches k or more, they can also recover the secret. Here we adopt a $(1, n, n)$ ramp scheme, and suppose the conditional probability is even, and thus

$$\forall \overline{\mathrm{X}} : \Pr(\overline{\mathrm{x}} = \overline{\mathrm{X}}) = \mathrm{c}\Pr(\mathrm{x} = \bigoplus_{i=1}^{n} \mathrm{x_i}) \tag{7}$$

c is a Constant, in order to make sure $\sum \overline{X} \Pr\left(\overline{x} = \overline{X}\right) = 1$

We generalize now condition (2) in the following way:

$$\Pr\left(\overline{x} = \overline{X}, \overline{y} = \overline{Y}, \cdots\right) = c\Pr\left(x = \bigoplus_i X_i, y = \bigoplus_i Y_i, \cdots\right)Z \tag{8}$$

We define $z = L(x)$ as a linear transformation over the field $GF(2^m)$, x and z are split into n parts,$z_i = L(x_i)$, $0 \leq i < n$.

The linear transformation will not disclose any information about the key when channel attack occurs, which is called a security circuit. One of the features of the security circuit is that arbitrary one part z_i of the output is only related to x_i. Similarly, Considering multiple inputs are used, that is $z = LL(x, y, \cdots)$,z_i is only related to $(x_i, y_i \cdots)$. Because the linear transformation and nonlinear transformation have some similar characteristics, so we can construct the safety circuit of nonlinear transformation.

If z_i does not depend entirely on $(x_i, y_i \cdots)$ for $z = LL(x, y, \cdots)$, that is mean z_i and $x, y, \cdots$ are irrelevant, and thus, the calculation of z_i does not disclose any information about $x, y, \cdots$, by adding conditions, we can ensure that z and z_i are irrelevant.

We Defined $z = N(x, y, \cdots)$ as a nonlinear over the field $GF(2^m)$, a set of functions must satisfy the following three properties [12].

Property 1 (Non-completeness). Every function is independent of at least one share of each of the input variables $x, y, \cdots$

$$z_1 = f_1(x_2, x_3, \cdots, x_n, y_2, y_3 \cdots, y_n, \cdots) = f_1(\overline{x_1}, \overline{y_1}, \ldots)Z \tag{9}$$

$$z_2 = f_2(x_1, x_3, \cdots, x_n, y_1, y_3 \cdots, y_n, \cdots) = f_2(\overline{x_2}, \overline{y_2}, \ldots)Z \tag{10}$$

$$\cdots$$

$$z_n = f_n(x_1, x_3, \cdots, x_{n-1}, y_1, y_3 \cdots, y_{n-1}, \cdots) = f_n(\overline{x_n}, \overline{y_n}, \ldots)Z \tag{11}$$

Property 2 (Correctness). The sum of the output shares gives the desired output

$$z = \bigoplus_{i=1}^{n} z_i = \bigoplus_{i=1}^{n} f_i(\cdots) = N(x)Z \tag{12}$$

Property 3 (Balance). A realization of $z = N(x, y, \cdots)$ is balanced if for all distributions of the inputs $x, y, \cdots$, and for all input share distributions satisfying (8) the conditional probability

$$P_r\left(\bar{z} = \overline{Z}\middle| z = \bigoplus_i Z_i\right)Z \tag{13}$$

is constant.

Since the input of the previous stage is the output of next stage, the property 3 ensures that the data can be synchronized during processing.

Theorem 1. *The minimum number of shares required to implement a product of s variables with a realization satisfying Properties 1 and 2 is given by*

$$n \geq 1 + s \tag{14}$$

This shows that to achieve a nonlinear transformation we need at least 3 shares. Since not all variables are independent, there may be other solutions that require a lower number of shares

Corollary 1. *The maximum number of shares required to implement a function N of u variables over $GF(2^m)$, equals $1 + 2^{mu}$.*

Condition (2) shows that any bias present in the joint distribution of x and y is due to biases in the joint distribution of x and y. Under this condition, we can prove the following.

Theorem 2. *In a circuit implementing a set of functions satisfying Properties 1 and 2, when the input satisfies (7), all the intermediate results are independent of the inputs $x, y, \cdots x$, and the output z. Also the power consumption, or any other characteristic of each individual function f_i are independent of $x, y, \cdots$ and z.*

Theorem 2 shows that the power consumption of any single function is independent of input $x, y, \cdots$ and output z, and there is no dependency between the power consumption and data, and DPA attacks no longer work.

3.2 Implementation Scheme of S-Box SM4

Bilgin et al. proposed the implementation scheme of AES S-box based on TI. Next, we will propose a new implementation scheme of SMS4 S-box based on TI. Our scheme can be divided into the following three steps, as shown in the following figure (Fig. 2).

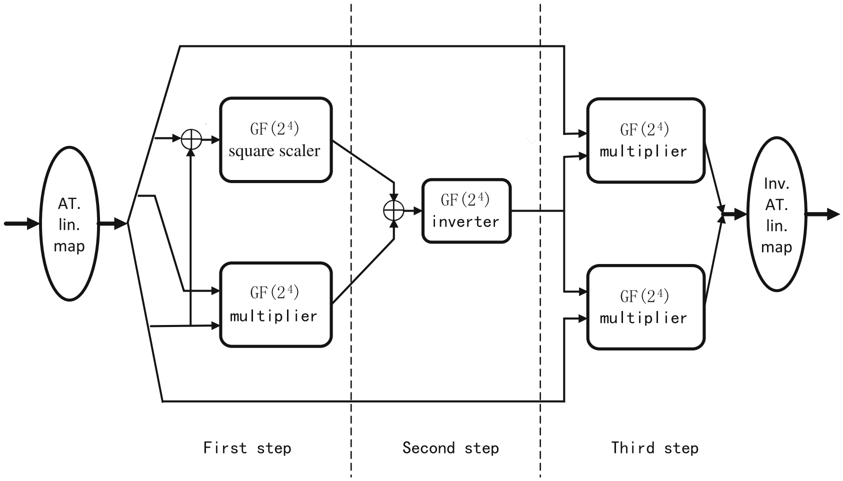

Fig. 2. This picture simply shows the framework of our scheme, it is divided into three steps, and uses three multipliers, one square scaler as well as one inverter.

As shown in the figure above, we divide the implementation into 3 steps, in this scheme, the main calculation part is composed of three multipliers and one inverter, now we will introduce how a multiplier and the inverter are calculated internally follow the scheme implementation steps.

As is shown in the figure above, there is a AT.lin.map part before the input entering into the multiplier, which can complete the first affine transformation and divide the input into four shares. We assume that the input consists of a and b, output is c,a is split into a_1, a_2, a_3, a_4 and b is split into b_1, b_2, b_3, b_4 The formula is calculated as follows in the multiplier

$$c_1 = (a_3 \oplus \mathrm{a}_4) \oplus (b_2 \oplus \mathrm{b}_3) \oplus \mathrm{b}_2 \oplus \mathrm{b}_3 \oplus \mathrm{b}_4 \oplus \mathrm{a}_2 \oplus \mathrm{a}_3 \oplus \mathrm{a}_4 \tag{15}$$

$$c_2 = (a_1 \oplus a_3) \oplus (b_1 \oplus b_4) \oplus b_1 \oplus b_3 \oplus b_4 \oplus a_1 \oplus a_3 \oplus a_4 \tag{16}$$

$$c_3 = (a_2 \oplus a_4) \oplus (b_1 \oplus b_4) \oplus b_2 \oplus a_2 \tag{17}$$

$$c_4 = (a_1 \oplus a_2) \oplus (b_2 \oplus b_3) \oplus b_1 \oplus a_1 \tag{18}$$

In the second step, similarly, the input and output of the inverter are divided into four shares, here we assume that the input are e_1, e_2, e_3, e_4 and output are f_1,f_2,f_3,f_4, by using the decomposition method [13], we can quickly calculate the result, the formula is as follows

$$f_1 = e_2 \oplus e_3 \oplus e_1e_3 \oplus e_2e_3 \oplus e_2e_3e_4 \tag{19}$$

$$f_2 = e_4 \oplus e_1e_3 \oplus e_2e_3 \oplus e_2e_4 \oplus e_1e_3e_4 \tag{20}$$

$$f_3 = e_1 \oplus e_2 \oplus e_1e_3 \oplus e_1e_4 \oplus e_1e_2e_4 \tag{21}$$

$$f_4 = e_2 \oplus e_1e_3 \oplus e_1e_4 \oplus e_2e_4 \oplus e_1e_2e_3 \tag{22}$$

In the third step, the input first enters the two multipliers, like the first step, the input needs to be divided into four shares for computation and then entered the Inv.AT.lin.map part, which will complete the second affine transformation and output the final results are obtained.

4 Conclusion

In this paper, we propose a new implementation scheme of SMS4 S-box against first-order DPA attack, which is based on secret sharing and multi-party computation. In the design process of our scheme, we always follow the basic principle of TI, and ensure that when the data of S-box is grouped, which will always follow the three properties, non-completeness, correctness, and uniformity, therefore, this scheme is secure against first-order DPA attack theoretically. Our next work is to study how to validate our scheme with experimentsthe, resist higher-order DPA attacks [14], and look for another better grouping schemes based by using TI.

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The Prediction Model of Online Social Networks' Evolution Based on the Similarity of Community

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Abstract. It is one of the key problems in network research to discover the evolution of community in social network, study the evolution of community and forecast the development trend of community. How to more faithfully reveal the evolution of the community in complex networks has always been the goal pursued by all researchers. Based on the evolutionary prediction model of event-based community, this paper constructs four kinds of event framework models by using community similarity algorithm and edge similarity algorithm, and through the WS small world network simulation data set test. In the premise of improving the accuracy of prediction, it does not significantly reduce the number of community events found, with good predictive performance.

1 Introduction

In recent years, the dynamic community discovery algorithm [2] becomes gradually mature, which makes lots of communities discovered. Baseing on the event-frame community evolution prediction research become the hotspot in this field. The event [1] is the changing situation in the dynamic network of community at different time snapshot. Specifically speaking, it means observing and predicting the evolution of the community by calculating the shared node or edge of the community on two adjacent or non-adjacent time snapshots. Actually, the event-frame was first proposed by Palla et al. [3], who defined six events of evolutionary patterns by observing changes in neighborhood communities. Growth represents the community's growth situation of the scale at its adjacent time snapshot in the dynamic network. Contraction represents the community's contraction situation of the scale at its adjacent time snapshot in the dynamic network. Merging indicates the situation in which some communities in the dynamic network merge into a community at its adjacent time snapshot. Splitting indicates the situation in which a community split into some communities at its adjacent time snapshot. Birth represents the situation that in a dynamic network a community does not exist at the adjacent time snapshot. Death represents the situation that a community does not exist at the next adjacent time snapshot in a dynamic network. Asur et al. [4] proposed an event- frame under different time snapshots to describe the various relationships between communities, which defines four types of events–form, birth, merge, split and dissolve. All of them are used to describe and study the community evolution under different time snapshot. Based on the work of

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Asur et al., Zhang et al. [1] use the index of similarity to define the community event and put forward seven kinds of community event-frame, which greatly improves the discovered number of communitys. But they just consider the similarity of inter-community nodes, ignoring the importance of the edge between inter-node. For example, the community formed by three strangers evolved into the community formed by three good friends. Actually, the community nodes did not change, but the two communities are obviously different.

Based on the research of Zhang et al., this paper considers the influence of the edge on the community relationship, introducing the similarity of the edge. By using the similarity theory of node and edge, this paper improves the four-type community event-frame, and redefines the events of merging and splitting to make them more realistic. Finally, through the simulation of the network data set detection framework, this paper proved the rationality of the framework.

2 Related Knowledge

The problem of community discovery and evolution in dynamic networks has become a hot topic in the field of complex network analysis. Event-frame is one of the main research methods. Since Palla [3] has proposed the concept of event-frame for the first time, many researchers have proposed some relevant definitions of events. However, there are some problems, such as high time complexity or too strict definition, which can not be used to faithfully reveal the evolution process and the changing of communities in complex networks. Zhang et al. [1] use the concept of similarity to define the community event and put forward seven kinds of community event-frame. it improves the discovered number of all kinds of events to some extent. But they only focus on the similarity nodes of the two community, ignoring the importance of the edge between inter-node in the dynamic community. Newman [6, 7] believes that community is to meet the sub-graph internal relations closely and the sparse structure of the sub-graph relationship by using the view of Graph theory. It is obvious that

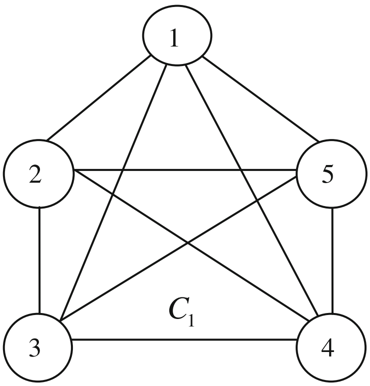

Fig. 1. Before the evolution

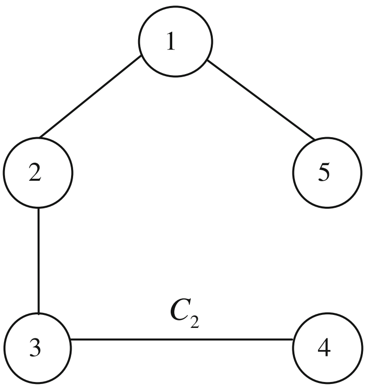

Fig. 2. After the evolution

nodes and edges are equally important in the picture. As shown in Figs. 1 and 2, the two communities C_1 and C_2 have the same node, but the two communities are obviously different because of the difference in the connection between nodes. Combined with Zhang Xuewu's research, this research increased the impact of the edge on community evolution, depict the community event more meticulously and improve the accuracy of the event that's found.

2.1 Overlapping Community

The formation of the network community [7] is the aggregation of individuals or groups that have a common interest for a topic. A person can be interested in different topics at the same time, just like that one person participates in two interest groups at the same time, which results in the appearance of the overlap of the community. So the overlapping communities can be defined as the node with common interest and the collection of edges between nodes and nodes. The community structure can be expressed by $C_i^a = (N_i^a, E_i^a)$ [8]. In this structure, C_i^a represent the community a at time i, N_i^a, E_i^a respectively express the collection of nodes and edges of community a at time i. The different communities of $C_1\{1, 2, 3, 4, 5, 6\}$ and $C_2\{5, 6, 7, 8, 9, 10\}$ have the same node 5 and 6, which forms a overlapping community.

2.2 Dynamic Network

The social network [9] show the relationship between individuals, while the definition of relational structure is usually based on the type of interaction, and is changing along with time, such as the friendship, the employment relationship and so on. The network is an extension of the human real world in the virtual world, so the network is also dynamic. The dynamic network can be see as a combination of static networks under several adjacent time snapshots. While the $A_i\{N_i, E_i\}$ represents the static network at the ith time, N_i and E_i respectively express the collection of edges between nodes with common interest at time i.

2.3 Community Similarity

By using the similarity index to measure the similarity of the community nodes and the similarity of edge between nodes in the two different time snapshots, the formula of the similarity node can be defined as follows:

$$N_{sim}\left(C_i^a, C_j^b\right) = \frac{\left|N_i^a \cap N_j^b\right|}{Max\left\{|N_i^a|, \left|N_j^b\right|\right\}}$$

For this formula, C_i^a, C_j^b respectively represent the community a and b at the time I and j. $\left|N_i^a\right|$ indicates the number of nodes of the community a at time i. $\left|N_j^b\right|$ represents that the number of nodes of community b at time j. $\left|N_i^a \bigcap N_j^b\right|$ indicates the same number of nodes in two communities. And the corresponding formula of similarity is:

$$E_{sim}\left(C_i^a, C_j^b\right) = \frac{\left|e_i^a \cap e_j^b\right|}{Max\left\{|E_i^a|, \left|E_j^b\right|\right\}}$$

Among this, $\left|E_i^a\right|$ indicates the number of edge of the community a at the ith time. $\left|E_j^b\right|$ indicates the number of edge of community b at the jth time. e_i^a indicates the collection of the edge of the community a in which two communities share a common node, and e_j^b indicates the collection of the edge of the community b in which two communities share a common node. While the $\left|e_i^a \bigcap e_j^b\right|$ is the number of the same sides of the two communities. The values of the two formulas conform to the following rule:

$$0 \leq N_{sim}\left(C_i^a, C_j^b\right), E_{sim}\left(C_i^a, C_j^b\right) \leq 1$$

Setting threshold values for the two similarity values respectively, when the two similarity values are greater than the respective threshold values, the two communities are considered to be similar.

2.4 WS Small-World Network

As a transition from a fully regular network to a completely random network, Watts and Strogtz introduced the ws small world model for the first time in 1998, and the model reacts well with the fact that there is a relatively small distance between any two nodes in a large-sized network system. Meanwhile, there are two relatively short relative distances and it shows two characteristics of the relatively large clustering coefficients, which can be a good response to the real network world.

3 Model Building

Because of the change of the dynamic community, the temporary concealment of the community node or the limitation of the community discovery algorithm, it is possible to create the illusion that there is no community at some time. However, in the long term, there is community in fact. If the paper just compares the situation of the community in the network of adjacent moments, there must be a big error. Such as the formation of the community, as long as there is no similar community in the former t time snapshots, we can treat this community as a newly community. For the merging and splitting of the community, some communities at the time i can achieve the effect of merging at the time j through the continuous evolution. Therefore, this paper requires that the effect of merging must be achieved within t time, so that the community has occurred the evolution of merging.

3.1 Formation

As long as the community C_i^a is not similar to any community in its previous t moments, we can think that C_i^a is a new formed community. The formula is as follows:

$$Birth\left(C_i^a\right) = \exists \left\{ \begin{array}{l} N_{sim}\left(C_i^a, C_j^b\right) < \alpha \cap \\ E_{sim}\left(C_i^a, C_j^b\right) < \beta \end{array} \right\}$$
$$(i - t \le j < i, j \in Z)$$

3.2 Dissolve

Be similar to the birth of the community, if there is no community that is similar to the community C_i^a in the later t moment, we can say that the community is dissolving. And the formula is as follows:

$$Death\left(C_i^a\right) = \exists \left\{ \begin{array}{l} N_{sim}\left(C_i^a, C_j^b\right) < \alpha \cap \\ E_{sim}\left(C_i^a, C_j^b\right) < \beta \end{array} \right\}$$
$$(i < j \le i + t, j \in Z)$$

3.3 Merging

The community is located in the former t moments. If there are several community $\left\{C_j^1, C_j^2, \cdots, C_j^n\right\}$ and union set C_j^B that is similar to the C_i^a at time j in the network, it can be thought that C_i^a is the merging of the communities of $\left\{C_j^1, C_j^2, \cdots, C_j^n\right\}$. The formula is as follows:

$$Merge\left(C_i^a\right) = \exists \left\{ \begin{array}{l} N_{sim}\left(C_i^a, C_j^B\right) < \alpha \cap \\ E_{sim}\left(C_i^a, C_j^B\right) < \beta \end{array} \right\}$$
$$(i - t \le j < i, j \in Z)$$

3.4 Splitting

Be similar to the merging of the community, the community is located in the later t moments. It is required that within the t moment, if there are several community $\left\{C_j^1, C_j^2, \cdots, C_j^n\right\}$ and union set C_j^B that is similar to the C_i^a at time j in the network, we can think that the community has split. The formula is as follows:

$$Split\left(C_i^a\right) = \exists \left\{ \begin{array}{l} N_{sim}\left(C_i^a, C_j^B\right) < \alpha \cap \\ E_{sim}\left(C_i^a, C_j^B\right) < \beta \end{array} \right\}$$
$$(i < j \le i + t, j \in Z)$$

4 Experimental Results and Analysis

4.1 Experiments Settings

The main purpose of the experiment is to measure the degree of compliance between the model and the reality, and to compare with other event-frame to measure the effect of dealing with concrete data. This paper makes a comparative experiment on each event and analyze the data. This paper also used the discovery algorithm of overlapping community. While the data set uses the generating algorithm of ws small world model network. Table 1 is the set parameters when generating the network and the number of edge in the network after the network is generated.

Table 1. Parameters generated by ws small-world network

The number of node	The number of edge
500	1514
700	2118
900	2649
1100	3156
1300	3682

The algorithm mentioned in this paper mainly uses three parameters, they are the similarity of the community node and edge, and the certain time interval t. The parameter α and t are adopted from the numerical value in the paper of Zhang Xuewu. In the Fig. 3, when the parameter α is equal to 0.5, the number of occurrences of various events has reached a balance. So the value of the parameter α is 0.5. And because the definition of β is the same to the parameter α, so the value of the parameter β also set as 0.5, which not only plays a role of threshold value which has a good distinction between events, but also plays a role of protecting the community unchanged, so that the number of nodes

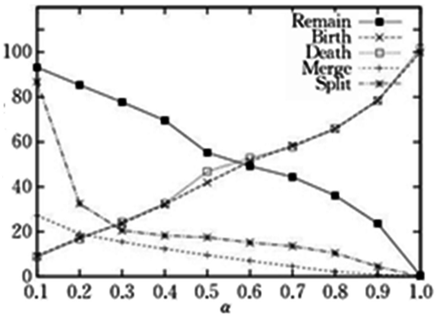

Fig. 3. The effect of parameter α on the event [1]

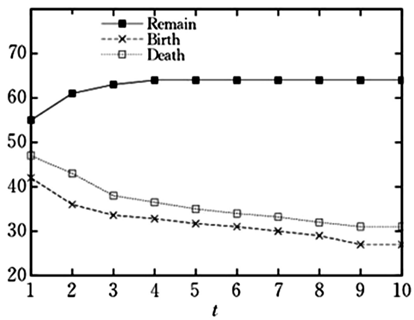

Fig. 4. The relationship between the number of events and the time [1]

in a similar community maintain more than half of the original. From the Fig. 4 we can see that when the t is equal to 3, the number of occurrences of various events reaches a certain value, so the value of t is 3. In the experiment, the machine language used mainly contains two parts: the first one is the Java language used in the discovery algorithm of overlapping community, the second one is the Matlab language used in the event tracking of community. And the experimental environment is Intel CPU 3.0 GHz and 4G memory.

4.2 The Comparison of the Number of Events

Through the ws small world network generated algorithm, we can get the network in four moment. It can be seen from the Figs. 5 and 6 that the number of generated disappearance events is less than that of Zhang Xuewu. The reason are as follows: the algorithm of Zhang Xuewu only considers the similarity of nodes and its constraint is less than that of the algorithm in this paper. The difference between the two algorithm is the community in which the nodes plays a role in the change of the community. Meanwhile, in this paper, the number of nodes and edges is few, so in the real network owning hundreds of thousands of between the two models should be greater differently. And in this way, the algorithm of Zhang Xuewu will produce a large error, which can not adequately reflect the evolution of the community and can not better discover the law of community evolution.

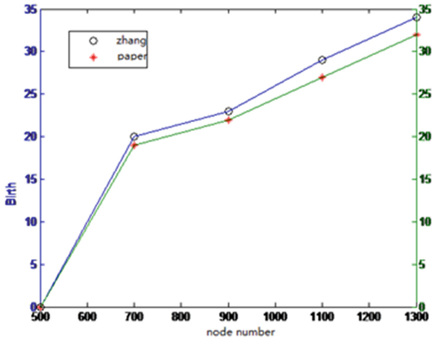

Fig. 5. The number of birth event comparison

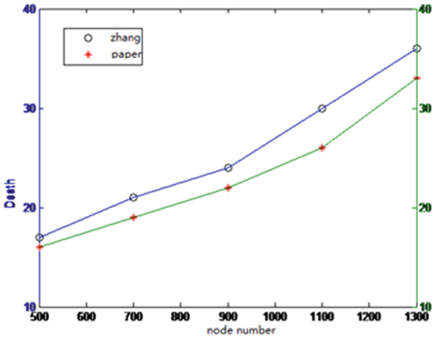

Fig. 6. The number of death event comparison

It can be seen from Figs. 7 and 8 that the number of corresponding events found by the algorithm in this article is more than Zhang Xuewu found. So it firstly proves the existence of the situation proposed in this paper, and with the increase of the number of nodes, the difference between them gradually increased. This indicates that the data set has a highly liveness, and its amplitude of variation in several adjacent time snapshots is greatly. Meanwhile, it also shows that the event model proposed in this paper can better reflect the real evolution of the community for the high activity data sets comparing with the event model made by Zhang et al.

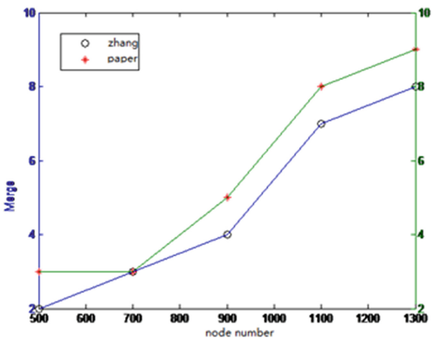

Fig. 7. The number of merge event comparison

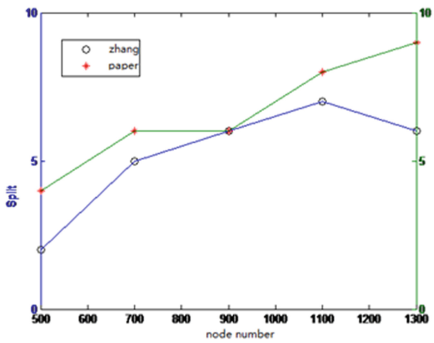

Fig. 8. The number of split event comparison

5 Conclusion

Based on the continuous improvement of overlapping community discovery algorithm, this paper further observed the community discovered by the algorithm and studies the evolutionary relationship between the communities. On the basis of a large number of studies made by Zhang et al., this article further observed the relationship of the edge of community under different time snapshot, and defined the similarity relationship of the edge. At the same time, this article for the first time used the similarity algorithm of the node and the similarity algorithm of the edge to redefine the event-frame simultaneously, so as to make each event more close to the actual situation of community evolution. Meanwhile, through the comparative simulation experiment, it is found that the new event-frame improving the accuracy of the event detection but it does not seriously affect the number of the event detection. However, there are some deficiencies in the article. For example, there is no real dataset to examine the event-frame.

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A Game Model of APT Attack for Distributed Network

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Abstract. Considering the lack of theoretical analysis for distributed network under APT (advanced persistent threat) attacks, a game model was proposed to solve the problem based on APT attack path. Firstly, this paper analyzed the attack paths of attackers and proposed the defensive framework of network security by analyzing the characteristics of the APT attack and the distributed network structure. Secondly, OAPG(an attack path prediction model oriented to APT) was established from the value both the attacker and the defender based on game theory, besides, this paper calculated the game equilibrium and generated the maximum revenue path of the attacker, and then put forward the best defensive strategy for defender. Finally, this paper validated the model by an instance of APT attack, the calculated results showed that the model can rational analyze the attacker and defender from the attack path, and can provide a reasonable defense scheme for organizations that use distributed networks.

1 Introduction

With the development of science and technology, many infrastructures opened up the public networks to increase their cyber awareness and operated efficiency, but, the computer worms and the virus caused great threat to informational security at the same time [1]. Especially, the wide application of Facebook, Twitter and SNS in the past years, the network of interpersonal relationship has become a new growth point, and it is becoming a breakthrough for cyber penetration that it includes the Trojan of web, related methods of social engineering and Strategies of mail [2]. In 2016, through the intelligence of cyber threat monitoring, the number of security incidents caused by APT (Advanced Persist Threat) had increased rapidly, and the losses were becoming more and more serious. This shows that the traditional methods have been difficult to guard against APT attacks [3].We will face more serious situation in the field of cyber security, and APT attacks will become the focus of internet.

At present, the cyber security is usually used by automated tools and techniques to reduce vulnerabilities, such as using topological vulnerability analysis (TVA) [4]. The target of the APT is national organizations, large enterprises and other major departments [5]. Traditional technologies of cyber security focus on one-time attack, it is a

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serious shortage to face of persistent, hidden and complex APT attacks [6]. But, if the defender used the game theory to analyze the APT attack, it can find the possible attack path and provide a suitable defense framework, in addition, it also can systematically considered the strategic behavior of attacker and defender to design defense strategy based on each cost [7], it can provide defensive ideas reasonable and effective for defender.

2 Related Work

Game theory is a theory used for the problem analyses and decision formed before it happens. It has been applied in many fields such as military, political and social production in the long ago. At present, it start combining with cyber communication and cyber security, game theory analyzes all kinds of attacks in the network from the benefit point of view, and then develops the defensive strategy with the highest efficiency and the best action. For example, Game-theoretic methods have been widely used in modeling attacker-defender interactions in communication networks [8], and modeling cyber-physical systems by using the method of game theory [9] this research had been take game theory in network space modeling, it can withstand some network attacks, but it can't resist the advanced attacks with flexible methods and stealthy action. Later, Flipit game model achieves the password resetting and key management to prevent unknown attack [10], Flipit game model is used to establish a game framework for controlling shared resources to prevent APT attacks [11], A game model is created between attackers and cloud users to capture hidden APT attacks [12].This fully embodies the game theory having the important value for the implementation of active defense in network. But these studies are only realization of certain cyber functions to prevent APT attacks, However, this is not provide a specific program to prevent APT attacks for organization.

In the target of APT attacks, many important departments and large enterprises has become a key target, how to ensure the security of important resources, it is currently a hot issue. The traditional defense measures for the APT attack is very difficult to work. Our work is establishing the model according to the characteristics of distributed network and APT attacks, Firstly, finding the attack paths through the previous case analysis. Secondly, we are establishing the defensive framework of network security. Lastly, we are establishing the model from the benefit of attacker and defender based on game theory. Through calculation, we can get the profitable path for attacker and the best scheme for defender.

3 Model Initialization

3.1 The Attack Step of APT

Based on the statistical analysis of APT attacks in recent years, hackers generally use e-mail, websites, known vulnerabilities and 0day vulnerabilities to penetrate the target when they launched an attack. When an attacker starts an action to a target, it is divided into five steps: intelligence gathering, directional attack to intermediate host (commonly known as “broiler”), lateral diffusion to target, collection of information and eliminate traces of intrusion. There are many ways of APT attacks, and attackers can use these steps flexibly in an action. Figure 1 is a schematic diagram of the APT attack procedure:

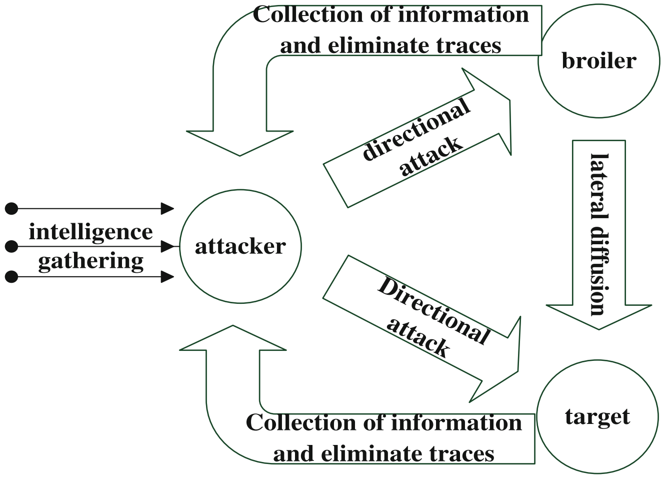

Fig. 1. Steps of APT attack

3.2 Characteristic of Distributed Network

Distributed network is able to connect computers in different locations and realize resource sharing and distributed network with high reliability and easy to control, it will not lead to paralysis of the entire system when the local failure; distributed network structure is easy to expand, if you wanted to add new nodes, you could connect to the network at any point. Therefore, many important departments and large enterprise often adopt the distributed network to realize the unified management of all departments and regions. Figure 2 shows a simple framework of distributed network.

3.3 Building the Network Defense Framework

An attack path prediction model oriented to APT [13] is proposed by X Fang, L Zhai in 2014, it is a game model for APT attack, named OAPG. The model uses game theory to judge the path of APT attack, and then proposes effective measures to defender. Through the analysis of cyber accidents in recent years and combining the common measures of network defense, this paper puts forward framework of cyber defense, as shown in Fig. 3:

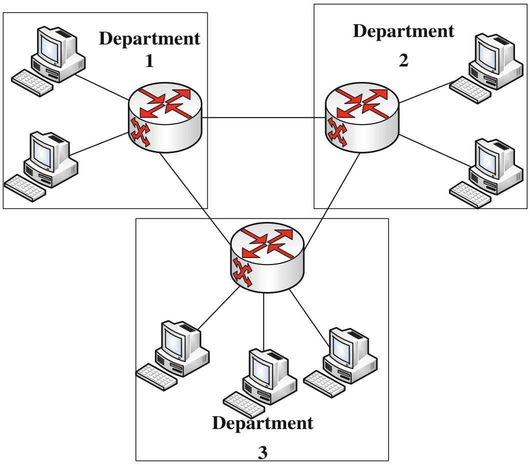

Fig. 2. Frame of distributed network

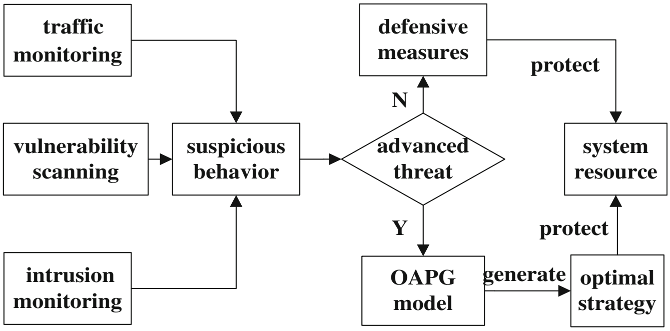

Fig. 3. Framework of cyber defense

4 Establishing the Game Model

In the attack-defense confrontation of network, both offensive and defensive resources are limited. Whatever the attacker or the defender, they want to make the biggest gains at a lesser cost by adopting a series of measures, from this point of view, the equations are established from the respective benefits in this model.

4.1 Model Definition

Definition 1: The OAPG model $(G\{S_i, S_i^j, P_i^j, V_i, U_k(S_i^j)\})$ is divided into five parts.

S_i: Participator of the game, the attacker is represented by S_1, the defender is represented by S_2.

S_i^j: Strategy of the participator, S_1^m represents the strategy of S_1 , S_2^m represents the strategy of S_2.
P_i^j: Probability of the strategy S_i^j is used.
V_i: Node of the game.
$U_k\left(S_i^j\right)$: Benefits of the participator in the game,for example $U_1\left(S_1^1, S_2^1\right)$ represents the benefits of attacker use of the strategy S_1^1 and the defender use of strategy S_2^1 for attacker; $U_2\left(S_1^1, S_2^1\right)$ represents the benefits of attacker use of the strategy S_1^1 and the defender use of strategy S_2^1 for defender.

Definition 2: T represents the value of important destination, t_i represent the value of node.

Definition 3: r_i refers to the degree of association between the attacker's target node and node i, and the higher the degree of association, the closer the relationship is.

$$t_i = T \times r_i \tag{1}$$

Definition 4: c_i represents the cost of attacker.

Definition 5: d_i represents the cost of defender.

Definition 6: f_i represents the damage factor. When the attacker capture a host, the damage to the system depending on the privilege obtained, and $(0 \leq f_i \leq 1)$

Definition 7: q_i represents the probability of attacking successfully, and the probability of success is closely related to the strategy of the attacker and the defender, and $(0 \leq q_i \leq 1)$.

4.2 Network Attack-Defense Game

The attacker can choose different methods and paths, if the defender did not take any defensive strategy, the attacker could get the privilege of important host easily. So, we can get the revenue function of attacker.

$$U_1 = t_i \times f_i - \sum_{i=1}^{n} c_i \tag{2}$$

But, when the attacker uses the strategy S_1^i and the defender uses the strategy S_2^j, we can get the revenue function of attacker.

$$U_1\left(S_1^i, S_2^j\right) = t_i \times f_i \times \prod_{i=1}^{m} q_i - \sum_{i=1}^{n} c_i \tag{3}$$

Because the difference of functions (1) and (2) is the defender takes or not takes defensive strategy, in addition to the cost of implementing defensive strategy, we can get the revenue function of defender based on functions (1) and (2)

$$U_2\left(S_1^i, S_2^j\right) = t_i \times f_i \times \left(1 - \prod_{i=1}^{m} q_i\right) - \sum_{i=1}^{n} d_i \tag{4}$$

After calculating the revenue of all strategy for the attacker, we can get the payoff-matrix of attacker.

$$\begin{bmatrix} U_1\left(S_1^1, S_2^1\right) & U_1\left(S_1^1, S_2^2\right) & \dots & U_1\left(S_1^1, S_2^n\right) \\ U_1\left(S_1^2, S_2^1\right) & U_1\left(S_1^2, S_2^2\right) & \dots & U_1\left(S_1^2, S_2^n\right) \\ \dots & \dots & \dots & \dots \\ U_1\left(S_1^m, S_2^1\right) & U_1\left(S_1^m, S_2^2\right) & \dots & U_1\left(S_1^m, S_2^n\right) \end{bmatrix}$$

And after calculating the revenue of all strategy for the defender, we can get the payoff-matrix of defender.

$$\begin{bmatrix} U_2\left(S_1^1, S_2^1\right) & U_2\left(S_1^1, S_2^2\right) & \dots & U_2\left(S_1^1, S_2^n\right) \\ U_2\left(S_1^2, S_2^1\right) & U_2\left(S_1^2, S_2^2\right) & \dots & U_2\left(S_1^2, S_2^n\right) \\ \dots & \dots & \dots & \dots \\ U_2\left(S_1^m, S_2^1\right) & U_2\left(S_1^m, S_2^2\right) & \dots & U_2\left(S_1^m, S_2^n\right) \end{bmatrix}$$

(The row represents the offensive strategy, and the list represents the defensive strategy).

Through the payoff-matrix of attacker, we can calculate the average revenue when attacker using different strategies

$$\overline{U_1^m} = \frac{\sum_{i=1}^{n} U_1\left(S_1^1, S_2^n\right)}{n} \tag{5}$$

Through the payoff-matrix of defender, we can calculate the average revenue when defender using different strategies.

$$\overline{U_2^n} = \frac{\sum_{i=1}^{m} U_1\left(S_1^1, S_2^m\right)}{m} \tag{6}$$

Definition 8: Nash equilibrium, in the OAPG model $G\left\{S_i, S_i^j, P_i^j, V_i, U_i\left(S_i^j\right)\right\}$, strategy $\left(S_1^*, S_2^*\right)$ is the unique equilibrium,for all the people in the model, the strategy is the best strategy for dealing with the other participator. So: $\forall S_1^m$, $\exists\, U_1\left(S_1^*, S_2^m\right) \geq U_1\left(S_1^m, S_2^m\right)$, and $\forall S_2^m$, $\exists U_2\left(S_1^m, S_2^*\right) \geq U_2\left(S_1^m, S_2^m\right)$.

Through Definition 8, we can get the equilibrium point of revenue both attacker and defender. getting the best offensive path for attacker and the best defensive strategy for the defender, and then calculating the probability P_i^j of each strategy is used, lastly, putting forward the optimal defensive strategy.

5 Application of the Model

In order to verify the OAPG model, we took very famous "Aurora" as an example to attack an enterprise, Aurora is a network attack from China in the middle of December 2009. It mainly includes the following steps:

1. Collecting information from target organizations on various social networks;
2. Using dynamic DNS providers to build phishing sites or send malicious mail to targets, when someone clicks on a web site or mail, the malicious program will be downloaded remotely and run automatically.
3. Establishing a connection to the victim host by SSL security tunnel, continuous monitoring and access to relevant authority.
4. Through exploiting the employee's host to penetrate to the target, obtaining useful information and returning it.

When hackers penetrate to an enterprise by using APT attack, it will investigate the target location, network technology and personnel distribution of some of the available information by intelligence gathering, and then put the mail with a malicious program or phishing sites to lure the target, when the attacker control of a host, it will be carried out the lateral diffusion by operating this host, lastly, it will elevate privileges to achieve the goal of data access or operation by using Trojan, virus or a loophole etc. Through Figs. 1 and 2, we can get the attack path that often used by the APT attack, as shown in Fig. 4:

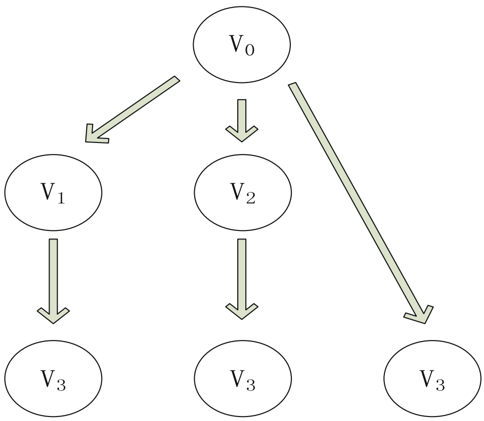

Fig. 4. Diagram of APT attack paths

Through Fig. 4, we can get the strategies of attacker.

$S_1^1 : V_0 \rightarrow V_1 \rightarrow V_3$, The attacker penetrates from node V_0 to node V_1, and then penetrates to node V_3.
$S_1^2 : V_0 \rightarrow V_2 \rightarrow V_3$, The attacker penetrates from node V_0 to node V_2, and then penetrates to node V_3.
$S_1^3 : V_0 \rightarrow V_3$,The attacker penetrates from node V_0 to node V_3 directly.

We set the target of the attacker to access data of the node 3, and if the attacker could access the node 3, the damage ($f_i = 0.9$) to system is huge. The correlation of nodes V_1, nodes V_2 with node V_3 is shown in Table 1.

Table 1. Correlation between nodes and target nodes

Target	Correlation of degree
V_1	0.4
V_2	0.6

Here, we set the total value of the offensive target is 100($T = 100$), other nodes with different degrees of correlation, the value is also different. The value of each node can be calculated by Definition 3 and Table 1.

$$t_1 = T \times r_1 = 40 \tag{7}$$

$$t_2 = T \times r_2 = 60 \tag{8}$$

After extensive investigation and research, the enterprises that use of distributed network generally have the following characteristics in the overall layout, the department 1 is opened to public, the department 2 is used to connected the department 1 and the department 3, the department 3 is managed strictly, so, the cost is different to attacker (Table 2).

Table 2. Cost of implementing offensive strategies

Paths	Cost
$V_0 \rightarrow V_1$	5
$V_0 \rightarrow V_2$	10
$V_0 \rightarrow V_3$	30
$V_1 \rightarrow V_3$	15
$V_2 \rightarrow V_3$	10

Defensive costs will follow the changes of defensive strategies. Defensive costs are shown in Table 3.

Table 3. Cost of implementing defensive strategies

Defensive measures	Cost
S_2^1: patch vulnerability to department 1	30
S_2^2: Close web services department 1	90
S_2^3: patch vulnerability to department 2	35
S_2^4: Close web services department 2	100
S_2^5: patch vulnerability to department 3	60
S_2^6: Close web services department 3	110

Based on the analysis of the "Aurora" and combined with the actual situation of a company, we can get the penetration probability of the attacker, as shown in Table 4:

Table 4. Probability of penetration of the attacker

Offensive paths	Defensive measures					
	d_1	d_2	d_3	d_4	d_5	d_6
$V_0 \rightarrow V_1$	0.5	0	0.8	0.8	0.8	0.8
$V_0 \rightarrow V_2$	0.7	0.7	0.2	0	0.7	0.7
$V_0 \rightarrow V_3$	0.4	0.4	0.4	0.4	0.7	0
$V_1 \rightarrow V_3$	0.6	0.6	0.6	0.6	0.4	0
$V_2 \rightarrow V_3$	0.8	0.8	0.8	0.8	0.5	0

So, we can compute the payoff matrix of attacker by formula (2):

$$\begin{bmatrix} 7 & -5 & 23.2 & 23.2 & 8.8 & 12 \\ 30.4 & 30.4 & -5.6 & -10 & 11.5 & 22 \\ 6 & 6 & 6 & 6 & -3 & -30 \end{bmatrix}$$

We can compute the payoff matrix of defender by formula (3):

$$\begin{bmatrix} 33 & 0 & 11.8 & -53.2 & 1.2 & -20 \\ 9.6 & -50.4 & 40.6 & -10 & -1.5 & -20 \\ 24 & -36 & 19 & -46 & 3 & -20 \end{bmatrix}$$

Through the payoff matrix of attacker and the payoff matrix of defender, we can calculate the average revenue of the strategies of the attacker and defender by using formulas (5) and (6).

The average revenue of each attacker's strategy is shown in Table 5:

Table 5. Average revenue from strategies of attacker

Strategy of attacker	Payoff
S_1^1	11.5
S_1^2	13.1
S_1^3	−2.5

The average revenue of each defender's strategy is shown in Table 6:

Table 6. Average revenue from strategies of defender

Strategy of defender	Payoff
S_2^1	22.2
S_2^2	−28.8
S_2^3	23.8
S_2^4	−36.4
S_2^5	16.3
S_2^6	−20

We calculated the probability of each strategy being used by Tables 5 and 6,

$$(p_1^1, p_1^2, p_1^3) = (46.7\%, 53.3\%, 0);$$
$$(p_2^1, p_2^2, p_2^3, p_2^4, p_2^5, p_2^6) = (47.3\%, 0, 50.7\%, 0, 2\%, 0)$$

Based on the above results, combining with the definition of the 8, we can get the equilibrium point of attacker and defender, that is the attacker using the optimal strategy S_1^2 and the defender using the optimal strategy S_2^3, Their earnings are at their best, and the defensive strategy just can resist the offensive intention of the attacker at the moment, so, the best defensive strategy is to adopt strategy S_2^3, but, the attacker may use strategy S_1^2 or strategy S_2^3 by calculating the probability, in order to ensure the absolute safety of system resources, we can take the method of combining S_2^1 and strategies S_2^3.

6 Conclusion

In recent years, high-profile targeted attacks showed that even the most secure and hided networks can be compromised by motivated and resourceful attackers, and the system administrator may not be immediately detected that such a system compromised [14]. So, we need better methods to defend this attacker, this paper presents a method of game theory and combines the classic theory of game theory with the defense of APT attacks, it's consistent with the actual cost of spending in the network, it can provide a good idea for the prevention of APT attacks. However, because of the variety of APT attacks, the path and mode need to be further studied. In this paper, a game model framework for APT attacks is proposed, and the game of each node needs to be further refined.

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Quality CloudCrowd: A Crowdsourcing Platform for QoS Assessment of SaaS Services

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Abstract. The adoption of Software as a Service (SaaS) has grown rapidly since 2010, and the need for Quality of Service (QoS) information is a significant factor in selecting a trustworthy SaaS service. In the existing literature, little attention has been given to providing QoS information with the SaaS service offering. SaaS providers offer a description of the overall QoS and service performance when they make their service offer; however service user satisfaction is a crucial factor in service selection decision-making. Crowd sourcing has grown in popularity over the last few years for performing tasks such as product design and consumer feedback, in particular, attracts the researchers in the field of client feedback on services or products. In this paper, we propose a novel framework for providing missing QoS values to the cloud marketplace called "Quality CloudCrowd". Our proposed framework comprises of several parts; however, the development of the QCC platform for collecting missing QoS values is the core element of this structure and is the focus of this paper.

1 Introduction

Software as a Service (SaaS) applications are increasing in popularity and are widely accessed and used by a countless users around the world. According to recent reports by Gartner [1], the size of the SaaS market is expected to grow 20 percent in 2017 to reach $46.3 billion. SaaS providers attempt to provide users with a satisfying experience, regardless of the network environment and hardware capabilities they faced. Quality of Service (QoS) is a significant factor for building a trustworthy relationship between clients and service providers, and it is essential for cloud service selection and cloud service composition. A considerable amount of research has been published about the discovery of cloud services information on the World Wide Web (WWW) [3].

The existing literature does not take into account methods for providing the missing values of QoS attributes. Crowdsourcing has growing in popularity over the last few years for performing various tasks and obtaining ideas from Internet users (also known as Internet Crowd), internet crowd such as product design

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and consumer feedback [5]. Crowdsourcing could also be used to gather QoS values, for example; [7] proposed a QoE model for YouTube to identify unreliable QoE results. In this paper we therefore propose novel framework called Quality CloudCrowd (QCC). This framework introduces a new method to provide a solution for missing QoS values by collecting users' opinions and analyzing them to contribute to QoS values. We define the "the assessment of QoS" as the overall user acceptance of SaaS applications. According to the definition of QoS, the QoS attributes are either subjective or objective [6]. In this study, we focus on subjective attributes through collecting user reviews and feedback about SaaS services. The development of the crowdsourcing Web platform to gather and populate the missing QoS values is the core feature of the QCC Framework.

Crowdsourcing has recently been used in various domain applications to tackle multiple complex problems, ranging from marketing challenges to QoS assessment [13]. It is an innovative way to collect user reviews to provide QoS values of cloud services, whereby users can give their opinions and evaluation after using a service. The QCC crowdsourcing Web platform is available to all users; it is a web platform which is open to a more diverse range of participants at low economic cost. The key features of the proposed platform are that users can share their experiences through user feedback on the services they have purchased. The crowdsourced data is then stored in a local database (SQL). The rest of the paper is organized as follows. Section 2 focuses on related work on QoS values. Section 3 we briefly introduce the Quality CloudCrowd (QCC) platform. Section 4 we present the implementation and testing of our work, and in Sect. 5 we conclude the paper and outline our future work.

2 Related Work

In this section, we discuss some efforts in the field of cloud service information discovery, including Quality of service values, and also discuss the motivation for our work. Most existing studies in the area of cloud service information discovery focus on using semantic technologies to enhance discovery for cloud services information over the Web. For instance, a semantic-based approach proposed by [12] adds semantic annotation to the cloud service profile. The service profile usually consists of the following attributes: service name, service price, service features, and service level of agreement. The author proposes to have an ontology for each attribute and then combines all of the ontologies to construct a global service profile ontology. The final global ontology has 64 concepts and 128 properties. The main shortcoming of this approach is that it does not take into account the need for QoS attributes in selecting the best service.

Another approach by [9] presented an agent-based cloud discovery approach to support cloud services discovery through Web search engines. The system is composed of three main components, namely: query processing agent, filtering agent, and reasoning agent. The query-processing agent is responsible for consulting the cloud ontology concepts to enrich user queries and generate alternative queries if it is necessary to obtain more results. The filtering agent excludes invalid Web pages from the search results. The reasoning agent takes advantage of the cloud ontology to determine the measure of similarity between available services and the user's requirements. However, this study selects and ranks services according to functional requirements to choose the best service, and fails to consider critical Quality of Service (QoS) parameters.

Another study by [11] designed and developed a crawler engine to discover cloud services via the Web. A key feature of this study is that it provides a local repository for cloud service information. However, the collected dataset does not provide sufficient cloud services information such as whether the QoS assessments are quantitative values. Alkalbani and Hussain [2] proposed a central repository for SaaS services. The repository is supported by the open source Nutch-Hadoop crawler which crawls cloud Web portals (cloud reviews) to retrieve information on cloud services and stores them in a local repository. A key shortcoming of this work is that the repository lacks primary service information, such as QoS, and only provides two attributes of each service, namely the name and the URL of the service.

As discussed above, there is no publicly available Web source or Web platform for Cloud QoS assessments; therefore this research work this gap by proposing the first publicly available web platform for SaaS QoS assessment called Quality CloudCrowd (QCC). One of the contributions of this study is that it employs a crowd sourcing approach and Internet Crowd contributions to evaluate SaaS services. A thorough review of the existing work reveals that our work is the first to propose a crowdsourcing approach to QoS assessment of SaaS. The QCC platform is a part of this framework and comprises of several elements as shown in Fig. 1. The whole framework is briefly explained in the next section.

3 QCC Framework

To address the research issue described in the previous section and achieve our objectives, we propose an intelligent framework for providing QoS values of SaaS services. The QCC framework is composed of two layers, an application layer and a data layer. The Application layer is an application user interface which includes a registration form. Registration is needed for the retention of user records; follwoing registration, the main crowdsourcing page opens. The application offers different options for collecting QoS values, such as giving survey feedback and submitting reviews about the services used. These data can potentially be used to generate genuine insight into how users feel about SaaS services. They could also provides a level of analysis using tools such as machine learning techniques to obtain more details about consumers' experiences. The data layer refers to the data storage function of application, which consists of three database: Crowdsourced database, data analysis database and Bluepages database. The Blue pages database contains information about SaaS services [4].

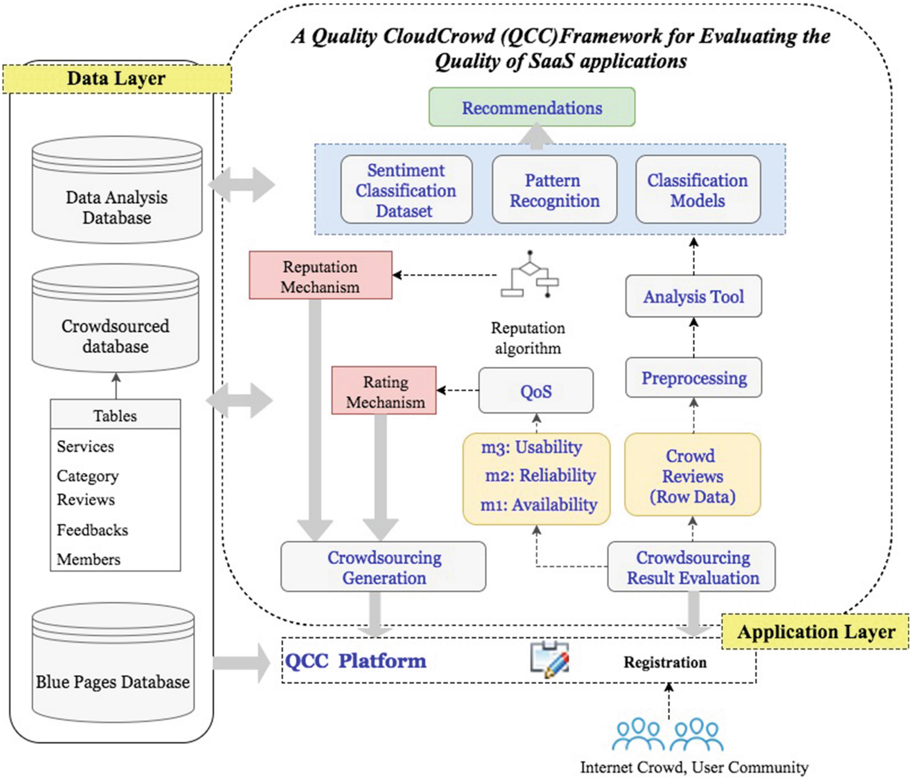

Fig. 1. QCC: a novel framework for evaluating the quality of SaaS services

4 Prototype Implementation

In this section, we present the prototype implementation for the QCC crowdsourcing application. This application is engineered to be characteristic of the typical web architecture of a front-end, a business logic layer and a database layer. The application is called "Cloudia". This application is designed for users who have used cloud services and intend to share their experience and provide feedback to other users. To build a well-engineered crowdsourcing platform, We followed crowdsourcing methodology [10] through the Software Development Life Cycle (SDLC) phases [8]. The application was build incrementally. The functional requirements were gathered and the crowd-sourcing tasks determined, which included listing SaaS services, reviewing SaaS services and a discussion board. The use cases was also developed and the application layout sketched. Hypertext preprocessor (php) was used to build the architecture, with MYSQL being used for the infrastructure. The application has demarcated functions of *Sign-Up* and *log-in*, while the main page includes functions such as *Review page* and *Post review*. We conducted various tests to test the application's functionality. For example, *Reviews* and *Rating* are the main features of the website, so it was necessary to make sure any reviews posted meet certain criteria, such as the character length of the review. In addition, we had to ensure that verified users (Those who have actually purchased and used the product in question) are prioritized, so we created an option for them to provide a receipt for their purchase. Our rating system is based on a 1–10 scale, and representation uses a visual aid instead of number input. This is as simple as selecting the number of stars a user wishes to give to a product, which is both functional and fast. We also provided a way for users to participate in open discussion about products with other users ensuring that users are not able to make blank posts.

5 Conclusion

In this paper we have presented a novel framework for QoS assessments for SaaS services. A key element of this framework is the development of a crowd sourcing Web platform, and this is the focus of the paper. We show that our proposed framework can use crowdsourcing technology to obtain the missing QoS values of SaaS services. This study is the first to use the Internet Crowd knowledge to fill the missing QoS values of SaaS services. In future studies, we will extend our approach to include the evaluation of the QoS of other cloud services such as Infrastructure as a Service (IaaS) and Platform as a Service (PaaS).

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Host Based Intrusion Detection and Prevention Model Against DDoS Attack in Cloud Computing

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Abstract. Cloud computing has become an innovative technology. Recent advances in hardware and software have put tremendous pressure on administrators, who manage these resources to provide an uninterrupted service. System administrators should be familiar with cloud-server monitoring and network tools. The main focus of the present research is the design of a model that prevents distributed denial-of-service attacks based on host-based intrusion detection protection systems over hypervisor environments. The prevention model uses principal component analysis and linear discriminant analysis with a hybrid, nature-inspired metaheuristic algorithm called Ant Lion optimisation for feature selection and artificial neural networks to classify and configure the cloud server. The current results represent a feasible outcome for a good intrusion detection and prevention framework for DDoS-cloud computing systems based on statistics and predicted techniques.

1 Introduction

Cloud computing facilities have grown sharply in recent years due to the rise in demand of cloud based services [1]. This has put tremendous pressure on developers to provide sufficient hardware and software resources. In addition, system administrators need to ensure the efficient energy and hardware utilisation of cloud computing facilities [2], while system administrators need to address the security of cloud-based services, such as data storage and transfer and applications of on-demand services. Therefore, it is important to monitor cloud computing resources and their applications. This study provides a thorough review of the cloud computing tools used for monitoring performance of cloud infrastructure at the consumer and provider end.

Revolutionary advances in hardware, networking, middleware and virtual machine technologies have led to the emergence of new, globally distributed computing platforms – namely, cloud computing – which provide computation facilities and storage as services accessible from anywhere via the Internet without significant investments

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in new infrastructure, training or software licensing. Infograph reports that 63% of financial services, 62% of manufacturing, 59% of healthcare and 51% of transportation industries are now using cloud computing services [3].

As cloud computing services are becoming more practical and popular due to their convenience and economic advantages, security vulnerability has become a continuous threat, for both cloud service providers and clients. A distributed denial-of-service (DDoS) attack that degrades and downs service availability constitutes the major security concern; this is a cyber-security threat in which multiple systems across the Internet are used to flood a target device or network with packets [3].

A typical example of DDoS architecture occurs when many distributed devices across a network are infected with DDoS zombies (also called 'agents' or 'demons') and commanded by an attacker to launch attacks on a target. Such structured attacks are designed to damage Internet applications, generate heavy traffic, reduce network performance and disable services; they are not, however, designed to compromise usernames and passwords or to steal data. To fight these armies of zombies, therefore, cloud computing needs an intelligent army of specifically developed solutions against sophisticated DDoS attacks. This concern surrounds the uncertainty that stateful devices – such as firewalls, intrusion detection systems (IDSs), intrusion prevention systems (IPSs) and load balancers – can become fault points when a network is under attack. Particularly, traditional firewalls fail during a DDoS attack, since it consumes the central processing unit (CPU) such that enabling synchronised (SYN) flood protection on the firewall becomes useless [4].

The major drawback of the current, host-based IDPS is that it is difficult to manage because information has to be configured and managed for every host. Some defence methods cannot detect any DDoS attack randomly [5]. Furthermore, an IDPS cannot detect any profile other than that which is predefined by the network administrator. Although these drawbacks are overcome by misuse detection, this method cannot detect anything other than predefined rules, and the system rules must be updated constantly. Thus, it is necessary to build an IDS that overcomes the drawbacks of and is much more efficient than the existing system.

The present, conceptual model study implements a model for preventing DDoS attacks in hypervisor through host-based IDPSs. It was designed using two main aspects: data analysis, which is practical for large datasets that belong to the DDoS attack, and swarm intelligence, which is for training and classification based on the selected intent of the attack and blacklisted Internet providers (IPs). The common goal of our and other, related approaches is to detect DDoS attacks.

2 Literature Review

The changing and aggressive nature of the attacks make them a severe threat that is difficult to counter. As DDoS attacks grow larger and longer, single appliances and even some hosted solutions are unable to withstand them. Recent heavy attack loads have been breaking records in size. According to Akamai Technologies [6], the number of distributed DDoS attacks doubled in 2016. A close look at the type of attacks reveals that network time protocol (NTP) reflection attacks almost quadrupled, increasing by 276% over the same period. Companies in the gaming and software industries are frequent targets of hackers that leverage on DDoS as an attack vector Fig. 1.

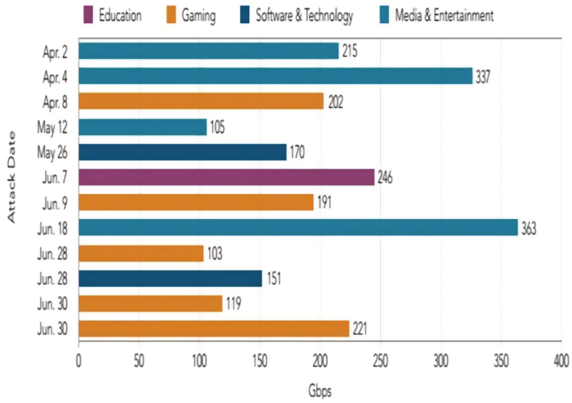

Fig. 1. In 2016, 12 attacks exceeded 100 Gbps and two separate DDoS campaigns exceeded 300 Gbps.

Cloud computing encounters both traditional and contemporary security threats. It is vulnerable to core technology vulnerabilities, such as web applications and services, virtualisation and cryptography; essential cloud characteristic vulnerabilities, like unauthorised entry, Internet protocol vulnerabilities, and access to management interfaces; and flaws in known security controls, together with common vulnerabilities, such as injection vulnerabilities and weak authentication schemes.

Assailants discover vulnerabilities and utilise them for attacks. There have been many attacks against virtual machines on cloud computing platforms, such as attacks on virtualisation and on hypervisors and various port scanning, backdoor channel, user-to-root, flooding and insider attacks (e.g. internal denial-of-service attacks via zombies in the cloud).

A core technology in cloud computing is virtualisation technology. Key components of cloud computing infrastructure are virtual machines (VMs). For instance, virtualisation technology enables the execution of several operating system environments, or VMs on a single hardware system. A VM has applications as well as operating systems. It implements programs the way a real machine would. Virtualisation creates blind spots of invisible networks or network traffic in the same server infrastructure.

An important study states that cloud services are usually made available to customers via the Internet. Standard Internet Protocols and mechanisms are used for communication between the customers and the cloud [7]. The communication process involves the transmission of either data/information or applications between the customer and the cloud [8].

The challenges include denial-of-service (DoS), eavesdropping, IP-spoofing based flooding, man-in-the-middle attack (MIMT) and masquerading. Solutions to these challenges are also employed conventionally, such as Internet security protocol (IPsec), intrusion detection and prevention systems.

A very strong and new form of attack on the availability of Internet services and resources is DDoS [9]. A DDoS attack is any act intended to cause a service to become unavailable or unusable. There are no inherent limitations in the number of machines that can be used to launch a DDoS attack, which utilises the dispersed nature of the Internet through hosts owned by different entities around the world.

As shown in Fig. 2, the DDoS attacker first distributes various types of DDoS attack tools to target networks from behind. Next, the attacker creates thousands of zombies, which represent active and passive attackers. Thus, the victims are now exposed to DDoS attack, and always without their knowledge. This attack mechanism applies to all types of computer networks.

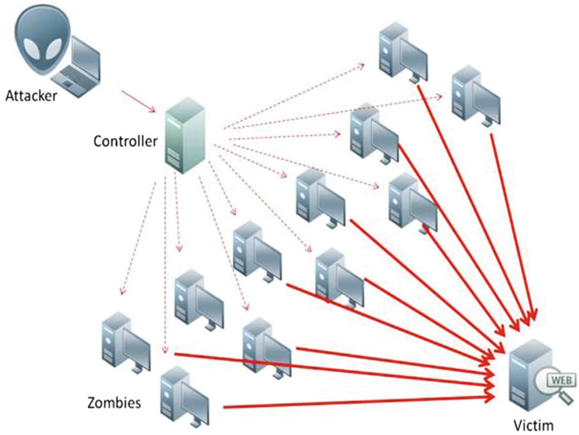

Fig. 2. DDoS attack.

The vectors for DDoS attacks may vary, but the end goal remains the same, which is to overpower firewalls, servers or other perimeter-defined devices by sending request packets at very high packet rates. The network becomes overwhelmed with too much traffic, so that people are no longer able to access the website.

In cloud computing, the drawbacks in hypervisor security has non-zero attack services [10]. Thus, the real security question for the cloud starts with feasible security on the cloud hypervisor. Hypervisors can detect such attacks, which leads us to rethink the integrity of the security hypervisor. More potent attacks attempt to take control of the hypervisor itself; such attacks include malicious VM hyperjacking and traditional network security threats, such as traffic snooping (intercepting network traffic) and address spoofing (forging VM, MAC, or IP addresses) [11].

One of the major attack types is that which hits the hypervisor and leads to a transmission control protocol (TCP) SYN flood of DDoS attacks, which overhead the cloud resources. Another limitation of IDPS is that it has to evaluate whether it fulfils the security requirements of the cloud computing environment [12].

The disadvantages of the prevention mechanism are related to false positives, but these occur mainly when the user does not have a practical understanding of computers. If a procedure that the user is trying to perform appears as a malicious activity in the IPS and the user's connection is cut, the IT department has to spend a significant amount of time checking on every computer that encounters a false positive scenario [13]. Not all types of attacks are known, and new ones appear constantly. Thus, attackers can always find security loopholes to exploit so that they can gain access to the sensor network. Such intrusions will go unnoticed and will likely lead to failures in the normal operation of the network.

3 Methodology

The proposed conceptual model to deal with this, as shown in Fig. 3, aims to synthesise the hypervisor as a host-based IDPS that analyses the IPs from the dataset and blocks the attacks of TCP and user datagram protocol (UDP) DDoS. Host-based IDPSs have two theoretical phases inside the hypervisor, the IDS and IPS models. The IDS model has five phases: the future extraction and traffic aggregation phases, and the future selection using principal component analysis (PCA), linear discriminant analysis (LDA) and artificial neural network (ANN)-based classifications. IPS models spontaneously start after alerting the IDS model. The IPS model has three phases, which involve reconstructing the table IPs and Ant Lion fitness, classifying ANN and filtering attacking source IPs, the latter being the most important.

The monitoring, aggregation, and correlation of alerts are performed in a distributed manner for an IDPS as a host base inside the hypervisor to maximise the possible advantages of hybrid deployment. The hypervisor locally analyses the correlated alerts. The normal and anomaly IPS with DDoS attack are in the cloud server. The IDPS generates alerts in the above two cases. Thus, the IDS allow good packets to pass, and the IPS updates and blocks suspicious IPs. In addition, a sensor from the IDS phases primarily matches the IP and another feature in the dataset. The details of processes are explained in the following subsections.

A. Feature selection using PCA and LDA with optimised ALO

There are many dimensionality reduction algorithms that are used to select the best features, such as PCA and LDA. Here, three algorithms were used to reduce the dimensionality of data and select the most optimal features (Fig. 4). In the first phase, PCA is used to analyse the covariance of each feature. In second phase, the LDA, as a supervised classification technique, provides more class reparability and further reduces the dimensionality of the feature set. The final phase of IDS involves optimising the outcome of PCA and LDA by ALO.

It is worth mentioning that several variants of LDA have been investigated to address the vanishing of within-class scatter under the projection to a low-dimensional subspace in LDA. However, some of these proposals are ad hoc, while others do not address the generalisation problem for new data. Although LDA is preferred in many applications

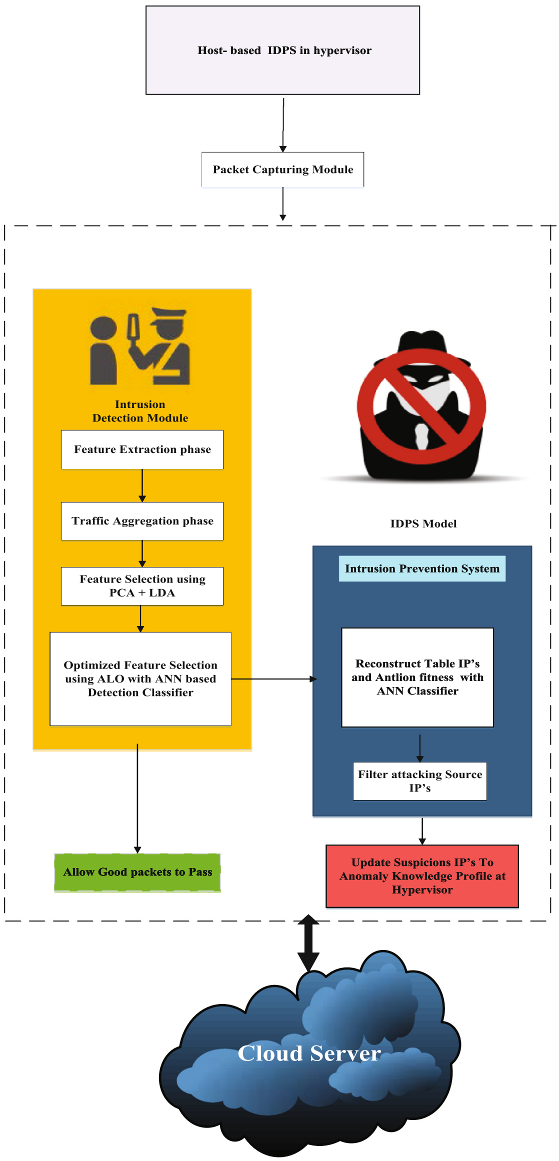

Fig. 3. The architecture of the host-based IDPS on a hypervisor cloud computing server.

of dimension reduction, this method does not always outperform PCA. A hybrid dimension reduction model that combines PCA and LDA is thus proposed to optimise the discrimination performance in a generative manner. The main goal is to enhance data discrimination, which is achieved with subspaces learned with either PCA or LDA.

This learning mechanism differs from existing proposals in that this mechanism is guided by a hybrid model and thus directly addresses the generalisation problem for new

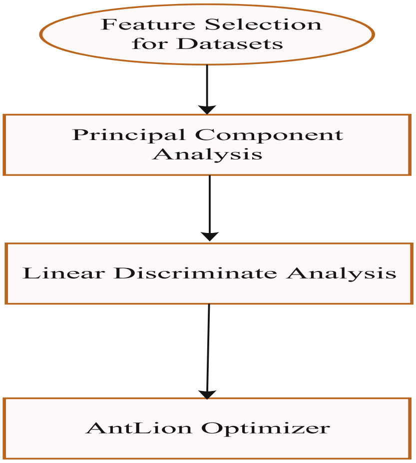

Fig. 4. The three-phase hybrid model of dimensionality reduction algorithms.

data. In addition, it has developed computational strategies to estimate optimal subspaces. The problem in using this model is simply stated as follows: given a set of labelled training data from different classes and another set of unlabelled testing data from the same group of classes, each testing data is identified by relying on the new model. Both sets consist of feature vectors. The details of the three features selection algorithms may be shown thus:

LDA Algorithm

(1) Compute the mean vectors for the input features dataset (x_i)

$$\text{Mean} \qquad \bar{x} = \frac{1}{n} \sum\nolimits_{i=1}^{n} x_i \tag{1}$$

(2) Calculate the scatter matrices, within class (S_w) and between class (S_B):

a.
$$S_w = \sum\nolimits_{i=1}^{n} (Px_i - \overline{Px})(Px_i - \overline{Px})^t \tag{2}$$

b.
$$Ant_i^t - Ant \quad postion \tag{3}$$

where i = M – overall mean

(3) Find the linear discriminants by computing the eigen values for $S_w^{-1} S_B$. Select the linear discriminants for the new feature set by sorting and choosing eigen vectors, *W*, with the highest eigen values.

(4) The new feature set obtained by the linear discriminants is then used to obtain transformed input dataset by following equation:

a.
$$Y = X.W \tag{4}$$

PCA algorithm

(1) Compute mean vectors for the input features dataset (x_i)

$$\text{Mean:} \quad \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{5}$$

(2) Calculate the scatter matrix – covariance matrix:
a.
$$S_w = \sum_{i=1}^{n} N_i(\overline{Px} - m)(P\bar{x} - m)^T \tag{6}$$

(3) Compute Eigen vectors and eigen values.
(4) Sort the eigen vectors in descending order, W
(5) Project the principal components onto the input features dataset by using the equation
a.
$$\mathrm{Y} = \mathrm{W}_{\mathrm{x}}^{\mathrm{T}} \tag{7}$$

6) Compute mean vectors for the input features dataset (x_i)

$$\text{Mean:} \quad \bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{8}$$

(7) Calculate the scatter matrix – covariance matrix
a.
$$S_w = \sum_{i=1}^{n} (Px_i - \overline{Px})(Px_i - \overline{Px})^T \tag{9}$$

(8) Compute mean vectors for the principal components (Px_i)

$$\text{Mean:} \quad \overline{Px} = \frac{1}{n}\sum_{i=1}^{n} Px_i \tag{10}$$

ALO Algorithms

1. Initialise population of ants and antlions randomly, X^t

   Compute the best fitness for both antlions and ants.

$$X^t = [0, cumsum(2r(t_1) - 1), cumsum(2r(t_2) - 1), \ldots, cumsum(2r(t_n) - 1)]$$

2. Determine best fit antlions and label them as elite.
3. While for each Ant Lion:
   Choose an Ant Lion by Roulette Wheel
   Compute random walks
   Normalise
   Update Ant Position
   End for
   Calculate ant fitness
   Replace antlions by their fittest counterparts
   Update Elite antlions

End while
4. Return Ant Lion fitness

Containing three phases as stated, the IPS model will automatically start after investigating all futures of the dataset that send any suspect DDoS packets to the IPS. After ending the procedure, any anomaly IP will be blocked by the IPS and, in the overall operation, will be integrated IDPS as a host based in the hypervisor.

Detection classifier – ANN

The Ant Lion fitness of the ALO (output) is used to classify the normal traffic from attack traffic. The best-fit Ant Lion obtains the highest fitness values. The ANN-feedforward neural network uses the Ant Lion as shown in Fig. 5. Filter attacking source suspicious IPs: An initial profile is generated over a period (typically days, sometimes weeks) and is sometimes called a training period. Profiles for anomaly-based detection can either be static or dynamic. Once generated, astatic profile is constant unless the IDPS is specifically directed to generate a new profile. A dynamic profile is adjusted constantly as additional events are observed. The corresponding measures of normal behaviour also change because systems and networks change over time. A static profile will eventually become inaccurate and thus should be regenerated periodically, for example, an attacker can perform small amounts of malicious activity occasionally and then slowly increase the frequency and quantity of activity. If the rate of change is sufficiently slow, the IDPS might think the malicious activity is a normal behaviour and include it in its profile. Malicious activity might also be observed by an IDPS while it builds its initial profiles.

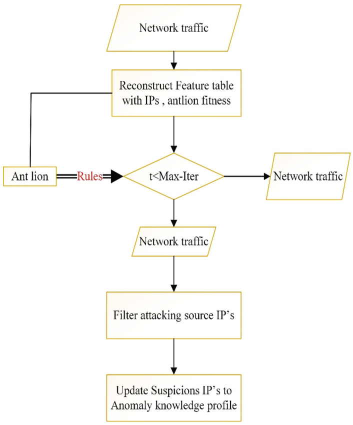

Fig. 5. Reconstructed feature table with IPs and ALO fitness.

- Blacklists and whitelists: After the proposed host-based integrated IDPS on hypervisor introductions based on any suspicious IPs, the host-based intrusion detection and prevention system (HIDPS) will take immediate action against any anomaly DDoS packet. The hypervisor will unitise a list of malicious activity-associated discrete entities, such as hosts, TCP or UDP port numbers, internet control message protocol (ICMP) types and codes, applications, usernames, URLs and filenames or file extensions. Blacklists, also known as hot lists, are typically used to allow HIDPSs to recognise and block activity that is highly likely to be malicious; this list may also be used to assign a higher priority to alerts that match entries on the blacklists. Some IDPSs generate dynamic blacklists that are used to temporarily block recently detected threats (e.g., activity from the IP address of an attacker). A whitelist is a list of discrete entities that are known to be benign. Whitelists are typically used on a granular basis, such as in protocol-by-protocol, to reduce or ignore false positives involving known benign activity from trusted hosts. Whitelists and blacklists are commonly used in signature-based detection and stateful protocol analysis.

Experimental Results

All result, till update are impressive and feasible. In fact, we have measure both the IDS, and IPS in term of detection rate for three types of selected attacks – which are TCP sync, TCP push and ICMP DDoS attack. These attacks came from CIDA DDoS 2009 attack, and UCLA datasets. The reason to select these types of datasets are due to their nature of real time capturing. However, TCP shows the highest detection rate as shown the Fig. 6, the deviation reached 100% of detection-which mean zero error classification. Then TCP push and ICMP will less percentage of classification and detection rate. While, in IPS also shows a high percentage of detection and prevention. This happen because the normalization enhanced by ALO. Again, TCP sync shows the full detection and prevention rate in term of comparison with TCP push and ICMP (Fig. 7).

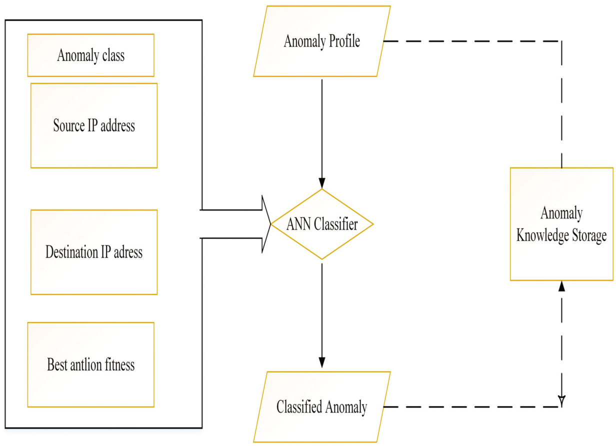

Fig. 6. ANN-based detection classifier.

Also, we have calculated the highest IP's that hit the server, and we notice that it came from CIDA datasets. The IP 172.162.222.64 was the most repeated attack for TCP. Which mean it accruing many flooding massages to the cloud server. And our work has a good result in term of detection and prevention (Fig. 8).

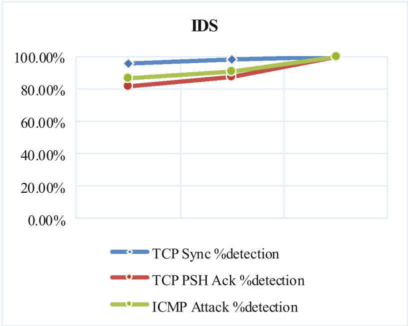

Fig. 7. The IDS detection rate

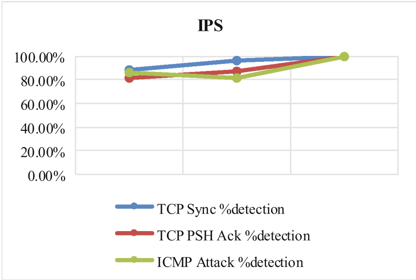

Fig. 8. IPS detection and prevention rate

4 Conclusion

This unique conceptual model design is based on two important science methods and statistical procedures combined with smarm intelligence algorithms. PCA with LDA is used as a statistical procedure, and ALO with ANN is also proposed as swarm intelligence. The proposed model of HIDPS is based on moulding IDS alone and then integrated with IPS in the hypervisor environment. The IDS should be efficiently developed from PCA, LDA and the output dataset optimised from these by ALO, using the ANN classifier for any anomaly IPs, which will be sent to the IPS or else allow the good packets to pass. IPS uses ALO after taking the decision from IDS and using the ANN classifier to finally prevent and send the suspicious IP to the black list, which is shown in the hypervisor of the cloud server. While, this work in progress it will convert to the full model in near future for PhD thesis (Fig. 9).

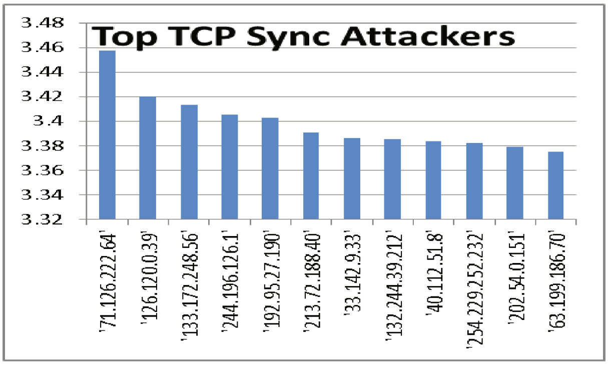

Fig. 9. TCP IPs attack from CIDA dataset

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A Policy Based Framework for Software Defined Optical Networks

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Abstract. The Network Management System (NMS) consists of Management Information Base (MIB) objects that enable policy based monitoring and management of Simple Network Management Protocol (*SNMP*) infrastructure. The emerging technological architecture of Software Defined Networks (SDN) is related to the NMS on the north-bound interface and the concept of policy control is central to SDN. Therefore, much effort has been focused on policy languages and abstractions tailored to SDN. This paper presents a context-aware policy framework that allows network operators to have dynamic functionality of policy management in SDN. The proposed scheme has been validated in a SDN controller supporting NMS with a new MIB schema. Our use cases and experimental results show the usefulness of the proposed policy based framework incorporating a simulation-assisted pre-setting mechanism for local policy decisions in cases where there are issues when communicating with the SDN controller.

1 Introduction

With the rapid growth of advanced technology and its flexibility, new network management architectures like SDN have been developed. SDN separates the network control planes from the data control plane enabling virtualization [1]. Our previous research on virtualization capabilities like geographically isolated and transparent resource provisioning [2] and live migrations [3, 4] show the net benefit of cloud computing. SDN uses the OpenFlow protocol [5] to manage data and switching control. OpenFlow-like protocols are required to implement the SDN paradigm using the new network elements to incorporate Network Function Virtualization.

On the other hand, *SNMP* is a TCP/IP protocol that is widely used for network management and monitoring through objects defined in MIB devices. Each MIB device' statistics is obtainable by the *snmp* Object IDs (OID) periodically (for example, *ifTable* objects in MIB II). Hence, a polling mechanism is required for continuous monitoring in a NMS [6]. The MIB schema and syntax together with a policy engine will be capable

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of allowing the SDN controller to make real-time decisions about the cost and benefits of a network.

Recent years have also seen much research development in Policy-Based Network Management (PBNM) [7] with the goal of mapping high-level business policies to the appropriate configuration of network devices controlled by the NMS. Hence, the concept of policy is central to a SDN that performs new services based on software implemented features defined in a logically centralized control plane.

The NMS communicates with the SDN controller on the north-bound interface, which can result in dealing with management and control signals, especially changing datacenter requirements to the NMS and the delay in signal while prioritizing the business policies. Therefore, the motivation of this work is to embed the MIB and some limited intelligence with the help of pre-defined policy configuration inside the SDN controller. This is for the network status updates to rationalize into actionable outputs more quickly than with the traditional hierarchical management topology.

1.1 Related Work

Various research groups have been working on Policy Framework and Resource Provisioning to contribute to policy based management. There are also potential research going on in policy frameworks for SDN applications especially over optical networks. In [8], an active Meta-MIB concept is presented for effective semi-automate policy based management. The Meta-MIB contains the state of the network and monitors its integral devices to prevent any impairment of network services. Meta-MIB also verifies policy compliance at certain levels.

Omari *et al.* [9] proposed policies for the VACM (View Based Access Control Model) aiming at integrating the policy concept into the *SNMP*v3 framework. It sets rules to map authorization and standardization as part of the *SNMP*v3 management framework. Policies are maintained in a database allowing a manager and management applications to enforce enterprise authorization policies.

In [10] a novel policy-based mechanism is presented to provide context-aware network-wide policies for SDN applications. The authors have implemented the policy engine with a policy flow based on property graph models for Optical Network.

However, the main disadvantages of these approaches are the scalability or network mapping and discovery issues. Gateway-based approaches have a performance issue and the mapping process introduces an additional processing cost and delay.

In summary, this paper is unique in the following aspects:

- The paper introduces a unique policy based framework with generic SDN monitoring capability using a MIB;
- The SDN architecture is extensible as our approach can handle multiple types of events by adding an attribute that describes the event type, and any other type specific attributes needed;
- The SDN architecture is also scalable by handling as many events as possible locally by forwarding policies using MIB agents that have limited communicative power,

along with a centralized controller. Therefore, Events can be handled locally by the MIB agent receiving the event, without communicating the controller.
- Simplified traffic management policies result; and
- The framework is applicable to many use cases.

The rest of the paper is organized as follows: Sect. 2 describes the Policy Management system and the architecture to integrate with SDN. Section 3 provides details of the policy framework model and illustrates our proposed scheme. Section 4 describes the use cases for the proposed architecture with experimental setup and configuration details together with discussions of the results. Finally, Sect. 5 provides conclusions and a view for future work.

2 Policy Based Management for SDN

In a distributed system, placing network intelligence to manage network elements is an emerging challenge due to the exceptional growth of data traffic. NMS involves MIB Object IDs (OIDs) and is operated by *snmp* like protocols and maintains a database for network provisioning. The database also stores stateful information regarding the resource capabilities and their status. The management mainly relies on policies that are either activated manually or automated depending on the circumstances of the business requirements. This is important to set the priory depending on the customers, applications, volume of data to be transferred and time of day to maximize the efficiency of the network policy. Policy and resource monitoring and allocation also need to be revisited as these will ultimately feed into the MIB Engine that will run the Policies required to operate in the SDN. This also has to deal with emergency scenarios where migration is required in a very short period of time.

2.1 Policy Based Management

New software defined networking capabilities and network controls are required to enable efficient and secure cloud computing for high capacity applications, including dynamic optical Terabit scale networking. The SDN paradigm using the new network elements and Network Function Virtualization will necessitate real-time higher level executable policies across the management control plane between the main network elements. Therefore, various MIB aspects and indicative attributes and metrics are required from the physical layer and other optical components to allow for the potential 5G integration. This will benefit other MIB schema and syntax to be exported, and allow the SDN Orchestration Engine to make real-time decisions about the cost/benefits of migration, replication etc.

A policy based enterprise MIB schema using underlying performance attributes will populate a dynamic MIB data structure. These low level attributes will be augmented with a stateful representation of the current network configuration and traffic load which will be closely coupled to the scheduling algorithms that will suggest reconfigurations to the SDN controller to be pushed down to the network elements as shown in Fig. 1.

This stateful representation of the network can be used to monitor data from the network to be maintained on a per-link basis: average queuing delay, data loss, modulation scheme, encoding scheme, throughput, utilization, jitter and other metrics using Web Services.

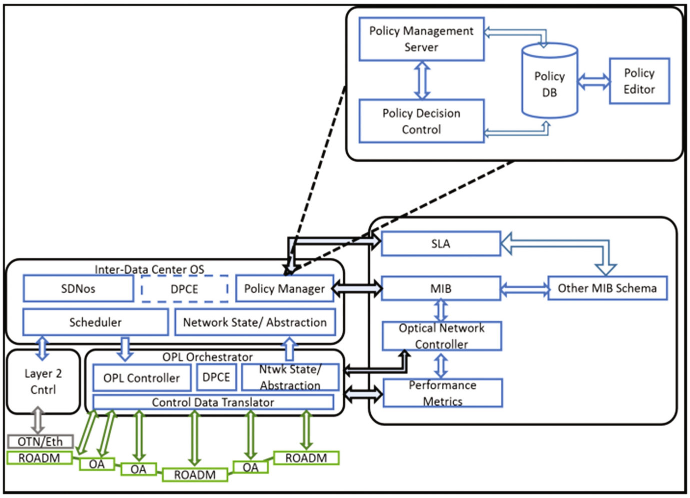


Fig. 1. Example of policy based network management of a data center in a software defined optical network.

Policy Manager: By looking in detail into the policy based MIB, we can find many sub modules that collaborate together to provide the Datacentre (DC) customers with their requested services. Different performance monitoring modules for the optical network performance can be used in this framework to make sure the MIB Agent is providing the service to the DC management system. The Management system will also take into consideration the different QoS requirements, performance metrics and the MIB data generated from the application to provide a feed to the Policy manager. **Policy Decision Control**: resides in a policy management server known as Policy Decision Point (PDP) unlike the Policy Enforcement Point (PEP) that is a component of a client and managed remotely [11]. PDP is an application that determines the rules whether access to a resource should be granted. **Policy Management Server:** The policy control contacts the Server for accessing any configuration, user authentication, accounting and policy database. Usually *SNMP* is used for this communication while other protocols can be used depending on different implementations or interoperability of the different devices.

Policy Database (DB): The MIB policy database contains different information about resources, scheduling, security techniques and fault tolerance information generated (e.g. generated from applications). According to the service requirements and network conditions, the management system will choose the suitable techniques that satisfy the customer.

3 The Proposed Policy Based Monitoring Framework

We demand for more flexible and dynamic networking services with the widespread development of Internet and mobile applications. Moreover, with the different virtual infrastructure it has become a new challenge for many carriers to deploy a variety of new services by effective provisioning of network resources. SDN helps us to make networks reconfigurable and extensible such that new services can be deployed with existing network devices. With separate controller plane and data plane, SDN brings networks programmability of the data plane and centralization of the controller plane. However, conventional Operations Support Systems (OSSs) were developed to manage networks in a standard fashion with a Management Information Base or any proprietary management framework. Although SDN provides a new framework in managing SDN-enabled devices, a new issue arises on how SDN-enabled networks and devices can be monitored and controlled by current OSSs.

This paper focuses on the performance management and aim to develop an efficient policy based scheme to monitor traffic statistics data on a software defined optical network at the controller plane using MIB. The RYU framework [12] used in this work is a full featured but lightweight and relatively easy to use OpenFlow controller with well-defined network plugins written in Python. The Ryu Controller with NETCONF and OF-config network management protocols supports most widely deployed SDN communications standards. The Ryu Controller can use OpenFlow to interact with the switches and routers to modify how the network will handle traffic flows. It has been tested and certified to work with a number of OpenFlow switches, including Open vSwitch and contributions from well-known vendors.

3.1 SDN Framework with MIB

In this work, an architecture using the RYU controller with MIB schema network controls is presented to enable efficient and secure cloud computing for high capacity applications, including dynamic optical switch networking. The RYU framework using the network resources and Network Function Virtualization will necessitate real-time higher level executable policies across the management control plane between the main network elements as shown in Fig. 2. The MIB schema and syntax with the policy engine will be capable of allowing the SDN controller to make real-time decisions about the cost/benefits of migration and replication. These include:

- MIB definitions specific to RYU
- RYU can send *snmp* trap messages as notification originator.
- Currently, *snmp* sends only a coldStart trap message on startup and specific traps on datapath enter/leave event.
- For other RYU components to utilize the *snmp* agent, a policy based MIB tool is developed as an extensible agent to provide detailed information to the SDN controller.

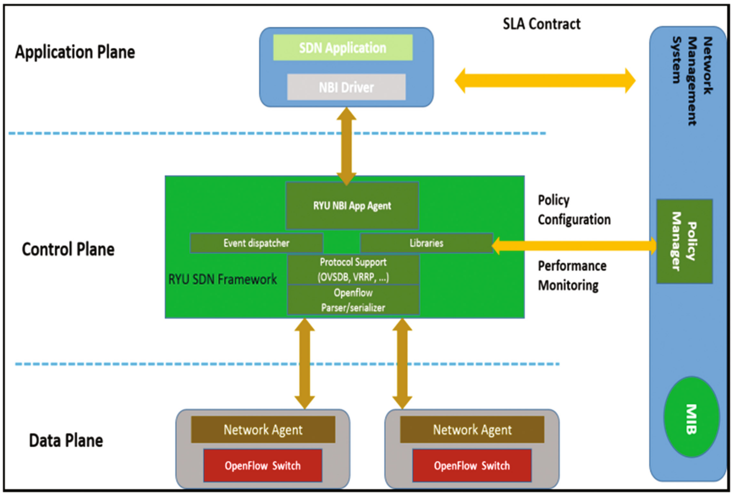


Fig. 2. The architecture of the proposed SDN framework with MIB

A typical operation of the MIB schema in this SDN architecture is illustrated below:

Step 1: The Policy Manager receives the set of policies specified by the SDN controller through the Management APIs at the management console. The NMS SET operations based on the policy configurations, which are typically the MIB Scripts in Python and loads the action script.

Step 2: The Policy Manager Performs the monitoring of the action policies ensuring there is no conflict or unreachability issues.

Step 3: The new configuration (MIB Script) is applied by setting action scripts for local devices and sends the updated policies to the relevant devices.

3.2 The Policy Architecture

In theory, most of the policy architectures are created based on a policy information model or policy engine. Although policies are usually defined using ECN rule [13] i.e., *events* => *conditions* => *actions*, which is based on specific conditions with a goal of mapping high level policies to specific network configurations dynamically, the policy manager is liable to enforce the policies through the policy enforcement point. Usually, when the monitored value captured by each monitoring element (the MIB agent in our case) is sent to the *Condition Analysis* component that contains the ECA rules to decide whether or not a reconfiguration is needed. ECA rule is significant to the systems including personalization, big data management and business process automation to explored for M2M (machine-to-machine) networking, Internet of Things (IoT), cognitive computing and the semantic web.

The concept of policy evaluation known as the identification of Situations, which is not only just the evaluation of set of conditions but also detailed analysis for the policy engine to act in a distributed environment. Hence, the suggested framework works on distributed decisions in a policy system depending on the given input by the policy flow. This is to ensure the desired state for each node through the set of internal policy configurations.

Our approach for the distributed policy system uses MIB schema. For the network components, its correlations and constrains are modelled in Mininet [14], while a MIB database can be created through transformations using applications on top of the RYU controller development framework as a proof of concept. As the policy models are based on configurations modelled in Mininet with transformations for representing the network, internal node architecture and policies as virtualization, the configuration of network infrastructure, virtualization substrate and policies can be performed, for instance, via the RYU framework. Hence, the network operator has full visibility of the managed objects using the MIB and each client has access to its own network.

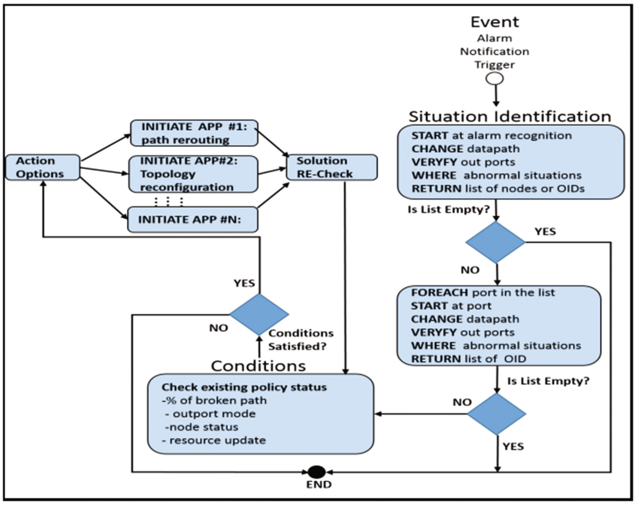


Fig. 3. Example of proposed policy based model using MIB schema

The proposed policy flow (*event => situation identification => condition analysis => actions selection and execution*) is depicted in Fig. 3. After some link failure between switches/nodes the situation identification is performed over current network state information using MIB schema via MIB database queries as shown in pseudo-code queries. The situation analysis allows the verification of potential interfaces that could be reconfigured to solve the problem and if additional nodes/switches have been affected. After that, pre-configured system policies are evaluated to determine if and which actions should be performed. After action execution, the situation is re-checked to determine if the actions performed have solved the problem, and if not, other actions could be triggered. For instance, if a broken link is not being solved via an alternate Ethernet switch, and if the link is critical (business requirement), and other conditions are satisfied, the datapath could be re-routed using direct optical links. However, different applications can be initiated within the policy flow. The main goal of our policy engine is to provide policy-based control of the network framework with the virtualization underlying the scope of this work. The proposed architecture allows the provider to expose an abstracted topology to the client, mapped by the SDN controller and *snmp* protocol to several physical nodes interconnected in a leaf-spine topology. Moreover, each client is responsible for its own resource provisioning and policies by means of its own mechanisms as they could manage their own physical network.

4 Use Cases and Experiment Results

4.1 Experiment Setup

The optical Space Switch is the switching fabric of the optical network architecture built on hybrid network [15]. The leaf switches are simultaneously connected an optical space switch known as '*direct link*' in this paper (a switching substrate that provides an optical circuit between any idle input and output ports, without optical to electronic conversion [16]) as depicted in Fig. 4.

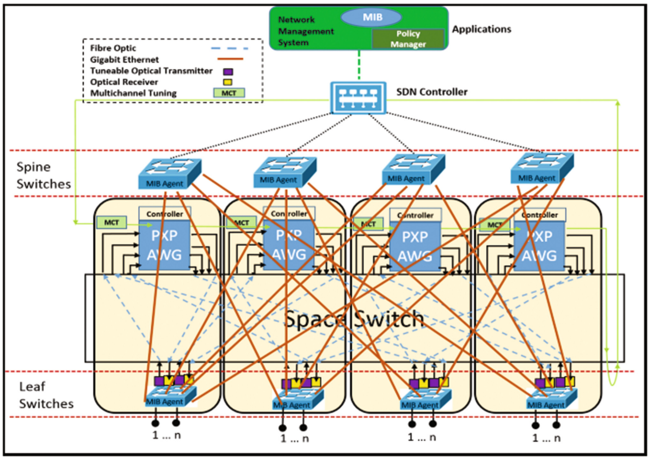


Fig. 4. Illustration of a software defined monitoring using MIB in a leaf-spine topology

The first set of experiments considers a leaf-spine topology simulation with direct fiber links between leaf-switches. Here, we have monitored the network statistics i.e., throughput, packet drops etc. of some nodes in the RYU based framework using a MIB. The second set of experiments validates the policy engine in a SDN controller in the leaf-spine topology where the *snmp* protocol is used to gather the MIB statistics. The simulation scenario shows the importance of the proposed policy engine when any node is unable to communicate with the SDN controller or any issues with the network management.

4.2 Configuration Details and Results for SDN Using MIB

Mininet version 2.2.1 and open flow version 13 is used for these experiments. All the experiments are done over 1000 run with 95% confidence interval. The VMs are created considering iperf [17] TCP packets. Table 1 shows the configuration details for SDN with MIB monitoring experiments.

Table 1. Configuration details for leaf-spine topology.

Parameters	Value
Servers/Hosts	16
Leaf switches	4
Spine switches	4
Bandwidth	
Host to Leaf switches	1 Gbps
Leaf to Spine (EDGE Level) switches	1 Gbps
Traffic	TCP
Polling Interval	60 s

In this scenario, we are monitoring the end to end throughput between two nodes using MIB OID, where (i) data transfer is done through a direct fibre link and (ii) data transfer through Ethernet switches (i.e., without fibre links). Figure 5 shows that the average throughput is better using the direct link considering various VM workloads. The average throughput could increase up to 5% compared to without a direct link with lower VMs (i.e. a VM size of 50 MB). However, we couldn't find a significant throughput difference between the two approaches by increasing the VM size (i.e. 1–2% difference observed). In the next experiment, we have monitored the packet drop attributes between two nodes during end-to-end data transfers over UDP parallel connections. We have measured the packet drop rate to evaluate the network performance using MIB OID. Here, *iperf* UDP connections are used with a constant bit rate of 100 Mbits/s to measure the network performance by calculating the average packet drops for 10 s considering the direct fiber links (the experiment is done over 1000 run with 95% confidence interval). Figure 6 shows the outcome of the experiments while the average packet drops rate outperforms using direct links with respect to no direct fibre links. The figure shows that for up to 6 parallel connections, similar packet drops are obtained whether using or not using the direct links However, the drop rate dynamically increases with no direct links with the increase of the number of connections as illustrated in the figure. This can be up to a difference of 2% as clearly observed for 10 parallel connections.

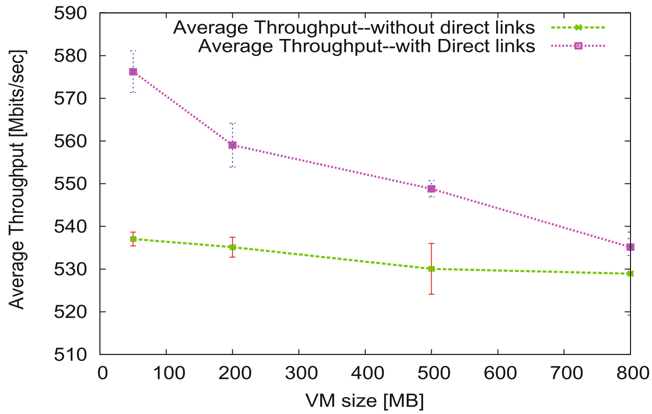


Fig. 5. Comparison of throughput with various VM sizes

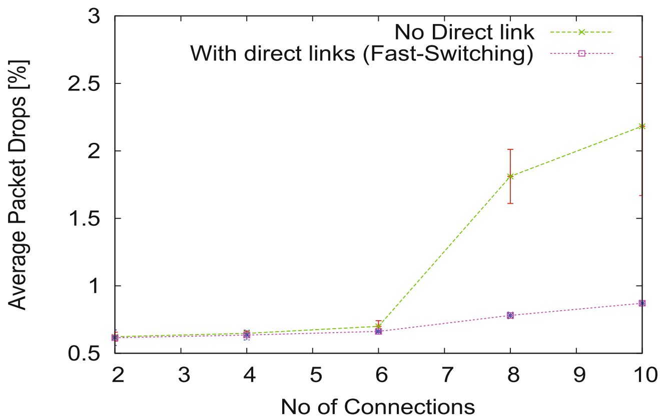
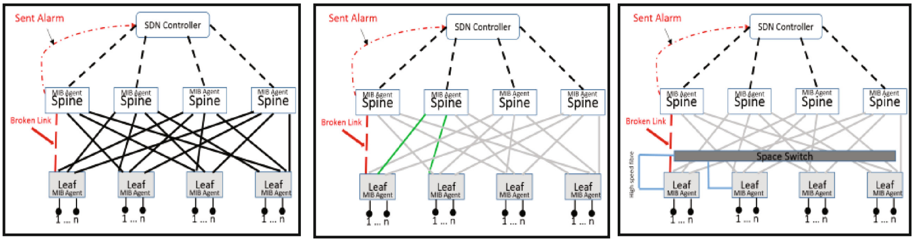


Fig. 6. Comparison of packet drops with or, without direct links

4.3 The Use Case Scenario

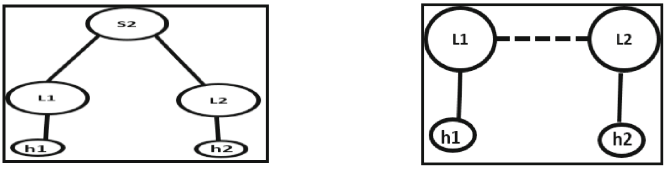
Figure 7 shows the use case scenario of emergency migration of VMs in a datacentre network. The scenario is considered during a broken link between a Leaf switch (L1) and a Spine switch (S1) and therefore the MIB agent triggers an alarm to the SDN controller. The SDN controller receives the alarm and therefore, the emergency migration can be done using an alternative path suggested by the SDN controller. Usually the controller selects an alternative path through another spine switch. However, this paper examines an architecture with policy based software defined monitoring that interfaces with direct fibre optical leaf switches. The SDN controller updates the MIB information while any link is broken and triggers a policy configuration file related to the fibre optic direct link and initiates the datapath for the optical switching. Finally, the MIB agent sends updates to the SDN controller when the migration is done.



(a) (b) (c)

Fig. 7. Use case Scenario: Emergency Migration in a Leaf-Spine topology (a) Alarm sent to the controller as Broken link between a Leaf and a Spine Switch, (b) Alternative path chosen by the controller, (c) direct fiber link chosen by the controller.

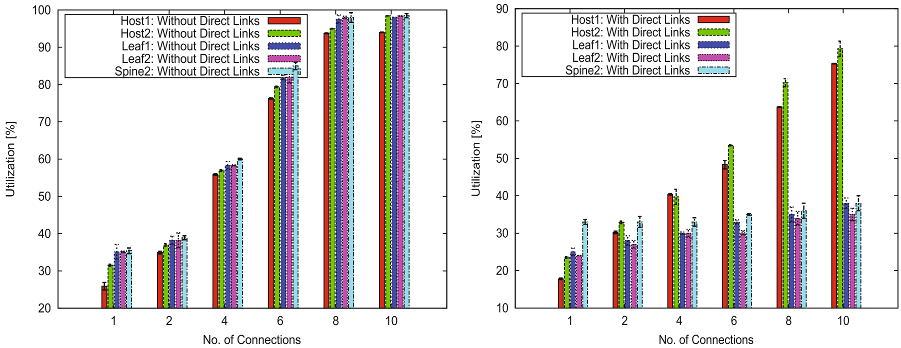
Figure 8(a) shows an example of the simulation environment while an alternate path is chosen by the SDN controller after an alarm is sent during MIB monitoring. Here *S2* is the alternative spine switch suggested by the SDN controller when data transfer is happening between host1 *h1* and host *h2*. The Leaf Switch used here is Leaf 1 *L1* and Leaf 2 *L2*. Figure 8(b) shows the policy based approach of software defined monitoring using a fibre direct link between Leaf 1 *L1* and Leaf 2 *L2* deployed by the policy configuration script. Hence, any of the Spine switches will not be used in this scenario. However, we have compared the proposed policy based approach without or with the direct fibre links.



(a) (b)

Fig. 8. Experimental setup for the use case scenario (a) Without any direct fibre link, (b) With direct fibre links.

Figure 9 (a) shows the overall effect of the policy based approach without the direct link where all the hosts and switches mostly utilizes all its CPU with the increase of the parallel connections and therefore may reduce the overall performance for the unnecessary utilization. In contrast, with the direct link the overall CPU utilization is lower as shown in Fig. 9(b). The policy based approach helps to configure the fiber direct link to prevent over utilization of the CPU (in this case should not cross a maximum utilization level for any devices, which may reduce the overall performance of any services).



(a) (b)

Fig. 9. Management (a) Without direct fibre links, (b) Proposed policy management with direct fibre links

5 Conclusion and Future Work

This paper presents a policy based framework for monitoring software defined optical networks and is validated in a SDN controller using a new MIB schema. Our use case experiments show that the simulation-assisted datacenter policy framework allows network elements to dynamically react to specific situations in case of failure in communications with the controller or in case of strict timing requirements. Although this works considers some pre-defined policy mechanisms, the benefit should not be limited only to the use cases and the framework can be applicable for network management with intelligence. In future we intent to (i) validate the approach in a real testbed network, (ii) perform scalability test, and (iii) extend the concept and implementation to a multi-provider network setting, where SLA could be different.

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Application of Genetic Algorithm and Simulated Annealing to Ensemble Classifier Training on Data Streams

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Abstract. Data stream classification is fast growing research area due to increasing number of practical applications in modern technology. SPAM filtering, weather forecast are just two well known examples. Nonetheless, high pace of incoming data makes classical algorithm inefficient as they usually use batch processing methods. What more, the characteristic of the data can change over time what makes classifiers obsolete. Their continuous updating can help, but cannot by applied in classical batch algorithms. On-line or chunk base training could be a solution. The last one is based on repeated extracting data chunks from data stream and using them for adaptation. In case of many difficult classification tasks ensembles of classifies work much better that systems based on single one classifier. Unfortunately the ensembles require additional training of their fusion model. In this paper we present the ensemble for data stream classification and compare two optimisation methods used for its training: Genetic Algorithm and Simulated Annealing. Results of experiments on several benchmark datasets shows that both methods are equally effective in term of accuracy and outperform several competing methods.

1 Introduction

Stream processing is fast growing area of research due to increasing number of their applications. Weather prediction, spam filtering, fraud detection are just few examples [20, 24]. Classical algorithms which use batch training mode, where entire learning set is processed many times, cannot be applied for data stream processing. Firstly, size of the stream is growing continuously. Secondly, characteristics of the data can change over time, the phenomenon which is called Concept Drift [18]. The change can affect prior probability of classes or class conditional probability [9], what affects posterior probability of classes and makes classifier obsolete. An important feature of the drift emergence is its dynamics. Its most popular taxonomy includes: sudden drift, where the change takes place at given moment of time, and gradual one, where the change is spread

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in time [17]. But, in literature one can find also another very special drift type called recurring context, which cover all those situations where past concepts can appear again [6]. The solution presented in this paper is designed for this type of drifting streams.

To keep the system up to date classifiers should be adopted to incoming data. That can be realised in several ways. On-line algorithms apply changes after extracting each sample from the stream. In chunk base learning, samples from the stream are collected temporally in data chunk. Its size usually is fixed and limited, although, in more sophisticated methods it can vary depending on data characteristics. When the chunk is filled with samples, it is used to update the system in a process which is similar to batch one, but uses samples collected in the last chunk only. The model of the system is preserved and updated with each subsequent chunk, what allows to collect the knowledge conveyed with each chunk.

There are many algorithms designed especially for data stream processing. The first ones were: STAGGER proposed by Schlimmer and Granger [15], IB3 proposed by Aha [1], and the suite of FLORA by Widmer and Kubat [23]. Since then many new methods have been proposed. We would like to mention a group which gathers ensemble methods [4]. They show high ability of elevating classification accuracy by fusion of elementary predictors [2]. But, on the other hand, training must be applied not only to ensemble members, which are called elementary classifiers, but fusion model has to be updated too. Ensemble can be updated on demand. This approach is widely used by algorithms with drift detection [11]. Alternatively updating can be done continuously [13]. There are several possible options to be implemented in the last strategy. If ensemble consists of on-line classifiers, they are trained each time new samples is extracted. On-line bagging and on-line boosting are the two most popular on-line ensemble techniques [14]. A chunk base update is applied in Accuracy Updated Ensemble [5], which is a representative of methods which refresh the ensemble by replacing its members witch new ones. Usually the committee size is fixed [16]. Therefore recently created classifier replaces the "oldest" one in the committee or such that shows the worst classification accuracy measured on recent data chunk. Removing classifiers from the committee means that its knowledge is lost. In case of processing streams with recurring context permanent forgetting might be costly, because when the concept emerges again new classifier must be created from scratches.

In previous work [12] we proposed Evolutionary Adapted Ensemble (EAE). This algorithm maintains small voting committee and large pool of all created classifiers. Removed from the committee classifiers are put into the pool for further use. Ensemble training was based on selecting committee member from the pool. This procedure allowed to recall all past concepts [8].

In this paper we compare application of two popular optimisation algorithm for EAE training. Originally we used Genetic Algorithm (GA) for that purpose. We chose GA because they had presented high effectiveness in training highly accurate ensembles. On the other hand their computational complexity was too high for processing data streams. Therefore we decided to implement training procedure which used Simulated Annealing (SA) [19]. There were two reasons to select SA. First, contrary to GA, SA does not maintain huge population of individuals which represents possible solutions. SA processes only one single solution named a point. Secondly, GA consists of several genetic procedure such as mutation, crossover, selection, all affecting population. SA consists of only one specific procedure named annealing which affects the point. The question is whether SA can compete with GA in term of accuracy, what is a feature of primary importance. Therefore a motivation and the purpose of this paper is to check, whether application of SA in ensemble learning allows to obtained similar results comparing to GA, and whether both methods used for EAE ensemble training allow create system successfully competing with other ensemble methods.

The rest of the paper is organized as follow. Model of the ensemble classification algorithm is presented in Sect. 2. Next, some details of GA and SA based training procedures are provided in Sect. 3. Evaluation of the EAE is presented in Sect. 4. The last section conclude the results and set some propositions of further researches.

2 Ensemble Classifier Model

Let us start with presentation of the ensemble classification model. The aim of the classification is to assign an object to one of possible classes, which can be drawn from set $\mathscr{M}$. The set is predefined and consists of M classes. A classification algorithm Ψ makes decision based on observation of selected attributes x.

$$\Psi(x) \rightarrow \mathscr{M}, \tag{1}$$

The ensemble $\bar{\Psi}$ collects number of elementary classifiers Ψ_k preserved in a pool Π.

$$\Pi = \{\Psi_1, \Psi_2, ..., \Psi_K\}. \tag{2}$$

Only selected classifiers from Π contribute in decision making. Let Ξ^{SAE} states for a set of indexes of classifiers taken from the pool which join the decision making committee.

$$\Xi = \{c_1, c_2, ..., c_E\} \tag{3}$$

To make the decision the ensemble performs weighted fusion of discriminating functions. Let $\mathscr{W}$ be a set of weights, where w_e states for the weight assigned to e-th classifier in the committee.

$$\mathscr{W} = \{w_1, w_2, ..., w_E\} \tag{4}$$

Finally, the formula of the ensemble decision is defined in (5)

$$\Psi(x) = \arg\max_{i=1}^{M} \sum_{e=1}^{E} w_e d_{c_e}(x, i), \tag{5}$$

where $d_{c_e}(x, j)$ states for discriminating function which represents support given by e-th member of the committee for class j. Note, that e-th member of the committee is a classifier with index c_e, i.e. Ψ_{c_e}.

The ensemble is trained to minimise misclassification rate using learning set LS, i.e. set of pairs of the features x and respective class label j.

$$LS = \{(x_1, j_1), (x_2, j_2), \ldots, (x_N, j_N)\} \tag{6}$$

The training is realized by manipulating with two sets of parameters of the model (5):

1. Ξ^{SAE} - indexes of classifiers which form the committee, and
2. $\mathscr{W}$ - values of classifiers' weights.

The objective of training is to minimize misclassification error rate (7).

$$Q(LS) = \frac{1}{N}\sum_{n=1}^{N} L(\Psi^{SAE}(x_n), j_n) = \frac{1}{N}\sum_{n=1}^{N} L(\arg\max_{i=1}^{M} \sum_{e=1}^{E} w_e d_{c_e}(x_n, i), j_n), \tag{7}$$

where L is loss function. In our model we choose a zero-one loss function.

3 Training Algorithms

We applied chunk based training. It means that data samples are extracted from the stream sequentially and collected in a chunk, i.e. temporary storage of fixed size. The size of chunk is arbitrarily chosen parameter. The training procedure is lunched when the chunk is full. When procedure is finished, the samples are removed from the chunk and process goes to next phase, i.e. new samples from the stream fill the chunk and the process is repeated. An outline of the training algorithm is presented in Listing 1.

Algorithm 1. Overview of ensemble training algorithm

Require: $LS, \mathscr{V}, Q, \Pi, Params$
Ensure:
if IS EMPTY Π **then**
  $\mathscr{V}$ = INIT()
else
  $Drift$:=DETECTDRIFT($\mathscr{V}, Q, LS$)
end if
if $Drift$ OR IS EMPTY Π **then**
  Ψ:=CREATECLASSIFIER(LS)
  ADD Ψ TO Π
end if
$\mathscr{V}, Q, Params$ = OPTIMISEENSEMBLE($\mathscr{V}, LS, Params$)
RETURN $\mathscr{V}, Q, \Pi^{SAE}$

There are five input parameters:

1. LS - a valid data chunk,
2. $\mathscr{V}$ - the most recent ensemble model
3. Q - a misclassification rate,
4. Π - a pool of elementary classifiers.
5. $Params$ - other algorithm parameters

The algorithm aims at finding optimal configuration of ensemble model $\mathscr{V}$ which minimise misclassification rate (7). $\mathscr{V}$ takes form of vector consisting of two parts (8).

$$\mathscr{V} = [\Xi, \mathscr{W}] = [c_1, c_2, ...c_e, w_1, w_2, ..., w_e] \tag{8}$$

Compound nature of the $\mathscr{V}$ vector must be considered, because both its parts need to be treated separately. While the $[\Xi$ is the vector of integers with constituents varying from 1 to K, the $\mathscr{W}$ is the vector of real numbers taking values from range $< 0, 1 >$.

The pool of classifiers Π is updated in two cases: when the algorithm is launched for the very first time and the pool is empty or when the drift is detected (Algorithm 1 Lines 1–9). A model of elementary classifiers is chosen arbitrarily. We used error base drift detector. If detect change when error evaluated on current chunk LS is significantly higher then previous one. The difference is arbitrarily chosen parameter and is stored in $Params$ structure.

Having got pool updated, algorithm trys to find optimal configuration of the ensemble by setting respective constituents of $\mathscr{V}$ (Algorithm 1 Lines 10). Two optimisation algorithms were implemented and used for that purpose: Genetic Algorithm, and Simulated Annealing. Both algorithms have a stochastic nature, i.e. they browse solution space in iterative and stochastic meaner, although, in both cases the process is performed quite differently. Details are provided in subsequent subsections.

3.1 Simulated Annealing

Simulated Annealing (SA) is an optimisation algorithms which is inspired by an respective physical process. The ensemble model (8) takes form of a point which represent $\mathscr{V}$ and is altered in series of iterations. Number of iteration is parameter chosen arbitrarily and stored in $Params$ structure.

Initialisation. SA initialisation (INIT() procedure (Algorithm 1 line 2) means generating new point $\mathscr{V}$. Because the pool Π is empty, both $\mathscr{V}$ constituents Ξ, and $\mathscr{W}$ are filled with zeros, what means that the committee does not consist any member.

Annealing. Annealing is a main procedure of optimisation. It generates new trial point $\mathscr{V}$ at a some distance from current one. The distance is generated as random vector of the same size as V. It has to be also remembered that Ξ consists of integers in a range between 1 and K and $\mathscr{W}$ is a real number vector, therefore, $\mathscr{W}$ can be manipulated using standard random number generator with zero means and variation proportional to a temperature.

The temperature controls the annealing and is decreased gradually in each iteration. Next, the trial point is evaluated with a target function (7) and compared with previous one. If the trial point makes better ensemble than the old one, it becomes a new $\mathscr{V}$. Otherwise the trail point can still become a new $\mathscr{V}$ with some small probability which is proportional to the current temperature. The annealing process is repeated until the maximum number of iteration is reached.

3.2 Genetic Algorithm

Genetic algorithms are well known optimisation methods successfully used for variety of applications. They process population of individuals which represent solutions of optimisation problems decoded in form of chromosomes. In our case the chromosome takes form of $\mathscr{V}$ vector. Due to particular form of $\mathscr{V}$ we tailored genetic procedure to our purposes as follow. *Initialisation.* Genetic Algorithm initialisation generates population of individuals (INIT() (Algorithm 1 line 2). The size of population is a chosen parameter. After initialisation all individuals are filled with zeros. *Selection.* Selected individuals from the population are chosen to be processed by genetic operators described later in this section. The selection is controlled by the fitness of individuals, which is counter proportional to misclassification rate (7) of ensemble formed using model encoded in respective chromosome. Individuals showing smaller misclassification rate are much likely to be chosen. *Elite.* To ensure that the best solutions, obtained at a given iteration, are preserved for future, two best individuals join offspring population. *Mutation.* Mutation is a procedure which injects some randomness into selected individuals' models. Each chromosome is affected by adding some noise generated with random number generators. Naturally, all aforementioned constraints which refer to Ξ and $\mathscr{W}$ are valid. *Crossover.* Because our chromosome has a form of vector, a classical standard two-point crossover operator can be used. It exchanges parts of chromosomes of two selected parents at randomly selected cutting points and creates two children. *Offspring population.* Elite and children created by mutation and crossover operations form new population. It is evaluated again, and the individual which represents the ensemble showing the smallest misclassification rate is returned as current ensemble model - the winner.

4 Evaluation

To evaluate performance of presented ensemble model and both training algorithms, series of tests were carried on empirical data. Apart from two presented algorithms, several competing classifiers were also tested for comparative purposes.

4.1 Experimental Set Up

Environment. All the experiments were carried on in MATLAB 2014 framework using OPTIMTOOL toolbox, and PRTools toolbox [7]. *Data streams.* Twelve

Table 1. Details on benchmark datasets

Dataset	Samples	Classes	Attributes	Noise	Remark
MOALED Set1	100000	10	24	10%	6 concepts
MOALED Set2	100000	10	24	10%	2 concepts
MOHyperi Set1	100000	2	10	5%	2 concepts affecting 5 attributes
MOHyper Set2	100000	2	10	5%	2 concepts affecting 10 attributes
MORBF Set1	100000	5	10	10%	2 concepts affecting 5 attributes
MORBF Set2	100000	5	10	10%	2 concepts affecting 10 attributes
MOSEA Set1	100000	2	3	10%	Classifier function 1 [16]
MOSEA Set2	100000	2	3	10%	Classifier function 5 [16]
MOSTAGGER Set1	100000	2	3	10%	Classifier function 3 [15]
MOSTAGGER Set2	100000	2	3	10%	Classifier function 1 [15]
MOWaved Set1	100000	3	21	10%	2 concepts affecting 5 attributes
MOWaved Set1	100000	3	21	10%	2 concepts affecting 10 attributes
Airlines	539383	2	7	0%	
CovtypeNorm	581012	7	54	0%	
Powersupply	29928	2	24	0%	

benchmark data streams generated using MOA [3] framework and three real streams were selected for tests. Details on datasets are presented in Table 1. Additionally, some MOA datasets featured concept drift with recurring context.
Classifiers. Seven algorithms were implemented and tested

1. DDM - Single Classifier created on recent concept using Drift Detection Method DDM [10]
2. AUE - Accuracy Updated Ensemble AUE [5]
3. AWE - Accuracy Weighted Ensemble AWE [21]
4. EN (Rep.Old) - Ensemble updated by replacing the oldest classifier in the majority voting committee.
5. EN (Rep.Worst) - Ensemble updated by replacing the classifier with the highest individual misclassification rate. Majority voting strategy was used for decision making.
6. EN (GA) - Presented in this paper ensemble trained by Genetic Algorithm
7. EN (SA) - Presented in this paper ensemble trained by Simulated Annealing algorithm

Testing procedure. Evaluation of the performance were realized using the *Test-Then-Train* procedure. Samples from the stream were added to the chunk. Then the chunk was used for testing the classifier and the misclassification rate was recorded. Next, training procedure was launched with the chunk.

All tests were repeated 10 times, therefore presented results shows average misclassification rates.

4.2 Results

Analysis of results in Table 2 do not allow to point one the single one best classifiers due to differences in classifier positions in tests. What more, tested classifiers showed quite similar quality, what additionally makes analysis difficult.

Table 2. Average misclassification rate of tested algorithms

	DDM	AUE	AWE	Ens (Rep old)	Ens (Rep worst)	Ens (GA)	Ens (SA)
MOALED Set1	0.2711	0.2718	0.2709	0.2541	0.2525	0.2432	0.2462
MOALED Set2	0.2711	0.2718	0.2709	0.2539	0.2521	0.2428	0.2459
MOHyperi Set1	0.0790	0.1272	0.0844	0.1355	0.1355	0.1356	0.1353
MOHyper Set2	0.0790	0.1272	0.0844	0.1047	0.1008	0.0970	0.1009
MORBF Set1	0.4786	0.4991	0.4769	0.3662	0.3578	0.3474	0.3581
MORBF Set2	0.2885	0.1383	0.2841	0.2597	0.2533	0.2409	0.2453
MOSEA Set1	0.1205	0.1231	0.1254	0.1374	0.1276	0.1227	0.1255
MOSEA Set2	0.1279	0.1254	0.1323	0.1325	0.1339	0.1290	0.1315
MOSTAGGER Set1	0.0100	0.0100	0.0100	0.0000	0.0000	0.0000	0.0000
MOSTAGGER Set2	0.0100	0.0100	0.0100	0.0000	0.0000	0.0000	0.0000
MOWaved Set1	0.2032	0.1762	0.1985	0.1943	0.1897	0.1847	0.1881
MOWaved Set1	0.2032	0.1762	0.1985	0.1945	0.1903	0.1855	0.1877
Airlines	0.3706	0.3378	0.4291	0.3749	0.3671	0.3448	0.3523
CovtypeNorm	0.4920	0.1799	0.2291	0.6544	0.6165	0.4541	0.4821
Powersupply	0.8663	0.8540	0.8520	0.8373	0.8358	0.8030	0.8076

Therefore, much more informative is analysis of Friedman rank test in Table 3. One can see that both presented in this paper ensembles, En (GA) and En (SA) got two highest ranks.

Table 3. Friedman rank and results of results Schafer post-hoc tests of statistical significance of the ranks' difference

Algorithm	Rank	Statistically better then
Ens (GA)	2.33	Ens (Rep. Old),DDM, AWE
		Ens (Rep. Worst)
Ens (SA)	3.20	Ens (Rep. Old), DDM, AWE
AUE	3.87	
Ens (Rep. Worst)	4.03	
AWE	4.80	
DDM	4.87	
Ens (Rep. Old)	4.90	

One fact shall be also highlighted. DDM, AWE, and AUE were originally designed for processing data stream with concept drift. Therefore superior position of EN (GA) and EN (SA) in tests on streams with drift proofs that both methods are quite effective in adaptation to changing stream characteristics.

Further conclusions shall be drawn from analysis of post-hoc Schafer test. As it can be seen, there is no statistical difference between EN (GA) with the highest rank 2.33, and EN (SA) with second rank 3.2. That is quite positive result which tells us, that both training algorithms are equally effective for ensemble training, what was expected by us. What more, both EN (GA) are statistically better then other tests algorithms and GA (SA) statistically outperformed Ens (Rep. Old), DDM, AWE.

This is a second very encouraging result because it showed that our proposition is quite effective and gets no worst, and quite often even better results than competing methods.

5 Conclusion

In the paper we presented two heuristic optimisation methods applied for ensemble training: Genetic Algorithm and Simulated Annealing. Both methods were used for adapting of the classifier ensemble to changing data stream characteristics. Results showed that there is no significant difference between the two in term of classification accuracy. What more, both methods showed superior positions over competing methods what makes them interesting options among other ensemble techniques used for processing streaming data. Although it has to be underlined here, that training algorithms which uses such a sophisticated optimisation algorithms like GA or SA are highly time consuming. Therefore they are recommended for application in tasks where data stream pace is not high or where few second lags, which is caused by training, does not disturb regular system work. In other words, their application in real time system has to be examined. Therefore further tests shall be done on new implementation using more efficient programming languages and frameworks such like C++ for example. The other area of further researches might cover investigation on creating classification framework which use the Cloud and distributed computation technologies. The first one seems to be appropriate for storing massive data streams, the last one can help to optimise training time.

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Security and Understanding Techniques for Visual CAPTCHA Interpretation

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Abstract. This paper attempts to present a new idea of data understanding and security processes for visual CAPTCHA recognition and interpretation. The proposition is dedicated to using visual CAPTCHA application including understanding processes, semantic analysis and recognition, to information security aspects. A new CAPTCHA scheme dedicated to authentication procedures with distortion algorithms will also be presented. In our solution we propose various shape and size distortions as well as new type of added noise. Paper in particular will present new directions of CAPTCHA applications, especially for understanding, security and support data management processes.

Keywords: Security algorithms · Understanding processes · Visual captcha · Data management processes

1 Introduction

Nowadays, many different techniques are dedicated to data security processes [2, 9–11, 13] and the main focus is put on testing their vulnerability. Various security levels shown by this algorithms are the result of applied cryptographic method for data protection [1, 2, 10, 12]. The most important techniques include cryptographic protocols for information security, data splitting and sharing as well as information hiding algorithms.

A new solution is CAPTCHA analysis. CAPTCHA's (Completely Automated Public Turing test to tell Computers and Humans Apart) main purpose is to protect website resources from automated malicious software [12, 14]. It disables hackers from creating fictitious profiles, that could be used for phishing, spamming or theft. A typical CAPTCHA is a set of distorted numbers or letters generated by a computer program. The expression should be relatively easily readable, but impossible to be detected by another artificial intelligence software. Due to recent advances in technology, many types of CAPTCHAS have been broken, which creates the demand for a new, more secure design technique.

Text based CAPTCHA scheme must resist many popular image processing methods including segmentation, recognition and random guessing, which are allowing to detect letters based on their size, pattern, color, position and shape. The strength of CAPTCHA is confirmed when the failure of the automated detection algorithm is higher than 99,99% [12].

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Based on conducted observations and research, designs elements increasing the vulnerability of CAPTCHA can be assessed [3, 12], this includes: small input space, limited amount of generated objects, color of letters, lack of randomness and noise, simple layout as well as many others. Before designing any CAPTCHA scheme, it is important to fully understand the recognition techniques that can be used by malicious software. Even one weak point of the image can potentially jeopardize the whole security of CAPTCHA. Single symbol extraction is the usually most important part in the detection process, because it allows to determine how many letters are present in a scheme and how they are distributed over the image. The first task of the detection algorithm is usually to split CAPTCHA into parts that contain individual characters, allowing the later applied recognition algorithm to detect individual letters. Having in mind that different forms of noise and distortion can be applied to the image, detection algorithm main focus is usually put on finding regions of interests and efficient components extraction. This may include application of various filters, edge-detection masks, thresholding and segmentation.

2 Recognition Process in CAPTCHA Analysis

Recognition process in CAPTCHA procedures can be based either on image correlation techniques or components extraction [1]. In character components extraction, scheme is searched fort for the distinguish elements of the letter, which are later singled out of the scheme and stacked with each other. This extraction can be based on segmentation methods or filtering. The most likely correct combination of components that could form an individual characters is then tested. It is important to note that when an original letter in rotated to some angle or very distorted, testing becomes even more complex and requires application of much more advanced recognition techniques.

Recognition is also often also based on skeletonization algorithms [1, 5]. Topological skeleton of the letter can be extracted based on its geometrical and topological properties such as length and width of the character components, direction, connectivity of the boundaries and topology [7]. Since every letter has characteristic points in which the components are coming together, detection of such coordinates could help determine which type or style of the letter algorithm is dealing now.

Segmentation attacks that could help detect character components on scheme rely on extracting main shapes of letters and numbers by partitioning the image into multiple segments based on pixel values. Edge detection is also an important step in image segmentation, which usually is focused mainly on differing characters from applied noise. Based on segmentation, different correlation methods and machine learning, modern algorithms are capable of breaking very complex CAPTCHAS. Despite that, there are still however a few designs, which when applied to the generated CAPTCHA image may challenge the detection algorithm and prevent it from extracting the correct symbols. The stages of this processes are the following:

- Input – to increase the difficulty, input letters or numbers should be provided in different font styles, including capital and small letters.

Human eye is often used to recognizing different styles of fonts, but for the detection algorithm it would require a creation of a bigger symbol database.

- Randomness – randomly generated symbols or words in reference to their size and content are more difficult to detect, by disabling the possibility of using the word or image database.
- Color – letters of a colour similar to their background are also more challenging to detect, due to the fact that a threshold cannot be applied in this situations.
- Noise – ideally, noise should give false detections for the harmful detection algorithm.
  In practice, it is very difficult to generate a useful noise without overshadowing the content.
- Distortion – distortion disables malicious software from using simple correlation and shape-based detection methods.
  A slight change in letter's width or orientation creates an obstacle forcing the detection program to use more intelligent methods.

3 Examples of CAPTCHAS

Nowadays, many websites use CAPTCHAS for data security and authentication processes [2, 10, 11]. The main idea behind this solution is providing an intelligent verification process, which should determine whether system is dealing with human or automated software.

Currently, around the WEB we can find a very different forms of CAPTCHAS including [1]:

- text-based CAPTCHAs,
- image-based CAPTCHAs,
- audio-based CAPTCHAs,
- motion-based CAPTCHAs,
- hybrid CAPTCHAs.

The most common scheme is text-based CAPTCHA. Here are tree, very widely used examples:

- Gimpy – CAPTCHA proposed by Yahoo, designed to pick up eight words from an English dictionary and aligns their distorted versions with each other.
  In order to entry the service, user are must type three randomly chosen examples out of the presented selection.
- ReCAPTCHA – this CAPTCHA contains a set of one of two images, which could be either a part of a real-life image (for example a newspaper), or automatically generated scheme.
  The main idea relies on the fact that characters visible on scanned images or photos are very difficult to be detected by an automated program.
- Google CAPTCHA – this solution was proposed by Google and shows a simple word, which could contain up to 19 letters, that is significantly distorted by sine function.

Letters are always in the same color. This CAPTCHA is very safe due to its skewness and easily readable by humans due to its simplicity.

Figure 1 presents examples two of the most common text-based CAPTCHA images. Gimpy (CAPTCHA used in Yahoo! chat rooms) relies on the fact that it is very challenging to write algorithm that could with great success detect a distorted overlapping words without providing too many false detections. This scheme however can be easily broken by human that can almost instantly recognizes and extract common words from an English dictionary. The second example, which presents Re-CAPTCHA designed by Google, takes slightly different approach. If forces user to type two sets of digits from slightly distorted images. Although this could be very easily solved by human user, two very diverse styles of generated CAPTCHA would force the malicious software to apply machine learning methods and increase the solving time.

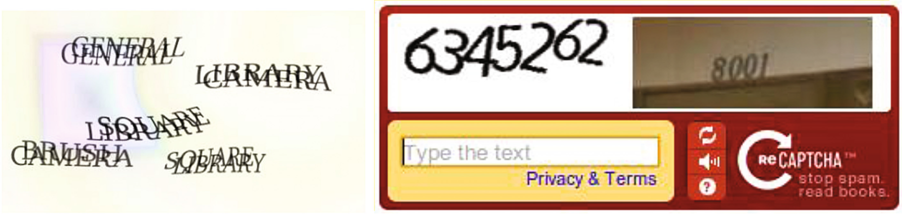

Fig. 1. Examples of Gimpy and Re-CAPTCHA.

4 Example of New Visual CAPTCHA

In this paper we propose a new CAPTCHA design method, dedicated to authentication procedures by using the aspects of cognitive processes like semantic meaning, context understanding and cognitive analysis [5–7]. The main idea behind the presented solution relies on the randomness of size, style and placement of CAPTCHA letters. Our goal was to design scheme that is resistant to various forms of attack. Because symbols can be detected based on skeletonization and recognition algorithms, it was important not only to distort their shape, but also to influence the core of letters to a degree, that would prevent program from extracting characteristic points as well as outline.

In this solution the main data is secured by different types of distortions, especially by a vertical and horizontal skewness. The vertical and horizontal distortion appears to be very successful in many CAPTCHAS. It is due to the fact that it forces the detection algorithm to first detect the change of shape, and then correctly align the skeleton of a symbols. In the presented algorithm, letters were first horizontally and vertically shifted (up to 45° angle) and then rotated to a random degree (between −45° and 45°). Examples of proposed distortions are presented in Figs. 2 and 3.

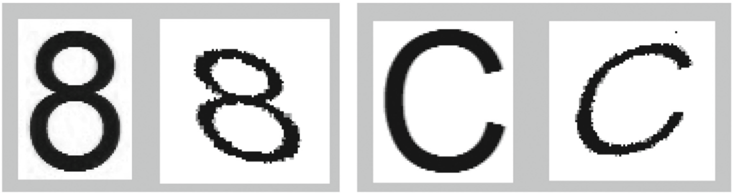

Fig. 2. Examples of vertical and horizontal distortion – number 8 and letter C.

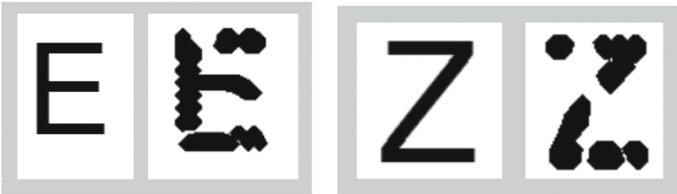

Fig. 3. Examples of distorted outline and thickness – letters E and Z.

Figure 4 presents the examples of vertical and horizontal distortion applied on a random symbols.

Fig. 4. Different types of distortions generated by CAPTCHA algorithm.

Example of visual CAPTCHA with proposed algorithm, is presented in Fig. 5.

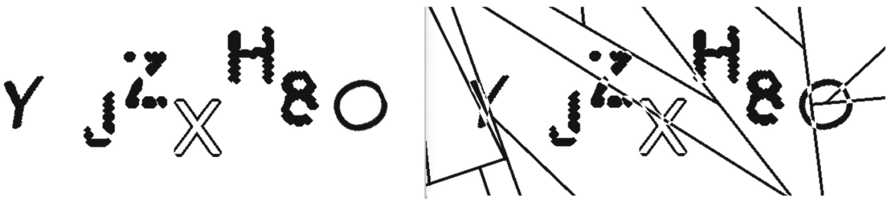

Fig. 5. Example of generated CAPTCHA with added noise.

Figure 5 presents the example of computed CAPTCHA, generated by our MATLAB algorithm. As input we used .jpg images of capital letters of English alphabet and as well as Arabic numerals, both written in Arial font. The first step in creating CAPTCHA image is to choose number of symbols which are going to be visible on a scheme. Because most CAPTCHAS consist of 7-letter words, the algorithm randomly computes a set of 5 to 10 letters and digits. In ‘for’ loop each symbol is then assigned its individual style, including size, shape, skewness and angle to which it will be rotated and then placed on the main scheme, with vertical and horizontal coordinates also randomly evaluated. Position of the following symbol depends on placement of a previous letter/ digit.

Due to the fact that generated text is very clear, additional noise should not decrease its readability.

Our proposition of CAPTCHAS can be used in following areas, and especially for:

- data security,
- verification procedures,
- authentication algorithms,
- cognitive analysis,
- data recognition processes,
- support data (secret) management [8].

Our proposition is very useful, because is independent of the users. Algorithm generate CAPTCHAS for different users, but don’t know them. Additionally, for each of them can generate different CAPTCHAS.

5 Conclusion

Secure data processes are very important and consist of many different solutions. The new directions of verification processes include data analysis, semantic meaning and recognition processes. This class of data security algorithms contains CAPTCHA protocols. The presented idea could be used in visual CAPTCHA applications to secure data/ information and enrich the authentication procedures for personal users. Our focus was centered around strengthening the defense against harmful, phishing software, dedicated to breaking CAPTCHAS.

Presented scheme could be considered easily readable, but its level of security depends on its strength against potential attacks. We believe that our CAPTCHA should withstand basic skeletonization, edge detection and recognition algorithms due to inconsistency in shape, thickness and outline of letters. Future work could be focused on applying different types of noise and adding more shape-changing algorithms.

Hence this is a text-based CAPTCHA, it is not suited for visually impaired users, however touch screen interface with tactile feedback [4] and zooming option can potentially increase its readability.

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Convergence Analysis of PSO for Hyper-Parameter Selection in Deep Neural Networks

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Abstract. Deep Neural Networks (DNNs) have gained enormous research attention since they consistently outperform other state-of-the-art methods in a plethora of machine learning tasks. However, their performance strongly depends on the DNN hyper-parameters which are commonly tuned by experienced practitioners. Recently, we introduced Particle Swarm Optimization (PSO) and parallel PSO techniques to automate this process. In this work, we theoretically and experimentally investigate the convergence capabilities of these algorithms. The experiments were performed for several DNN architectures (both gradually augmented and hand-crafted by a human) using two challenging multi-class benchmark datasets—MNIST and CIFAR-10.

Keywords: Convergence analysis · PSO · Hyper-parameter selection · DNNs

1 Introduction

DNNs have proved their ability to outperform most of state-of-the-art approaches and even human experts in many machine learning tasks [1]. Performance of such deep architectures is very dependent on the hyper-parameter values of these models. The hyper-parameters are often tuned by practitioners in a trial-and-error process which is infeasible in large search spaces. Therefore, automated selection approaches gained attention in the literature. They include techniques which do not utilize the information concerning the search space acquired during the execution, and those which build a surrogate model of the search space to exploit only its most-promising regions.

In [2,3], we proposed two PSO approaches (sequential and parallel) to optimize hyper-parameter values for any DNN. Although the experiments showed that our techniques remarkably outperform human experts in selecting appropriate hyper-parameters (the optimized models performed much better compared with state-of-the-art DNNs), we did not formally prove their convergence abilities.

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Interestingly, such proofs are commonly skipped in works from the evolutionary computation field. Here, we tackle this issue and investigate—both theoretically, using the Markov-chain theory, and experimentally—the convergence characteristics of our PSO methods.

1.1 Contribution

The contribution of this paper is two-fold:

– We theoretically analyze the convergence capabilities of our PSO for the hyper- parameter selection in DNNs. We have already applied this Markov-chain based approach for proving the convergence of genetic and memetic techniques [4]—here, we show that it can be easily tailored to other EAs.
– We experimentally investigate the PSO characteristics (number of processed swarm generations, convergence time and the size of the archive containing already-visited positions in the solution space) for two benchmark multi-class datasets: **MNIST** and **CIFAR-10**, and for various DNN architectures (also hand-crafted by a human). This analysis, together with our previous efforts [2, 3] give the full understanding of PSO applied to the hyper-parameter selection (executed on one and multiple GPUs).

1.2 Paper Structure

In Sect. 2, we review the literature on selection of DNN hyper-parameters. Our PSO is briefly presented in Sect. 3, whereas the theoretical analysis of its convergence capabilities is given in Sect. 4. The experiments are discussed in Sect. 5. Section 6 concludes the paper.

2 Related Literature

There exist two families of approaches aimed at automating the hyper-parameter selection in DNNs: *model-based* and *model-free* algorithms. In the former techniques, the surrogate model of the solution space is built to guide the search efficiently. In the Bayesian-regression models, the hyper-parameter selection is turned into the trade-off between the exploration of unknown regions of the hyper-parameter space, and exploitation of those parts which contain well-performing parameter values. The density function p of the validation error is estimated in Spearmint [5]—for a set of parameters, it becomes $p(f(\boldsymbol{\lambda})|\boldsymbol{\lambda})$, where $\boldsymbol{\lambda}$ are hyper-parameter values, and $f(\boldsymbol{\lambda})$ is the error over $\boldsymbol{V}$, using the history of observations $\mathcal{H} = (\boldsymbol{\lambda}, f(\boldsymbol{\lambda}))$. The downside of such approaches is their inference time which grows cubically with the number of observations. Other model-based hyper-parameter selection techniques encompass tree-structured Parzen estimators [6], covariance matrix adaptation evolution strategies [7], radial basis function surrogate models [8], and genetic algorithms [9]. In [2,3], we proposed PSO and parallel PSO for this task.

Model-free algorithms include grid and random searches (GS and RS) which often do not benefit from the historical information attained during the search. In GS [10], the underlying DNN is trained for all joint hyper-parameter combinations in the pre-defined ranges (commonly with the logarithmic step) is search of the best parameters. The computational burden induced by GS is mitigated in RS, where the hyper-parameter combinations are randomly sampled from the entire solution space. The RS process may be intensified in high-quality regions of the hyper-parameter space [11].

3 PSO for Hyper-Parameter Selection in DNNs

In PSO [2], the initial (random) population of s particles evolves in time (Algorithm 1, lines 1–16) in search of $\boldsymbol{\lambda}^D$ (the desired hyper-parameters), for which the fitness $f(\boldsymbol{\lambda}^D) \geq f(\boldsymbol{\lambda})$ for all $\boldsymbol{\lambda} \in \chi$, where χ is the set of all combinations in the solution space. Each *i-th* particle represents the combination of hyper-parameters $\boldsymbol{\lambda}_i \in \mathbb{R}^k$ ($\boldsymbol{\lambda}_i^*$ is the best known position of this particle, and $\boldsymbol{\lambda}^S$ is the best position visited by the swarm). This position is modified according to the particle velocity (line 4), which is affected by the parameters $\boldsymbol{r_p}$ and $\boldsymbol{r_g}$ (randomly sampled from a uniform distribution $\mathcal{U}(0,1)$ to diversify the search), alongside the inertia weight ω, and acceleration factors ϕ_p and ϕ_g. The fitness is the classification accuracy obtained for the validation set $\boldsymbol{V}$ (line 6). Since the fitness of the *i-th* particle is *independent* from the other individuals, the fitness evaluation is an inherently parallelizable operation (rendered in light red in Algorithm 1). It is the most computationally intensive part of PSO, because it encompasses training the DNN and classifying $\boldsymbol{V}$. In parallel PSO [3], the fitness evaluations are performed concurrently by the slaves (GPUs). Afterwards, the best position of each particle and the best swarm position are updated (lines 7–12). The evolution may be terminated if the (i) maximum time has elapsed, (ii) the hyper-parameters of the desired quality have been retrieved, (iii) they cannot be improved, or (iv) the maximum number of generations $G_{\max}$ have been processed.

Algorithm 1. PSO for the hyper-parameter selection in DNNs.

1: **while** termination condition is not met **do**
2:     **for** $i = 0, 1, \ldots, s$ **do** ▷ For all particles in the swarm
3:         $\boldsymbol{r_p}, \boldsymbol{r_g} \sim \mathcal{U}(0,1)$ ▷ Sample stochastic components of the velocity update
4:         Update velocity: $\boldsymbol{v}_i \leftarrow \omega \boldsymbol{v}_i + \phi_p \boldsymbol{r_p}(\boldsymbol{\lambda}_i^* - \boldsymbol{\lambda}_i) + \phi_g \boldsymbol{r_g}(\boldsymbol{\lambda}^S - \boldsymbol{\lambda}_i)$
5:         Update position: $\boldsymbol{\lambda}_i \leftarrow \boldsymbol{\lambda}_i + \boldsymbol{v}_i$
6:         Calculate fitness $f(\boldsymbol{\lambda}_i)$
7:         **if** $f(\boldsymbol{\lambda}_i) > f(\boldsymbol{\lambda}_i^*)$ **then**
8:             $\boldsymbol{\lambda}_i^* \leftarrow \boldsymbol{\lambda}_i$ ▷ Update best particle's position
9:             **if** $f(\boldsymbol{\lambda}_i^*) > f(\boldsymbol{\lambda}^S)$ **then**
10:                 $\boldsymbol{\lambda}^S \leftarrow \boldsymbol{\lambda}_i^*$ ▷ Update best position in the swarm
11:             **end if**
12:         **end if**
13:     **end for**
14:     Verify termination condition
15: **end while**
16: **return** $\boldsymbol{\lambda}^S$ ▷ Return best hyper-parameter values

4 Convergence Analysis of PSO

We exploit the Markov chain theory to prove the convergence of our PSO techniques for the hyper-parameter selection in DNNs [4]. For the sake of completeness, let us recall the following definitions:

- If the transition probability between two states $\mathcal{S}_i$ and $\mathcal{S}_j$, denoted as $p^{(\cdot)}_{(i,j)}$ is independent from time τ, thus $p^{(\tau_1)}_{(i,j)} = p^{(\tau_2)}_{(i,j)}$, for all states $\mathcal{S}_i$ $(i = 1, 2, \ldots, n)$ and times ($\tau_1 \neq \tau_2$, and $\tau_1, \tau_2 = 1, 2, \ldots$), then the corresponding Markov chain is homogeneous over the finite space of states $\mathcal{S}$. The non-homogeneous Markov chains are called time inhomogeneous.
- If for all possible pairs of states $(\mathcal{S}_i, \mathcal{S}_j)$, where $\mathcal{S}_i, \mathcal{S}_j \in \mathcal{S}$, there is a point in time τ for which $p^{(\tau)}_{(i,j)} > 0$, then the corresponding Markov chain is irreducible. In other words, a Markov chain is irreducible, if all its states communicate with each other (the state $\mathcal{S}_i$ communicates with the state $\mathcal{S}_j$, if they are accessible from one another, thus $\mathcal{S}_i \leftrightarrow \mathcal{S}_j$). If two states do not communicate (e.g., $\mathcal{S}_i \rightarrow \mathcal{S}_j$ but $\mathcal{S}_j \nrightarrow \mathcal{S}_i$), these states are transient.

The proposed PSO (both sequential and parallel) can be modeled as discrete-time Markov chains $\{X^{(\tau)}\}$ $(\tau = 0, 1, \ldots)$, with a finite number of n states $\mathcal{S} = \{\mathcal{S}_1, \mathcal{S}_2, \ldots, \mathcal{S}_n\}$. All the states are divided into two types: the states of globally (or Pareto) optimal solutions (hyper-parameter configurations) are referred to as *essential* states ($\mathcal{S}^e$), whereas the other are *inessential* (intermediate) ones ($\mathcal{S}^i$). The inessential states are visited during the optimization process which should finally lead to the essential state. The probability of reaching the state $\mathcal{S}_j$ from $\mathcal{S}_i$ $(i \neq j)$ is:

$$p^{(\tau)}_{(i,j)} = \Pr\left\{X^{(\tau)} = \mathcal{S}_j \middle| X^{(\tau-1)} = \mathcal{S}_i\right\}, \tag{1}$$

with some initial state probabilities:

$$\pi_i = \Pr\left\{X^{(0)} = \mathcal{S}_i\right\}, \tag{2}$$

where $\pi_i \geq 0$, and $\sum_{i=1}^{n} \pi_i = 1$.

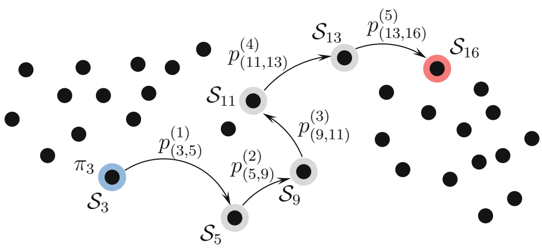

Fig. 1. Example state transitions in PSO. This figure is inspired by [4].

An example swarm evolution is rendered in Fig. 1. All states are shown as black dots, the initial state is annotated with light blue, the intermediate states are grayed, and the final state is shown in light red. Therefore, we have:

$$\mathcal{S}_3 \rightarrow \mathcal{S}_5 \rightarrow \mathcal{S}_9 \rightarrow \mathcal{S}_{11} \rightarrow \mathcal{S}_{13} \rightarrow \mathcal{S}_{16}, \tag{3}$$

where $\mathcal{S}_3$ is the initial state (with its initial probability π_3), $\mathcal{S}_{16}$ is the final state, and the other ones are the intermediate ones. Each transition is annotated with an arrow and the corresponding transition probability.

In PSO, the probabilities of reaching one state from another can be modeled as transition matrices of two operations: selection and updating the particle's position ($n \times n$ matrices, $\boldsymbol{S}$ and $\boldsymbol{U}$). A transition matrix becomes:

$$\boldsymbol{T} = \boldsymbol{S}\boldsymbol{U}, \tag{4}$$

since the particles are selected and their positions are updated. As mentioned in Sect. 3, all particles always survive, thus this operation is not dependent on time. On the other hand, updating the position of each particle in the swarm depends on the position of the best individual, and the velocity of each particle (both dynamically change during the optimization). Therefore, the transition matrices $\boldsymbol{T}$ are non-negative and dependent on time.

There is a non-zero probability that the selection and position update process do not change the individual's position, if the particle has already lost its momentum. However, once the optimal (or nearly-optimal) hyper-parameters have been found, the probability that this position in the solution space is captured is 1.0 (it is stored as the best position in the swarm). The best individual changes its position to explore the (unknown) neighborhood of already traced regions of the solution space. The swarm further evolves towards the essential states, and the probability of reaching the essential state in PSO is $\Pr\{\text{best visited position} \in \mathcal{S}^e\} = 1.0$ as $\tau \rightarrow \infty$ ($G_{\max} \rightarrow \infty$). □

5 Experiments

PSO (sequential and parallel) was implemented in Python with NumPy. The DNNs were trained using Keras[1] with a TensorFlow backend over CUDA 8.0 and CuDNN 5.1. The experiments were run on in two setups:

- **Setup A**: Computational cluster with Intel Xeon E5-2698 v3 (40M Cache, 2.30 GHz) with 128GB of RAM processors and NVIDIA Tesla K80 GPU 24GB DDR5 nodes. We used 1 or 6 nodes in this setup.
- **Setup B**: Workstation with Intel i7-6850K (15M Cache, 3.80 GHz) with 32 GB RAM and NVIDIA Titan X Ultimate Pascal GPU 12GB GDDR5X.

The PSO parameters remained constant for all experiments, and where experimentally set to $\omega = \phi_p = \phi_g = 0.5$ (search parameters). For all experiments,

[1] See: https://github.com/fchollet/keras; last access date: July 29, 2017.

we exploit 10-fold cross-validation (each experiment is run 10× with no fold overlaps), where $|\boldsymbol{T}| = 9\,|\boldsymbol{V}|$. The training set $\boldsymbol{T}$ is used for the DNN training, while $\boldsymbol{V}$ is exploited to find the fitness. The generalization performance is quantified as the accuracy over the unseen test set Ψ. The DNNs are trained for a maximum of 100 epochs using batches of size 128 (multi-class log loss is minimized). Finally, the ADAM optimizer steers the learning rate [12].

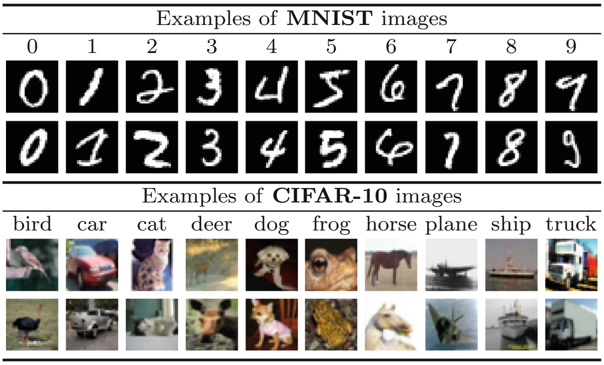

Fig. 2. Example **MNIST** and **CIFAR-10** images.

We used the **MNIST** and **CIFAR-10** datasets, for which we quantify the classification performance of the DNNs. MNIST is a dataset of handwritten digits (70,000 grayscale images, 28×28 pixels), whereas CIFAR-10 includes more challenging real-life color images (60,000 images, three channels, 32×32 pixels). Both sets are balanced, and they are divided into 10 classes (see examples in Fig. 2). We focus on the convergence capabilities of our PSO (for different DNNs)—more details on the performance of the PSO-optimized DNNs, and the comparisons with the state of the art can be found in [2,3].

5.1 Analysis and Discussion

In this section, we verify not only the convergence time of our algorithms for hand-crafted and existent architectures (LeNet-4 [13], LN-4), but also the number of generations processed before reaching convergence alongside the number of visited points in the search space (they are cached in the *archive* during the execution). Also, we present the classification scores of the optimized DNNs and briefly compare it with the state of the art.

5.1.1 Optimizing DNNs for MNIST

In this experiment, we investigated the convergence of PSO and parallel PSO executed in **setup A** to optimize our DNN (SimpleNet, SN) together with the state-of-the-art LeNet-4 architecture (much deeper than all of the SN variants) on MNIST.

An example network is presented in Fig. 3—it consists either of a number of *blocks* (convolutional and max pooling layers), or a single block preceded by convolutions, terminated with the Softmax activation. The SN networks are named as SimpleNet-`Blocks#[(Convolutions#)]`. The hyper-parameters for each layer are gathered in Table 1.

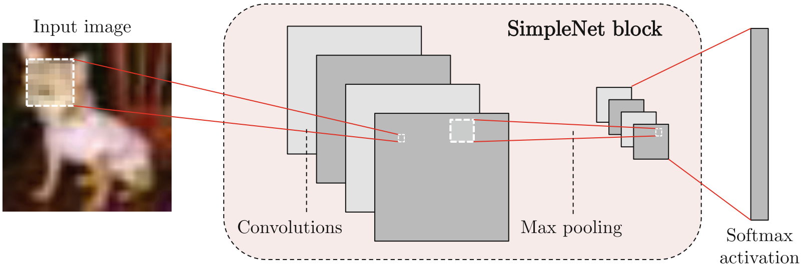

Fig. 3. Experimental SimpleNet-1 network applied to an example CIFAR-10 image.

Table 1. Parameters of the layers in the SimpleNet building block.

Layer type	Parameter	Values
Convolutional (C)	Receptive field size ($s_F \times s_F$)	$s_F \geq 2$
	Number of receptive fields (n)	$n \geq 1$
Max pooling (P)	Stride size (ℓ)	$\ell \geq 2$
	Receptive field size (s_P)	$s_P \geq 2$

Here, we investigated various swarm sizes: $s = \{4, 6, 10, 16\}$ for SimpleNet-1 (PSO for $s = \{4, 10, 16\}$ was executed in the dual-mode GPU setup with the early termination condition as shown in [2], whereas for $s = 6$ on 1 and 6 GPUs with no early stopping, and $G_{\max} = 100$). For LeNet-4, we ran two experiments: the parallel PSO was executed on 6 GPUs and $s = 6$ particles ($G_{\max} = 100$), and PSO run using a single GPU processed $s = 5$ particles.

In Fig. 4, we present the number of visited positions during the swarm evolution (*archive size*) and the convergence time (in seconds), being the time after which the best hyper-parameters could not be further improved (a part of the plot is zoomed for clarity). Increasing the number of particles in the swarm for the dual-GPU setup causes a consistent increase in both archive size and the convergence time—more hyper-parameter configurations are evaluated. For a very small swarm ($s = 4$), the search converges quickly for all folds. This convergence time grows for larger s (some particles still have momentum and it can lead to better hyper-parameters). However, the gain in the classification accuracy is not significant (Table 2). Although the speedup is far from being linear for 6 GPUs compared with 1 GPU for SimpleNet-1 (for $s = 6$ particles the speedup is $\mathcal{S} = 3.69$),

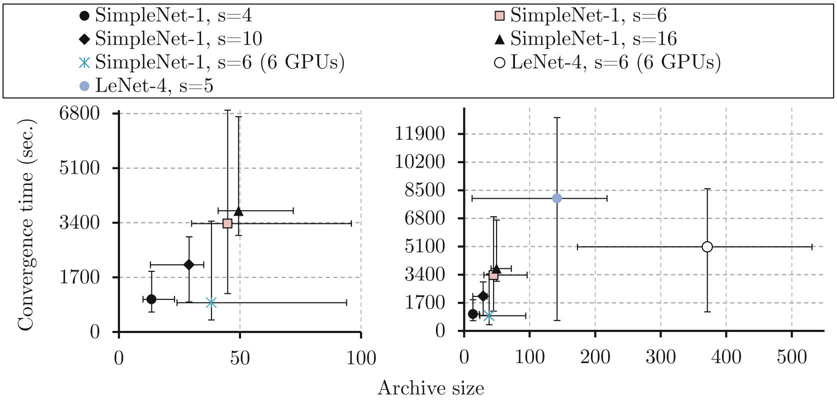

Fig. 4. The number of positions in the solution space visited during the evolution (archive size) vs. the convergence time (in sec.) for MNIST (the left part of this plot is zoomed for clarity). The vertical and horizontal bars show the minimum and the maximum values.

the convergence time significantly drops for the parallel PSO (interestingly, the number of visited positions is similar). This non-linear speedup can be attributed to the presence of the archive during the search—in relatively small search spaces the optimization converges to the final solution quickly and adding more GPUs does not decrease the execution time notably. Theoretically, the convergence of a parallel PSO could be derived from a sequential PSO (the size of the search space remains the same for both configurations). However, the number of visited positions may slightly differ (see e.g., Fig. 4 for SimpleNet-1, $s = 6$ for 1 and 6 GPUs) due to random swarm initializations.

The number of processed swarm generations for MNIST is visualized in Fig. 5. This number drastically drops for PSO with $s = 16$ particles for SimpleNet-1 (com-

Table 2. Classification error for MNIST (the PSO-optimized DNNs are boldfaced).

Classifier	Error rate (%)
SimpleNet-1, s = 4 [2]	**1.13**
SimpleNet-1, s = 6 [3]	**1.12**
SimpleNet-1, s = 10 [2]	**1.12**
LeNet-4 [13]	1.1
SimpleNet-1, s = 16 [2]	**1.08**
Boosted LeNet-4 [13]	0.7
LeNet-4 with PSO [2]	**0.66**
LeNet-4 with Parallel PSO [3]	**0.55**
MultiColumn DNN [14]	0.23

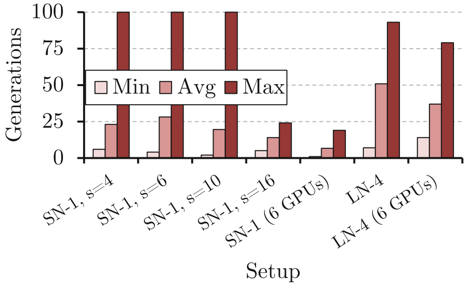

Fig. 5. Minimum, average and maximum numbers of generations processed before reaching convergence for the MNIST dataset.

pared to e.g., the same DNN architecture optimized using $s = 10$ particles). It indicates that the computation burden induced by appending new particles to the swarm is very significant (clearly, more models must be trained during the optimization), but the generalization performance of the final DNN is only slightly improved (the error rate dropped from 1.12 to 1.08, and this difference is not statistically important at $p = 0.05$ using Wilcoxon test [2]). Hence, smaller swarms should be preferred in practice.

5.1.2 Optimizing DNNs for CIFAR-10

In this experiment, we investigated the convergence of PSO and parallel PSO executed in **setup B** to optimize SimpleNet-based architectures for CIFAR-10. The convergence time alongside the size of archives are rendered in Fig. 6. Similarly to MNIST, increasing the swarm size causes a notable increase in the convergence time of PSO. Interestingly, prepending additional convolutional layers in SimpleNet does not affect this time very significantly (more convolutions allow for extracting more low-level features in the shallow part of the network—it becomes a key point for improving the overall performance, as presented in Table 3). As in the case of MNIST, the scores are not statistically different for various swarms ($p = 0.05$, Wilcoxon test). However, augmenting the DNNs helps boost the generalization significantly [2]. Although our optimized models were not of the state-of-the-art quality (see e.g., Fractional MaxPooling in Table 3), they contained notably less layers (they are faster to train) and were not hand-crafted by a human specifically to this dataset. It clearly shows that gradually augmented DNN architectures can be optimized using PSO (with proved convergence capabilities, see Sect. 4) even for very challenging multi-class sets in affordable time.

In Fig. 7, we visualize the number of generations executed before reaching convergence for CIFAR-10 (since the number of hyper-parameters affects the size of the solution space, it also affects the number of generations). Prepending two convolutional layers to SimpleNet allowed not only for obtaining higher quality classification but also for decreasing the average number of processed generations (the archive sizes were approximately the same for both setups, see Fig. 6). Additionally, the minimum number of generations was much smaller for all augmented

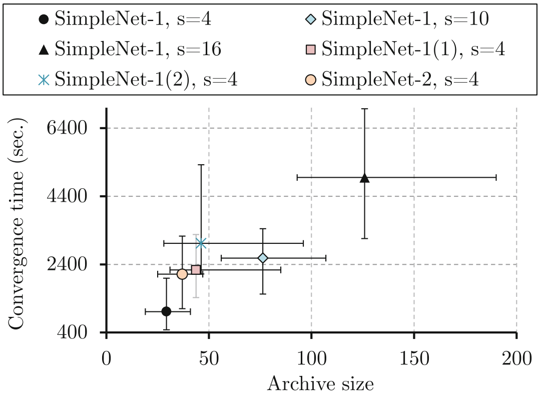

Fig. 6. The number of positions in the solution space visited during the evolution (archive size) vs. the convergence time (in sec.) for CIFAR-10. The vertical and horizontal bars show the minimum and the maximum values.

Table 3. Classification error for CIFAR-10 (the PSO-optimized DNNs are boldfaced).

Classifier	Error rate (%)
SimpleNet-1, $s = 4$ [2]	**48.94**
SimpleNet-1, $s = 10$ [2]	**46.40**
SimpleNet-2, $s = 4$ [2]	**44.89**
SimpleNet-1, $s = 16$ [2]	**44.92**
SimpleNet-1(1), $s = 4$ [2]	**42.48**
SimpleNet-1(2), $s = 4$ [2]	**41.53**
Fractional MaxPooling [15]	3.47

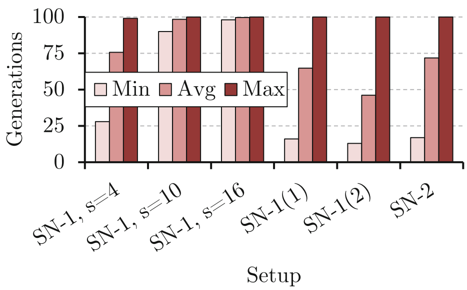

Fig. 7. Minimum, average and maximum numbers of generations processed before reaching convergence for the CIFAR-10 dataset.

architectures compared with SimpleNet-1. Although it may be a good indicator that the search finished prematurely (particles lost their momentum in less than 25 generations), perhaps in a local minimum of the search space, it requires further investigation.

6 Conclusions

In this paper, we analyzed and proved—both theoretically, using the Markov-chain theory, and experimentally—the convergence capabilities of our sequential and parallel PSO for optimizing hyper-parameters in DNNs. We investigated the convergence time, number of processed generations and number of visited points in the search space (which is dependent upon the number of DNN hyper-parameters) before reaching convergence for two well-known multi-class datasets. The reasoning that we applied for proving the convergence abilities of PSO can be easily tailored to any other evolutionary techniques for different optimization problems. Finally, it can be used to verify how far the obtained solution is from the optimal one (for problems for which the optimal solution is known).

Our current works are focused on developing a comprehensive evolutionary algorithm for optimizing not only the DNN hyper-parameters but also the underlying architecture itself. It will make them much easier applicable in emerging real-life scenarios (e.g., in the medical-imaging field). Finally, it will be interesting to incorporate the convergence analysis scheme into evolutionary algorithms to trace their convergence abilities at runtime.

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Embedding Strategies in Multi-secret Steganography

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Abstract. This paper discusses the different embedding strategies in multi-secret steganography. Each secret is related to one selected embedding procedure, which may depend or not on personal features or characteristics. Such multi-way embedding approach allows to reveal secrets independently of each other. Presented idea may be used in single-user system in which one person stores a number of secrets or in multi-user cloud or fog computing systems.

Keywords: Multi-secret steganography · Cryptographic protocols · Information hiding

1 Introduction

Nowadays hiding steganographic data in a carrier is a challenging task because of still evolving methods of steganalysis. We can hardly find an algorithm with high level of undetectability, which is practical in daily use. Hence new solutions are being sought in this field.

This paper describes a few strategies of multiple secrets hiding into one container. They are based on idea of multi-secret steganography [1], which is described in Sect. 2. In Sect. 3 there are presented three approaches to this problem with some possible applications.

2 Multi-secret Steganography

Multi-secret steganography is a branch of steganography which main objective is to create additional invisible, and secure communication channels. It is realized by hiding many secrets in a single container. This task may be accomplished with use of various steganographic methods, but also with assumption that all messages are needed to be reconstruct unambiguously and in lossless way, in other words one information cannot be overwritten by another.

Each secret may be associated with individual steganographic key, which is used in embedding and extracting algorithms. These two methods constitute multi-secret steganographic system, as shown in Fig. 1. The embedding algorithm takes as input a container, set of secrets and corresponding keys; then generates object (e.g. digital

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image) with hidden secrets on its output. This carrier together with matching key is thereafter transmitted to extracting algorithm, which on its base decodes the secret message. To reveal specific information, one should use appropriate key, which is presented in Fig. 1 as flows in different colors.

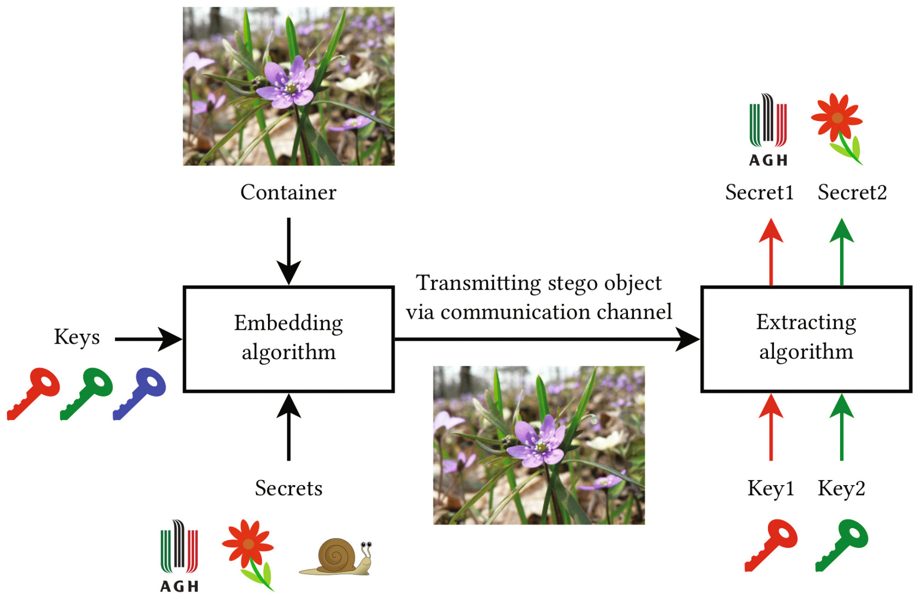

Fig. 1. Multi-secret steganography scheme.

The idea of multi-secret steganography was also described in more detailed way in [1].

3 Multiply Secrets Embedding Strategies

We can distinguish a few approaches to multiply secrets embedding in single carrier. The messages may be placed totally independently of one another, for example in separate parts or areas of the container. The alternate technique is to locate the secrets in the same region, but in non-collision manner. Finally, the messages can be embedded one within another and then hidden in the next container. All these strategies are illustrated in Fig. 2.

Independent embedding is suitable for carriers with separated sections, like files consisted of header and data part. The appropriate containers for this approach are JPEG images, network packets or Word documents. Each information may be embedded in different location, so the collision problem is eliminated. On the other hand, the number of secrets that can be hidden with this method is dependent on medium type and often limited to two or three. As a few examples we can list: JPEG header + coefficient modification (JSteg, JPHide [2], F5 [3], OutGuess [4]); Word file macro + unused space

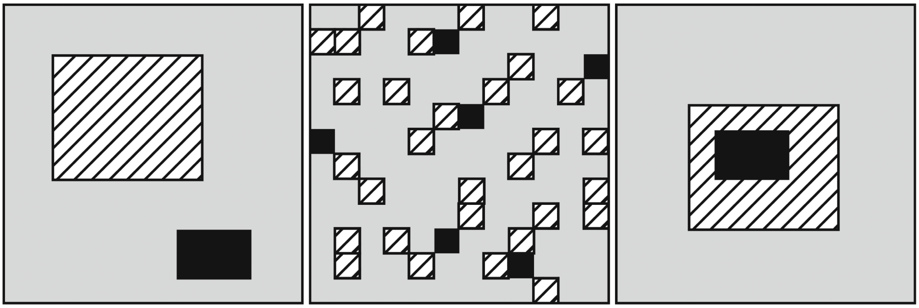

Fig. 2. Multiply secrets embedding strategies. Left: independently (different secrets in different areas); middle: interlacing (different secrets in the same parts of container); right: multi-level (one secret in another one as container etc.).

[5]; different layers of LSB embedding [6]; header of network package + data part [7, 8]; combination of image + audio steganography in video files [9]; choosing compression algorithm in OOXML file + zero-size image [10] or various fields of network package [11, 12].

If all messages are hidden in a single location, a few issues should be considered. First of all, the sum of lengths of all secrets should be less or equal to carrier capacity. If this condition is not met, the messages cannot fit into the container. In this case some messages have to be removed or another carrier has to be chosen. The second problem is secrets placement in the container. They should be located more or less randomly and also one cannot collide with any other. To deal with this issue, it is convenient to use steganographic keys [13, 14]. They prevent overwriting and scatter the messages all over the available space. The benefit of this approach is that it can be applied to any carrier and theoretically unlimited number of messages (if container capacity is sufficient).

The last possibility is to treat a container with hidden message as next secret and embed in into another carrier. This approach is called multi-level steganography and does differ significantly from remaining two. In this case, to recover a secret, it is necessary first to decode all secrets from lower levels. For example on the right side of Fig. 2 to read inner message (black filled), an access to middle message (striped) is required. The latter may be reveal only with outer container (lightgray). On the other hand, it is impossible directly to get inner secret without decoding the middle one. This property is a big advantage from security point of view. The main flaw of this method is the rapid growth of required capacity. It turns out that to add next level, another container is needed and its capacity should be able to accommodate the previous secret. Given that the majority of steganographic algorithms has maximum capacity which not exceeds twenty percent, it is clear that multi-level approach is convenient for short messages, but later is less practical.

All the presented ways of embedding several secrets in one container may be used in practical applications. All of them have some advantages and limitations, which also should be considered during selection of final solutions.

4 Conclusions

This paper presents a number of approaches to multiply secrets hiding in one cover, including independent embedding, interlacing and multi-level steganography. In conclusion, it should be pointed out that presented methods may be combined and used in various configurations depending of the needs. In this way it is possible to create new steganographic systems, which are able to secure messages in diverse ways. This property opens new possibilities in information protection, especially when one secret is much more important than others, or when we would like to intentionally facilitate to reveal not important artificial secret, protecting in stronger manner the other ones.

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Query Expansion Based on WordNet and Word2vec for Italian Question Answering Systems

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Abstract. Recently, Question Answering (QA) systems have emerged as efficient solutions for helping users find proper answers to questions pertaining to a specific situation. One of the major modern paradigms for QA is based on Information Retrieval (IR) techniques, where the text of a user question is evaluated in order to extract a collection of relevant keywords, formulate queries on the top of them for a search engine and extract candidate answers from documents matching with the queries. Nevertheless, in the case of semantically complex and rich languages, like Italian, many concepts can be expressed in a variety of distinct linguistic forms. This problem particularly arises when QA is applied to smaller sets of documents pertaining to a closed domain, where an answer might appear only once, and its exact wording might differ partially or completely from the one used in the query. To solve this issue, this paper proposes a hybrid approach of Query Expansion (QE) where lexical resources and word embeddings (WEs) are combined to generate synonyms and hypernyms of relevant words extracted from the user question and contextualize this set with respect to the corpus of interest and with respect to the peculiar question. An experimental session has been arranged in order to compare the proposed QE approach with other different techniques and evaluate its impact of with respect to the accuracy of a QA system in extracting proper answers to factoid questions from documents pertaining to the Cultural Heritage domain. The experiments showed the effectiveness of the proposed solution with respect to three different evaluation metrics typically used in literature.

1 Introduction

In the last few years, Question Answering (QA) systems have become very popular in helping users find proper answers to questions pertaining to a specific situation, mainly thanks to their use in personal digital assistants such as Siri, Google Assistant, Alexa, and Cortana. Typically, QAs aim at finding the suitable answers to natural language questions submitted by the user, in both non-structured and structured Knowledge Bases (KBs).

Most current QAs focus on factoid questions that can be answered by single or multiple facts in a KB, i.e. short strings expressing a person name, a temporal expression,

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or a location. To this aim, one of the major modern paradigms for factoid QA is based on Information Retrieval (IR) techniques, where the text of a user question is evaluated in order to extract a collection of relevant keywords, determine the likely Lexical Answer Type (LAT) (e.g. a date, a location, or a person), and formulate queries by exploiting them for a search engine. In detail, query formulation in these systems is typically performed by transforming each unstructured question into a query specifying both the estimated LAT and the relevant keywords contained in the question and, then, the query is submitted to a search engine able to extract candidate answers from unstructured KBs, compatible with the LAT and matching with the keywords. Thus, as more the unstructured questions are formulated by using terms expressed in the same form of the sentences in the corpora, as more likely candidate answers are correct.

Nevertheless, in the case of semantically complex and rich languages, like Italian, many concepts can be expressed in a variety of distinct linguistic forms [1]. As an example, considering the Italian question "*Chi affrescò la volta della Cappella Sistina?*", (in English, *"Who frescoed the vault of the Sistine Chapel?"*), and assuming to extract the answer from the Italian sentence *"Il soffitto della Cappella Sistina, dipinto da Michelangelo tra il 1508 e il 1512, è una pietra angolare dell'arte dell'alto Rinascimento"*, (in English,*"The Sistine Chapel ceiling, painted by Michelangelo between 1508 and 1512, is a cornerstone of high Renaissance art"*), they contain two concepts, namely *frescoed* and *vault*, appearing in two other distinct linguistic forms, *painted* and *ceiling*, respectively, but having the same meaning.

This problem particularly arises when QA is applied to smaller sets of documents pertaining to a closed domain. Indeed, in open-domain QA systems, the availability of many corpora of documents augments the likelihood of finding an answer written by using terms expressed in the same form of the ones extracted from the user question to formulate the query for the search engine.

On the contrary, in closed-domain QA systems applied to smaller sets of documents, an answer might appear only once, and its exact wording might differ partially or completely from the one used in the query. To solve this problem, in the past, a variety of *Query Expansion* (QE) approaches has been successfully applied, by using several data sources and employing a plethora of automatic methods. Their goal has been to expand user queries with additional terms and, thus, increase the likelihood of matching the particular form of the answers as they appear [2, 3]. However, the proper selection of the expansion terms is still an open challenge and it demands ad-hoc methods and/or frameworks able to evaluate the semantic similarity of words, so as to assess how much two terms are related between them. Many approaches [4–6] exploit linguistic and domain specific resources, i.e. KBs or thesauruses, to evaluate the lexical-semantic relations of relevant words extracted from the user's question and, accordingly, generate their synonym and hypernyms to expand user queries. However, the use of linguistic resources has not substantially improved the IR performance [7], since they typically provide a linguistic but general knowledge, which fails to capture the specific knowledge characterizing the domain of application.

On the contrary, other approaches, like semantic vectors [8, 9] and neural probabilistic language models [10], do not lay on linguistic knowledge about the user natural language. Indeed, they propose to capture the similarity between linguistic terms by evaluating the content of the corpus and, then, measuring either the correlation between each pair of terms by co-occurrence [11] or mutual information [12], or assessing the cosine or the distance between vectors representing the terms in a high dimensional semantic space [8, 9]. These approaches are mainly based on the idea that words appearing in the same context share also the same semantic meaning, thus they consider words to be as similar as they appear in the same documents or paragraphs. However, these approaches may produce misleading results when applied to estimate synonyms of linguistic terms, since they can assume the same meaning also for unrelated words, antonyms or words with different part-of-speech tags, based on their similar occurrence within the documents of interest.

Starting from these considerations, this paper proposes a hybrid strategy of QE based on *lexical resources* and *word embeddings* (WEs) for Italian factoid QA systems, where (i) *lexical resources* are used to generate a set of synonyms and hypernyms of relevant words (such as *nouns, adjectives* and *verbs*) extracted from the user question, (ii) this set is contextualized by selecting only the ones contained in the corpus of interest, (iii) it is further filtered and ranked by employing a semantic similarity metric, defined on the basis of a WE model trained on an extended corpus belonging to the same domain of the corpus of interest. Moreover, a case study is presented and discussed, in order to experimentally evaluate the retrieval effectiveness of the proposed QE approach in Italian QA systems.

In the following, Sect. 2 introduces related work. Section 3 describes the proposed QE approach, whereas its experimental evaluation with respect to the case study is detailed in Sect. 4. Finally, Sect. 5 concludes the work.

2 Related Work

In the past, several approaches have been proposed for increasing the success rate of the query process in IR, by improving the indexing and matching phases [13–15]. In this context, existing QE approaches aim at expanding the queries to improve the efficiency of the retrieval, and they can be classified according to the global or local analysis used to evaluate the documents in the corpus being searched for [16]. *Local Analysis* expands queries using the documents that are related to them, like top-retrieved documents. *Global Analysis* makes uses of external resources or document collections in order to evaluate word occurrences and relationships in the corpus as a whole, and use this information to expand user queries.

QE via *Pseudo-Relevance Feedback (PRF)* is a common *Local Analysis* technique to improve retrieval effectiveness in many models [17, 18]. PRF is based on the use of contextual words to expand the query, and it works in two phases: the former proposes to send the user question to the IR engine; the latter expands the query terms by using a subset of the terms extracted from the IR results. In [19, 20] expansion terms are obtained by an equi-frequency partition of the documents coming from pseudo relevance feedback and by using tf-idf scores. PRF models have proven to be particularly effective in improving the retrieval performance, but they typically fail to evaluate the semantic similarity between feedback terms and the query to expand [21].

With respect to *Global Analysis* techniques, [4–6] exploit linguistic resources, such as WordNet, to evaluate the lexical-semantic relations of words. In detail, *WordNet* is not only a lexical database for the English language, but it is a lexical reference system whose design is inspired by contemporary psycho-linguistic theories on human lexical memory. The terms, indeed, are not arranged in alphabetical order, but by the affinity of meaning. It groups nouns, verbs, adjectives and adverbs into synsets, sets of synonyms, each expressing a distinct concept, and are interconnected with semantic and lexical relations to other synsets. Each synset is associated with a single meaning, shared by all the terms contained in it. However, the use of linguistic resources has not substantially improved the IR performance [7], since they typically provide a linguistic but general knowledge which fails to capture the specific knowledge characterizing the domain of application.

Moreover, some other QE approaches apply a data-driven *Global Analysis* to analyse the content of the whole corpus in order to measure the correlation between each pair of terms by co-occurrence [11], mutual information [12], cosine or distance between vectors representing the terms in a high dimensional semantic space [8, 9], and so on. These approaches determine the expanding terms by finding the words in the corpus with the highest correlation value with respect to the user query terms. In detail, QE *vector-based* approaches use a corpus to create a mathematical representation of terms and sentences in order to obtain a high dimensional vector space where words and sentences similarity is calculated as a distance among vectors (*cosine, euclidean,…)*, where the *cosine* similarity metric is typically chosen as the most suitable one, especially in case of Italian Natural Language text, as shown in [13]. This *vector-based* representation of words is typically called *WEs*.

Recently, the availability of large corpora has facilitated the creation of applications based on WEs and they have become a promising source for QE [8–10], since they generate expanded terms from billions of words, in contrast to others approaches, like PRF, that extract terms from the more relevant documents. In detail, *Word2vec* [22] uses a large amount of text to build WEs able to capture words relationships without external annotations. *Word2vec* is available in two variants: (i) *Continuous Bag-of-Words* model (CBOW); (ii) *Skip-Gram* model. In particular, the first one predicts target words from source context words, while the second one uses a dual approach, predicting source context words from the target ones. Statistically, CBOW is better for a dataset with short sentences with a high number of samples, whereas Skip-Gram is better for a dataset with long sentences and a low number of samples.

QE approaches based on WEs have showed to improve the average retrieval performance, but they often result unstable across queries [3, 23]. Moreover, WEs may produce misleading results when applied to estimate synonymous of linguistic terms, since they can assume the same meaning also for unrelated words or antonyms, based on their occurrence within the documents of interest. In fact, on the one hand, WEs do not generate real synonyms, but just words whose corresponding vectors result "*close*" in the vector space. As an example, the word "construct" is often close in the vector space to the word "destroy" since both words often occur in the same context of usage. On the other hand, words resulting relatively close in the vector space, may present completely different morpho-syntactic categories, such as "construct" and "construction", which are a noun and a verb, respectively. Summarizing, to the best of our knowledge, none of the existing approaches have investigated the use of a hybrid strategy for QE based on both lexical resources and WEs, with the goal of overcoming the limits of the single techniques. In the next section, the details of the proposed approach are widely presented.

3 The Proposed Hybrid QE Approach

The proposed QE solution is devised to operate in a typical QA pipeline, after a set of relevant keywords is extracted from the user question, by intervening in the query formulation for a IR engine [24]. Its goal is, on the one hand, to efficiently expand the number of relevant words specified within the queries, through the generation of their synonyms and hypernyms, so to increase the likelihood of the query to match the particular form of the answers in the domain corpus. On the other hand, it is also aimed at limiting the number of introduced words, by selecting only the ones being relevant to the user question, so as to reduce noise produced by the unrelated ones. It essentially consists of the following phases:

- *generation phase*, where *lexical resources* are used to determine candidate expanding terms on the basis of relevant words extracted from the user question;
- *contextualization phase,* where candidate synonymous and hypernyms are contextualized with respect to the corpus of interest;
- *ranking and filtering phase*, where WEs are used to rank and filter candidate synonymous and hypernyms on the basis of their semantic similarity to the user question.

The *generation phase* starts after the extraction of keywords, and, in particular, nouns, verbs and adjectives from the user question. In this phase, *Wordnet* is used to generate a set of synonyms and hypernyms for each relevant word extracted from the user question [25]. More formally, denoted with **N** the set of natural numbers, with **W** the set of words contained in the language of interest **L**, with **Q** the set of questions existing in **L**, and with $\mathbf{K}_q$ the set of relevant keywords extracted from the question, the *generation phase* evaluates the tuples

$$(t_1, t_2, \ldots, t_n) \mid \mathrm{t_i} \in \mathbf{K}_\mathrm{q} \subseteq \mathbf{W} \wedge 1 \leq \mathrm{i} \leq \mathrm{n} \wedge \mathrm{i},\ \mathrm{n} \in \mathbf{N}.$$

in order to compute, for each term t_i, the list $sh(t_i) = (sh_{t1}, sh_{t2}, \ldots, sh_{tm})$, where sh_{ti} are the synonyms and hypernyms produced by *WordNet* for t_i, with $m \in \mathbf{N}$. Note that, synonyms and hypernyms are collected in a unique list, without imposing distinct weights to their different semantic relations with t_i.

Then, the *contextualization phase* evaluates the lists $sh(t_1), sh(t_2), \ldots, sh(t_n)$ in order to discard synonyms and hypernyms that are irrelevant and useless for the QA. To this aim, the proposed approach applies a key strategy where *global analysis* techniques and local resources are properly combined in order to preserve, for the query formulation, only linguistic terms appearing in the corpus of interest. In detail, the corpus of interest is evaluated, only once in a preprocessing phase, in order to determine domain nouns, verbs and adjectives. As a consequence, in order to not insert in the query linguistic terms not appearing in the domain sentences, the terms $sh(t_i)$ are filtered by selecting only the ones contained within the corpus of interest. More formally, denoted with $\mathbf{C}$ the set of domain documents, and with $\mathbf{K_C}$ the set of relevant domain nouns, verbs and adjectives extracted from $\mathbf{C}$, the *contextualization phase* evaluates each list $sh(t_i)$ in order to determine the *contextualized* form of the list

$$sh'(t_i) = (c_1, c_2, ..c_k) \mid sh'(t_i) = sh(t_i) \cap \mathbf{K_C} \wedge \mathrm{k} \in \mathbf{N}$$

Finally, the *ranking and filtering phase* evaluates the lists $sh'(t_i)$ in order to select, for each list, the most relevant synonyms and hypernyms among the candidate ones, by choosing the most appropriate subset for replacing the term t_i in the user question. To this aim, a WE model has been trained on an extended corpus belonging to the same domain of the corpus of interest and, then, a similarity function has been defined on it in order to estimate the semantic similarity of candidate synonyms and hypernyms to the user question.

The idea here proposed is to use WEs to validate the candidate synonyms and hypernyms generated by *WordNet*, by evaluating their similarity in a semantic vector space. In detail, denoted with $\mathbf{R}$ the set of real numbers, the trained WE model provides a function f_{w2v}:$\mathbf{W} \rightarrow \mathbf{R}^n$ able to associate at every word $w \in \mathbf{W}$ a real vector of arbitrary dimensionality. In this vector space, denoted with ss_{w2v}:$\mathbf{W}^2 \rightarrow [0, 1]$ a semantic similarity function between words, $ss_{w2v}(\mathrm{w}_1 \in \mathbf{W}, \mathrm{w}_2 \in \mathbf{W})$, and denoted with cos_{w2v}:$\mathbf{R}^n \mathrm{x} \mathbf{R}^n \rightarrow [-1, 1]$ the cosine similarity function of vectors computed by *Word2vec*, the function ss_{w2v} is typically defined on the basis of the cosine similarity of their vector representations, i.e.

$$ss_{w2v}(\mathrm{w}_1 \in \mathbf{W},\ \mathrm{w}_2 \in \mathbf{W}) = \left| \cos_{\mathrm{w2v}}\left(f_{w2v}(\mathrm{w}_1), f_{w2v}(\mathrm{w}_2)\right) \right|$$

In accordance with the cosine similarity definition, two vectors $x \in \mathbf{R}^n$ and $y \in \mathbf{R}^n$ are cosine similar if they point in the same direction, and the angle describes a measure of diversity from each other. Cosine, therefore, represents similarity in geometric terms, measuring their proximity in the space. Angle cosine tells us that if the vectors are orthogonal, they are the most dissimilar, if they are parallel, they are the most similar.

Starting from the function $\mathrm{ss_{w2v}}$ and given a set of linguistic terms $\mathrm{t_i} \in \mathbf{K}_\mathrm{q}$ extracted from the user question, the similarity function has been defined based on the idea of determining the most relevant synonyms and hypernyms $c \in sh'(t_i)$, by selecting the ones maximizing the average of semantic similarity among them and the relevant words $\mathrm{w} \in \{\mathbf{K}_\mathrm{q} - \mathrm{t_i}\}$. More formally, denoted with shq_{w2v}:$(\mathrm{w}_1 \in \mathbf{W}, \mathrm{w}_2 \in \mathbf{W}, \mathrm{q} \in \mathbf{Q}) \rightarrow [0, 1]$ a semantic similarity function able to estimate the adequacy of a word $\mathrm{w}_1 \in \mathbf{W}$ in the substitution of a word $\mathrm{w}_2 \in \mathbf{W}$ in the user question q, the function shq_{w2v} has been defined on the basis of the function $\mathrm{ss_{w2v}}$, as follows:

$$shq_{w2v}(\mathrm{w}_1, \mathrm{w}_2, \mathrm{q}) = \begin{cases} \dfrac{1}{card\{\mathbf{K}_q - \mathrm{w}_2\}} \displaystyle\sum_{t \in \{\mathbf{K}_q - \mathrm{w}_2\}} \left[ss_{w2v}(\mathrm{w}_1, \mathrm{t})\right] & \textit{if } \mathrm{w}_1 \in sh'(\mathrm{w}_2) \wedge \mathrm{w}_2 \in \mathbf{K}_\mathrm{q} \wedge \mathrm{q} \in \mathbf{Q} \\ 0 & \textit{otherwise} \end{cases}$$

The *ranking and filtering phase* ranks the elements of each list $sh'\left(t_i\right)$, and selects the first $\beta \in \mathbf{N}$ elements maximizing the function shq_{w2v}. In detail, denoted with

$$\begin{aligned} &\beta.\underset{\mathrm{x}\in\mathrm{W}}{\operatorname{argmax}} f(\mathrm{x},\mathrm{y},\mathrm{z}) = \left(x_1, x_2, \ldots, x_\beta\right) \mid \\ &\quad f(x_1,\mathrm{y},\mathrm{z}) = \max_{x\in W} f(x,\mathrm{y},\mathrm{z}) \wedge f(x_2,\mathrm{y},\mathrm{z}) = \max_{x\in\left\{W-x_1\right\}} f(x,\mathrm{y},\mathrm{z}) \wedge \ldots \\ &\quad \ldots \wedge f(x_\beta,\mathrm{y},\mathrm{z}) = \max_{x\in\left\{W-x_1-x_2-\ldots-x_{\beta-1}\right\}} f(x,\mathrm{y},\mathrm{z}) \end{aligned}$$

the *ranking and filtering phase*, for each list $sh'\left(t_i\right)$, composes the filtered list

$$\beta.sh'\left(t_i\right) = \beta.\underset{\mathrm{w}\in sh'\left(\mathrm{t}_i\right)}{\operatorname{argmax}} \left[shq_{w2v}\left(\mathrm{w},\mathrm{t}_i,\mathrm{q}\right)\right]$$

The proper value of $\beta \in \mathbf{N}$ can be experimentally determined by selecting the one maximizing a given metric, such as *Accuracy@1*, *Mean Reciprocal Rank* (MRR) [26] or *Confidence Weighted Score* (CWS) [26].

Finally, the query to submit to the IR engine is built, by using for each original term t_i, its list of contextualized and filtered synonyms and hypernyms $\beta.sh'\left(t_i\right)$.

4 Experimental Evaluation

The proposed QE approach has been implemented in a Python QA pipeline, developed in a previous work [24], in order to test and evaluate its effectiveness in QA systems. In detail, the developed QA pipeline transforms each user question into a structured query specifying (i) the question's LAT, (ii) the detected Named Entities (NEs) occurring in the question, where NEs are things which can be identified by their proper names, such as persons, organizations, locations, and so on, and (iii) some relevant words appearing in the question, such as nouns, verbs and adjectives. Such relevant words, which are not NEs, are the question terms which are taken into account for the QE with the goal of increasing the likelihood of the query to match the particular form of the answers in the domain corpus.

The experimental session has been arranged in order to evaluate the impact of the proposed QE approach with respect to the accuracy of this QA pipeline in extracting proper answers from selected documents to factoid questions. The case study here considered has consisted of an Italian corpus pertaining the *Cultural Heritage* domain, composed of 16 unstructured documents crawled from the web. Moreover, a set of approximately 880 factoid questions has been formulated, whose expected answers are short and concise pieces of text extracted from sentences in this corpus.

In order to apply the proposed approach, some pre-processing steps have been performed.

First, the domain corpus has been pre-processed in order to annotate the sentences within the documents with respect to the classes of information that user can ask about. In detail, the classes *Person*, *Artifact*, *Date* and *Location* have been considered and, accordingly, the corpus has been annotated. As an example, consider the following piece of text within the corpus:

```
The <Artifact>Sistine Chapel<Artifact> is the most
famous artwork painted by <Person>Michelangelo<Person>
<Date>between 1508 and 1512<Date>, ...
```

the *Sistine Chapel* is a NE annotated as *Artifact*, *Michelangelo* is a NE annotated as a *Person*, and "*between 1508 and 1512*" is a piece of text annotated as a *Date*.

Secondly, the set of relevant nouns, verbs and adjectives has been extracted from the corpus in their inflected form, known as lemma (root word), in order to be used in the *contextualization phase*.

Finally, a WE model to use in the *ranking and filtering phase* has been trained on an extended corpus, belonging to the same domain of the corpus of interest, and extracted from Wikipedia by selecting documents focused on the category *art*. This training has been performed as follows. First, each document of this extended corpus has been processed through three separate phases in order to improve its quality and accuracy: (i) *lemmatization*, (ii) *stop word removing* and (iii) *textual patterns replacing*. *Lemmatization* has been implemented using *Tint*[1], a Java-based pipeline for NLP in Italian, with the goal of replacing each word with its lemma. S*top words removing*, implemented as a java procedure aimed at removing words from the corpus on the basis of the *Snowball stop words list*[2], wipes out words that are classified as not semantically relevant in the Italian language, such as prepositions, determiners, conjunctions, and so on. *Textual patterns replacing* is in charge of replacing some common textual patterns in the corpus with ad-hoc tokens. As an example, several types of date formats appearing in the documents, such as *"(1388 – 1455)", "1513 – 14", "30/03/1732", "358 b.C.", "12 march1345",* and so on, are classified as belonging to the date pattern, and, accordingly, labelled with the unique token *"DATE"*. At the end of these phases, the resulting corpus has been submitted to an optimized *Word2Vec* python library, named Gensim [27], by using the CBOW model and applying negative sampling.

After these preprocessing steps, the performance evaluation has been concretely performed as follows.

Each factoid question is submitted to the QA pipeline, its LAT is estimated and the NEs, eventually appearing in the question, are detected. Then, before formulating the query to be submitted to the IR engine, the proposed QE approach is applied to expand the relevant words extracted from the questions. Such relevant words are firstly preprocessed via *lemmatization* with the goal of making them able to properly match the sentences in the domain documents. Successively, the IR engine is invoked to retrieve the most relevant documents with respect to the submitted query, by comparing the relevant words inside the query with the lemmatized form of words in the documents. Finally, the QA pipeline generates answers from the documents retrieved by the IR engine by choosing and ranking the sentences on the basis of the estimated LAT of the question, the detected NEs, and the lemmatized relevant words extracted from them.

[1] http://tint.fbk.eu/.
[2] http://snowball.tartarus.org/algorithms/italian/stop.txt.

The performance of the QA pipeline has been evaluated by applying three distinct metrics, namely *Accuracy@1, MRR* and *CWS*. *Accuracy@1* denotes the percentage of correct responses that the QA pipeline ranks with the highest score, i.e. the number of corrects answers reported in first position. *MRR* [26] denotes the average across the queries of the reciprocal of the ranks assigned to the correct answers. *MRR* penalizes QA systems not able to retrieve an answer in the top positions. Finally, *CWS* [26], also known as *Average Precision*, is as lower as a QA system ranks wrong answers in first positions. As first experiment, the 880 factoid questions of the case study have been submitted to the QA pipeline, and the abovementioned metrics have been computed, as reported in Fig. 1. In this respect, Fig. 1 reports *Accuracy@1*, *MRR*, and *CWS* computed across different values of the β parameter, used in the *ranking and filtering* phase to set the number of synonyms/hypernyms generated by the proposed QE approach.

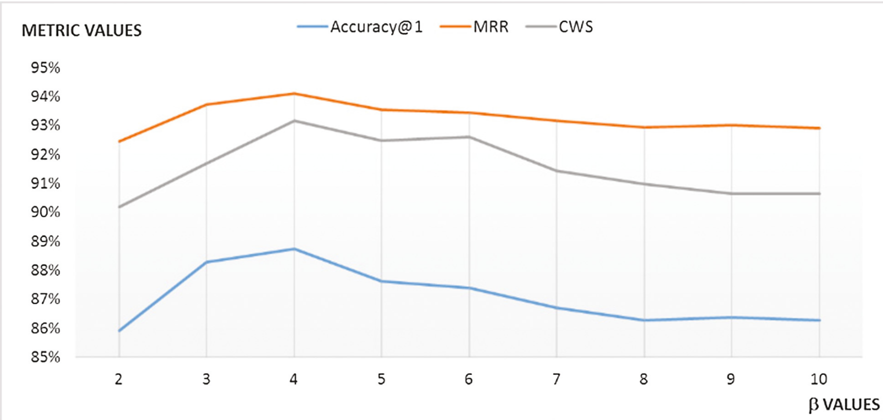

Fig. 1. The *Accuracy@1*, *MRR*, and *CWS* metrics achieved by the proposed QE approach for the considered case study.

It is worth noting that, on the average, all the considered evaluation metrics rapidly grow up as the β parameter increases, and the maximum of the performance is achieved when the proposed QE approach is applied for generating $\beta = 4$ synonyms/hypernyms of relevant words in the questions. On the contrary, for higher values of the β parameter the noise produced by the generated synonyms/hypernyms seems to be predominant with respect to the gained advantages.

Then, as second experiment, the proposed QE approach has been compared with different QE strategies which are typically used in literature: (i) *No_QE*, where no QE technique is used; *(ii) QE_WordNet*, where each query has been expanded by using the synonyms/hypernyms generated only by *WordNet*; and (iii) *QE_w2v*, where each query has been expanded by only using *Word2vec*. In detail, on the one hand, these QE approaches have been evaluated with respect to the number of correct answers that the QA pipeline ranks in first, second, and third position, i.e. ranked as *top1*, *top2*, and *top3*, as reported in Fig. 2.

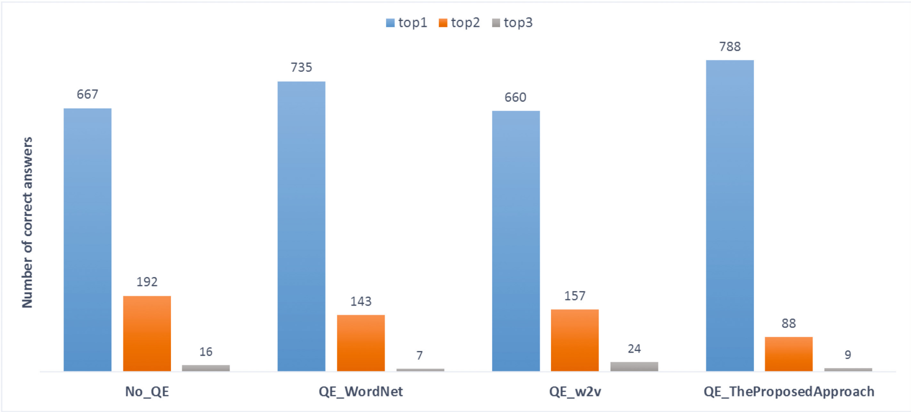

Fig. 2. The number of correct answers ranked as *top1*, *top2*, *top3* for the proposed QE approach compared with the QE strategies *No_QE*, *QE_WordNet*, and *QE_w2v*.

As showed in Fig. 2, the *QE_w2v strategy* produces a worsening in the number of corrects answers also with respect to the *No_QE* strategy, due to the great noise generated from terms extracted from *Word2vec* that often are neither synonyms nor hypernyms, but just words frequently occurring in the corpus together with the ones to expand. On the contrary, the use of synonyms and hypernyms, extracted from *WordNet*, showed to be an efficient QE strategy able to increase the number of correct answers in first position with respect to the *No_QE* and the *QE_w2v* strategies. However, the best performance has been achieved by the proposed QE approach, that has been able to increase the number of correct answers in first position, from a minimum of 7.2% over the QE_*WordNet* strategy, up to a maximum of 18.1% over the *No_QE* strategy.

Finally, in order to compare the proposed QE approach with the other QE strategies with respect to the considered evaluation metrics, *Accuracy@1*, *MRR*, and *CWS* metrics have been computed for the different QE strategies, as reported in Fig. 3.

The proposed QE approach has produced the best results with respect to all the considered metrics, with a response time equal to about 1 s and higher of about 10% than the ones measured in the *no_QE* case. In detail, *Accuracy@1* increases of about 7.2% when the proposed solution is applied, with respect to the *QE_WordNet* strategy. Moreover, the experiments showed that the proposed solution has also reduced both the number of questions not having correct answers in the top positions, evaluated with *MRR*, and the number of questions having wrong answers in first position, evaluated with *CWS*.

5 Conclusion

This paper has described a hybrid strategy of QE based on *lexical resources* and WEs for Italian factoid QA systems. As innovative contribution of this work, the proposed approach uses, on the one hand, a *lexical ontology* to generate synonyms and hypernyms of relevant words extracted from the user question and, on the other hand, contextualizes

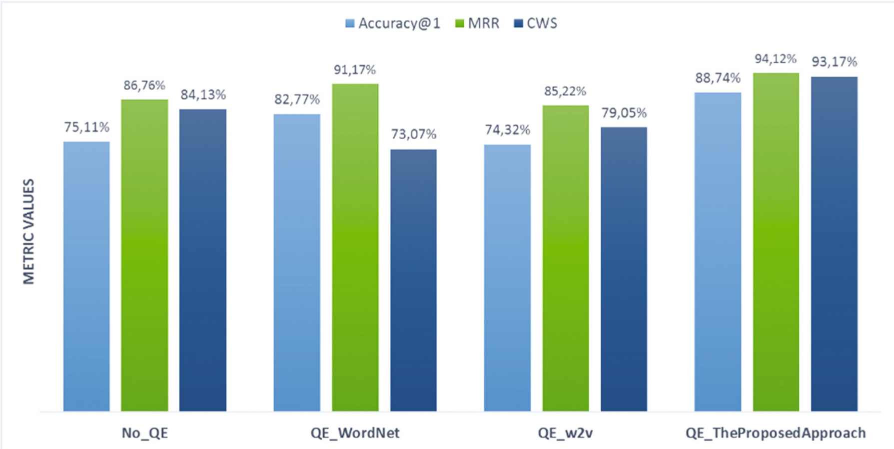

Fig. 3. The *Accuracy@1*, *MRR*, and *CWS* metrics achieved by the proposed QE approach, for the considered case study, compared with other QE strategies *No_QE*, *QE_WordNet*, and *QE_w2v*.

this set with respect to the corpus of interest and with respect to the peculiar user question. Indeed, the set of candidate synonyms and hypernyms for the QE is ranked and filtered taking into account their presence within the domain corpus and their semantic similarity to the user question, with the goal of reducing the noise produced by the unrelated terms.

An experimental session has been arranged in order to evaluate the impact of the proposed QE approach with respect to the accuracy of this QA pipeline in extracting proper answers from selected documents to factoid questions. The case study here considered has consisted of an Italian corpus of 16 unstructured documents pertaining to the *Cultural Heritage* domain and approximately 880 factoid questions. The proposed QE approach has been compared with other different QE methods typically used in literature, by using three evaluation metrics, namely *Accuracy@1*, *MRR*, and *CWS*. The experiments showed the effectiveness of the proposed solution, which has produced the best results giving lower values than the other methods for the considered metrics. Next step of the research activities will be focused on: (i) a more systematic and rigorous performance evaluation of the proposed approach on larger corpora; (ii) the application of the proposed QE approach to other closed domains in order to assess its level of effectiveness; (iii) the study of other related knowledge-based paradigms to investigate the integration of domain and/or context specific constraints able to further increase the success rate in QAs.

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Tuning SyntaxNet for POS Tagging Italian Sentences

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Abstract. Part-of-speech (POS) tagging is a Natural Language Processing (NLP) technique extremely relevant in Question Answering systems and becomes more complex when these systems operate on spoken language. For the use case of Italian spoken language, here considered, enclitic forms are very difficult to be tagged, since they consist of one or more pronouns appended as suffixes to verbs. This work describes a case study aiming at investigating how to refine SyntaxNet, the NLP framework released by Google, to efficiently tag enclitic forms in Italian. In particular, first, a forward selection of different features is presented, aimed to assess their influence on POS tagging performance of SyntaxNet in Italian. Second, further features are added, as suggested by morphological rules characterizing Italian enclitics, in order to improve POS tagging performance. Finally, a qualitative and quantitative evaluation with respect to sentences coming from real spoken dialogs is performed, showing very promising results.

1 Introduction

In the last years, a novel category of intelligent systems has gained an increasing relevance, the so-called Cognitive Systems, able to learn, reason, and pervasively engage with humans in a natural, personalized, reactive and/or proactive way. Such systems make use of different technologies, ranging from Artificial Intelligence [1] to Natural Language Processing (NLP) [2], up until Cloud and Security Computing [3–5], in order to pervasively and securely provide decisional support for solving complex problems.

In particular, a great deal of attention has been paid to a specific typology of Cognitive Systems, i.e. Question-Answering (QA) systems. They mainly work by providing short, relevant answers to natural language questions that can be textual or spoken. Part-of-speech (POS) tagging and syntactic parsing are two NLP techniques extremely relevant for QA systems, since they are widely used to elaborate questions and determine the corresponding answers.

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In particular, POS tagging helps assign the proper grammatical tag (e.g. noun, verb, pronoun) to each word for a given text or sentence. Typically, it precedes the syntactic parsing in the analysis of a text or a sentence, thus strongly influencing its success and revealing to be a critical activity for QA systems to understand the structure of sentences and questions.

The complexity of POS tagging increases when QA systems operate on spoken sentences and/or on spoken questions [6]. Indeed, the structure of spoken language is different from that of written language, and some of the anchor points used in processing, such as punctuation, must be inferred and are, therefore, error-prone. It is also necessary to deal with spoken-language phenomena, including linguistic deviations as disfluencies, repetitions, restarts, and corrections, affecting the accuracy of POS tagging, usually measured on well-formed textual snippets.

This problem affects most of spoken languages and, as a consequence, also QA systems based on them. In particular, for the use case of Italian, here considered, beyond linguistic deviations, spoken language is also richer than the written one, in clitic pronouns, i.e. pronouns that normally substitute verbal complements, and from a semantic perspective, represent the corresponding arguments. They can be appended as a suffix of variable length to a flexed verb, resulting in a unique word or token, or can precede a flexed verb, remaining disjoint from it. The first typology is called enclitic and is more frequent in not formal and/or friendly contexts, and thus can appear more frequently as input of a QA system. The second typology is called proclitic and is more common in formal writing or speech.

It appears evident that proclitic forms are simpler to be tagged than enclitic ones, because, in these latter, pronouns and verbs are combined to form single words. Therefore, the POS tagging of enclitic expressions represents a typical and often unsolved bottleneck for Italian NLP.

Actually, the state-of-the-art system for POS tagging in Italian is represented by TINT [7], even if it does not show a high accuracy in tagging enclitic expressions. On the other hand, SyntaxNet [8], which is the NLP framework released by Google, is able to operate, with its pre-trained Parsey Universal [9] model, across 40 languages, including Italian and, even if its performance in terms of global accuracy is lower than TINT, it exhibits a better capacity to tag enclitic forms.

In the light of these considerations, this work describes a case study aiming at investigating how to refine SyntaxNet for improving its capacity to label the enclitic forms with the most appropriate POS tags in the Italian language. The choice to investigate SyntaxNet is due to its better "local" behavior in tagging enclitics with respect to other existing solutions, with the final aim of including it into a QA system operating on spoken Italian.

In particular, firstly, a forward selection approach is presented, aimed to assess the Parsey Universal model with respect to the POS tagging task in Italian, by exploiting a particular dataset, i.e. the standard Italian Corpus (ISDT) [10, 11]. To this aim, different sets of features adopted in this multilingual model have been progressively considered, starting from the simplest possible configuration, in order to evaluate their influence on the performances. Secondly, this model has been enriched with a further set of features (variable length suffixes), suggested by morphological rules characterizing Italian enclitics, and, then, re-trained and re-tested on the same dataset in order to assess its new performances. Finally, a qualitative and quantitative evaluation with respect to sentences from real spoken dialogs has been performed, also comparing the results achieved by the final enriched model with respect to the ones obtained by TINT.

The rest of the paper is made as follows. In Sect. 2, some preliminary notions about POS tagging are given and similar approaches existing in literature are presented. Section 3 outlines the study of the Parsey Universal model with respect to the POS tagging task by means of the forward selection approach. Section 4 describes the improvements of that model with a further set of features and discusses the qualitative and quantitative evaluation with respect to sentences from real spoken dialogs. Section 5 concludes the work.

2 Background and Related Work

POS tagging, as critical task for most NLP systems, has received a great deal of attention in the recent past. The most performing POS taggers are usually based on supervised classifiers trained on windows of text, which are then fed to a bidirectional decoding algorithm during inference [12, 13]. For instance, supervised approaches have reached accuracies around 97.3% for the English Language [14]. In general, POS tagging models resemble a bi-directional dependency network, and can be trained using a variety of methods including, for example, support vector machines, neural networks or bi-directional Viterbi decoders.

In detail, POS tagging can be modeled by way of a pair of sequences, one input sequence and one output (tag) sequence. For example, the sentence:

(1) `Jane went shopping with Mary`

can be interpreted as the sequence of words [Jane; went; shopping; with; Mary]. In order to identify the parts-of-speech of all the words in the original sentence, we can produce an output sequence like the following (2):

(2) `[Noun; Verb; Noun; Preposition; Noun]`

Here, every element in the input sequence is associated with exactly one element in the output sequence (called its tag), which is the element at the same index.

To facilitate the comparison of POS tagging approaches, a proposal to standardize best-practices was published by Google, consisting in a tag set [15] of twelve universal POS categories, covering the most frequent parts-of-speech that exist in most languages. In addition to this coarse tag set, they also developed a mapping from fine-grained POS tags for 25 different treebanks to this universal set.

Successively, Google universal part-of-speech tags [14] and Stanford Dependencies [16] joined into a cross-linguistically consistent treebank annotation, consisting in a part-of-speech and parsing tag set, which became the standard de facto for annotation schemes, and is commonly known as Universal Dependencies (UD) [17].

The UD morphological features aimed to provide a stripped down basic set of features crucial for analysis and are widespread across languages, among which Italian. In fact, UD POS tags are currently employed by both the most relevant annotated Italian corpus (e.g., ISDT and PAISA' [18]) and NLP systems processing Italian [19].

Table 1 summarizes the list of coarse universal POS tags available from UD. The whole set of universal POS tags, including coarse and fine-grained tags, is available at [17].

Table 1. Universal Dependencies (UD) coarse POS tag set.

Tag value	Tag description
ADJ	Adjective
ADP	Adposition
ADV	Adverb
AUX	Auxiliary
CCONJ	coordinating conjunction
DET	Determiner
INTJ	Interjection
NOUN	Noun
NUM	Numeral
PART	Particle
PRON	Pronoun
PROPN	Proper noun
PUNCT	Punctuation
SCONJ	Subordinating conjunction
SYM	Symbol
VERB	Verb
X	Other

With reference to the state-of-the-art for POS-tagging in Italian using UD tag set, the most recent study was published in 2016, as reported in [20]. In this work, the state-of-the-art NLP systems for Italian are compared on the ISDT Treebank. This study did not include some interesting POS taggers, such as SpaCy [21], BIST [22], TINT and SyntaxNet, with its native models called Parsey McParseface and Parsey Universal, pre-trained, respectively, for English and for other 40 different languages, among which Italian. Among these taggers and those reported in the study above-mentioned, we have experimentally proved that TINT reaches on the same treebank the greatest value of accuracy, i.e. 98.54%, resulting as the effective state-of-the art for POS tagging in Italian language.

Despite the best behavior of TINT in POS tagging in terms of absolute accuracy, we have also experimentally proved that the pre-trained Parsey Universal model of SyntaxNet obtains a value of accuracy, with respect to enclitic forms, equal to about 74%, higher than the one reached by TINT, i.e. 66%, on the same treebank previously mentioned. This better behavior in tagging the enclitic forms is extremely relevant in QA systems, where spoken dialogues contain a higher frequency of such expressions, and thus, represents the motivations for which SyntaxNet models have been investigated and improved in this study, as described in the following.

3 Forward Selection for Assessing Performance of SyntaxNet Model

The first step of this study has regarded the application of an incremental approach, based on a forward selection of the features used by Parsey Universal model of SyntaxNet with respect to the POS tagging task in Italian by exploiting the ISDT dataset.

As reported in the Google code documentation [23], SyntaxNet is a neural-network NLP framework, whose architecture is depicted in Fig. 1. As reported in the figure, with respect to the POS tagging task, sentences are processed left-to-right. For any word of the sentence considered, some features of that word and a window around it are extracted and concatenated to form an embedding representation. Successively, this embedding representation is used as input to a feed-forward neural network classifier, which predicts a probability distribution over POS tags. Since the assignment of a new tag is performed in left-to-right order, prior decisions about words already tagged (this set is called *stack*) are also used as features for subsequent ones not yet tagged (this set is called *buffer*).

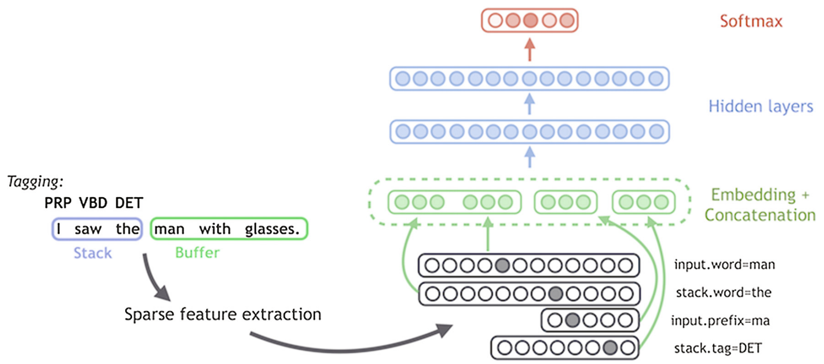

Fig. 1. SyntaxNet architecture.

Parsey Universal model of SyntaxNet makes use of the following seven types of different features:

- *words:* the word under analysis together with a window of three words around it;
- *tags:* tags assigned (predicted) to the neighboring words in the window and preceding the current word under analysis;
- *suffixes:* endings of all the words occurring in the window considered;
- *prefixes:* beginning of all the words occurring in the window considered;
- *capitalization*: case-folding converting all characters to lower case;
- *char_ngram:* subset of characters (ngrams) in all the words occurring in the window considered;
- *other:* any symbol not including an alphabetic character (e.g., punctuation, hyphens, digits).

The strategy adopted has been aimed to: (*i)* probe if any dominant (more significant) group of features exists over the whole set; (*ii)* test if, by increasing the set of more significant features, any remarkable improvements could be reached in POS tagging accuracy.

In order to deploy the forward selection approach, we have trained several new Parsey Universal models of SyntaxNet over the ISDT treebank. In particular, we have planned multiple diversified training cycles, each considering a type of features extracted from the initial overall set. It is worth noting that 2-characters and 3-characters length prefixes and suffixes have been considered as two group of features, i.e. families of prefix and suffix features.

The adopted approach is based on an incremental extension of the features number included in each subset for repeating a training step. Features selection for the succeeding new training loops has been driven by accuracy results and discriminant

Table 2. POS tagging accuracy after applying the features forward selection

LOOP	Features combination	POS tagging accuracy
	Words	66.02%
1	Words + capitalization	66.98%
	Words + char_ngram	71.02%
	Words + other	67.03%
	Words + prefix2, prefix3	75.01%
	Words + suffix2, suffix3	78.02%
	Words + tags	81.04%
2	Words + tags + capitalization	68.02%
	Words + tags + char_ngram	74.98%
	Words + tags + other	67.97%
	Words + tags + prefix2, prefix3	85.02%
	Words + tags + suffix2, suffix3	80.99%
3	Words + tags + prefix2; prefix3 + capitalization	69.03%
	Words + tags + prefix2; prefix3 + char_ngram	71.02%
	Words + tags + prefix2; prefix3 + other	73.99%
	Words + tags + prefix2; prefix3 + suffix2; suffix3	89.04%
4	Words + tags + prefix2; prefix3 + suffix2; suffix3 + capitalization	69.82%
	Words + tags + prefix2; prefix3 + suffix2; suffix3 + char_ngram	90.76%
	Words + tags + prefix2; prefix3 + suffix2; suffix3 + other	75.04%
5	Words + tags + prefix2; prefix3 + suffix2; suffix3 + char_ngram + capitalization	91.43%
	Words + tags + prefix2; prefix3 + suffix2; suffix3 + char_ngram + other	75.92%
6	Words + tags + prefix2; prefix3 + suffix2; suffix3 + char_ngram + capitalization + other	92.54%

behavior analysis among the earlier steps. Each time, the most performing combination of features has been selected as the standing base for the succeeding training sessions. Table 2 summarizes results obtained after applying the features forward selection approach.

As evidenced by this set of experiments, we have assessed that the whole set of features are contributing, sometimes with different weights, to improve POS tagging accuracy. Finally, as reported in Table 2, the value of POS tagging accuracy obtained by considering all the types of features is around 92.54%. This value is greater than the one obtained by using the pre-trained Parsey Universal model of SyntaxNet, which has been experimentally evaluated as equal to about 89.77.

4 Improvement of SyntaxNet Model for Tagging Enclitics

The POS tagging accuracy values of both the pre-trained and the re-trained Parsey Universal models of SyntaxNet with respect to only the enclitic forms have been experimentally evaluated over the ISDT corpus as both equal to about 74%. In order to further improve this value, that is, however, greater than that obtained with TINT, as already reported in Sect. 2, a modification to the features set has been acted, according to the features forward selection approach.

In detail, to the basic set of seven types of features, one new group, including three different length suffixes (respectively, of four, five and six characters), has been added. This choice has been suggested by some morphological rules of Italian language. Roughly speaking, enclitic expressions in Italian can be represented by single words composed of flexed verbal forms plus suffixes of six characters at most, consisting of one or two pronouns. As an example, Table 3 shows some frequently recurring suffixes of variable length in Italian.

Table 3. Sample suffixes for Italian enclitic forms

Suffix	Length	Word example
Gliene (it to/for him/her)	6 chars	Comprar-gliene (buy it for him/her)
Melo (it to/for me)	4 chars	Dim-melo (tell it to me)
Gli (to him)	3 chars	Donar-gli (give to him)
Ti (you /to you)	2 chars	Chiamar-ti (call you)
Mi (me /to me)	2 chars	Parla-mi (speak to me)

Successively, as last experiment, we have re-trained the Parsey Universal model of SyntaxNet adding the three variable length suffixes to the basic features set. After training, we have performed again the test over the same test set as the previous experiments. We have experienced a not very remarkable improvement in the global POS tagging accuracy over the selected dataset, thus reaching a little improvement with respect to the preceding result (92.546% vs. the old 92.544%). On the other hand, a remarkable improvement has been obtained with respect to the POS tagging accuracy of enclitic forms, thus passing from the 74% to the 100% over the ISDT dataset. This better performance does not increase significantly the overall accuracy, since the test set considered is essentially a formal written text containing only 19 enclitic tokens over a total of about 9000 words.

In order to qualitatively evaluate the behavior of this enriched version of the Parsey Universal model in POS tagging enclitic forms, we have compared it with respect to the state-of-the-art POS tagger TINT, over a set of 32 sentences extracted from spoken dialogs, thus closer to the scenarios we are interested in. An excerpt of these sentences is reported in Table 4.

Table 4. Comparison of our enriched SyntaxNet model versus TINT in POS tagging enclitic forms in sentences extracted from spoken dialogues

Sentences containing enclitic forms	POS tag by TINT	POS tag by our model	Gold POS tag
Parlami del tuo viaggio negli USA (***Tell me*** *about your journey in USA*)	NOUN	VERB	VERB + PART
Parlaci della tua storia (***Tell us*** *about your story*)	NOUN	VERB	VERB + PART
Parlami (uppercase) (***Talk to me***)	PROPN	VERB	VERB + PART
parlami (lowercase) (***talk to me***)	NOUN	VERB	VERB + PART
Parlatevi (***Talk to each other***)	X	VERB	VERB + PART
sempre meglio **parlarsi** chiaro (*it is always better to* ***speak to each other*** *clearly*)	VERB	VERB	VERB + PART
Raccontami di quello che facevi (***Tell me*** *about what you did*)	NOUN	VERB	VERB + PART
Raccontami (uppercase) (***Tell me***)	PROPN	VERB	VERB + PART
raccontami (lowercase) (***tell me***)	NOUN	VERB	VERB + PART
Raccontaci la tua versione (***Tell us*** *your version*)	VERB	VERB	VERB + PART
Dimmelo (***Tell it to me***)	PROPN	VERB	VERB + PART
Dimmi cosa pensi (***Tell me*** *what you think*)	VERB	VERB	VERB + PART
Seguimi (***Follow me***)	X	VERB	VERB + PART
Seguimi nel ragionamento (***Follow me*** *in reasoning*)	VERB	VERB	VERB + PART
Ascoltalo (***Listen to him***)	VERB	VERB	VERB + PART
Ascoltami (***Listen to me***)	NOUN	VERB	VERB + PART
Ascoltami quando ti parlo (***Listen to me*** *when I am talking with you*)	VERB + PART	VERB	VERB + PART
Ascoltiamolo (***Let us listen to it/him***)	VERB + PART	VERB	VERB + PART
Vacci (***Go there***)	X	VERB	VERB + PART
Vacci da solo! (***Go there*** *by yourself*)	INTJ	VERB	VERB + PART
Vacci tu con Maria (***Go there*** *yourself with Mary*)	INTJ	VERB	VERB + PART

On these set of sentences, from a quantitative perspective, this enriched version of the Parsey Universal model has reached an accuracy in POS tagging enclitics equal to 93.75, whereas TINT has obtained a lower value, i.e. 31.25%.

At a first level analysis, it seems that TINT makes differences in assigning the right POS tag according to the word case-fold and according to the flexed form of a verb, thus assigning to verbal forms a strongly different POS (as a noun or an ordinal number, tagged as X in UD). The enriched version of Parsey Universal model here proposed allows, instead, to rightly recognize the expressions including an enclitic form, indifferently from the case-fold and the flexed form. It does not allow yet to split the verbal form from the enclitic pronoun, but a correct assignation as a verb is a critical aspect and remarkable advantage for the succeeding parsing activity.

5 Conclusions and Future Works

In this work, a case study has been presented, with the aim of investigating how to refine SyntaxNet, the NLP framework released by Google, for improving its capacity to tag the enclitic forms in Italian.

This study has first proposed a forward selection approach, aimed to assess the Parsey Universal model of SyntaxNet with respect to the POS tagging task in Italian. To this aim, different sets of features have been progressively considered, starting from the simplest possible configuration, in order to evaluate their influence on the performances. The experiments performed over the ISDT dataset have evidenced that the whole set of features originally considered in that model contributes, sometimes with different weights, to improve POS tagging accuracy. In particular, the value of POS tagging accuracy obtained by considering the whole set of features is around 92.54%. This value is greater than the one obtained by using the pre-trained Parsey Universal model of SyntaxNet, which has been experimentally evaluated as equal to about 89.77.

Second, the resulting model has been enriched with a further set of features, including three different length suffixes (respectively, of four, five and six characters), suggested by morphological rules characterizing Italian enclitics, and, then, re-trained and re-tested over the ISDT dataset in order to assess its new performances. The experiments have evidenced that a not very remarkable improvement has been obtained in the global POS tagging accuracy, thus reaching a little improvement with respect to the preceding result (92.546% vs the old 92.544%). On the other hand, a remarkable improvement has been obtained with respect to the POS tagging accuracy of enclitic forms, thus passing from the 74% to the 100%.

Finally, a qualitative and quantitative evaluation with respect to sentences from real spoken dialogs, thus closer to the scenarios we are interested in, has been performed, also comparing the final enriched model with TINT.

From a qualitative perspective, the enriched version of Parsey Universal model here proposed, differently from TINT, has shown its capability to rightly recognize enclitic forms, indifferently from the case-fold and the flexed form. Moreover, from a quantitative perspective, it has reached an accuracy in POS tagging enclitics equal to 93.75, whereas TINT has obtained a lower value, i.e. 31.25%.

In conclusion, the experiments performed in this study have evidenced that the enriched version of the Parsey Universal model obtained has reached very interesting performances with respect to the POS tagging task of enclitic forms, so revealing as a proficient tool to be used in QA systems to process spoken text. Further investigations will be performed as future work to assess these preliminary but promising results, thus encouraging us to identify also new and more performing models for Italian, evenly combining new features with different network parameters settings.

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ECT: A Novel Architecture for Evidence Collection in Forensic Investigation

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Abstract. Computers, smart-phones, wearable devices, and more generally any piece of technology that processes information can be used in a criminal way. Forensics investigation is becoming a crucial process to acquire and secure information and data that is stored on, received or transmitted by an electronic device for further examination during a trial. In this work, we adopt semantics-based technologies to compose a methodology supporting forensics investigations during the analysis process. Proposed methodology aims to infer hidden correlations among different informative sources, for example, integrating in a unique coherent stream the results of different forensic tools. We implement this methodology through a system able to generate additional assertion to data generated by forensics tools during extraction processes. Thanks to their formal representation, assertions enable enhanced retrieval and reasoning capabilities and so more efficient access to information resources. In order to prove effectiveness of the approach, we show some experimental results obtained in a simulated case of a digital investigation examination, evaluating recall and precision of query results, asking for a set of given evidences considered as ground truth.

1 Introduction

Cyber-security is becoming a hot topic in social, political, industrial and research fields. Information Technology (IT) systems are involved in almost all daily activities, related to business and industrial purposes, safety systems, education or entertainment, etc. [1,2]. The growing use of digital technologies increases the

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chances that a device should be the means or the witness of a crime. Thus we can use data generated, stored or transmitted by a digital device as evidences in a trial.

Birth and evolution of Computer Forensics is strictly related to the progress of information and communication technology. The development of new technologies promoted many changes in methodologies adopted to notice, collect, manage e analyse information during investigations (e.g. digital footprints, in a lawsuit [3,4]). The intangibility and volatility of these information, with the growing of volumes of data and the heterogeneity of digital media [5,6], complicate the work of Digital Forensic experts, because the manipulation and processing of data is related to a logical-inferential reasoning process, typical of scientific research and forensic analysis. Moreover, often, the big amount of information has to be correlated with similar non-digital evidences, usually in a really short time.

According to ISO/IEC 27037, a digital evidence is every kind of information that can be stored or transmitted in a digital form and that can be considered an evidence. The goal of Digital Forensics is not only collection, acquisition and documentation of data stored on digital devices, but, above all, it is the interpretation of evidences. Notice that correlation of information is a crucial phase in forensics analyses, because examiner must take into account of all kinds of information (considering the broadest meaning of term), such as context of investigation, acquired clues, investigative hypothesis, and many other elements, not necessarily in digital form. Correlation of these information is the only mean to allow for the contextualization of digital evidences, promoting them as clues.

According to previous considerations, experts have to face many challenges during the different phases of forensic investigations:

- the admissibility of acquired data must be preserved: this assumes that examiner will not alter data avoiding to alter its probative value.
- the complexity of data, in terms of volume and heterogeneity, requires sophisticated data reduction computation;
- the lack of standard format for file produced by different practices and tools usually restricted to particular subset of activities, leads to consistency and correlation problems;
- the absence of tools that assist in integration of data gathered from heterogeneous sources, such as hard disks, memory, etc., in order to find traces and to reconstruct the events.
- the unification of timeline events from multiple sources or devices.

All these correlation problems reflect on the presentation phase too: since results of investigation have to be presented to a court's jury avoiding misunderstanding or ambiguities, the examiner have to agree on the set of terms and definitions with multiple parties involved in the analysis process, due to their different levels of expertise.

In this work we present a methodology to enrich the analysis and correlation process of a forensics investigation through the adoption of Semantic Web technologies. The addition of semantic assertion to data generated during various analysis phases, should improve the presentation results, enabling more accurate correlation of traces and more powerful searches.

The paper is structured as follows: Sect. 2 presents theoretical background in the area of Digital Investigations discussing basic principles of digital evidence and presenting some challenges in the field; Sect. 3 presents the proposed methodology; in Sect. 4 we describe the system architecture we propose to implement the methodology; in Sect. 5 there is a short presentation of related work that has also merged partially or fully these two areas; finally, in Sect. 6 we present some conclusions remarks.

2 Digital Investigations and Digital Evidences

Digital evidence is the main element of any forensics process. Literature offers many definitions of digital evidence, such as:

- any data stored or transmitted using a computer that support or refute a theory of how an offence occurred or that address critical elements of the offence such as intent or alibi [7]
- information of probative value stored or transmitted in digital form [8]
- any digital data that contain reliable information that supports or refutes a hypothesis about an incident [9]

The intrinsic weakness of digital evidences make them easy prone to alterations or modifications, even from examiners that, if not experienced, may compromise and contaminate the *scena criminis* status [10]. Thus, its rigorous and authenticated management is of extremely importance.

In [11] author has identified three basic properties of digital evidence, namely fidelity, volatility and latency.

1. *Fidelity* refers to Chain of Custody forensic principle, and involves the adoption of techniques that grant the integrity of evidences through the process;
2. *Volatility* is related to the nature of the support were evidences are stored (disk, memory, registers, etc.): this property affects considerably the acquisition and analysis of evidences;
3. *Latency* involves the presence of additional information to contextualize and interpret a digital encoding. The focus of current work is on this property.

A Digital Forensic Investigation has to follow a set of principles and procedures, regulated by Budapest Convention on Cybercrime, to correctly manage the life-cycle of digital evidence, from acquisition to analysis and presentation [12,13].

This regulation can be considered a first set of *best practices* consisting the fundamental principles of Digital Forensics. It provide for adequate technical measures to adopt in order to guarantee a correct conservation and integrity of acquired data.

3 Methodology

This section describes the proposed methodology for digital evidence integration and correlation. The methodology workflow is presented in Fig. 1.

The first "Data Collection" phase involves all the acquisition operations and aims at generating inputs for next phases. During this phase the examiner must respect the chain of custody principles and has to be compliant with acquisition best practices, depending on analysed media (hard disks, mobile devices, etc.). During this phase preprocessing and data reduction may be applied too, using techniques such as KFF (Known File Filter), in order to reduce the amount of data managed by next phases.

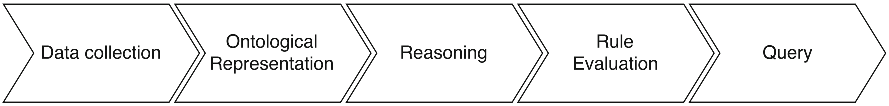

Fig. 1. Phases of the proposed methodology.

The goal of "Ontological Representation" phase is to transform the acquired data, by software or even hardware parsing tools, into a set of triplet constituting the RDF data model [14]. Ontologies used in this step can be created ad-hoc or even fetched from shared repositories. Outputs can be stored using different formats, such as RDF/XML or RDF/OWL.

Ontological representation of data is processed during "Reasoning" phase, through an OWL-based reasoner that infers additional axioms on the basis of instances' relations. The reasoner can infer different types of new axioms, enriching the asserted instances with information regarding the definition of their class, properties or subclasses. Moreover, thanks to subclass hierarchy, property relations or property restrictions, reasoner can dynamically classify and correlate instances with higher precision compared to asserted data.

SWRL Rules can assert additional axioms that cannot be inferred through OWL. SWRL Rules are evaluated, during "Rule Evaluation" phase, by a rule engine in order to insert newly inferred axioms into the ontology. This operation is realized with the support of external Rule Engines that translate inferred axioms into RDF data model to permit ontology integration.

By using SPARQL language it is possible to query endpoint hosting for the sets of triplets constituting asserted and inferred axioms. This implements the "Query" phase.

4 System Architecture

In this section is presented an implementation of a system architecture of the proposed methodology, with a brief discussion of the tools and techniques used.

Thanks to its flexibility, methodology can be implemented in different ways, so system architecture can be updated among the evolution of semantic technologies.

Our overall system consists of an ontology and five modules: Evidences Manager, Semantic Parser, Inference Engine, SWRL Rule Engine and a Query and Visualization module. An overview of the architecture is presented in Fig. 2. Its main components are further discussed below.

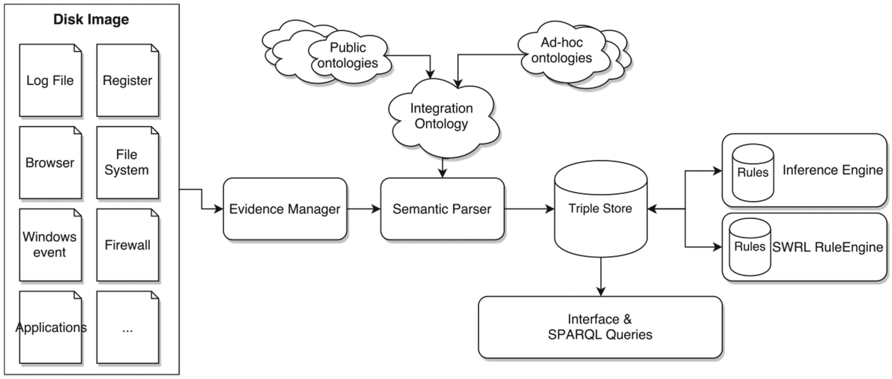

Fig. 2. System architecture for proposed methodology.

Evidence Manager

The evidence manager loads binary content of digital evidences, identifying the type of given source and verifying its integrity through hash values. This module provides tools to extract knowledge from a forensic image, like user files, browser history, Windows registry, etc. The extraction process uses forensics tools like Hachoir (for binary file manipulation) and Plaso (for timeline creation). The knowledge extracted consists of a set of attributes, including temporal information (date, time and timezone), a description of the information source (source and sourcetype), a description of the event. Many of these fields are structured and ready to be used as instances attributes; instead, some of them, like description of the event, are non-structured fields and they require further processing based on regular expression or NLP tecniques. The output of this module is a ïňĄle containing all the footprints retrieved from the disk image.

Semantic Parser

Semantic parser module generates an OWL representation of knowledge extracted from digital evidence in the previous step. This module instantiate the ontology, combined from public domain ones, if available, or custom ones. Ad-hoc ontologies can be created to integrate all the referenced domain ontologies or to define new classes, additional restrictions, new object properties, etc.

Ontology integration also promotes reuse of entities defined in other ontologies and increases system flexibility, since domain ontologies may not be easily modifiable.

Ontology population is made by creating an instance for each footprint item of acquired data, and by linking them each other according to formal object properties defined in the ontology schema.

Inference Engine

Inference engine performs automated reasoning, according to the OWL specifications, coming from domain ontologies or investigators knowledge. Reasoners can specify the granularity of inferences to be made, such as hierarchy relationship (an individual that is a member of a subclass is also a member of the parent class), or the generation of inverse object properties. Such kind of inferences can improve the performance of query execution. The goal of this step is to enrich the knowledge base with new inferred facts [15], increasing the examiner's knowledge on evidence. For example it is possible to infer a file type from its extension or to deduce the author of an action from user information in its active account.

SWRL Rule Engine

SWRL rules play a major role in the automated integration and correlation parts of the methodology. SWRL Rule Engine adopts SWRL rules in order to correlate different individuals or to establish relationships among individuals belonging to different ontologies but representing similar concepts. Saving SWRL rules in a separate text file promotes the decoupling and enables rules reuse. This module can be called before the reasoning engine make it able to process the axioms that can only be inferred by the SWRL rules, or you may execute the reasoning step twice, one before the rule engine and the other after it.

SPARQL Queries

The final module is responsible for accepting SPARQL queries from the user and evaluating them against a SPARQL query engine. The set of RDF triples that have been either asserted during the semantic parsing of the source data or inferred by the reasoning or the rule engine are loaded in-memory and SPARQL queries can be evaluated against it. Once more, the queries can be saved in separate files promoting reuse and decoupling.

5 Related Work

Many approaches adopting Semantic Web technologies have been proposed in literature. However, although correlation has been described as one of the most important goal of the analysis phase, current support for correlation analysis is poor among forensic tools.

DFXML (Digital Forensics XML) is an XML-based approach, providing a standardized XML vocabulary for representing meta-data of evidences, through various forensics-related XML tags such as `<source>`, `<imagefile>`,

<acquisition_date>, <volume>, etc. Another XML-based approach is described in [16], where authors proposed the DEX (Digital Evidence Exchange) format. DEX can also adopt an XML-based representation of the output of various forensics tool, but with an additional capability of tracing the specific instructions given and the sequential order of the tools used. Although these projects promote a standardized format and tool interoperability, they are missing to convey the semantic content of what they represent.

RDF-based approaches have found limited usage in the area of digital investigations, despite their ability to express arbitrary meta-data. RDF makes an important improvement due to the support of creating attributes with standard or custom types instead of only string types. The most famous adoption of RDF is in the AFF4 forensic format project [17]. AFF includes both a copy of the original acquired data as well as arbitrary meta-data, such as system-related information or user-specified ones [18–20].

An ontology-based approach is FORE project. FORE (Forensics for Rich Events) architecture [21] is composed of a forensic ontology, an event log parser and a custom-defined rule language, FR3. The forensic ontology is based on two main concepts that represent tangible objects and their state changes over time. Rules expressed in FR3 language are evaluated against the knowledge base in order to add new causality links between instances. By taking advantage of the OWL capabilities of referencing external ontologies, the authors are able to express correlation rules that combined concepts and events from disparate domains. In [22] authors use a blank ontology for encoding results retrieved from forensic tools emphasising relevant types of data and their relationships. Using an ontology query language (SQWRL) they extract additional information of probative value. In [23] authors introduce an approach based on a three-layered ontology, called ORD2I, to represent any digital events. ORD2I is associated with a set of operators to analyse the resulting timeline and to ensure the reproducibility of the investigation. Recent approaches uses modelling [24–26] and verification systems [27–29] for testing the soundness of the results. Moreover, hardware implementation [30,31] of dedicated functionalities are employed in order to increment data processing performances [32–35],

6 Conclusions and Future Work

In this paper, we propose a reusable methodology based on semantic representation, integration and correlation of digital evidence and an architecture that implements it. The approach is based on ontologies defining domain of digital incidents and on a set of tools for extracting information from disk image, populating the ontology, inferring and analysing new facts. The use of an ontology allows for the representation of knowledge with a unified model and for simplifying the building of analysis processes.

In future work, we plan to improve extraction phase by adding more information sources related to additional devices, such as Android and iOS. For the analysis, we plan to integrate new tools for event correlation based on pattern matching algorithm to detect illegal actions by identifying specific event sequences. Concerning the interface and query layer, will be proposed some enhancement regarding a graph visualization tool that easily show instances correlations.

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Modeling Instability for Large Scale Processing Tasks Within HEP Distributed Computing Environments

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Abstract. The scale of large processing tasks being run within the scientific Grid and Cloud environments have introduced a need for stability guarantees from geographically spanning resources, to ensure that failures are detected and handled preemptively. Performance inefficiencies within stacked service environments are a challenge to detect, where failures stem from a multitude of causes, often requiring expert intervention. Online reporting and classification of performance fluctuations can aid experts, central services, and users to target service areas where optimizations can be introduced. This paper describes an approach for modeling performance states for production tasks running within the ALICE Grid. We first provide an overview for the ALICE data and software workflow, focusing on the production job computational profile. Data center event state is then developed, based on data center job, computing, storage, and user behavior. With across site analysis, we then train groups to classify service domain states. Our approach is able to detect periods of service instability and the affected service domains. This can guide users, central, and data center experts to take action in advance of service failure effects.

1 Introduction

Distributed computing encompasses a broad range of complex systems: from personal computers participating in volunteer computing to sensors deployed within assisted driving vehicles. The term more widely has come to include computing cluster, data warehousing, as well as Grid and Cloud environments. For the past 50 years due to economical concerns we have observed repeating shifts between computer hardware consolidation and separation. From early specialized time-shared systems to general-purpose personal computers, we have once again reached an era of distributed heterogeneous environments. To keep up with the current trends, software development practices have evolved from lengthy formal methods and standard compliance towards stack-based interfaces, deployed within collaborative environments.

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For scientific software development formal software engineering practices are limited [7]. With High Energy Physics (HEP) experiments having an average code base of O(10^7) lines and rapidly changing subsystem configurations, HEP software developers are required to constantly adapt. From early years, HEP applications were programmed with data throughput performance in mind, rather than in-core floating point operation efficiency [21]. From the start, HEP software development environment was collaborative, with frequent releases and thorough community-based testing. Small batch releases have allowed developers to catch failures quicker and adapt to changing requirements [16]. Local task scheduling and distributed resource brokering are bound by data Input/Output (I/O) and task efficiency. For distributed environments data storage and transfer mechanisms are chosen according to the data access patterns and guarantee requirements. Software developed for HEP experiments is guided by operational data flow and domain-specific algorithms, where job efficiency becomes paramount as tasks scale.

Given the nature of scientific software goals, data variability, and data collection process, select domains to this day perform analysis manually [10]. Domain experts have observed, that their software solutions do not easily scale [1]. With such programming models as MapReduce, programming is not trivial, requiring proficiency in adapting application logic to the MapReduce model [18]. Given the scale and data acquisition rate of HEP experiments, the need for quick data computations exists [19]. With the potential performance gain of modern distributed computing models, refactoring highly critical applications is often not justified: whether due to cost or possibility of introducing errors [17]. Researchers, instead, recognize that tools should exist that will handle the necessary optimizations for newer software development models. For scientific applications it is a requirement that application development should be easy to develop for the expert, portable, and achieve performance as if though an expert programmer implemented it [13]. Methods beyond physical shipping should be used to facilitate data transfers for large data sets [9] Given the unique nature of scientific projects, scientists need tools that reduce the programming need for high-performance proficiency, while allowing the tools themselves to handle parallelism and hardware heterogeneity [20].

Wordwide LHC Computing Grid (WLCG)[1] is one of the largest scientific distributed computing environments in the world. It provides connected resources that span across continents, programming paradigms, and computing layers. From its historical roots of the MONARC hierarchical model [15], WLCG has evolved into an intercommunicating resource-aware infrastructure composed of data centers called *sites*. The A Large Ion Collider Experiment (ALICE) Grid is a HEP computing environment, built to accommodate for ALICE requirements.[2] It is designed to work with high rate data acquisition, reconstruction, simulation, and analysis for Proton- Proton (p-p) and Lead-Lead (Pb-Pb) collision events recorded at the Large Hadron Collider (LHC). In this work, we aim

[1] WLCG: http://wlcg-public.web.cern.ch/.
[2] ALICE Collaboration: Our Mission - http://aliceinfo.cern.ch/node/3935.

to define an operational profile methodology for the ALICE production software running within the Grid. First, we explore the experiment software and data flow. We then develop an event state vector to represent the state of services and production software running within data centers. The resulting methodology allows users and experts to detect and distinguish instabilities based on the service layer affected, allowing for targeted software performance optimizations to be implemented.

2 ALICE Software Workflow

ALICE is built using a set of tightly-coupled detector systems used for recording particle collisions from beams provided by the LHC. Each detector system is described according to the produced signal and its source [8]. Detectors are calibrated in such a way, that the same result is produced for the same metric measured. The metric and process of measurement is called *calibration*, which is performed during simulation and reconstruction phases [8]. With future interaction rates for pbpb collisions at 50 Kilo Hertz (KHz) and 200 KHz for p-p and Proton-Lead (p-Pb) collisions, currently deployed Detector Data Links (DDL)s already achieve rates of up to 5 Gigabit (Gb)/s. With increasing event sizes, the LHC experiments are taking steps to incorporate shared-memory and Message-passing Interface (MPI) models within their production workflows [11].

Monte Carlo (MC) simulation represents one of the most common type of jobs, constantly run on ALICE Grid. These simulations consist of embarrassingly parallel tasks that simulate collision events for detector subsystems [19]. Simulation results are used to validate correctness of detector code and its efficiency under varying event signal conditions [8]. Simulation framework recreates "statistical intrinsic fluctuations" using an MC approach, generating detector signals in the form of *digits*. These simulation techniques are fixed to the raw data and observed detector states.

Event reconstruction is a compute-intensive task considered to be the principle production job for the Grid. Data coming from the detectors are called *raw* and are first processed at Tier 0 (T0) data centers, along with calibration passes available from the Offline Condition Database (OCDB) used within Offline and

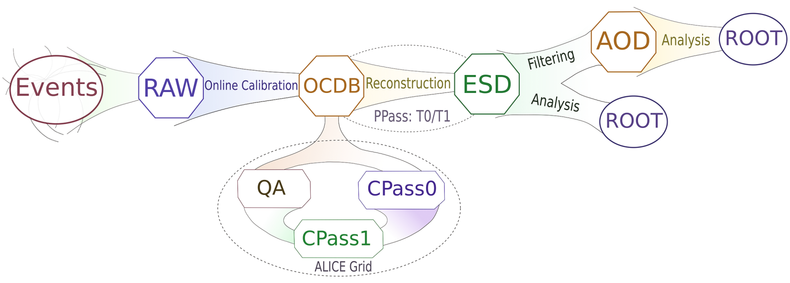

Fig. 1. ALICE data formats

Online environments. The process of reconstruction determines the *space-points* for each detector, that are subsequently used to find and fit tracks. Particle mass, charge, energy, and direction are stored within the Event Summary Data (ESD) objects, as shown in Fig. 1 [4,8]. First pass for the Pb-Pb data takes a minimum of two months to complete with subsequent passes taking 4–6 months [4,8]. Reconstruction and simulation jobs are centrally-managed, exploiting inherent event parallelism in order to distribute tasks across available resources.

The analysis phase tests user theory against reconstructed and simulated data [8]. It can be performed either through collective Physics Working Group (PWG) tasks called *trains* or through individual analysis tasks [22]. *Scheduled analysis*, such as analysis trains, are grouped tasks performed on the same data sets. For these tasks, *turnaround time* is crucial [3]. The train model improves resource usage and reduces data staging overheads, compared to normal analysis jobs [4]. ESDs can be further *filtered* into smaller Analysis Object Data (AOD) objects, containing more succinct charged particle tracks and jets. AOD reads are done from local disks and thus are I/O-bound, with throughput being limited by Central Processing Unit (CPU) speed. *Tag files* maintain event markers, used for selecting specific event data within RAW, ESD, and AOD objects. ALICE keeps two full copies of data at T0 and Tier 1 (T1) sites, whereas Tier 2 (T2)s are used for MC jobs, analysis tasks and maintaining replica of ESD and AOD objects [8].

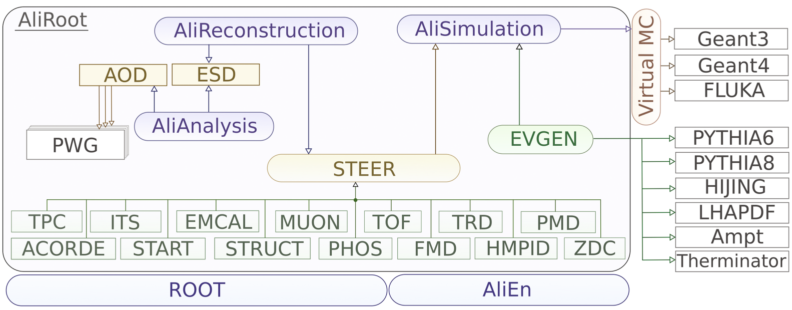

Fig. 2. AliROOT framework

The AliROOT framework is the software solution developed at ALICE used for reconstruction, simulation, analysis, and calibration passes. It implements a modular architecture for detector code that ensures flexibility during reconstruction, when select detectors may be absent from the run. The central STEER library contains base classes used by simulation, reconstruction, calibration, and analysis tasks, as shown in Fig. 2 [8]. AliROOT depends on external software packages, such as Geant3 and Geant4[3] for simulation, and ALICE Environment (AliEn) to provide Grid access. ROOT[4] written in C++, defines virtual

[3] Geant4 website: http://geant4.cern.ch/.
[4] ROOT Data Analysis Framework: https://root.cern.ch/.

interfaces and containers, allowing users to derive their own classes [8]. Originally developed to avoid code recompilation costs, through the years ROOT expanded to include features for data streaming, network support, mathematics library optimizations, and visualization [19].

Production jobs, such as reconstruction and simulation, are the main contributors to the overall Grid jobs. For the 2013–2014 period, 10% of resources were used for reconstruction, 60% for simulation, and the rest for user analysis and trains [8]. The fraction of user analysis done through trains, however, has been increasing in recent years to 70% [22]. User analysis currently holds the lowest efficiency among all job types [3]. Simulation jobs were observed to have the highest job efficiency, with reconstruction job efficiency decreasing over the past 4 years [5].

Principle HEP motivation for having scaling performance is to be able to produce more accurate models faster [19]. Therefore, SymmetricMultiProcessors (SMP) and Massively Parallel Processors (MPP) are two data parallel architectures considered, where data layout and load balancing are a challenge for HEP. Choice for which approach to use is guided by the task algorithm. Techniques for MPP systems, such as message merging, overlapping communication, data layout optimization, and replica jobs are commonly employed [19]. ALICE currently uses data parallelism mechanisms to designate a batch of tasks to specific data chunks. Furthermore, techniques such as caching, data prefetching, reduction of event size, and filtering are used to improve job efficiency.

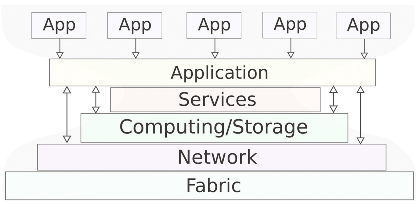

Fig. 3. Grid application-level software stack

HEP software development tends to focus on an Open Systems Interconnection (OSI) type application-level stack development, as shown in Fig. 3 [2,12]. The fabric layer is in charge of both physical and logical resources [12]. Computing and storage layers provision access to the computing resources, where the job is executed and Storage Element (SE), through which, data access is handled. Within such models, while all layers exhibit encapsulated behavior, inter-layer operation can occur, such that the application layer needs to be able to work with both resource and network layers in parallel. Additional software stacks can be deployed on top, where performance monitoring and failure detection becomes bound to the level of functionality exposed by individual Application Programming Interface (API)s. WLCG software stacks implement such functionality through client-server Remote Call Procedure (RPC) developed for tightly-coupled resources.

3 Event State Modeling

The goal of our research is to model the principle service layers, running during the life cycle of a production job. Thus, we have first considered job state metrics constructed based on their *expected* and *failed* states. Given that job states normally fluctuate between valid and error states, we wanted a measure that would capture the occurrence of exceeding number of jobs going into error, compared to normal states. Specifically for jobs, 12 valid states and 16 error states were considered based on the job life cycle. Since we could distinguish between the two types of states, an $S_{job}(t)$ parameter was constructed as shown in Eq. 1.

$$S_{job}(t) = \frac{\sum valid(t)}{\sum error(t)} \tag{1}$$

Similar to $S_{job}(t)$, we computed job agent state ratio $S_{jobagent}(t)$, where the job agent is in charge of jobs being executed on a domain of resources. For job agents, we have considered 4 valid states and 7 error states based on the job agent life cycle. When there are no job states in either category, we use value of 1 for the sum, for that type of states. WLCG sites provision variable set of resources, such that the number of jobs running at a site may scale up or down at any given time. Therefore, regardless of the number of running jobs, our parameter aimed to capture cases when over half of running jobs would go into error. Specific job states can also be manually triggered during normal operational conditions. Thus, it was imperative for us to capture conditions when there was an increase in the number of jobs experiencing errors. For $S_{job}(t)$, $S_{jobagent}(t) > 1$ the ratios were set to 1. We also wanted to have a metric that reflected an increasing number of jobs going into error within a short period of time. Therefore, we have used the sum of Median Absolute Deviation (MAD)s over a window of error types, as shown in Eq. 2.

$$Err_{job}(t) = \sum median(|Error_i - median(Error)|) \tag{2}$$

Storage represents a critical part of the computing workflow, that incurs considerable number of failures as a result. WLCG was designed to facilitate tasks and data to be replicated across sites, allowing site schedulers to deal with jobs that are I/O bound. While production tasks are operationally consistent, they depend on network variability, affecting storage performance. At the same time, storage issues may also affect the job performance during reading and writing stages. We have initially developed state ratios, similar to $S_{job}(t)$, however, the resulting metric produced a noisy measure, suggesting either an unusual transfer state life cycle or a low number of transfers occurring at any given time at the site. Instead, we have used transfer throughput $throughput_{transfers}(t)$ and $lost_{transfers}(t)$ as the sum of the number of lost transfers.

Network failures within data centers tend to be associated with hardware component degradation, link utilization, and misconfiguration. Network modeling has been shown to deviate from Stochastic Model (SM), with potentially unknown latency variations observed for forWide Area Network (WAN)s. MONitoring Agents using a Large Integrated Services Architecture (MonALISA) records Round Trip Time (RTT), jitter, and packet loss through the *ABPing* module for the $RTime$ metric [14]. RTT is the interval between sending and receiving acknowledgment of a test Transmission Control Protocol (TCP) packet between two network points [6]. The lower the $RTime$ means better network *quality*[14]. Coefficients for packet loss tend to be set high in order to detect link packet loss. Observed $RTime$ node peaks on links are used to detect *unstable* links within the network. We have defined $STime$ based on $RTime$, shown in Eq. 3, as the mean of k outgoing and incoming transfers for c_{Loss} and c_{RTT} coefficients set to $RTime$ values. We also define $STime_{dev}$ parameter, as shown in Eq. 4, that uses MAD across incoming and outgoing transfer sets $STime$ to reflect deviation within immediate site network.

$$STime(t) = mean(c_{RTT}\mathrm{RTT}(t,k) + c_{Loss}\mathrm{Loss}(t,k) \tag{3}$$

$$STime_{dev}(t) = median(|\mathrm{STime}_i - median(\mathrm{STime})|) \tag{4}$$

Reliability within a data center is generally viewed from the perspective of the reliability of computing nodes. We have developed a metric based on overall node utilization, as shown in Eq. 5, where n is the number of nodes and N_{cores} is the number of cores for the selected node.

$$\mathrm{Util}(t) = \frac{\sum_{i=1}^{n} \mathrm{Load}_i}{\sum_{i=1}^{n} N_{cores\,i}} \tag{5}$$

We have considered two utilization metrics for site computing nodes $Util_{nodes}(t)$ and storage nodes $Util_{xrootd}(t)$. Given the priority and consistent behavior of production jobs, we have also computed production job efficiency $User_{efficiency}(t)$, as shown in Eq. 6. For individual tasks, efficiency is defined as the ratio of sums for elapsed CPU Δt_{CPU} and wall clock Δt_{Wall} times across all cores running the task on the site, where n is the number of cores used by the job. From the site stability perspective, efficiency may be used to reflect currently running software performance, as well as transient failures within storage and network.

$$Efficiency = \frac{\Delta t_{CPU}}{\Delta t_{Wall}} \tag{6}$$

Finally, the site event state at time t was constructed as the vector $\{S_{job}(t),\ S_{jobagent}(t),\ Err_{job}(t),\ Err_{jobagent}(t),\ STime(t),\ STime_{dev}(t),$ $throughput_{transfers}(t),\ lost_{transfers}(t),\ Util_{nodes}(t),\ Util_{xrootd}(t),$ $User_{efficiency}(t)\}$. While the above event state vector includes a complete set of parameters, individual site event states differed e.g. Only select sites report storage. Therefore, for overall site testing we have considered a minimal event state vector, consisting of job and job agent states, and production job efficiency.

4 Results

For clustering event state parameters we have evaluated K-Means and Clustering Large Applications (CLARA) from R *stats* and *cluster* packages. During

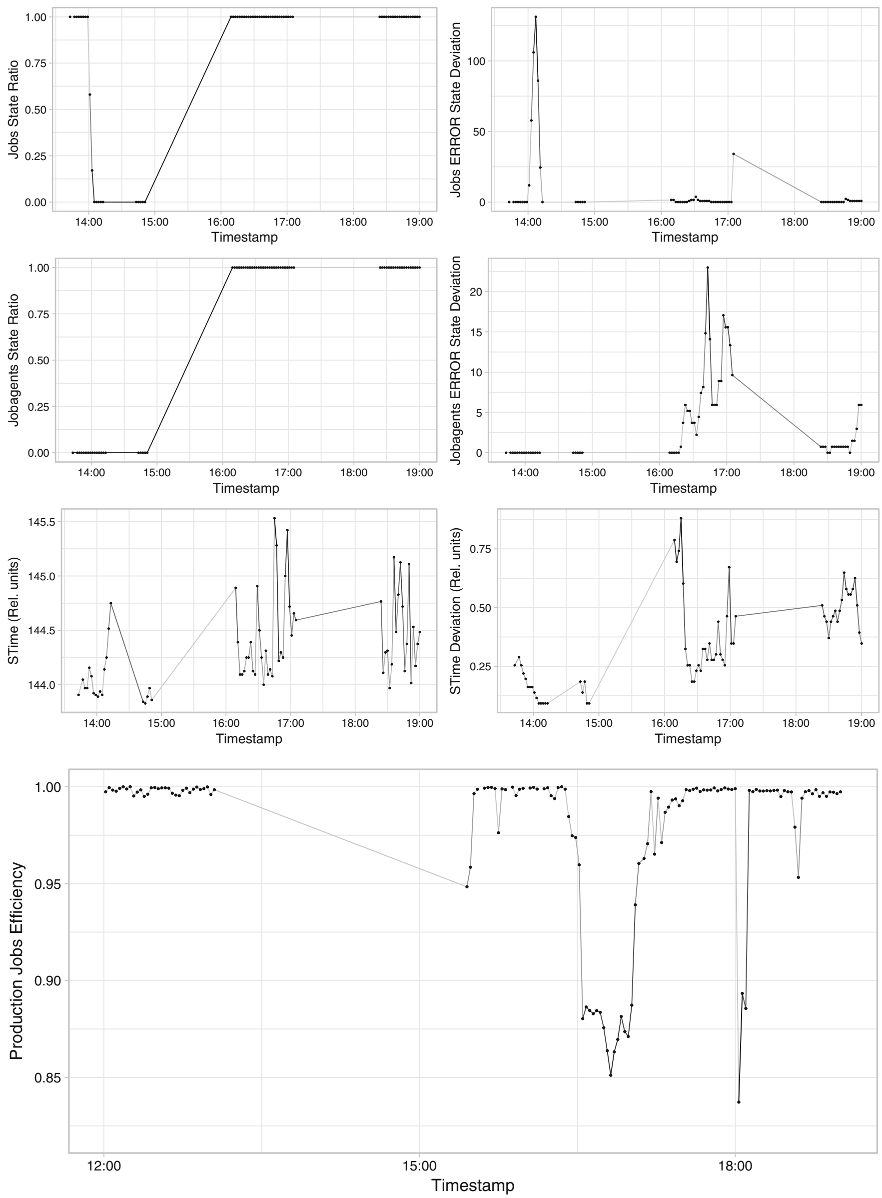

Fig. 4. Event state for a selected site on 10/07/2015

the development stages we have also tested smaller data sets using Partitioning Around Medoids (PAM), for which Mahalanobis distance was used from the R *StatMatch* package. We have considered two test cases: site-based and across-site clustering. In the former case, each site maintained its own event state vector, whereas for overall clustering we have considered minimal event states. Given that we aimed to evaluate clustering stability in time, we split the data into training and testing sets. For each test case, we have evaluated clustering approaches according to how well the data was clustered using Average Silhouette Width (ASW) and Calinski-Harabasz (CH) criterions, implemented within the R *fpc* package.

Early on we have observed that select sites did not report all event state parameters for storage. From initial analysis using PAM, for site-based evaluation, we have further reduced event state vector, as we have observed that for majority of sites job and job agent ratios to be colinear. Figure 4 demonstrates sample minimal event state for a selected site. From the plots we observe, that the site potentially experienced issues during two periods starting at 14:00 and 17:00. In the first case, we note that the number of jobs going into error increased within a short period of time, which was followed by complete loss of monitoring data. In the second case, we see only job agent error state deviations before loss of signal occurs, with production job efficiency being affected. While it is reasonable to suggest an instability in the first case, signal loss at 17:00 did not seem to significantly affect running jobs, job agents or the network afterwards. We conclude, that signal loss does not imply an instability, as the causes may stem from monitoring agents themselves, rather than site operations. Therefore, we have adjusted our analysis to consider site events in terms of time-independent *states*.

To assess the quality of the chosen clustering approach we have computed ASW and CH criterions on both training and testing data. For site-based evaluation, locally optimal event state vector and the number of cluster groups were chosen based on returned criterion values. We have performed across-site evaluation by choosing a minimum event state vector, consisting of parameters that are reported by all sites. The medoids generated from the training data were then used to cluster the data points from the testing set. For both site-based and across site clustering we observe similar results, producing testing ASW > 0.5 for most sites.

Figure 5 demonstrates the results from the site-based testing. We note, that while most sites, demonstrated strong clustering for training and testing, five sites have shown weaker clustering results on the testing set. This corresponds to the aforementioned storage observations and rare events. For across-site training and testing, we have ASW of 0.63 and 0.56 respectively, when using seven cluster groups. This suggests, that our clustering approach produced cluster groups of significance which are stable in time.

Figure 6 further examines cluster sizes for training and testing sets for site-based and across-site clustering cases. We note, that for across site testing, clustered group sizes differed by 18% in total. For site-based clustering, we observe

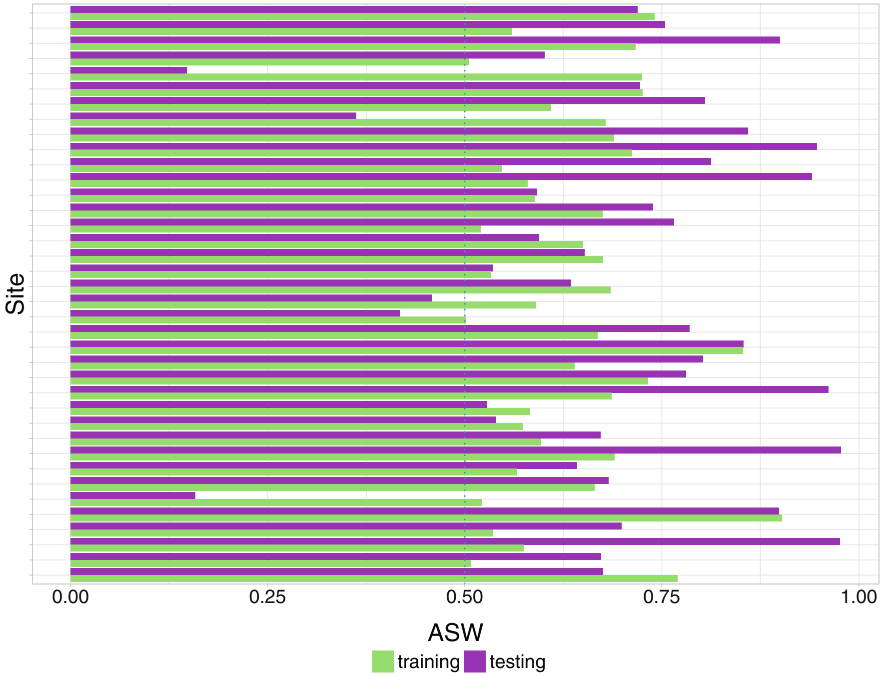

Fig. 5. Site-based training and testing evaluation for a subset of sites

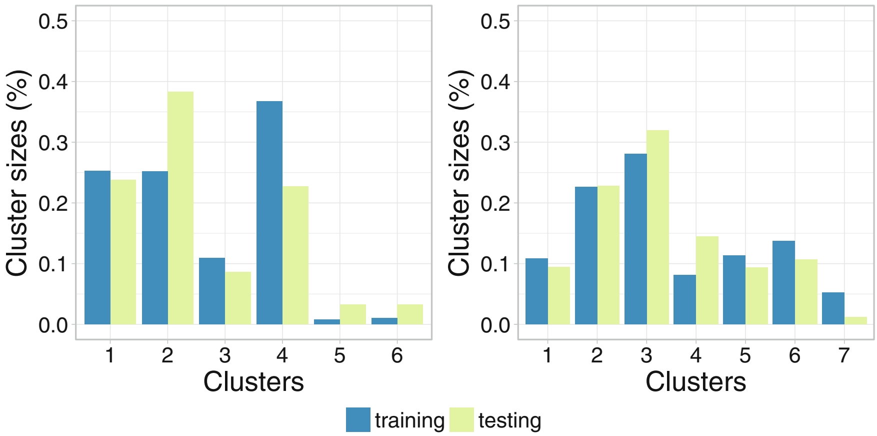

Fig. 6. Cluster group size evaluation for a select site (left) and across site (right) cases

pronounced variations between trained and tested sets, with groups containing fewer points. Cluster group 2 for site-based case medoids reflect high storage throughput and user efficiency, while exhibiting low error deviations within jobs and job agents. Group 6 on the other hand, shows high throughput and error deviations in transfer states. For across-site clustering, groups 3 and 4 correspond to medoids with low network variation, high production job efficiency, and low job error state deviations. We label these groups as *normal*. Groups 2 and 7, in this case, reflect medoids with STime of 500 and 308, signifying occurrences of *packet loss*. Group 6 includes states where *all* services are affected, demonstrating high deviations in job error states, low network quality and low production job efficiency. The use of this metric can be further used to construct a site stability measure based on the event state vector. Overlaying the group domains and introducing an event selection process, thus allows us to detect events that correspond to an instability.

5 Conclusions

This work examined the software workflow for the ALICE computing environment, observing that job efficiency presents a bottleneck, affected by the state of computing, storage, and network services. We have then developed a methodology to detect operational instabilities for these services, running within data centers of varying scale. Our approach has confirmed, that distinct regions of service instability can be detected regardless of site specifics. Further reliability modeling techniques can be used to model the pre-failure period, allowing for autonomous agency to be introduced at any service layer to ensure survivability of dependent services when failure occurs.

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An Algorithm for Migration and Resource Planning in Cloud Technologies

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Abstract. Cloud technologies are currently rising and many companies are working to deploy and operate their infrastructure using a private cloud that is run on their own resources and where they want to get the most out of their operation and usage. The operation of such infrastructure is sensitive to resource planning, and it is necessary to plan these resources and use them in a deliberate manner.

This article deals with resource planning and the algorithm for solving the migration of a virtual instance (virtual machine or virtual appliance) to the most appropriate hypervisor using an analysis of the usage of virtual instance and physical hypervisors in the past. This algorithm collects data from agent on infrastructure and evaluates the load of individual components (hypervisors and virtual instances). Based on these data can migrate instances between hypervisors and increase the efficiency of the environment.

Keywords: Cloud · Resource allocation · Virtualization · Virtual instance · Algorithm

1 Introduction

For the highest availability of services in virtualization and cloud technologies, it is sometimes necessary to address the migration of resources between several virtualization guests (hypervisors). Basically, it's a virtual server moving from one server to another.

Each service may show specific usage and properties, for example, the difference may be a static web page, an application server, or a database server. At a time when such migration, whether automated or manually induced, which is going to occur, it is necessary to address the question of where to move such an instance.

This article discusses the theoretical solution to the migration problem, especially the algorithm, for finding the most suitable virtualization guest for running a migrated instance.

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1.1 Virtualization

A virtualization emulates a physical computing resource, such as personal computers, servers, processors, memory, storage, network, stand-alone applications, or services as a virtual instance, which are running on one or more physical machines, so called hypervisors [4].

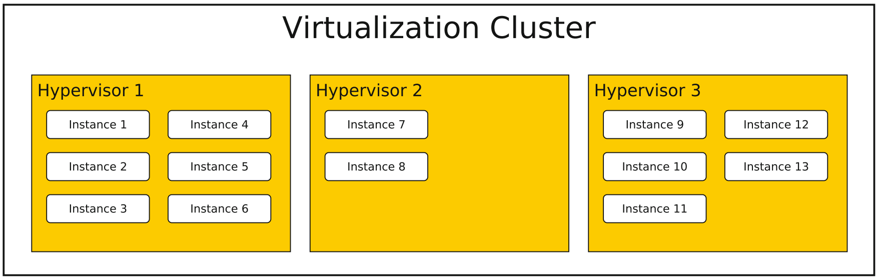

Fig. 1. Virtualization

Types of virtualization used in today's technologies include virtual machine virtualization and container virtualization. For easier identification, these virtualized sources can be called virtual instances (Fig. 1).

A virtual instance is an instance that offers services to users or other services. These services can include, for example, database services, application services, network services, web sites, and more.

The virtualization is important for efficient allocation of resources, and is based on the virtualization of computing resources and hence on the possibility of offering more services at once. This resource virtualization is primarily based on the fact that there is a difference between faster growth of physical hardware computing power options and slower growth in the demanding performance of today's applications.

1.2 Resource Virtualizations and Allocations

As has been written, the virtualization is mainly used to efficiently allocate physical resources and offer them multiple instances.

The virtualization principle is based on the fact that the physical resource is virtually offered and allocated to virtual instances. To maximize efficiency in resource allocation, cloud infrastructures are over-dimensioned, for example, one physical processor is in the virtual world of 5 virtual processors, the virtualization ratio in this case is 5:1.

This overdimension can not occur on any physical resource, as there may be situations where inappropriate physical and virtual resource ratios can lead to instability or the fall of the entire infrastructure.

1.3 Resource Variables

The important resources that are useful in monitoring the performance of virtual infrastructures and the use of physical means of virtual guests, namely hypervisors, include:

- CPU usage per instance (average and variances) and on hypervisor (average, variances, variaces of situated virtual instaces and their intersections),
- memory usage per instance (average and variances) and on hypervisor (average, variances, variaces of situated virtual instaces and their intersections),
- network usage per instance (average and variances) and on hypervisor (average, variances, variaces of situated virtual instaces and their intersections),
- storage usage per instance (average and variances) and on hypervisor (average, variances, variaces of situated virtual instaces and their intersections).

These parameters are based on the fact that all hypervisors are the same. If this is not the case, the observed parameters can be expanded by differences (e.g., unavailability of a network, faster or slower disk, etc.).

However, a higher priority than the average values observed are the deviations in the higher requirements, i.e. the time at which these fluctuations occur and how large such fluctuations are.

1.4 Effective Migration

There may be a situation where you need to migrate a virtual instance to another hypervisor. This can happen, for example, as a result of a hardware error or only due to the virtual instance being relocated, for example because of a planned downtime or to make more efficient use of physical resources. This migration must be done as quickly and efficiently as possible so as not to lose data or to minimize service downtime. Another important factor may be the correct placement of the virtual instance on the right host. The factor that may affect placement efficiency may be the current or long-term use of individual guests, which is usually not the same, which is based on the differences between the claims of the individual instances.

In cloud infrastructures (for example, in Openstack), it is common for hypervisors to be connected to the same network and are identical to physical hardware.

In order to be able to efficiently allocate and migrate virtual instances, the virtualization trends and the trends of claims of individual instances must be monitored. For this, it is important to determine which resources are to be tracked, what is the time to track these resources, and how to deal with these data.

1.5 Offline and Live Migration

Migration can be divided into two basic types - offline and live migration. The difference in this is that there is no downtime of the running system during live migration, and in offline migration, the instance is first turned off, then de-migrated to a new hypervisor and then turned on. The live migration advantage is that the system is not switched off and there is no downtime, but the disadvantage is that this migration is demanding, that is, it takes a long time, and it is difficult for migrations to carry out this migration. By contrast, off-line migration has an advantage in speed, but the disadvantage is to shut down the system during migration.

2 Problem Definition

The introduction highlighted issues related to resource allocation, virtual instance migration and resource extraction monitoring in virtual infrastructures.

If virtual instance migration is required to another physical hypervisor, this migration can be done randomly to any hypervisor in the infrastructure. Such a process may, however, cause inefficiencies in the location of such an instance.

On Fig. 2, on Fig. 3 and in Table 1, there are graphs of the use of two hypervisors that show ineffectiveness in allocations for individual hypervisors. On hypervisor 1, inefficiencies occur at times t4 to t7, when the demand for physical resources is 100% or higher. By contrast, at the same time and throughout the timeframe, hypervisor 2 is used at 40 and 50%, respectively.

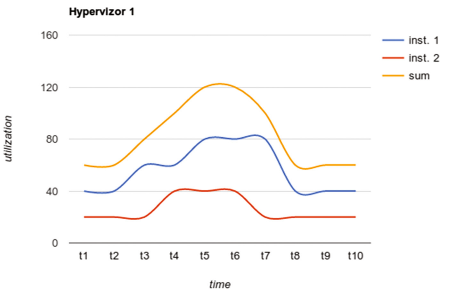

Fig. 2. Utilization of hypervizor 1

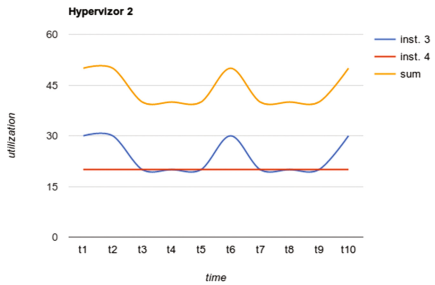

Fig. 3. Utilization of hypervizor 2

Table 1. Table of load (in % of hypervisor performance)

Utilization (%)	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10
Instance 1	40	40	60	60	80	80	80	40	40	40
Instance 2	20	20	20	40	40	40	20	20	20	20
Sum (hypervizor 1)	**60**	**60**	**80**	**100**	**120**	**120**	**100**	**60**	**60**	**60**
Instance 3	30	30	20	20	20	30	20	20	20	30
Instance 4	20	20	20	20	20	20	20	20	20	20
Sum (hypervizor 2)	**50**	**50**	**40**	**40**	**40**	**50**	**40**	**40**	**40**	**50**

For example, an instance generates large processor time requirements, we need to demigrate this instance and randomly choose the hypervisor to locate this instance without the slightest thought. In such a procedure, it may happen that this instance gets to a hypervisor where the exact same instance is, and the hypervisor will be extracted to processor time, e.g. because of many processor-demanding instances. This is inefficient, because by oversizing physical resources in the cloud, these instances begin to drag on physical resources that are deficient and begin to experience physical hardware fronts. These issues can occur with any parameter that is introduced in Chap. 1.3 and which occurs in cloud technologies to overdimension.

For more efficient migration of virtual resources, it might be helpful to monitor extraction parameters on individual virtual instances and physical hypervisors. As soon as an instance needs to be moved, the values of the individual parameters would be compared and the most ideal physical hypervisor can be selected according to predefined rules, and then the instance can be migrated.

For an elimination of this inefficiency introduced in this chapter could occur by moving instance 4 to hypervisor 1 and instance 2 to hypervisor 2. After these migrates, inefficiency would only occur at time t5 to t7 but only at the level of allocation of 100% and that is more acceptable, as the demand for resources would only be overwhelming.

3 Related Works and Commercial Solutions

This problematics is addressed in corporate infrastructure by the expert's assessment of the technology, that determines where the migration is to take place based on knowledge. However, there may be an inaccurate estimate [12].

In virtualized infrastructures, the efficient allocation of memory is primarily solved, because memory is one of the most vulnerable to the lack and allocation of [7]. In order to ensure the correct and sustainable state of virtual infrastructure, it is important to monitor the load [1,2].

Another important factor for the decision is the separate cloud structure and its usage [3,6,17]. If the cloud is used by multiple users, it is possible to divide the resources between users into the resouce pools, which then the user can be assigned and set up limits over which user can not draw more. This further brings more opportunities and challenges for usage tracking. The monitoring of resource extraction by users should also be complemented by automation with pre-defined possible rules [11].

Resource planning is, in the long run, virtualization infrastructures needed by [14,18]. There are few cloud environments where there is no need to expand the entire environment. Environments need to be expanded before all resources are exhausted throughout the environment, so it is not possible to add additional virtual instances to such cloud. The cloud provider should have created a plan to develop the cloud environment and implement this plan. This limitation is related to the need to comply with SLA parameters for the infrastructure and its availability [8]. SLA parameters can be defined for the general availability of technology, but also for its performance, which can be increased at a time when physical requirements are higher than physical resources are available.

One of the ways to deal with the load prediction on virtualized infrastructure is to make a model and its simulation [5]. Such modeling is not possible only on the basis of technology but also the cost model of the entire infrastructure or data center [16].

3.1 Microsoft Hyper-V and VMware vSphere

To address this issue, individual commercial technologies are very similar and all offer opportunities for offline and online migration of virtual instances.

Microsoft and Hyper-V have several options to migrate, from exporting and importing a virtual instance, through Quick Migration to Live Migration [13].

The first option is to export the virtual instance using the `Export-VM` PowerShell command to some storage, transfer to a new hypervisor, and then import it using the `Import-VM` command. For Hyper-V solutions, PowerShell, Hyper-V console, or System Center console are used. VMware also offers the option of offline and online migration [15]. Offline migration consists of turning off a virtual instance, moving it, and then turning it on. Online migration is possible with vMotion or Storage vMotion.

For none of these migrations, there is no advanced analysis of the target environment and its load. Only basic compatibility verification is performed.

3.2 OpenStack

OpenStack is a more open migration of instances between hypervisors and its automation or self-creativity according to the actual needs of the environment, mainly due to the OpenStack project being developed as Open Source technology [9].

There can use both off-line and online migration. Offline migration is done using the `nova migrate` command And online migration is possible with the `nova live-migration` command, for which it is possible to manually specify the hypervisor to which the instance is to be migrated via live migration. It is also possible to help with a sequence of other commands, for basic analysis of the current load of the environment load [10].

4 Solution Desing

The proposed solution is to collect data on the use of individual hypervisors and the claims of individual virtual instances. This solution implements the environment mining monitoring, where data from hypervisors will be collected in the environment to serve to analyze historical data. Such implementation can vary depending on the actual needs of the environment and the input parameters.

Before implementation, it is necessary to determine in advance how the data will be collected, which data will be collected, how often they will be stored and how they will be handled. Data collected is important not only for the evaluation itself, but also for the very complexity of the steps taken and the daily routine, which involves evaluating the state of the environment.

There are several approaches to evaluating collected data. It is possible to monitor only some parameters or all the parameters presented in Chap. 1.3. It is also possible to add weight to individual parameters, so that these scales are then included in the final evaluation. For example, since one of the most critical values is known to be memory, it can be given the highest weight, and on the contrary, the network may be less weighty because the capabilities in current networks are sufficient for most applications and systems.

If weighing the individual parameters, it is a good idea to introduce an empty index for each hypervisor when this index is calculated based on the average load. Or, it is possible to calculate this index for each hypervisor based on the time axis, for example, for each hour each hypervisor can have a calculated index, as it is assumed that the system's load will change at the time of loading.

It is also appropriate to provide the indices and individual instances accordingly. This load index shows resource usage for each virtual instance. These indices subsequently help us to make a quicker decision on the suitability of migration to a particular hypervisor because these values are already calculated. Evaluating and searching for an ideal hypervisor for a given instance is simply a search for the same course, respectively. The void index is compared with the inverse course of the load index, and mainly based on available resources.

4.1 Components

This suggested solution should have several components that will take care of individual parts, which are:

- monitoring and dashboard, that interact with users and inform about changes,
- agents, that are collecting data,
- data transaction system, that transform the collected data from the agents into a form suitable for further analysis,
- database, where historical data are stored,
- execution that perform individual migration and infrastructure actions.

4.2 Load Evaluation

A prerequisite for proper algorithm operation is the correct and efficient collection of individual parameters. There should be implemented algorithm for evaluation of load, which will analyze collected data. Data should be collected long enough to avoid overloading the entire system.

There can be a lot of traffic changes in the time, but each this change can not invoke migration, because each migration will increse load in environment. Also any traffic peak can be only random and will not occur in short or long future. The evaluation can be different for each environment and depends mainly on the requirements for specific environment so there can not be one simple evaluation algorithm. There can be mainly recommendations and proven procedures.

In this article there is defined an execution engine, which take care about the load evaluation. There can be defined rules and statements for load evaluation. Between these statements also should belong how the evaluation is prone to individual parameters and there can be implemented also mechanism how to migrate and workload.

The execution engine technical implementation itself depends on the chosen technologies and tools.

4.3 Manual Migration Workflow

The steps to be taken when a user invokes the virtual instance migration are:

1. The user invokes the request to migrate the virtual instance.
2. The execution engine performs a basic analysis of the environment based on the data stored in the database or performs a basic query on the agents.
3. The execution engine, if a suitable hypervisor is not found, will query all agents and perform a basic analysis to select a suitable hypervisor.
4. The execution engine, if a suitable hypervisor is found, will analyze and estimate how long migration will take to the new environment. The agent's query on the target environment can be migrated here.
5. The execution engine informs the user about the appropriate candidate for migration and asks whether to migrate.
6. User confirms migration.
7. The execution engine performs migration and, after successful migration, performs current environment analysis (only affected systems), updates the current state of the database and also informs the user of the migration made.

4.4 Automatic Migration Workflow

Automated migration can be implemented using similar rules as manual. The steps for such a migration can be:

1. Monitoring detects inefficiency in allocation.
2. Monitoring sends the hypervisor information to the executive engineer where this inefficiency has been detected.
3. The execution engine analyzes the affected hypervisor and selects suitable candidates for migration.
4. The execution engine can migrate based on clearly defined rules.
5. The execution engine performs migration and informs the user.

Automated migration is very prone to the requirements in the environment and may vary. The migration trigger may not only be based on inefficiency but only in the context of a regular analysis of an environment where it is determined that resource allocation efficiency can be improved over the long term. It also has to be eliminated to avoid migrating migration, when only hypervisors are migrated because migration itself takes time and loads resources.

Before running the proposed solution, you need to test this solution. Given that the solution will bring a certain amount of ambient intelligence and autonomy to the infrastructure, testing should be done outside the production environment or, possibly, on a minor subset of instances, i.e. hypervisors. The correctness of the proposed solution should be verified by an expert in the technology in the first iterations to verify that the migration behavior is desirable and does not bring instability to the system.

5 Conclusions

This article describes a theoretical migration model and resource extraction analysis in a virtualized environment.

A developed model analyzes the requirements of virtual instances and usage of physical resources on hypervisors. This model provides a basis for resource use tracking and can be used to efficiently allocate resources where one hypervisor is divided into virtual instances that do not encounter over time in the use of physical resources, and their peak in resource utilization is at a time elsewhere. This results in a long-term trend of effective spreading of the burden between hypervisors. It is also appropriate to supplement this model according to the current requirements for individual environments and the requirements of the operator, for example, when one operator prefers more use of fewer guests, but the other prefers less occupancy.

The analysis proposal hides a negatives which can degrade the effectiveness of migrating. One of the biggest drawbacks is the need to perform regular analyzes of the environment and analysis of this migration. However, these shortcomings can be eliminated using regular analyzes that will effectively analyze the environment as well as knowledge of long-term trends. Under these conditions, it is possible to immediately obtain the information and the most suitable target hypervisor to migrate a virtual instance.

Not only the testing but also the monitoring and operation of this algorithm are important for the sustainable operation of the infrastructure.

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Multi-level Orchestration of Cloud Services in OrCS

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Abstract. Orchestration is a well known topic in *old* web services literature. Anyway, what Orchestration means for Cloud services is not yet Clear. Services, especially at lower layers of Cloud Architecture, are complex: Scientific literature has focused on the problem of dealing with proper, efficient and even optimal allocation of Resources when deploying and delivering Cloud services. Hence, management of Resources is what is commonly addressed as *Orchestration* in the Cloud. Anyway, the increasing complexity of Cloud Architecture and the introduction of new paradigms like Internet of Things, introduced the problem of creating Value Added Services by composition, not only of Resources, but of Services too. In this work we describe an architectural solution for Orchestration at all Cloud Layers. The framework we propose (Orchestrator for Complex Services: OrCS) manages composition of services and resources in order to create composite service based on Cloud Design Patterns. It is based on a Workflow language for description of composition and it enables verification of composite services by means of Model Driven Engineering techniques, providing a precious and easy-to-use tool for Cloud Engineering.

1 Introduction

Web Services Orchestration, as well as Cloud Architecture are not novel topics, but during the last few years, Cloud systems increased in complexity. Orchestration took a new role in Cloud Architecture, focusing on the problem of optimize (physical and virtual) resources in complex, federated or multi-cloud environments. In addition, increased services complexity, has required the use of proper abstraction in order to ease Cloud Designers efforts. The introduction of Cloud Patterns in literature implicitly renewed the problem of managing complex Cloud services by composition. *Old* issues in Web Services Orchestration, intended as workflows of activities, returned as new problems in Cloud Orchestration: this term usually addresses automation, but no clear definitions, frameworks or

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languages have been provided, which solve the problem of *multi-level* Cloud Orchestration.

In [28,29] authors report some scientific issues on orchestration of Cloud Services: it is *Cross Cutting* the architectural levels of Cloud Systems (i.e. IAAS, PAAS and SAAS levels).

Some important issues are: (a) providers are responsible of the management and enactment of activities in orchestrated services; (b) orchestration involves services and resources in all levels of Cloud stack; (c) orchestration must face Quality of Service (QoS) of both component and composite services.

Hence, orchestration of Cloud services requires both *intra-layer* (i.e. between services in the same level of Cloud Architecture) and *inter-layers* composition (for example when a service in SaaS layer uses a PaaS or IaaS service).

In addition, a new trend in cloud services design and management grew up in the last years: the definition of extended Design Patterns [14] for Cloud computing. Most of Cloud Design patterns suggested by Big Vendors [11,32] are described as workflows.

The main effort in composition during last years focused on the choice of the services and resources to use in a composite Cloud Service in order to improve Quality of Service [16]. Many works deal with optimization problems [12,15]. Anyway, the most of these works lacks in a formal definition of the Orchestration problem. A tentative of providing a Cloud Orchestration Engine with an orchestration language is in [18] where COPE (Cloud Orchestration Policy Engine) is presented. Peer-to-peer and collaborative approaches to composition have been proposed too: in [6,33] where authors show the usefulness of the platform not only for efficient and reliable distributed computing but also for collaborative activities and ubiquitous computing [7]. The only mature work on Orchestration was made by OASIS in the Topology and Orchestration Specification for Cloud Application (TOSCA) [8]. Several works have been reported in literature about Cloud Pattern exploitation [17], but in general they contain only descriptions of different design patterns. At the best of our knowledge, this work is the only work which addresses composition in terms of both Cloud Computing Patterns and Workflow patterns. We think that these two concepts are strictly related at different layers of abstraction [2,3].

In order to achieve automatic Cloud Service composition, resources should carry out a semantic description of their functionality, as well as a semantic description of their parameters [1].

Actually, several semantics-based approaches for *simple* web services composition exist (a survey is in [9]). Some of them [19,20] exploit BPEL4WS orchestration language and OWL-based ontologies for services description.

In this context, it is clear that a framework able to manage composition by orchestration is appealing, which explicitly takes into account of Cloud Design Patterns, resources and services orchestration.

This work describes the Orchestrator for Complex Services: *OrCS*: a framework for automatic composition of Cloud Services which is driven by cloud patterns definition. The framework enables both design-by-patterns of composite

Cloud Services, it implements run-time manager and monitors for services, and it allows for automatic verification of composition soundness. Quality of Services (QoS) requirements can be verified too. The methodology where OrCS relies, is based on formal definition of an orchestration language, on the use of ontologies to describe Cloud services interactions and on a rule-based reasoner that enacts composition. The methodology is general enough to be used in the reverse way too: thanks to the formal description of patterns, the reasoner is also able to recognize if a Composite Service is an instance of a given pattern. In addition, Model Driven Engineering techniques have been embedded in OrCS, in order to fulfill validation and verification activities [4,5,30,31].

OrCS allows for building composite services in an easy way, simply declaring the kind of composition (i.e. the patten) to realize. Component services are automatically selected when declaring the semantics of services to implement and eventually the QoS to assure. Soundness of composition is evaluated too, providing answers to questions like: is the composite service able to end without errors due to wrong composition? Is its whole QoS compliant with a given Service Level Agreement?

2 OrCS Architecture

This section briefly introduces the architecture of OrCS framework. Remember that OrCS aims at designing, defining, analyzing and managing multi-layer Orchestration.

Figure 1 depicts the main component of OrCS.

A **User Interface** provides the tools to design Cloud Services and eventually to define the main structure of resources needed to run composite services.

We work upon the existence of several, eventually heterogeneous, Cloud Providers (**CloudA,** $\cdots$**, CloudN**). Each providers is able to instantiate common Cloud Resources like Computing Nodes, Virtual Storages or Virtual Network (inter and intra-clouds). In addition, Virtual Storages can of course maintain different sets of Data.

The architecture of the **Orchestrator** we are describing consists of:

- an **Execution Scheduler:** the scheduler reads the description of a composite service and executes the proper services when needed, eventually scheduling data migration too from a virtual storage to another if needed.
- a **Data Dispatcher:** It executes physical data migration and maintains information about data produced during the execution of the composite service.
- a **Broker:** it enacts common service brokering actions: if the resource is not yet acquired on a provider, it provides for acquisition and management. It is also responsible for the provisioning of the resources and their configuration.
- a **Deployer:** this component deploys needed services at SaaS (from a pool of available services)on proper resource in the Cloud.
- the **Resources Orchestrator Manager** interface with existent orchestrators [28]. At the moment this module supports COPE [18] and OpenStack HEAT Orchestrators.

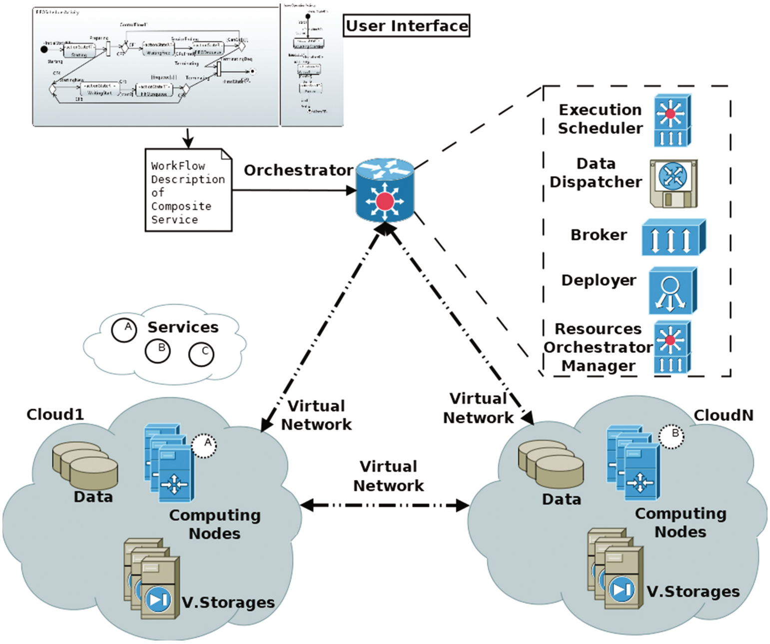

Fig. 1. OrCS Architecture

The workflow-based language we use for description of the whole service is called Operational Flow Language (OFL). The language is complex enough to describe several patterns, as well as simple enough to be defined by means of clear operational semantics. Compositional rules enable patterns description.

OFL is able to describe simple workflow graphs that are expressive enough to catch many control-flow and data-flow workflow patterns as explained in the next section. In addition workflow graphs described in OFL allow for the creation of analysis models by using Model Transformation techniques (see [23,24] for more details).

Composition and patterns are expressed by using a formal workflow language. Its semantics, together with a semantics-based definition of cloud resources and services, enables automatic composition of composite services.

In short, patterns are a good way to drive both composition and analysis of composite services.

Hence, if we know how to compose services in terms of patterns, we can automatically build and manage an orchestrated service that realizes our need (in terms of results and QoS).

Our methodology supports ontology-based description of services by using OWL-S [21] language. Anyway, OWL-S process model is not sufficiently expressive to characterize general composition [19]. We think that an effective semantics-based description of IOPE [22] (Input, Outputs, Preconditions and Effects) elements of Cloud services and resources, as well as a Semantics-based description of *what* the resource *is* and *does*, can be useful in the application of matching algorithms for the choice and the retrieval of Cloud services as described in [19] for simple Web Services.

OWL-S description of cloud services is not enough: as previously described, we need to define, for adequate matching, the role of resources and services both in composition and in Cloud Architecture.

Roles too are described in an ontology developed in previous work which addresses Cloud Architecture and Resources [25].

Finally, for what QoS analysis and composition concerns, the workflow graphs described in OFL allows for the creation of analysis models by using Model Transformation techniques [23,24].

Figure 2 depicts the components that underly the OrCS framework.

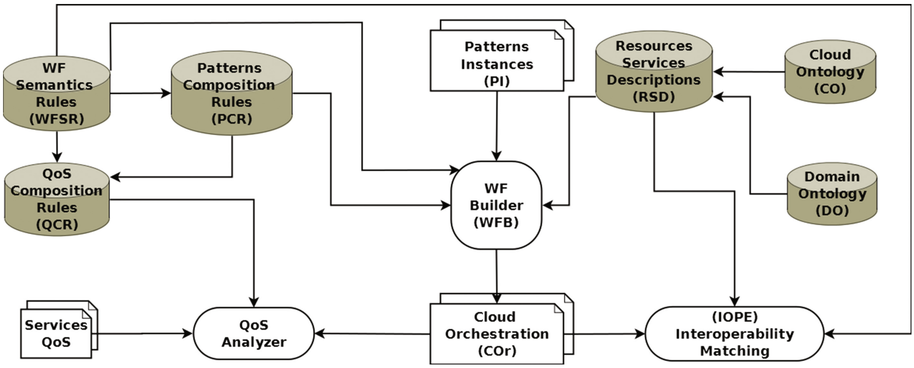

Fig. 2. OrCS components

The Components **WF Builder**, **Service Interoperability Matching** and **QoS Builder** respectively manage goals of:

- creating a workflow of composite services from patter-based description;
- analyzing preconditions for using components in orchestrated Cloud services;
- analysing QoS of composite Cloud services.

The WF (Workflow) Builder is based on a Knowledge Base of logic rules containing (a) the Operational semantics rules of OFL language (in the repository **WF Semantic Rules**); (b) the operational semantics rules for orchestration patterns description (**Patterns Composition Rules**). They are in turn defined in terms OFL. Results from WF Builder are skeletons used to implement Orchestrated Cloud Services. Proper back-end units can read skeletons in order to create stubs for different Vendors or APIs.

Inputs for the Service Interoperability Matching are **Cloud Orchestration** skeletons (declaring how services interacts) and the descriptions of component services and resources. Descriptions use OWL-S and IOPE grounding for cloud resources. In addition, the description of services functionalities depends on some domains of interest (i.e. financial services, E-Health etc.). Proper OWL ontologies (Domain Ontology) describe concepts and properties of these domain. In Addition there is the need for an Ontology describing abstract Cloud architectures, services an resources (Cloud Ontology [25]). The description of these ontologies is out of the scope of this work. Finally, QoS Analyzer takes Cloud Orchestration and QoS descriptions in order to build analyzable models [13,27] (by using **QoS Composition rules**). At the moment the analyser supports only performances and availability.

3 Orchestration in OrCS

Our workflow language has simple constructs that can be used to define complex composition patterns. Patterns are described like source code skeleton for implementing composite service.

We describe Orchestration by means of Cloud Patterns[1] [10,11,26]. Patterns are in turn defined by using a workflow-based language called Operational Flow Language (OFL).

In this section we briefly introduce the basic elements and operational semantics of OFL language. Than, we show how patterns can be defined by using OFL.

OFL is a workflow-based language. According to the definition provided by the Workflow Management Coalition[2] we consider a workflow process definition as a network of activities and their relationships. Each activity represents one logical step within a process, i.e. the smallest unit of work to be performed. The completion of an activity and the starting of another activity is a Transition point in the workflow execution. A Transition may be unconditional, but the sequence of the activity execution may also be decided at run time according to the value assumed by one or more logical expressions, in this case the sequence of operations depends on Transition Conditions that are evaluated after an activity has started or ended.

Some points are defined within the workflow that allow the flow of the activities to be controlled: AND-split is a point in where a single thread of control splits into two or more threads which are executed in parallel. AND-join is a point where two or more parallel activities converge into a single thread of execution. XOR-split is a decision point where only one of alternative branches is executed. XOR-join is a point in the workflow where two or more parallel activities converge in a single thread of execution without synchronization. OR-split is a decision point between several alternative workflow branches. OR-join is a point in which several alternative branches re-converge into a single thread. In the following XOR, AND and OR are called split or join Conditions. Figure 3 illustrates these elements.

[1] https://cloudpatterns.org, http://en.clouddesignpattern.org/index.php/Main_Page.
[2] http://www.wfmc.org/.

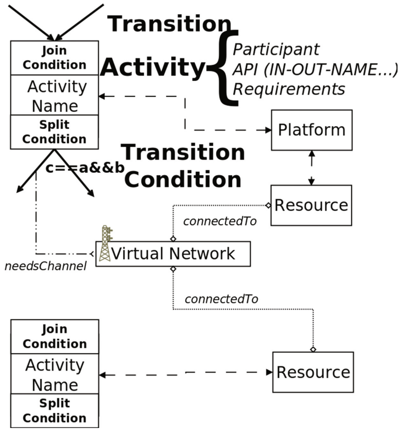

Fig. 3. Workflow elements

Therefore in the OFL language, workflow processes consist of a network of Activity nodes and edges (Transitions) identified by a pair od nodes $(FromActivity, ToActivity)$.

Activities represents atomic Cloud Service or resource invocation, as well as composite activities (i.e. sub workflow processes).

OFL skeletons are graphs defining preconditions and postconditions for cloud services execution and Cloud resources usage.

4 A Case Study

The example we want describe is inspired by a recent commercial study[3] reporting the importance of performing analytics over Weather, Geo-referenced data.

The main problem here is that analytics must cope with proper data about commercial activities in a given field and all drilled-up results both from weather and commercial fields, have to be collected and further analysed in order to achieve good results.

This obviously leads to the need of automatize a composite analytics service by exploiting Cloud platforms and resources.

Figure 4 resumes this scenario and the OFL representation of the composite process.

The top and the bottom of the figure depicts the two Cloud providers (here called CloudWeather and CloudPrivate) where some resources (four computational nodes and a Virtual Storage in CloudWeather; two computational nodes and a VirtualStorage in CloudPrivate) are deployed. On the CloudWeather provider, a PaaS Apache Spark Service is available, while an Hadoop service is available on the other provider.

[3] http://advertising.weather.com/big-data-weather-data-enhanced-business-strategy/.

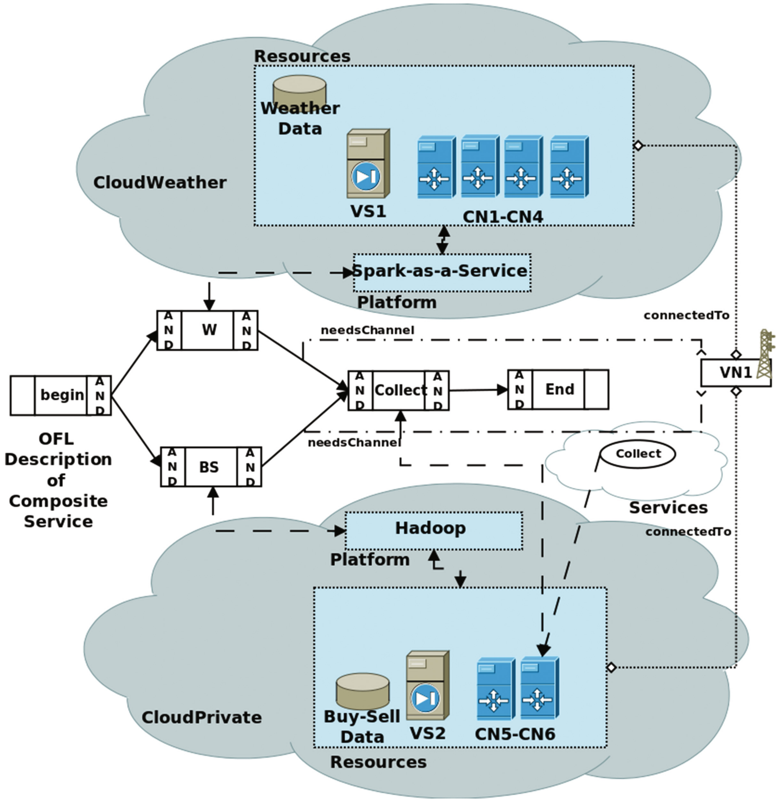

Fig. 4. Case study

The Workflow process describing composition is in the middle of the figure. It consists in two Activities executing in parallel after the beginning of the process: the first (W) requests the execution of analytics on the Spark PaaS, while the second (BS) enacts the execution of analytics on Hadoop. When both terminates, the Orchestrator controls the existence of the Virtual Network VN1. If it is not allocated, the Broker provides (if necessary resources exist) the necessary resource. Then, the Collect service is ready to start. The Deployer deploys the service on CN6: the activity can execute on proper data that are collected by this very service. The process can finally terminate leaving results on CloudPrivate Virtual Storage.

Data routing and some minor details are not reported for brevity.

5 Conclusions and Future Works

This work describes the OrCS overall architecture: a framework for Orchestrate Cloud Composite Services at different Layers of Cloud Architecture.

OrCS provides a Workflow language (OFL) that can be easily generated from Pattern-based description of composite services. In addition, its inner representation (the OFG graph) allows for analysis of composition. At the moment OrCS supports Openstack and HEAT, but future works include the management of more Cloud middleware in order to allow OrCS to be integrated in many multi-cloud and federated environments.

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Performance Analysis of AIN-PT, AIN-SLT and SIIT Network-Based Translators

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Abstract. This paper evaluates and compares the performance of some selected network-based translators (e.g. SIIT, AIN-SLT and AIN-PT). The rationale behind this paper is to investigate the performance of heterogeneous networks (i.e. IPv4/IPv6 networks) when different types of network-based translators are used. The SIIT protocol translates full IP packet headers when connections are initiated from IPv4-only networks to IPv6-only networks and vice-versa. Whereas, the AIN-PT protocol uses tunneling approach to achieve the interoperability between IPv4-only/IPv6-only networks without translating full IP packet headers. Similarly, the AIN-SLT protocol uses the IPv6/IPv4 socket Application Programming Interface (API) translation technique instead of translating the packet headers between two heterogeneous networks. This could be achieved by ending IPv6/IPv4 connection points at the application layer. The experimental results show that the performance analysis of AIN-PT protocol is much better than that of SIIT and AIN-SLT protocols.

1 Introduction

Since the Internet is now running out of public IPv4 addresses very soon, the reverse problem of lately deploying IPv6 address will appear. The reverse problem will most likely make the new installed connections have to be IPv6 only, as IPv4 addresses are going to be scarce or no longer available. Dual stack operation (dual connectivity) [1] will no longer be an option as a solution to let these systems communicate with the huge installed IPv4 base, making them rather isolated from the major existing Internet. A solution will need to be adopted to allow these systems to still be able to communicate with IPv4 hosts, as the present installed IPv4-only base is likely to be still around for considerable time to come. Translation as proposed by IETF is an option, but it has a number of disadvantages. As illustrated in [2, 3], the translation approach is used when communication is required between systems/networks operating in different IP versions. In this case, translation of the full IP headers from IPv4 to IPv6 and vice versa is required for every IP packet [4]. For interconnecting machines in heterogeneous IPv4/IPv6

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environments (IPv4-only connectivity to IPv6-only connectivity), translation is the only option. As far as interconnecting IPv4 and IPv6 network communication, several protocol translation mechanisms have been proposed, but they have many common limitations [3]. The paper first summarizes two mechanisms that could be used as the replacement of the existing network-based translators. The first mechanism uses the IPv4-in-IPv6 tunneling approach to interconnect between IPv4 and IPv6 networks, rather than to traverse a network of different IP versions as was the original purpose of the tunnels. The second mechanism uses the API translation technique on IPv4/IPv6 border network to interconnect between IPv4 and IPv6 networks. Thereafter, the paper evaluates the performance of these mechanisms in term of two important network performance metrics (e.g. Throughput and End-to-End delay) and compares the results with the original concept (e.g. SIIT mechanism) that translates the full IP headers when connections are initiated between IPv4-only and IPv6-only networks and vice versa.

2 The AIN-PT, AIN-SLT and SIIT Mechanisms

2.1 The AIN-PT Mechanism

AIN-PT technique [5] does not use the SIIT technique or any other translation-based technique to translate the IP headers between IPv4-only and IPv6-only networks. However, it uses the tunneling technique to achieve the interoperability between IPv6-only and IPv4-only networks without changing the IPv4 packets.

The AIN-PT protocol allows mixed (IPv4/IPv6) communication between two or more networks without using protocol translation. It could be installed either at the border network of IPv4 ISPs, or at the border network of IPv6 ISP. Moreover, it could be installed on IPv6 hosts that need to communicate with IPv4-only peers. The key point of this protocol is that: no modifications to any of legacy IPv4 infrastructure networks is required; the rationale behind this protocol is that having upgrading the newly installed IPv6-only hosts (small size), is much more likely achievable than upgrading the huge legacy IPv4-only hosts. Figure 1 shows the concept of this protocol when it is installed at the border IPv4/IPv6 networks. When it is installed at an IPv6-only network, this allows IPv6-only hosts to initiate communications with IPv4-only peers. This requires some AIN-PT modules be installed in the IPv6-only network. For example, DNS6 [7] and the upgrading the IPv6 host with Tunneler IPv4-in-IPv6, and Pseudo Link Module.

Figure 1 shows also the AIN-PT mechanism configured at the IPv4-only side. This allows IPv4 hosts to initiate communication to IPv6 hosts.

In summary, when the AIN-PT protocol is installed at the IPv6-only network, it allows IPv6-based applications that are either running on IPv6-only or IPv4/IPv6 hosts with IPv6 connectivity to initiate communications with IPv4-only or IPv4/IPv6 hosts with IPv4 connectivity. Likewise, when the AIN-PT protocol is installed at the IPv4-only network, it allows IPv4-only applications that are running on IPv4-only or IPv4 hosts with IPv4 connectivity to initiate communications with IPv6-only or IPv6 with IPv6 connectivity hosts. In both scenarios, the interoperability between heterogeneous networks will be achieved without translating the full IP headers between different networks.

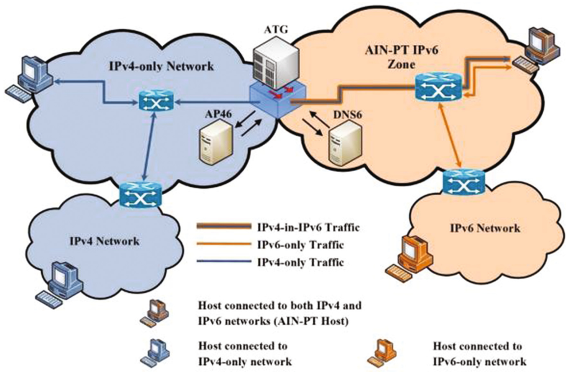

Fig. 1. The principle for the AIN-PT protocol.

The ISP network should have the ATG and either DNS6 (IPv6 network) or Address Pool IPv4 → IPv6 (AP46) (IPv4 network) installed. The IPv6 peer host should have the Tunneler IPv4-in-IPv6 and the Pseudo Network Interface modules installed in the same way as above.

The following subsections provide two examples to investigate the behaviour of AIN-PT protocol when a connection is initiated from an AIN-PT host to an IPv4-only peer, as well as from an IPv4-only host to an AIN-PT host.

Example 1: AIN-PT Protocol for Connection from AIN-PT Host to IPv4-only Host. This section provides an example to investigate the behavior of the AIN-PT installed at an IPv6 network. The AIN-PT host is trying to communicate with an IPv4-only host on the IPv4 Internet. The IPv6 address of the AIN-PT host is ‘A64:db8::12345’, and the port number is ‘333’. The destination IPv4 address of the IPv4-only host is ‘138.121.1.1’, and the port number is ‘80’. The IPv4 address of the ATG is ‘212.14.1.2’. Assume the NSP of the IPv6 network is ‘A64’, and the dummy IPv4 address is ‘100.100.100.100’. Figure 2 illustrates this example.

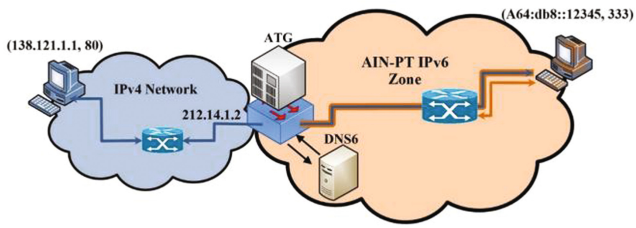

Fig. 2. An example when the AIN-PT installed at an IPv6 network.

Step 1: The IPv4 interface of the AIN-PT host tries to obtain an IPv4 address via DHCPv4 server. It sends a broadcast DHCP DISCOVER message with destination IPv4 address ‘255.255.255.255’.

Step 2: The Pseudo Link Interface receives the DHCPv4 packet and forwards it to the Tunneler $_{\text{IPv4-in-IPv6}}$ module.

Step 3: The DHCPv4 in the Tunneler $_{\text{IPv4-in-IPv6}}$ module receives the message, and responds via a DHCP OFFER message.

Step 4: The IPv4 interface of the AIN-PT host sends a DHCP REQUEST message to obtain the configuration information.

Step 5: The DHCPv4 in the Tunneler $_{\text{IPv4-in-IPv6}}$ module generates a DHCPACK message which contains the configuration information (dummy IPv4 address ‘100.100.100.100’) and sends it back the IPv4 interface of the AIN-PT host.

Step 6: When the IPv4/IPv6 application tries to resolve a host’s IP address located in an IPv4-only network, the DNS6 at the IPv6 network will resolve the IPv4 address ‘138.121.1.1’ and send it back to the application.

Step 7: The IPv4/IPv6 application uses the IPv4 stack in this communication.

Step 8: The Pseudo Link Interface receives the IPv4 packet and forwards it to the Tunneler $_{\text{IPv4-in-IPv6}}$ module.

Step 9: The Tunneler $_{\text{IPv4-in-IPv6}}$ module encapsulates the IPv4 packet into an IPv6 packet and configures the IPv6 addresses. It assigns the IPv6 address ‘A64:db8::12345’ as a source address and it synthesizes and assigns the IPv6 address ‘A64:138.121.1.1::’ as a destination address.

Step 10: The Tunneler $_{\text{IPv4-in-IPv6}}$ forwards an IPv4-in-IPv6 packet over the IPv6 network of the ISP.

Step 11: When the ATG receives the IPv4-in-IPv6 packet, it decapsulates the IPv4 packet, generates a pseudo port number (e.g. ‘4444’), and saves the <‘A64:db8::12345’, ‘333’, ‘4444’> in the ATG_AP64.

Step 12: The ATG replaces the source IPv4 address of the IPv4 header by its IPv4 address, and replaces the port number ‘333’ inside TCPv4 header by the pseudo port number ‘4444’.

Step 13: The ATG forwards the IPv4 packet over the IPv4 Internet.

Step 14: When the ATG receives a reply (IPv4 packet), it will extract the pseudo port number (‘4444’) from the TCPv4 header and search in for the pseudo port number of the session and retrieve the addressing information the ATG_AP64.

Step 15: The ATG configures source address and destination address of both IPv4 and IPv6 headers. As for IPv4 header, it replaces the destination address with the dummy IPv4 address ‘100.100.100.100’. As for IPv6 header, it assigns the address ‘A64:138.121.1.1::’ as a source address, and the address ‘A64:db8::12345’ as a destination address. Moreover, it replaces the port number ‘4444’ in TCPv4 header by ‘333’.

Step 16: The ATG injects the IPv4-in-IPv6 directly into the network interface.

Step 17: The AIN-PT host receives the packet and the Tunneler $_{\text{IPv4-in-IPv6}}$ inside decapsulates the IPv4 packets. These packets will be passed on to the IPv4 stack.

Example 2: AIN-PT Protocol for Connection from IPv4-only Host to AIN-PT Host. This section provides an example to investigate the behaviour of the AIN-PT installed at an IPv4 network. The AIN-PT host is trying to communicate with an AIN-PT IPv6 host. The IPv6 address of the IPv4-only host is ‘138.121.1.1’, and the port number is

'80'. The IPv6 address of the AIN-PT host is 'A64:db8::12345', and the port number is '333'. The IPv4 address of the ATG is '212.14.1.2'. Assume the NSP of IPv6 interface of the ATG is 'A46', and the dummy IPv4 address is '100.100.100.100'. Figure 3 shows this example.

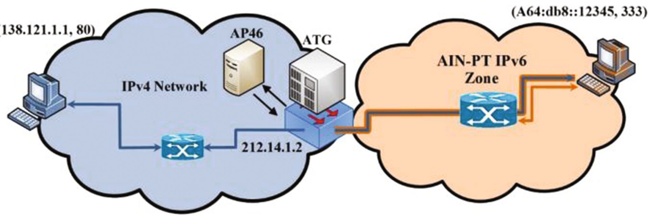

Fig. 3. An example when the AIN-PT is installed at an IPv4 network.

Step 1: When the IPv4-only application tries to resolve a host's IP address located in an IPv6-only network, the AP46 at the IPv4 network will resolve the IPv6 address 'A64:db8::12345' of that IPv6 host (AIN-PT host). After that, the AP46 will map the resolved IPv6 address 'A64:db8::12345' with the IPv4 address of the IPv4-only host '138.121.1.1', and sends the IPv4 address of the ATG '212.14.1.2' back to the IPv4-only host.

Step 2: The IPv4-only host sends an IPv4 packet to ATG device.

Step 3: The ATG device looks up in the ATG_AP46 table to search for the source IPv4 address of the session. If no entries were found, it queries the AP46 for an IPv6 address in terms of the IPv4 address '138.121.1.1'

Step 4: The AP46 send the IPv6 address 'A64:db8::12345' to the ATG device.

Step 5: The ATG configures the source address and destination address of both IPv4 and IPv6 headers. As for IPv4 header, it assigns the address '212.14.1.2' as a source address and the dummy IPv4 address '100.100.100.100' as a destination address. As for IPv6 header, it assigns the IPv6 address of the ATG 'AP46:212.14.1.2::' as a source address, and the address 'A64:db8::12345' as a destination address. After that, the ATG replaces the source port number '80' in the TCPv4 header by the pseudo port number '4444', and encapsulates the IPv4 packet into an IPv6 packet. Finally, it records <'138.121.1.1', '80', '4444', 'A64:db8::12345'> into the mapping table (ATG_AP46).

Step 6: The ATG sends an IPv4-in-IPv6 packet to the AIN-PT host.

Step 7: The Tunneler $_{\text{IPv4-in-IPv6}}$ inside AIN-PT host caches the 'A46' because the IPv6 prefix of the received source IPv6 address is different than the current Pref64 'A64'. Thereafter, it decapsulates the IPv4 packet.

Step 8: The IPv4 packet will be passed on the IPv4 stack through the Pseudo Link Interface module.

Step 9: When the application at the AIN-PT replies, the Tunneler $_{\text{IPv4-in-IPv6}}$ will receive the IPv4 packet through the Pseudo Link Interface for encapsulation into an IPv6 packet.

Step 10: The Tunneler $_{\text{IPv4-in-IPv6}}$ configures the source and destination IPv6 addresses of the IPv6 header. It assigns the address 'A64:db8::12345' as a source address. Then, it gets out the 'AP46' from the cache and synthesizes and assigns the address 'AP46:212.14.1.2::' as a destination address.
Step 11: The Tunneler $_{\text{IPv4-in-IPv6}}$ sends an IPv4-in-IPv6 packet to the ATG.
Step 12: When the ATG receives an IPv4-in-IPv6 packet, it extracts the pseudo port number ('4444') from the TCPv4 header, and retrieves the addressing information for this session from the ATG_AP46.
Step 13: The ATG decapsulates the IPv4 packet, and configures both TCPv4 and IPv4 headers. As for TCPv4, it replaces the pseudo port number '4444' by '80'. As for IPv4 header, it assigns its IPv4 address '121.14.1.2' as a source address and the address '138.121.1.1' as a destination address.
Step 14: The ATG sends the packet to the IPv4-only host.

2.2 The AIN-SLT Technique

The AIN-SLT technique [6] is proposed to allow the (IPv4/IPv6) communication between networks using an API Level Gateway inside ABR device. The AIN-SLT should be installed at the border IPv4/IPv6 network. The DNS64 must be installed at the IPv6-only side, whereas the AP46 must be installed at the IPv4-only side. This allows IPv6-only hosts to initiate communications with IPv4-only peers. Similarly, this allows IPv4-only hosts to initiate communications with IPv6-only peers. Figure 4 shows the AIN-SLT installed at the border IPv4/IPv6 network.

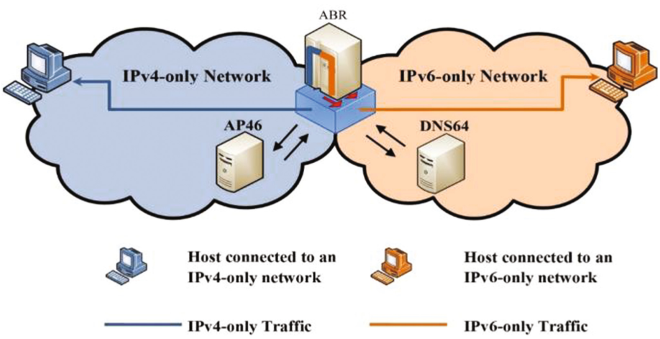

Fig. 4. The AIN-SLT installed at the border IPv4/IPv6 network.

Initiating a Connection from an IPv6-only Host to an IPv4-only Host. When an IPv6 application tries to resolve a host's IP address located in an IPv4-only zone, the DNS64 at the IPv4/IPv6 border of the IPv6 network will resolve the 'A' record(s) for the destination host. After that, it will create a mapping between the resolved record(s) and the source IPv6 address of the IPv6-only host, and send the IPv6 address of the ABR back to the requesting IPv6-only host. The IPv6-only host will transmit the IPv6 packets to the ABR device. The IPv6 packet will be received at the IPv6 interface of the ABR.

The API Level Gateway module at the ABR will receive the IPv6 payload, request the DNS64 for the previously stored mapping between source IPv6 source address and destination IPv4 address, carry out the appropriate addressing, and finally forward the received IPv6 payload to the IPv4/TCPv4/UDPv4 stack using the retrieved destination IPv4 address. As a result, an IPv4 packet will be transmitted to the IPv4-only destination host.

Initiating a Connection from an IPv4-only Host to an IPv6-only Host. When an IPv4 application tries to resolve a host's IP address located in an IPv6 zone, the customized DNS (Address Pool IPv4 → IPv6 (AP46)) at the IPv4/IPv6 border of the IPv4 network will resolve the 'AAAA' record(s) of the destination IPv6 host, map the resolved record(s) with the IPv4 address of the source IPv4-only host, and send the IPv4 address of the ABR back to the IPv4 host. The IPv4-only host will transmit the IPv4 packets to the ABR device. The IPv4 packet will be received at the IPv4 interface of the ABR. The API Level Gateway module at the ABR will receive the IPv4 payload, request the AP46 for the previously stored mapping between source IPv4 source address and destination IPv6 address, carry out the appropriate addressing, and finally forward the received IPv4 payload to the IPv6/TCPv6/UDPv6 using the retrieved destination IPv6 address. As a result, an IPv6 packet will be transmitted to the IPv6-only destination host. In summary, we can say that the AIN-SLT mechanism allows IPv6 (or IPv6-only) applications that are running on IPv6-only hosts to initiate communications with IPv4-only peers. Similarly, it allows IPv4-only applications that are running on IPv4-only to initiate communication with IPv6-only, by translating the IPv4/TCPv4/UDPv4 traffic into IPv6/TCPv6/UDPv6 traffic and vice-versa between different networks. In both cases, only address conversion is required, as the packet translation is being performed by the standard stacks of the ABR. If the ability to initiate communications is needed from both IPv4 and IPv6 sides, the AIN-SLT needs to be installed at both IPv4 and IPv6 edges.

The ISP network should have the ABR and either DNS64 (IPv6 network) or Address Pool IPv4 → IPv6 (AP46) (IPv4 network) installed.

2.3 Stateless IP/ICMP Translation Mechanism

The Stateless IP/ICMP Translation (SIIT) [4] is a translation mechanism that can be used to translate both the full IP and ICMP headers from IPv6 to IPv4 and vice-versa. The SIIT mechanism obsoletes and moves the NAT-PT [8] to the historic status. There are many drawbacks of the old NAT-PT technique. For example, it is tightly coupled with Application Level Gateways (ALGs) and there many security concerns discussed in [9]. The SIIT mechanism uses IPv4-compatible IPv6 addresses [10] and algorithmically maps between IPv6 and IPv4 addresses. The SIIT mechanism can be installed on both IPv6 and IPv4 nodes. If SIIT is installed at an IPv6 node (i.e. host/router), it will translate all the transmitted IPv6 traffic (IPv6 packets and ICMPv6 headers) into IPv4 traffic by translating between IPv6/ICMPv6 and IPv4/ICMP headers. Likewise, the SIIT will translate the received IPv4 traffic (IPv4 packet and ICMPv4 headers) into IPv6 traffic by translating between IPv4/ICMP and IPv6/ICMPv6 headers and vice-versa.

3 Considerations of Deploying AIN-PT and AIN-SLT Protocols

The protocols (AIN-PT and AIN-SLT) can be deployed to alleviate using protocol-based translators to communicate between heterogeneous networks. Additionally, they address all the network interoperation scenarios between IPv4 and IPv6 networks. The AIN-PT protocol requires installing software modules at the IPv6 hosts. The AIN-PT software modules could preferably be standard installed and enabled on all general-purpose computers (offered by OS vendors) but installing them later would not be a major issue. As indicated previously, nothing needs to be installed at the IPv4-only hosts. Therefore, this could make the AIN-PT protocol the preferable option for the "commercial" IPv4-only ISPs to allow their customers to initiate communications with new installed IPv6-only connected servers as long as the AIN-PT software modules are installed on these IPv6 servers. The AIN-PT protocol could be used in organizations with a huge number of IPv4-only hosts as these AIN-PT software modules are not needed to be installed on these hosts. The AIN-SLT protocol is easier to deploy than the AIN-PT protocol as it does not require the installation of any software modules at the end-users' hosts (IPv4 or IPv6 hosts). However, the AIN-SLT protocol has some security concerns and it does not translate the ICMP messages except in some particular network interoperation scenarios. As a result, this will probably make the AIN-SLT protocol not widely used by ISPs for translating between heterogeneous networks. In summary, the AIN-PT protocol is a good solution for ISPs or organizations to allow their IPv4-only customers to initiate communications with new launched IPv6-only connected servers. On the other hand, the AIN-SLT protocol is still an experimental protocol and hence, it needs additional improvements before being widely used.

4 Limitations of AIN-PT and AIN-SLT Protocols

The AIN-PT and AIN-SLT protocols are subject to bottlenecking and single point of failure. The two protocols work in stateful operation. Thus, the scalability issue could deteriorate the IPv6 performance in the network (i.e. large mapping tables). The author suggests a possible solution to resolve this problem by installing multiple tunneling gateways at the ISP side as follows. When the AIN-PT protocol is installed at an IPv4 network, the tunneling gateways can be operated by implementing an effective load-balancing algorithm at the local DNS of ISPs. This would help to equally distribute the tunnels among these gateways. This solution is applicable to resolve the scalability issue in the AIN-SLT protocol as well. Similarly, when the AIN-PT is installed at an IPv6 network, resolving this problem by installing an effective load-balancing at the local DNS of the ISP is not possible as the requesting IPv6 host will receive the real IPv4 address of the destination host. The author suggests a possible solution to overcome this problem by assigning anycast addresses to these tunneling gateways. This solution may reduce the chance of bottlenecking and single point of failure. However, it will not equally distribute the tunnels among the tunneling gateways. Additionally, the AIN-PT's traffic cannot traverse firewalls and the mechanism must be installed at both the ISP side and end-user's IPv6 hosts. The ICMP translator in the AIN-SLT mechanism translates the ICMP messages only for connections initiated from IPv6 networks to IPv4 networks (stateless operation), and the IPv6 interface of ABR must be configured with IPv4-embedded IPv6 addresses. The AP46 of both the AIN-PT and the AIN-SLT protocols only maps one record for a particular IPv4-only host if this host wants to communicate with an IPv6 peer. This record must be changed each time the IPv4-only host wants to communicate with another IPv6 peer. Similarly, the DNS64 of the AIN-SLT protocol only maps one record for a particular IPv6 host in case this host wants to communicate with an IPv4-only peer. This record must be changed if the IPv6 host wants to communicate with another IPv4-only peer.

5 Performance Analysis

This part evaluates the performance of AIN-PT, AIN-SLT and SIIT mechanisms and compares the results with the native protocols (e.g. IPv4 and IPv6). The key point of this comparison is to study the influence of these mechanisms with respect to the native IPv4 and IPv6 communications. The performance metric used in the simulation is the end-to-end delay (EED) [11, 12]. The OMNET++ [13] simulator was used as a simulation environment. The performance of the three mechanisms was compared with the performance of other IPv4 and IPv6 protocols in large-scale settings. Synthetic traffic was generated using the ReaSE [14] tool. The generated traffic was used to simulate a scenario when connections are initiated from IPv4-only region to an IPv6-only region and vice-versa. The ReaSE traffic generator has the ability to generate TCP traffic between IPv6 clients and IPv4 servers. Additionally, it can be used to configure the parameters of a traffic flow. The ReaSE tool was used in this simulation to configure packet sizes, specify IP addresses (course and destination addresses), etc. The main feature of this tool is the ability to generate traffic in seconds (i.e. generate traffic (ON/OFF)). In all conducted tests, the overall performance of networks that used one of these mechanism was measured as a function of the number of nodes (hosts) in these networks (i.e. 1000, 3000, 5000, 10000 nodes) versus packet sizes (i.e. 128 and 2048 bytes).

5.1 End-to-End Delay (EED)

The EED was analyzed for AIN-PT, AIN-SLT, SIIT, native IPv4 and native IPv6 based networks. The simulator measured the EED values. In each conducted test, different number of nodes and packet sizes were used. Figure 5 illustrates the EED values for all network types. It illustrates four different cases where EDD was calculated, in each case, for a specified number of packets in the network. The horizontal axis indicates the number of nodes (clients) in the network whereas the vertical axis indicates the EED in terms of milliseconds. The $EED_{NETWORK}$ indicates the EED of all nodes for the same packet size. The simulator works as follows. It calculates the EED_{NODE} for each node separately, and then finds out the $EDD_{NETWORK}$ as the average of all EED_{NODE} values. The $EED_{NETWORK}$ was conducted as given in Eqs. (1) and (2).

$$\left[\mathrm{EED_{NODE}} = \frac{\sum_{i=1}^{N} \mathrm{T_{end(i)}} - \mathrm{T_{start(i)}}}{\mathrm{N_{Rec}}} \right] \ldots \quad (1)$$

$$EED_{NETWORK} = \frac{\sum_{j=1}^{k} EED_{NODE}(j)}{k} \ldots \quad (2)$$

Where,

EED_{NODE}: EED value for a single node.
$EED_{NETWORK}$: EED value for the whole network at a specified packet size.
N_{Rec}: Total number of packets received at destination host.
T_{start}: Time of packet at source node.
T_{end}: Time of packet at destination node.
k: Total number of nodes in the local access network.

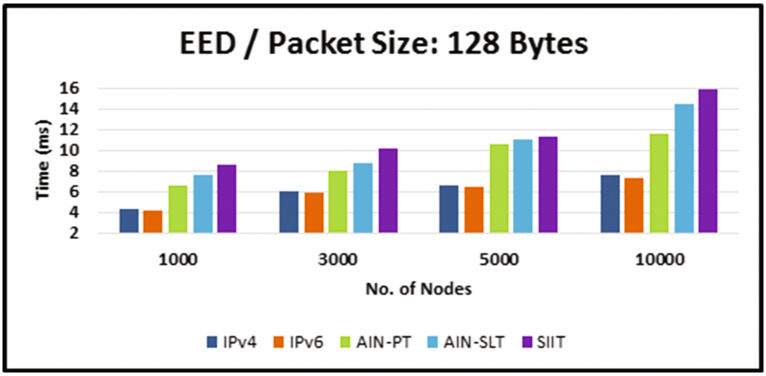

Fig. 5. The EED values when packet size = 128 bytes.

Apart from native protocols (IPv4 and IPv6 protocols), Fig. 5 shows that the AIN-PT mechanism achieved the best EED values among other mechanisms. The test was conducted when connections are initiated from IPv6 clients to IPv4 servers. It is clearly noticed that increasing number of nodes in the network increases overall overhead (e.g. routing, forwarding, translating, tunnelling, etc.) and hence, the overall EED values are increased. AIN-PT mechanism achieved better EED values than both AIN-SLT and SIIT mechanisms for the reasons explained in this paragraph. The AIN-PT works in stateless operation when connections are initiated from IPv6 hosts and destined to IPv4 servers. As a result, no address mapping is required, and instead, the IPv4-comptible IPv6 addresses were used in these connections. Additionally, the AIN-PT mechanism uses IPv4-in-IPv6 tunnels to achieve the interoperability between IPv6 and IPv4 networks. On contrary, the AIN-SLT works in stateful operation and hence it has to access large mapping tables to map between IPv4 and IPv6 addresses. In fact, this explains why the performance of AIN-SLT is deteriorated when increasing the number of nodes in the network. The variance in EDD values between AIN-SLT and AIN-PT can be explained by whether a stateless or a stateful operation was used. Moreover, the reason behind this significant increase in variance between both AIN-PT and AIN-SLT versus SIIT is that the AIN-PT uses IPv4-in-IPv6 tunnels, and the AIN-SLT translates between IPv4/IPv6 API sockets. However, the SIIT translates all the attributes in the IPv6 and IPv4 headers. The conducted simulation tests prove that the amount of overhead generated in encapsulation/decapsulation and API socket translations operations is less than the amount of overhead generated in translation of the full IP headers.

Figure 6 depicts the same scenario above, but when the packet size is 2048 bytes. It is clearly noticed that the EED values are decreased when larger packet sizes are used. In other words, larger packet sizes allow transmission of the same payload with a fewer number of packets, and hence this will lead to minimize the overhead and finally improves the overall EED in these mechanisms.

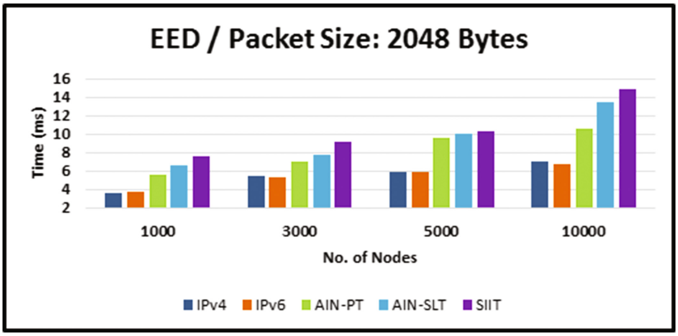

Fig. 6. EED values when packet size = 2048 bytes.

6 Conclusions

This paper presented and evaluated the AIN-PT, AIN-SLT and SIIT mechanisms. The translation approach is used when communication is required between systems/networks operating with different IP versions, however, it has a number of disadvantages. One of the main goals of this research was to limit the use of translation when considering the communication between two nodes connected to two different heterogeneous networks. The AIN-PT is a protocol, which uses an IPv4-in-IPv6 tunneling approach to allow communication between heterogeneous networks, without translating the full IP headers of the transmitted packets. The AIN-SLT protocol allows the communication between heterogeneous networks by terminating the IPv4/IPv6 connection points at the API layer; it translates the IPv4/TCPv4/UDPv4 traffic into IPv6/TCPv6/UDPv6 traffic and vice-versa by receiving the traffic from one IP version in the API layer and forwards it using the stack of the other IP version. On the other hand, the SIIT algorithm translates the full IP headers between heterogeneous networks. The simulation results show that the performance analysis of both AIN-PT and AIN-SLT is better than the performance of SIIT algorithm. Unlike IP-based networks, the simulation results showed that increasing the packet sizes in protocol translation or tunneling-based techniques leads to a decrease in the processing overhead, and hence, improves the EED values in these networks. Referring to the simulation results, we conclude that tunneling-based and API socket translation techniques produce a lower processing overhead than other protocol translation-based techniques.

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Hiring Doctors in E-Healthcare with Zero Budget

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Abstract. With the emerging technologies (such as video conferencing, smartphone, etc.) this is no longer a dream but a true fact, that for critical medical cases in hospitals, doctors from around the world could be hired, who will serve the patients by their physical or virtual presence. Earlier, this situation of taking the expert consultancies from outside a hospital had been studied with the perspective of mechanism design with money. In this paper, we propose algorithms based on the theory of mechanism design without money to hire experts from outside the hospitals where the patients are admitted, with a constraint that each patient has *zero* budget.

1 Introduction

E-healthcare system, which is emerging as one of the most upcoming technologies to provide an efficient and automated healthcare infrastructure, can employ the crowdsourcing technology [17] to enhance the services provided in that environment. Healthcare consultation (as for example consultation from physician, paediatricians, plastic and cosmetic surgeons, etc.) is said to be the crux of medical unit and operation suite. Earlier most of the literatures related to hospitals focused on scheduling operation theatres [3,5], and staffs [1,4] within the hospital itself. In our future references, hospital(s), medical unit(s), organization(s) will be used interchangeably. However, it is observed that, with the unprecedented growth of the communication media (especially Internet), it may be a common phenomena to hire expert medical staffs (especially doctors) for a critical operation from outside of the medical unit where the operation is taking place [16]. This event of hiring an external experts can be thought of as the special case of crowdsourcing [17] and participatory sensing [10]. For an operation or any other consultation how a well qualified personnel including doctors can be hired from outside of a medical unit where the patient is admitted, is addressed surprisingly less in literature. The challenges in this environment come from the following issues: (1) which doctors can be hired? (2) How to motivate the doctors to take part in the system as they may be very busy? (3) If the incentives are provided, how much can be offered? (4) If some renowned doctors are made themselves available for social work, how to grab the situation so that poorest people may be

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served efficiently to save their valuable life? An attempt has been made by [15] in the direction of hiring one or more expert(s) from outside of the hospital for a critical operation answering some issues related to the challenges mentioned in points 1, 2, and 3. In [15] incentives were provided to motivate the doctors for their participation. It may be the case, that due to some social awareness, some of the doctors may impart some social services to the downtrodden community free of cost. This situation is mentioned in point 4. In this paper, we have tried to address the practical situation discussed in point 4 above in a game theoretic settings with the robust concept of **m**echanism **d**esign **w**ithout **m**oney (MDWM) or under *zero* budget environment [6,8,13,14]. Previously, there had been some efforts in the direction of utilizing the concept of MDWM in one of its application domains namely *facility location problem*. In [2] the designer wants to locate a facility that minimizes the sum of all agents' distances to the facility on a real line.

In this paper, we have proposed an algorithm motivated by [8,14] to allocate the doctors to the patients so that they will be *happy*. By *happy* we mean that each of the participating patients gets their best possible doctor from the available doctors at the time of allocation.

The main contribution of this paper are: (1) In this paper, the problem of hiring doctors is cast as a without money problem or in *zero* budget environment. (2) The *truthful* mechanisms are proposed for allocating the doctors to the patients. (3) A simulation is performed for comparing our schemes with a carefully designed benchmark scheme.

The remainder of the paper is organized as follows: In Sect. 2 we describe the system model and formulate the problem as MDWM. In Sect. 3, we present two mechanisms: ***Ran****dom* ***p****ick-***a***ssign* ***m****echanism* (RanPAM) and ***T****ruthful* ***o****ptimal* ***a****llocation* ***m****echanism* (TOAM). Section 4 presents the more general set-up in matching market and the mechanism is proposed called ***T****ruthful* ***o****ptimal* ***a****llocation* ***m****echanism for* ***i****n****com****plete* ***p****references* (TOAM-IComP). A detailed analysis of the experimental results is carried out in Sect. 5. Finally, we present a summary of our work and highlight some future directions in Sect. 6.

2 System Model and Problem Formulation

Our proposed model consists of n hospitals. In each hospitals several patients (or agents) from different income groups are admitted who need expert consultation from outside of the hospital. It is assumed that the participating patients cannot misreport their income group, it is taken care by hospital authorities. Based on the income group each hospitals provides one ***b****elow* ***i****ncome* ***g****roup* (BIG) patient for the category under consideration. The *third party* selects n doctors out of all available doctors based on the quality of the doctors. In this set-up each hospital needs exactly one expert consultant and each expert consultant can provide their service to one hospital at a time. In our model, expert consultation may be sought for several categories of diseases given as $x = \{x_1, x_2, \ldots, x_k\}$. The set of available expert consultants for a particular category $i \in \{1, \ldots, k\}$ is denoted by $\mathcal{S}_i = \{s_1^{x_i}, s_2^{x_i}, \ldots, s_n^{x_i}\}$. The set of available BIG patients of particular category $i \in \{1, \ldots, k\}$ is denoted by $\mathcal{P}_i = \{p_1^{x_i}, p_2^{x_i}, \ldots, p_n^{x_i}\}$. When i^{th} *category* is mentioned, the index will be assumed as $i \in \{1, \ldots, k\}$, otherwise $i \in \{1, \ldots, n\}$. Each agent $p_i^{x_i} \in \mathcal{P}_i$ has a strict preference ordering over all $s_i^{x_i} \in \mathcal{S}_i$. The strict preference ordering of t^{th} agent $p_t^{x_i} \in \mathcal{P}_i$ in i^{th} category is denoted by $\succ_t^i$ over the set S_i, where $s_1^{x_i} \succ_t^i s_2^{x_i}$ means that in i^{th} category, t prefers $s_1^{x_i}$ to $s_2^{x_i}$. The set of preferences of all the agents in k different categories is denoted by $\succ = \{\succ^1, \succ^2, \ldots, \succ^k\}$. Where, $\succ^i$ is the preference of all the agents in i^{th} category over all the doctors in $\mathcal{S}_i$, represented as $\succ^i = \{\succ_1^i, \succ_2^i, \ldots, \succ_n^i\}$. The strict preference ordering of all the agents except agent t is represented as $\succ_{-t}^i$. Given the preference of the agents, our proposed mechanisms allocates one doctor to one patient. Let us denote such an allocation vector by $\mathcal{A} = \{\mathcal{A}_1, \mathcal{A}_2, \ldots, \mathcal{A}_k\}$; where, each allocation vector $\mathcal{A}_i \in \mathcal{A}$ denotes the allocation vector of agents belongs to the i^{th} category denoted as $\mathcal{A}_i = \{a_1^i, a_2^i, \ldots, a_n^i\}$; where $a_t^i \in \mathcal{A}_i$ is a $(p_t^{x_i}, s_j^{x_i})$ pair. Initially, one doctor is allocated to one patient randomly without loss of generality.

3 Proposed Mechanisms

In this section, firstly the RanPAM is given as a naive solution of our problem, that will help to understand better, the more robust ***D****ominant* ***s****trategy* ***i****ncentive* ***c****ompatible* (DSIC) mechanism *i.e.* TOAM motivated by [11,14].

3.1 Random Pick-Assign Mechanism (RanPAM)

The input to the RanPAM are: the set of n available patients, the set of n available doctors, and the set of preferences of all the agents for the available doctors in a particular category. The output of the mechanism is the allocated patient-doctor pairs. The algorithm is depicted in *Algorithm* 1.

Algorithm 1. RanPAM ($\mathcal{S}_i$, $\mathcal{P}_i$, $\succ^i$)

Output: $\mathcal{R} \leftarrow \phi$.

begin
  $k \leftarrow 0$, $j \leftarrow 0$, $p^* \leftarrow \phi$, $s^* \leftarrow \phi$
  while $\mathcal{P}_i \neq \phi$ **do**
    $k \leftarrow random(\mathcal{P}_i)$.
    $p^* \leftarrow \{p_k^{x_i}\}$
    $j \leftarrow random(\succ_k^i)$
    $s^* \leftarrow s_j^{x_i}$
    $\mathcal{R} \leftarrow \mathcal{R} \cup (p^* \cup s^*)$
    $\mathcal{P}_i \leftarrow \mathcal{P}_i \setminus p^*$; $\mathcal{S}_i \leftarrow \mathcal{S}_i \setminus s^*$
  end while
  return $\mathcal{R}$
end

– **Upper Bound Analysis:**
The upper bound on the RanPAM for all the k categories is: $T(n) = \sum_{i=1}^{k}(O(1) + (\sum_{i=1}^{n} O(1))) = O(kn)$.
– **Essential properties:**
There are two essential properties that will help to develop the further mechanisms in our paper: (1) **Blocking coalition**: For every $\mathcal{T}_i \subset \mathcal{P}_i$ let $\mathcal{A}_i(\mathcal{T}_i)$ $= \{u \in \mathcal{A}_i : u_i^{p_i^{x_i}} \in \mathcal{T}_i,\ \forall i \in \mathcal{T}_i\}$ denote the set of allocations that can be achieved by the agents in $\mathcal{T}_i$ trading among themselves alone. Given an allocation $a \in \mathcal{A}_i$, a set $\mathcal{T}_i \subseteq \mathcal{P}_i$ of agents is called a *blocking coalition* (for a), if there exists a $u \in \mathcal{A}(\mathcal{T})$ such that $\forall i \in \mathcal{T}$ either $u_i \succ_i a_i$ or $u_i = a_i$ and at least one agent is better off *i.e.* for at least one $j \in \mathcal{T}_i$ we have $u_j \succ_j a_j$. (2) **Core allocation**: This property exhibits the fact that the allocation will be free of *blocking coalition*. In other words it says that if any subset of agents form a coalition and reallocates themselves via some internal reallocation, all of the members of the coalition can't be better off.
– **Drawback:**
From the perspective of *blocking coalition*, it can be concluded that the RanPAM is suffering from the blocking coalition. This leads to the violation of one of the economic properties in MDWM environment named as *core allocation*.

3.2 Truthful Optimal Allocation Mechanism (TOAM)

Our main focus is to propose a mechanism that satisfy the three robust economic properties such as *Truthfulness* or *DSIC*, *Pareto optimality*, and *Core allocation* (defined earlier). The remaining two properties are defined as: (1) **Truthfulness or DSIC**: Let $\mathcal{A}_i = \mathcal{M}(\succ_i^i, \succ_{-i}^i)$ and $\hat{\mathcal{A}}_i = \mathcal{M}(\hat{\succ}_i^i, \succ_{-i}^i)$. TOAM is *truthful* if $a(i)^i \succeq_i^i \hat{a}(i)^i$, for all $p_i^{x_i} \in \mathcal{P}_i$. (2) **Pareto optimality**: An allocation $\mathcal{A}_i$ is *pareto optimal* if there exists no allocation $a_j^i \in \mathcal{A}_i$ such that any patient $p_i^{x_i} \in a_j^i$ can make themselves better off without making other patient(s) $p_k^{x_i} \in a_k^i$ worse off.

More formally, the proposed TOAM, can be thought of as a four stage allocation mechanism: *Main routine*, *Graph initialization*, *Graph creation*, and *Cycle detection*.

(a) **Main routine**
The idea lies behind the construction of *main routine* is to handle the system, consisting of patients and doctors partitioned on the basis of category $x = \{x_1, x_2, \ldots, x_k\}$. The algorithm is depicted in Algorithm 2.

Algorithm 2. Main routine ($\mathcal{C}$, $\mathcal{Q}$, x)

Output: $\mathcal{A} \leftarrow \{\mathcal{A}_1, \mathcal{A}_2, \ldots, \mathcal{A}_k\}$

begin
  $\mathcal{A} \leftarrow \phi$, $\mathcal{Q}^* \leftarrow \phi$, $\mathcal{C}^* \leftarrow \phi$
  for each $x_i \in x$ **do**
    $i \leftarrow select(\mathcal{C})$ ▷ Selects the index of the patient in $\mathcal{C}$
    $\mathcal{C}^* \leftarrow \mathcal{C}_i$
    $i \leftarrow select(\mathcal{Q})$ ▷ Selects the index of the doctor in $\mathcal{Q}$
    $\mathcal{Q}^* \leftarrow \mathcal{Q}_i$
    $\mathcal{A}_i$ = Graph initialization ($\mathcal{C}^*$, $\mathcal{Q}^*$, $\succ$) ▷ Call to graph initialization.
    $\mathcal{A} \leftarrow \mathcal{A} \cup \mathcal{A}_i$
  end for
  return $\mathcal{A}$ ▷ returns the final allocation in each category.
end

(b) **Graph initialization**

The input to the *graph initialization* phase is the selected set of patients and the doctors in each iteration of *for* loop of *main routine*. The *graph initialization* phase will generate a partially directed graph by utilizing the algorithm shown below in *Algorithm* 3.

Algorithm 3. Graph initialization ($\mathcal{C}^*$, $\mathcal{Q}^*$, $\succ$)

1: **begin**
2: $j \leftarrow 0$
3: $\mathcal{F} = \{0\}_{|\mathcal{V}|*|\mathcal{V}|}$ ▷ Adjacency matrix initialized to null matrix
4: **for** each vertex $c_t \in \mathcal{C}^*$ **do**
5:   $j \leftarrow Random\_assign(\mathcal{Q}^*)$
6:   $q^* \leftarrow \{q_j\}$
7:   $\mathcal{F}_{q^*, c_t} = 1$ ▷ Initially a doctor in $\mathcal{Q}^*$ is randomly assign to a patient in $\mathcal{C}^*$.
8:   $\mathcal{Q}^* \leftarrow \mathcal{Q}^* \setminus q^*$ ▷ Remove the assigned doctor in line 7 from the $\mathcal{Q}^*$
9: **end for**
10: Graph creation ($\mathcal{C}^*$, $\mathcal{Q}^*$, $\mathcal{F}$, $\succ$)
11: **end**

(c) **Graph creation**

The *graph creation* phase takes the partially generated graph as input along with the set of patients, doctors, and their preference profiles. Utilizing the preference list of the patients, the edges are placed from the members of the patient party to the members of the doctor party. The algorithm in shown in *Algorithm* 4.

Algorithm 4. Graph creation ($\mathcal{C}^*$, $\mathcal{Q}^*$, $\mathcal{F}$, $\succ$)

begin
$j \leftarrow 0$
for each vertex $c_t \in \mathcal{C}^*$ **do**
    if $\succ_t^i \in \succ^i$ **then**
        $j \leftarrow Select\_best(\succ_t^i)$ ▷ Select the index of the most preferred doctor from the preference list.
        $q^* \leftarrow \{q_j\}$
        $\mathcal{F}_{c_t,q^*} = 1$
    end if
end for
Optimal allocation ($\mathcal{F}$, S)
end

(d) **Optimal allocation**
The input to the *Optimal allocation mechanism* is the adjacency matrix $\mathcal{F}$ returned from the previous stage and an empty stack S. Line 8–18 determines the directed cycle in the graph represented by adjacency matrix $\mathcal{F}$. Line 19, reallocates as suggested by directed cycle. A call is made to the *graph creation* phase to generate the updated graph from the available number of patients and the expert consultants until the patients set and doctor set are not empty.

The proposed TOAM has several compelling properties. These properties are discussed next. (1) **Running time:** Total running time of TOAM: $O(kn) + O(kn^2) = O(kn^2)$; where k is the number of categories and n is the number of agents. (2) **DSIC:** Theorem 1 states that the TOAM satisfies the DSIC property.

Theorem 1. *The TOAM is DSIC.*

Proof. Due to limitation of space the detailed proof is not given.

(3) **Core allocation:** Theorem 2 states that the TOAM satisfies the *Core allocation* property.

Theorem 2. *The allocation computed by TOAM is the* unique core allocation.

Proof. Due to limitation of space the detailed proof is not provided here.

Algorithm 5. Optimal allocation ($\mathcal{F}$, S)

$\pi \leftarrow \phi$, $\hat{\mathcal{C}}^* \leftarrow \phi$, $\hat{\mathcal{Q}}^* \leftarrow \phi$
for each $v_i \in \mathcal{V}$ **do**
  Mark $v_i \leftarrow$ unvisited
end for
$\pi \leftarrow random(v_i \in \mathcal{V})$
Mark $\pi \leftarrow$ visited
$push(S, \pi)$
while S is non-empty **do**
  $\pi \leftarrow pop(S)$
  for each π' adjacent to π **do**
    if π' is unvisited **then**
      Mark $\pi' \leftarrow$ visited
      $push(S, \pi)$
    else if π' is visited **then**
      Exists a finite cycle.
    end if
  end for
end while
Allocate each $v_i \in \mathcal{C}^*$ in cycle the doctors it points in $\mathcal{Q}^*$
for all $v_i \in \mathcal{C}^*$ in the cycle **do**
  $\hat{\mathcal{C}}^* \leftarrow \hat{\mathcal{C}}^* \cup v_i$
end for
for all $v_i \in \mathcal{Q}^*$ in the cycle **do**
  $\hat{\mathcal{Q}}^* \leftarrow \hat{\mathcal{Q}}^* \cup v_i$
end for
$\mathcal{C}^* \leftarrow \mathcal{C}^* \setminus \hat{\mathcal{C}}^*$; $\mathcal{Q}^* \leftarrow \mathcal{Q}^* \setminus \hat{\mathcal{Q}}^*$ ▷ Deletes the allocated patient and doctor nodes.
$\mathcal{V} = \mathcal{Q}^* \cup \mathcal{C}^*$
if $\mathcal{C}^* \neq \phi$ and $\mathcal{Q}^* \neq \phi$ **then**
  Graph creation ($\mathcal{C}^*$, $\mathcal{Q}^*$, $\mathcal{F}$, $\succ$)
end if
end

4 More General Setting

In this section we have considered the more general and realistic setting where $m \neq n$ ($m > n$ or $m < n$). We also consider the interesting case where each patient may give the partial preferences over the doctors.

4.1 TOAM-IComP

As an extension of TOAM the TOAM-IComP is proposed motivated by [9,12] to cater the need of more realistic incomplete (or partial) preferences.

Algorithm 6. TOAM-IComP($\mathcal{S}_i$, $\mathcal{P}_i$, $\succ^i$)

Output: $\mathcal{F} \leftarrow \phi$.

begin
  $k \leftarrow 0$, $\ell \leftarrow 0$, $j \leftarrow 0$, $\hat{p} \leftarrow \phi$, $\hat{s} \leftarrow \phi$, $\mathcal{B} \leftarrow \phi$
  for $i = 1$ to n **do**
    $\mathcal{B} \leftarrow \mathcal{B} \cup i$
  end for
  for $i = 1$ to n **do**
    swap $\mathcal{B}[i]$ with $\mathcal{B}[Random(i, n)]$
  end for
  for each $p_j^{x_i} \in \mathcal{P}_i$ **do**
    $Assign(p_j^{x_i}, \mathcal{B}[\ell])$
    $\ell \leftarrow \ell + 1$
  end for
  $\mathcal{P}_i \leftarrow \text{Sort}(\mathcal{P}_i, \mathcal{B})$ ▷ Sort $\mathcal{P}_i$ based on random number generated.
  while $\mathcal{P}_i \neq \phi$ **do**
    $j \leftarrow pick(\mathcal{P}_i)$ ▷ Sequentially picks the patients based on the random number.
    $\hat{p} \leftarrow \{p_j^{x_i}\}$
    if $\succ_j^i \neq \phi$ **then**
      $k \leftarrow Best\_select(\succ_j^i)$
      $\hat{s} \leftarrow s_k^{x_i}$
      $\mathcal{F} \leftarrow \mathcal{F} \cup (\hat{p} \cup \hat{s})$
      $\mathcal{P}_i \leftarrow \mathcal{P}_i \setminus \hat{p}$; $\mathcal{S}_i \leftarrow \mathcal{S}_i \setminus \hat{s}$
    end if
  end while
  return $\mathcal{F}$
end

It is to be noted that, along with *truthfulness* the TOAM-IComP satisfies the previously discussed two economic properties: *pareto optimality* and *the core*. The input to the TOAM-IComP are: the set of n available patients in a particular category x_i, the set of m available doctors in a particular category x_i, and the set of preferences of all the patients for the available doctors in a x_i category. The output of the TOAM-IComP is the allocated patient-doctor pairs. The algorithm is depicted in Algorithm 6.

4.1.1 Upper Bound Analysis

The upper bound on the TOAM-IComP for all the k categories is given as: $T(n) = \sum_{i=1}^{k}((\sum_{i=1}^{n} O(1)) + (O(n \lg n)) + (\sum_{i=1}^{n} O(n))) = O(kn^2)$.

5 Experimental Findings

In this section, we compare the efficacy of the proposed mechanisms via simulations. Here, RanPAM is considered as a benchmark scheme and is compared with TOAM and TOAM-IComP.

5.1 Simulation Set-Up

For creating a real world healthcare scenario 10 different categories of patients and doctors are considered. One of the scenario that is taken into consideration is say there are equal number of patients and doctors present in each of the categories and each of the patients are providing strict preference ordering over the doctors. This scenario is referred as *Scenario-1* in the rest of the paper. Next, the more general scenario with equal number of patients and doctors but each of the patients are giving strict partial reference ordering over the doctors referred as *Scenario-2* in the rest of the paper. We have considered the utmost general set-up where there are n number of patients and m number of doctors such that $m \neq n$ ($m > n$ and $m < n$) and each of the patients are giving strict partial preference ordering over the doctors. The scenarios with $m > n$ and $m < n$ are referred as *scenario-3* and *scenario-4* respectively in the future references.

5.2 Performance Metrics

The performance of the proposed mechanisms is measured by the parameter:

• **Efficiency loss (EL):** It is the sum of the difference between the index of the doctor allocated from the agent preference list to the index of the most preferred doctor by the agent from his preference list *i.e.* EL $= \sum_{i=1}^{n}(\overline{I}_{i_{\mathcal{A}}} - \overline{I}_{i_{\mathcal{MP}}})$ where, $\overline{I}_{i_{\mathcal{A}}}$ is the index of the doctor allocated from the initially provided preference list of the patient i, $\overline{I}_{i_{\mathcal{MP}}}$ is the index of the most preferred doctor in the initially provided preference list of patient i. Considering the overall available categories $x = \{x_1, x_2, \ldots, x_k\}$, the total efficiency loss (TEL) of the system is given as: $TEL = \sum_{x}\sum_{i=1}^{n}(\overline{I}_{i_{\mathcal{A}}} - \overline{I}_{i_{\mathcal{MP}}})$.

5.3 Simulation Directions

To analyse the effect of manipulative behaviour of the agents on the proposed optimal mechanisms, the two directions are considered: (1) When all the agents are revealing true preference list. (2) When fraction of the agents are misreporting their true preference list.

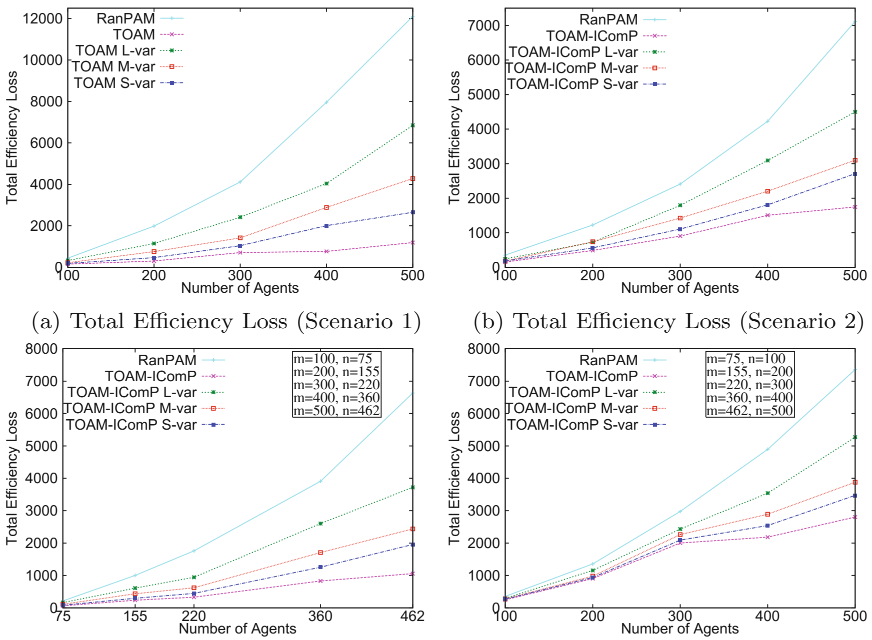
5.4 Result Analysis

As the patients are varying their true preference list, the next question that comes is that, how many of the patients can vary their true preference list. To answer this question, the calculation is done using indicator random variable.

- **Expected amount of variation.** The following analysis motivated by [7] justifies the idea of choosing the parameters of variation. Let $\mathcal{N}_i$ be the random variable associated with the event in which i^{th} patient varies his true preference ordering. Thus, $\mathcal{N}_i = \{i^{th}$ patient varies preference ordering$\}$. $\mathcal{N} = \sum_{i=1}^{n}\mathcal{N}_i$. We can write $E[\mathcal{N}] = \sum_{i=1}^{n}E[\mathcal{N}_i] = \sum_{i=1}^{n}1/8 = n/8$.

Here, Pr{i^{th} *patient varies preference ordering*} is the probability that given a patient whether he will vary his true preference ordering. The probability of that is taken as 1/8 (small variation).

In Fig. 1a and b–d, it can be seen that the TEL of the system in case of RanPAM is more than the TEL of the system in case of TOAM and TOAM-IComP respectively. This is due to the fact that, dissimilar to the RanPAM, TOAM and TOAM-IComP allocates the best possible doctors to the patients from their revealed preference list. In Fig. 1a, when the agents are varying (misreporting) their true preference ordering, then the TEL of the patients in case of TOAM with large variation (TOAM L-var) is more than the TEL in TOAM with medium variation (TOAM M-var) is more than the TEL in TOAM with small variation (TOAM S-var) is more than the TEL in TOAM without variation. As it is natural from the construction of the TOAM. Considering the case of partial preferences in Fig. 1b–d, when the subset of agents are varying their true preference ordering, then the TEL of the patients in case of TOAM-IComP with large variation (TOAM-IComP L-var) is more than the TEL in TOAM-IComP with medium variation (TOAM-IComP M-var) is more than the TEL in TOAM-IComP with small variation (TOAM-IComP S-var) is more than the TEL in TOAM-IComP without variation (TOAM-IComP).



(a) Total Efficiency Loss (Scenario 1)

(b) Total Efficiency Loss (Scenario 2)

(c) Total Efficiency Loss (Scenario 3)

(d) Total Efficiency Loss (Scenario 4)

Fig. 1. TEL for Scenario 1, Scenario 2, Scenario 3, and Scenario 4

6 Conclusions and Future Works

In this paper, we studied the problem of hiring renowned expert consultants (doctors) from around the world, to serve BIG patients of our society under *zero* budget environment. The work can be further extended to many different settings, e.g. multiple doctors are allocated to a BIG patient in different hospitals around the globe. The other interesting direction is studying the discussed setups under budget constraints environment.

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Metric Based Cloud Infrastructure Monitoring

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Abstract. Goal of the paper is to design dynamic, model-driven solution for agile service and network monitoring based on metrics suitable for managing large infrastructures and clustered applications in baremetal or cloud environments. The solution uses decetralised model where each node computes its states and passes the results to upper level cluster monitoring services. This is opposite approach than traditional monitoring where all logic is stored on central monitoring node or cluster of nodes.

Our proposed Monitoring solution offers automation of repetitive administration tasks and makes creation of monitoring infrastructure part of routine configuration tasks and make use of meta-data models already in place. Various monitoring scenarious are covered as Cluster and inter datacenter monitoring, advanced time-series analytics, corellations and trending with prediction algorythms and querying log event databases for unusual patterns. Emphasis is given to limiting the amount of output when failures occur presented to human operators, reducing the time to solve the problem and automating solution of most common issues.

Keywords: Monitoring · Logging · Metric · Time-series · Cloud infrastructure · Cloud application

1 Monitoring Overview

This paper presents a decentralized service-oriented monitoring solution. It is a collection of open-source tools to help you monitor and diagnose service availability problems in your application environment at the infrastructure level. To monitor something means to be aware of the state of various systems in your infrastructure, to continuously observe situation for any changes and faults which may occur over time. Monitoring solution is implemented as a stream processing engine and works like an expert system with root cause analysis capabilities.

Proposed tool is an operational health and response monitoring solution for the cloud built according modular reference architecture. It collects information from the entire deployments (servers, services, components, interfaces, hardware

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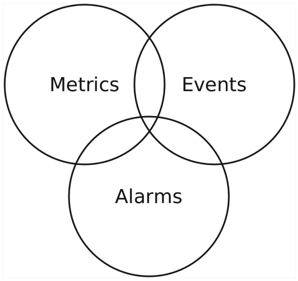

Fig. 1. General monitoring classification

devices etc.) and processes this data so that it can be easily consumed and analysed by end users [1,3].

The scope of monitoring landscape is very wide, but can be divided into several distinct categories. The three main categories shown on Fig. 1 overlap and no single monitoring tool has full support for all of these areas.

Eventually every area is handled by event monitoring, it is just a question of finding the right query to time series or event database with appropriate threshold. All these three areas need to be taken in consideration as each has a different perspective on the monitored systems [6–8].

1.1 Metrics

Measurements are taken from nodes, services and interfaces throughout the environment, metrics are calculated and aggregated from these. These metrics are visualised graphically and provide an in depth insight into the operational health and performance of the system. It is important that database supports analytical functions that are used for metric data normalisation and analysis. Time-series data collection for generating metric graphs rather that raising an alert, collectd with Graphite, Influxdb, Prometheus for example.

1.2 Events

Loading and parsing log content and other near log-type events, that are saved in lucene based database with several taxonomical indices. It might be visualised as time-series data or may generate alert like event monitoring system. Events are collected from log files, service notifications and other sources and are visualised using filters and queries to gain a deeper understanding of specific issues or behaviors within the system. Logstash, Heka, or Hindsight are examples for this category. Log processing solution has to support real- time processing of large amount of logs.

1.3 Alarms

This kind of monitoring soulution will alert you when some service goes down. Example tools of this category are Nagios, Shinken or Sensu. Alarms in monitoring handles event and visualizations. Alarms are generated from configured rules that are applied to the collected events and metrics.

2 Monitoring Comparison

Metadata definition plays the crucial role in defining agile monitoring as it contains all required data for monitoring configuration. System classification is used to assign metadata to various services covered by monitored systems.

The monitoring solution pickes up appropriate metadata from sources 1, 2 and 3 to configure monitoring, metering and logging checks [10,11].

In many cases, there is a generational difference between traditional monitoring tools and our proposed monitoring solution [2,5] (Table 1).

2.1 Push Versus Pull

With *push monitoring* architecture, metrics are periodically sent by each monitored system to a central collector. Examples of push architectures include sFlow, Ganglia, Graphite, collectd and StatsD (Fig. 2).

Table 1. Centralised versus decetralised monitoring

Traditional monitoring	Our monitoring proposition
Centralized monitoring	Distributed monitor
All-in-one (greenfield)	Adaptive (greenfield and adaptive)
Monolithic solution	Composable and specialized best-in-class components
Poor time-series scale and performance	Very high time-series scale and performance
Painfully scalable through federation of servers/proxies	Scalable by design

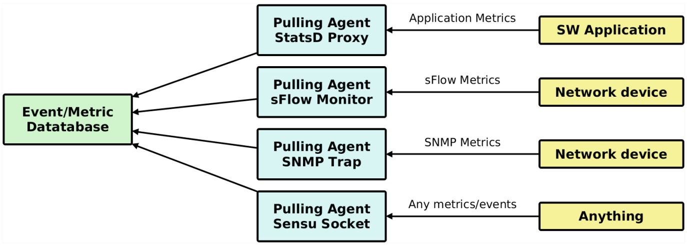

Fig. 2. Pushing monitoring architecture

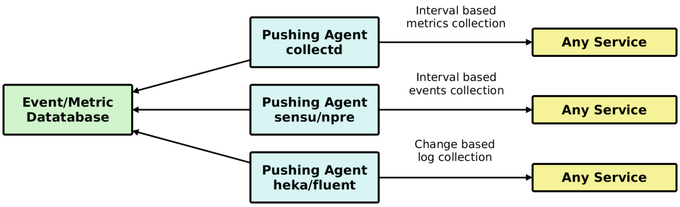

Fig. 3. Pulling monitoring architecture

Local agents perform checks within the actual system. All configuration management classes can have local checks defined and metadata needed to create these checks comes directly from internal node metadata. Monitoring client services are configured to perform checks on remote locations. All configuration management classes can have remote checks defined. The metadata needed to create these checks comes from global service catalog.

In a *pull monitoring*, a central collector periodically requests metrics from each monitored system. Examples of pull architectures include SNMP, WMI and libvirt.

SNMP trap receiver that translates SNMP traps to monitoring events. It is designed to listen for SNMP traps and dispatch events based on a preconfigured set of mappings. Monitoring clients may have TCP & UDP socket listening for external check result input. The monitoring client socket(s) listen on localhost port and expect JSON formatted check results, allowing external sources (e.g. your web application, backup scripts, etc.) to push check results without needing to know anything about monitoring system internal implementation. An excellent client socket use case example is a web application pushing check results to indicate database connectivity issues (Fig. 3).

The push model is particularly attractive for large scale cloud environments where services and hosts are constantly being added, removed, started and stopped [7]. Maintaining lists of devices to poll for statistics in these environments is challenging and the discovery, scalability, security, low- latency and the simplicity of the push model make it a clear winner.

The sFlow standard is particularly well suited to large scale monitoring of cloud infrastructures, delivering the comprehensive visibility into the performance of network, compute and application resources needed for effective management and control.

In practice, a hybrid approach provides the best overall solution. The core set of standard metrics needed to manage performance and detect problems is pushed using sFlow and a pull protocol is used to retrieve diagnostic information from specific devices [1,9].

3 Monitoring Solution Architecure

Following chapter explains how the monitoring solution works. The Sensing and Measurement component instruments the applications with sensors [5,7,8].

Measurements are turned into metrics which represent facts and conventions in an abstracted way using collectd and Heka.

Proposed monitoring solution relies on Nagios compatible checks. For collecting metric for further processing the collectd daemon is used, which has a small memory footprint and is reliable even at heavy loads.

Following Fig. 4 shows monitoring solution used for monitoring cloud infrastructure systems and overlay application workloads. Solid lines show information flow, dashed lines show flow of alarm logic definitions.

The monitoring has to offer high level perspective of running systems that will affect the end-users of our services, the status of datacenter and cluster systems as well as states of individual systems. From a high-level perspective, the monitoring solution implements data flow shown on Fig. 4.

3.1 Collectoring Data

Heka combines the benefits of a small memory footprint (around 130 M bytes) with speed and a pluggable micro-service bus architecture for Heka plugins. It has been reported to parse over a hundred thousand logs per second on an 8-core machine. Therefore, it provides an excellent mechanism to process log files and metrics in a very efficient way (Fig. 5).

The Collection component transforms critical logs into aggregate metrics such as HTTP error rate, HTTP request per second. The focus here is to find faults and detect anomalies. This is particularly relevant when large clouds are deployed, as anomalies tend to increase as the scale of the cloud increases.

The Monitoring solution Collector (or just the Collector) to gather all operational data that Mirantis thinks is relevant to increase the operational visibility of the OpenStack environment. The data is collected from a variety of sources including log messages, CollectD, and the OpenStack notifications bus.

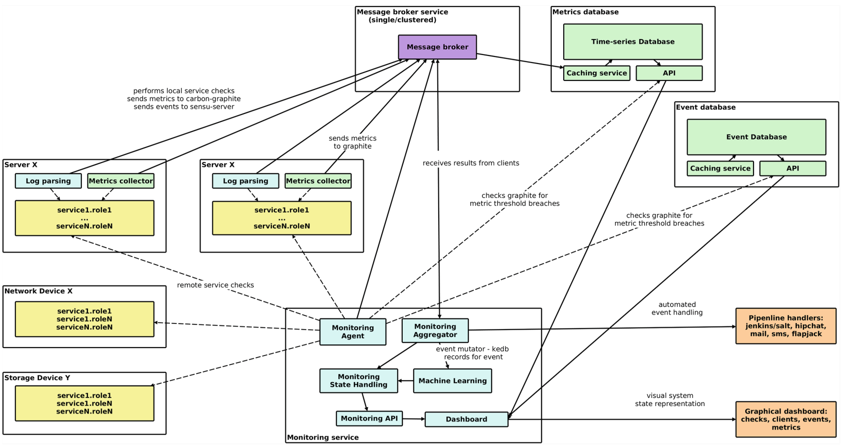

Fig. 4. Monitoring solution architecture

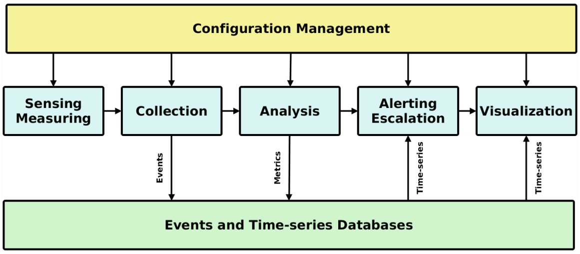

Fig. 5. Monitoring solution data flow

Pluggable external systems called satellite clusters which can take action on the data received from the Collectors running on the OpenStack nodes. Monitoring solution Aggregator is based on the same technical components as the Monitoring solution Collector that is Heka and CollectD. The Monitoring solution Aggregator performs additional metrics processing functions than the Collector in that it will aggregate metrics extracted from the HA cluster service endpoints logs such as the HTTP status code or HTTP request processing time.

The Collector is best described as a pluggable message processing and routing pipeline. Its core components are:

CollectD that is bundled with a collection of monitoring plugins. Many of them are purpose-built for OpenStack.

Heka, which is the cornerstone technical component of the Collector.

A collection of Heka plugins written in Lua programming language to decode, process and encode the operational data to be sent to external systems or satellite clusters.

The primary function of the Collector is to perform transformation of the collected data into an internal message representation that is based on the Heka message structure which in turn can be further exploited to, for example, detect anomalies or create new metric time series.

3.2 Storing Data

Storage is provided by Elasticsearch and InfluxDB. The metrics collected are data points organized in groups of consecutive and chronologically ordered lists also known as time-series. Metadata is defined to identify where those metrics come from and how they relate to one another. These are stored in a readily accessible format that can be consumed by different actors for visualization, aggregation and computation.

3.3 Visualising Data

The Kibana and Grafana tools are used to present a GUI. By using the correct visualisation tool, problems can become immediately apparent. Again, this is particularly important when an environment consists of 1000 s of nodes.

The Monitoring solution component is designed to provide a consistent and coherent representation of the cloud environment at these types of scale.

Visualization should help anticipate problems and visualise what is going on across the cluster (for at least the last 30 days) as opposed to a single node. An example of this would be "When is my disk going to be full? What is the aggregated throughput for all my servers?".

By combining Elasticsearch with Kibana, the Monitoring solution provides an effective way to search and correlate all service-affecting events that occurred in the system for root cause analysis including logs and notifications.

Likewise, by combining InfluxDB with Grafana, the Monitoring solution brings insightful metrics analytics to visualize how OpenStack behaves over time. This includes metrics for the OpenStack services status and a variety of resource usage and performance indicators. The ability to visualize time- series over a period of time that can vary from 5 min to the last 30 days helps anticipating failure conditions and planning capacity ahead of time to cope with changing demand.

4 Advanced Monitoring Features

Advanced monitoring can help operators to transform from a reactive culture (one that reacts to problems) into a forward-looking culture (one that solves problems before they occur or escalate). More importantly, proactive monitoring reduces the frequency of problems occurring over time within the environment where the complete monitoring solution is applied.

4.1 Monitoring Correlation

Monitoring solution has the ability to perform event correlation. By receiving events from multiple sources the aggregator service can relate or link these events and provide new "facts" that are more useful to the end user. This greatly simplifies the end user's understanding and workload as it removes the need to manually correlate events. Event correlation is used to provide the healthiness status of the systems based on the synthetic checks performed by the Collector against various components of the service (i.e. API endpoints, workers, agents, etc.).

In proposed monitoring solution events correlations are used to provide the health of services and node clusters. Additional correlations can be performed, for example, include additional anomaly detection events in the correlation. This includes but is not limited to the detection of an abnormal spike in the HTTP requests response time, the failure of a compute node which could then be further correlated with the OpenStack notifications that have been received and stored by the Collector stating what instance or tenant can be affected by the failure and so forth. More compelling anomaly detection and event correlation is planned for subsequent releases of Monitoring solution.

The aggregated metrics can then be further processed to *detect anomalies* such as an HTTP response time SLA violation or a sudden surge of HTTP 500 errors. Example anomaly detection watches if a particular service component has failed in the cluster to derive the overall status of a clustered service. It also includes the detection of spikes in error logs.

4.2 Monitoring Trends

If we want to directly correlate the activity between now and the same time some period ago. This is where the timeShift() function comes in. We can now easily correlate the changes over these cycles.

Monitoring graphite metrics is important integration step between event monitoring and time-series databases. Multiple services can publish metric data into Graphite and event monitoring just queries the stored data series. Sensu-plugins-graphite's check-graphite-stats.rb provides Nagios compatible check for querying metrics in Graphite, averaged over a period of time. Subscription remote-metering is used to trigger the check.

Elasticsearch holds data processes by various engines The check-es-query-count.rb plugin from sensu-plugins-elasticsearch checks an ElasticSearch query. Following example checks that the count of special_type logs matching a query of anything (*) at the host elasticsearch.service.consul for the past 90 min will warn if there are under 100 and go critical if the result count is below 1 (The invert flag warns if counts are _below_ the critical and warning values). Subscription remote-logging is used to trigger the check.

4.3 Root Cause Analysis

Root cause analysis is a method of problem solving used for identifying the root causes of faults or problems. A factor is considered a root cause if removal thereof from the problem-fault-sequence prevents the final undesirable event from recurring; whereas a causal factor is one that affects an event's outcome, but is not a root cause. Though removing a causal factor can benefit an outcome, it does not prevent its recurrence within certainty.

The primary aim of root cause analysis is to identify the factors that resulted in the nature, the magnitude, the location, and the timing of the harmful outcomes (consequences) of one or more past events; to determine what behaviors, actions, inactions, or conditions need to be changed; to prevent recurrence of similar harmful outcomes; and to identify lessons that may promote the achievement of better consequences. The Success is defined as the near-certain prevention of recurrence.

There may be more than one root cause for an event or a problem, wherefore the difficult part is demonstrating the persistence and sustaining the effort required to determine them. The purpose of identifying all solutions to a problem is to prevent recurrence at lowest cost in the simplest way. If there are alternatives that are equally effective, then the simplest or lowest cost approach is preferred (Fig. 6).

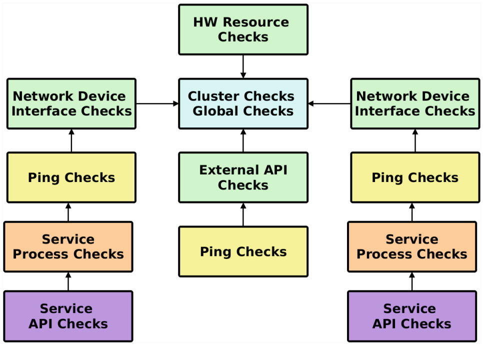

Fig. 6. Root cause analysis

One logical way to trace down root causes is by utilizing hierarchical clustering data-mining solutions (such as graph-theory-based data mining). A root cause is defined in that context as "the conditions that enable one or more causes". Root causes can be deductively sorted out from upper groups of which the groups include a specific cause. To be effective, the analysis should establish a sequence of events or timeline for understanding the relationships between contributory (causal) factors, root cause(s) and the defined problem or event to be prevented.

5 Conclusion

To get a complete view of monitored systems, all parts of monitoring landscape as log events, time series data and resulting threshold evaluations need to be covered and monitored. The preffered method of data collection is pull method, but not all services emit information about their inner state, so combination with push collectors is needed.

When monitoring complex systems multiple checks has to be defined for all managed services, external endpoints and hardware devices and all of them can send metrics, evaluate events by functional checks defined in a domain specific language for log parsing rules and metric evaluation, YAML in our case. It is important to be able to control flow of metrics, as with the scale your monitoring aggregators can be overwhelmed.

The well structured data can make advanced time-series analytics, corellations and trending with prediction algorythms and using machine learning with event and metric databases to search for unusual patterns. You can handle too many events in root cause analysis where only those events that do not depend on other raised events are being escalated. The other way to lower the number of alarm escalations is to use known error database to automaticly decide the severity of the problem.

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A Short Review for Ransomware: Pros and Cons

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Abstract. Recently, the software virus Ransomware spread like a cyclone wind. As a cyclone wind creates atmospheric instability, Ransomware similarly creates computer data instability. Each user moves in the direction of digitization. The user securely holds data in his/her computer, but what if the data are “abducted”. Ransomware is a software virus that parses user data. This software can lock the system in a manner in which a person is forced to pay a ransom to retrieve his/her data. Ransomware attacks not only home computers but also company computers. This software virus encrypts data such that it cannot be deciphered by a regular individual. Thus, an individual has to pay the ransom to decrypt the data. However, the generated files are unrecognized by the computer system. This study provides an intensive review of the WannaCry Ransomware, its effect on the world of information, and the preventive measures implemented to control this Ransomware.

1 Introduction

Security needs can be dramatically differentiated depending on risk activity and potential threats to these assets [1]. Executing and maintaining security may not be particularly troublesome or costly if the assets are effortlessly supplanted or if threats that could compromise security exist [2]. In addition, security maintenance of sensitive data will be an exceptional asset concentration. The purpose of an implementation overview is to identify real needs and determine whether the approach and methodology are consistent with these requirements.

Security has been a major concern since the start of networked computers [3]. Prior to the 1990s, systems were moderately phenomenal, and the total population was not composed of major Internet users [4]. In these circumstances, security was not so critical—in any case, an increasingly sensitive information network started to gain importance. During the 1970s and 1980s, specialists and researchers with Internet access indulged in useful mock attacks across the network. These mock attacks were harmless; however, in any case, they discovered safety gaps in ARPANET (the forerunner to today’s Internet) [5].

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From then on, the network had numerous customers with different careers, which, in turn, increased the security threat [6]. Prominent infringement of security occurred during this time, including the advancement of the expression “hacker” in the film War Games. However, in addition to congressional hearings and proposed enactments, genuine advances have been taken to restrain the threat [7].

Ransomware is showing no signs of slowing down, with the volume of mobile Ransomware increasing three times (i.e., 3.5 times) in the first months of the year according to the Kaspersky Lab Reports on malware for the first quarter of 2017. Ransomware affects all devices, systems, and networks, with 11 new families of Rill and 55,679 new modifications in the first quarter of 2017 [8].

In addition, the United States is the most affected country by mobile Ransomware in the first quarter, with Svpeng as the most widespread threat. The number of mobile Ransomware files recorded reached 218,625 during the quarter, compared with 61,832 in the previous quarter, which is more than 86%. Congur Ransomware is primarily a blocker that sets or resets the device PIN (access code) to provide the administrator with attacker rights on the device [9].

Several variants of the malware exploit these rights to install the module in the system folder, where it becomes nearly impossible to remove. Despite the popularity of Congur, Trojan-Ransom. Android OS. Fusob.h remains the most widely used mobile phone Ransomware, which accounts for approximately 45% of all threats or attacks monitored using Quester. Once executed, the Trojan queries the administrator rights, collects information on the device, including GPS coordinates and history, and loads the data on a malicious server. Based on the data obtained, the server can send back a command to lock the device. Figure 1 shows the road map of Ransomware based on Kaspersky Lab Reports for the first quarter of 2017 [10].

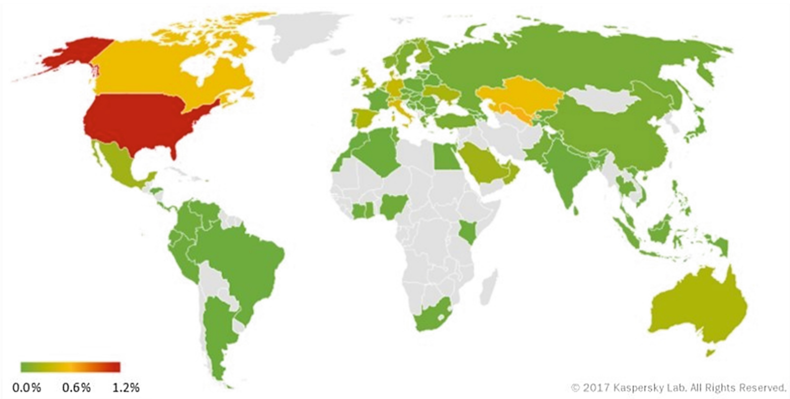

Fig. 1. Geography of mobile Trojan Ransomware in the first quarter of 2017 (percentage of all users attacked)

2 Intensive Review of Ransomware

Attacking large infrastructure organizations and/or individuals can be considered a terrorist attack. Apart from terrorist attack, intrusive people illegally obtain money through bitcoins. WannaCry, which was first discovered in April 2017, uses the hosting service dropbox files as part of its propagation method. The new variant uses MS17-010, a vulnerability in the Windows Server Messages Block (SMB) protocol with exploit code called EternalBlue to deliver its payload, including the Ransomware file. The affected files on the target system are encrypted with the WNCRY file extension virus. The flowchart of Ransomware's infection is shown in Fig. 2.

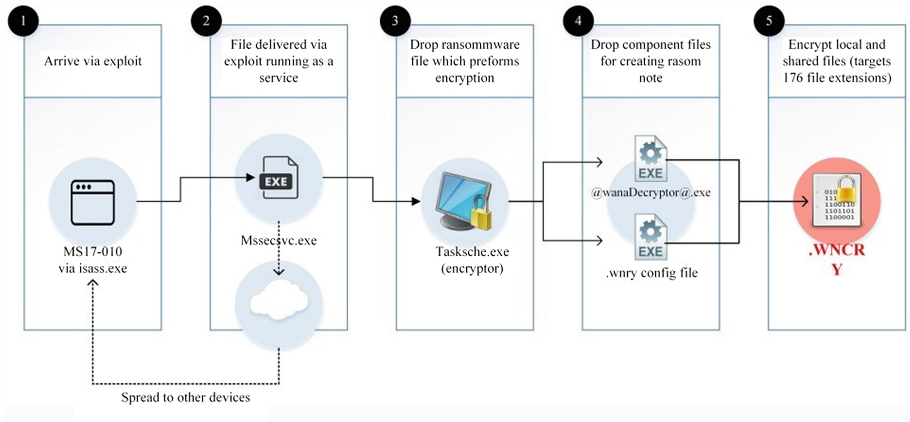

Fig. 2. Flowchart of Ransomware's infection

Ransomware is designed for direct revenue generation. The four most prevalent direct revenue-generating risks are:

- Misleading Applications show false defects.
- Rogue/Fake Antivirus show false infections (2008).
- Locker Ransomware locks the user out of his/her browser or device (2012).
- Crypto-Ransomware locks the user out of his/her data (2013).

Direct revenue-generating malware underwent four major pivotal points in the past decade. Each of these points indicates a shift from one type of malware to another, ultimately leading to Ransomware (Fig. 3).

Fig. 3. Ransomware 2016 highlight

Ransomware evolution has been significantly influenced by a range of developments in technology, economics, security, and culture. Similar to any real-life ecosystem, this threat has evolved and adapted to its surroundings to survive and even thrive. Those threats that cannot or do not adopt may eventually disappear. This Ransomware world is a significant example of evolution in action or Darwinian-style evolution, as shown in Fig. 4.

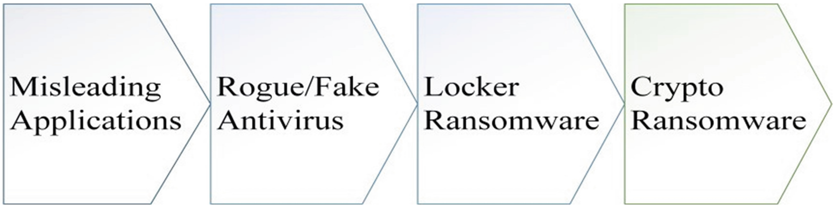

Fig. 4. Ransomware evolution

This section will focus on the most recent paper on Ransomware attacks. In addition, this section will provide more information on the importance of WannaCry, its process, and the damages that it can incur to its targeted governments and organizations.

A. WannaCry Ransomware attacks: where are we from it?

WannaCry is a root malware that affects machines with unpatched versions of the Windows operating system [11]. This virus uses a vulnerability in the SMB protocol found (and fixed) earlier this year. WannaCry is described as a Ransomware, which is specially created to screw in infected files on the concerned computer. WannaCry denies the client access until a ransom is paid to the hackers.

This variant renders the system unusable unless a payment is made. However, this variant was way before the Internet stream spread over floppy disks on a relatively small number of people who had computers and were asked to submit (by post) a bank check or payment instruction. Today, many people are currently in the distribution network of the largest malware worldwide, with bitcoin money as a resolution decision (also referred to as the "Internet"). Ransomware has existed for a long time, but its spread only recently peaked, particularly since the beginning of last year.

Many analysts and researchers have conducted reviews, discussions, research, and various measures to prevent cyber threats introduced by certain professionals [12–14]. In [15], Hiran et al. compared various machine learning systems or techniques utilized for malware, focusing on measurable examination.

In [16], four types of Crypto-Ransomware were analyzed. The researchers identified that all infections are dependent on reachable devices in the target frame and have the ability to slightly recover after the attacks have been identified or detected. By renaming the system tool that handles shadow duplicates, [16] provided a basic discussion of malware, malvertising, and the attack strategies utilized to distribute malignant notices and employed several measures to solve the problem. In [17], He presented HelDroid, a rapid, efficient, and fully automated process for detecting the Scareware and Ransomware samples of known and unknown goods.

This study analyzes a sample WannaCry obtained on May 14 in ytisf/theZoo (to the readers: if you do not know what to do, then do not go to the link and download the sample of the original files that can infect your PC).

B. Most critical works in 2017

In [18], a new system dynamic analysis called UNVEIL, which is specifically designed to recognize Ransomware, is presented. The key analysis is identifying a successful attack, in which the Ransomware files manipulate the desktop computer or the user. UNVEIL automatically creates and captures an artificial environment where the user interacts with the Ransomware user data. Similarly, the approach changes the desktop system to exhibit behavior similar to that of Ransomware. The evaluation shows that UNVEIL significantly improves the state of the art and is able to identify previously unknown severe Ransomware, which was unrecognized by the anti- malware industry.

PayBreak is rated for its effectiveness against 20 successful families of Ransomware in the real world and shows that their system can recover all 12 encrypted samples of these families, including the infamous CryptoLocker and the latest threats, such as Locky and SamSam files. Finally, PayBreak performs its mission to provide a negligible level of performance for common office workloads. Therefore, PayBreak is ideal as a proactive system protection online.

The case study in [19] presents the application of the literature to the analysis of a personal case. With more knowledge and awareness of Ransomware, users can avoid being attacked by this malware. Awareness on Ransomware attacks is helpful. In addition, this study provides a graphic format of "the Ransomware process," which shows the steps that Ransomware users follow.

The attack also affects the cloud server, as analyzed in [20]. They proposed a Ransomware prevention system based on the improved analysis and detection of abnormal behavioral system in the cloud, that is, CloudRPS. The system can defend against Ransomware through in-depth prevention. The network, file, and server can be monitored in real time. In addition, a cloud system installation collects and analyzes various information regarding the device to defend against attacks. [21] Finally, the aim of the system is to minimize the possibility of premature penetration and more rapidly detect Ransomware attacks on the system of the user.

C. Most critical works in 2016

In [22], CryptoDrop has been used as an early warning system that alerts a user on the activity of suspicious files. Researchers used a number of performance indicators. CryptoDrop can stop a process that appears to manipulate a considerable amount of user data. In [23], researchers proposed techniques that define and intensively monitor the processes and directories of certain files using statistical methods that are based on processor utilization, storage usage, and I/O rates that can detect the process for abnormal behavior. When the process detects that a suspected Ransomware is running, the proposed system will stop the process and take action to delete the programs associated with the process through the confirmation of users. Information regarding suspected and unusual procedures confirmed by users are stored in a database. The proposed technique can recognize Ransomware itself, but do not save the patterns.

In [24], the imprint of the SDN network can be used to reduce degradation caused by Ransomware. Specifically, CryptoWall is used to analyze the behavior of popular Ransomware. Based on this realization, they propose two methods for mitigating attacks in real time. Then, they described the design of a system based on SDN, which is implemented using OpenFlow. This system facilitates a timely response to the threat and is a crucial factor in the case of Crypto-Ransomware as shown in Fig. 5. The most important thing is that a draft of this kind will significantly affect the overall network performance. The experimental results confirm the feasibility and efficiency of the proposed approach.

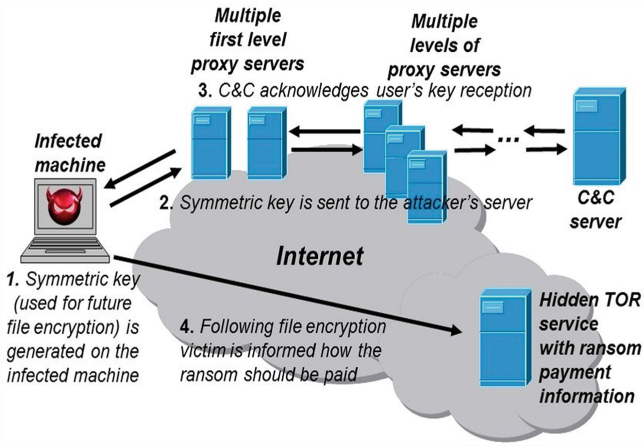

Fig. 5. Crypto-Ransomware

In [25], EldeRan, a machine learning approach for dynamically analyzing and classifying ransomware, is presented. EldeRan monitors and tests a series of actions performed by applications in the early stages of the installation and functions of Ransomware characters. Their tests on a data set of 582 Ransomware belonging to 11 families and 942 Goodware applications show that EldeRan reaches an area under the ROC curve of 0.995.

D. Most critical works in 2015

In [26], a method for safety analysis and detection is proposed. Malicious applications attack smartphones and steal personal data. What is even worse, the proliferation of attacks affects the healthy growth of the mobile Internet industry. The malicious application must be identified and treated to limit the increasing speed of informal application. Recognizing and analyzing the behavior of such attacks helps us understand the principle of the attack in depth, enabling us to take effective measures against malicious applications. This article describes the basic components of Android and the Manifesto, which is the reason for the frequent attacks on Android. This study analyzed malicious Ransomware that threatens mobile security and developed an automated analysis approach for such mobile malware detection.

Since 2009, bitcoin has become an increasingly popular currency on the Internet mainly because it resists regulation and provides anonymity. Bitcoin has been a useful tool for criminals and a lucrative target for crimes, which can be attributed to the same ideological and design choices that have driven the success of bitcoin so far. In [27], the landscape of crimes involving bitcoin, such as dark markets and bitcoin theft, has been monitored and assumptions regarding possible future opportunities, including tax evasion and money laundering, have been provided.

E. Most critical works in 2014

A document component to ensure the security of Android against Ransomware must be filled up, as discussed in [28]. His criticism of important mobile safety threats underwent moderation in 2013–2014 with enhanced techniques used in Android version 4.3. In addition, he suggested a cloud-based approach called Circumuti Mobile that detects Ransomware attacks.

Scholars have conducted extensive engine searches for Ransomware, and their results are reported in PCWorld [29]. Moreover, more than 600,000 computer systems have been attacked in the past six months, with five billion files kept hostage and more than one million dollars have been extorted from their creators.

In [30], a practical method for merchants associated with the identification of Ransomware is as follows. Storing: a database of profiles comprising a plurality of profile traders, with each trader associated with another trader and includes at least one trader identification identifier.

F. Most critical works in 2013

The burgeoning ransomware scam on Windows-based computers has affected dozens of victims in 2012, mainly in countries in Eastern Europe. In 2013, in other countries, fraud, including the US Ransomware hijacking of computers and files, requires cash when end users compromise websites or download a malicious application. In [31], vicious malware traveled from Europe to the US and around the world. Ransomware involved using fear and money was extorted from the victims. By pretending to be a security software, these programs not only accuse the user of committing a crime but also threatens to remove user access to a program or file if a fee is not paid.

3 Current Security Solution Against Ransomware

Figure 6, summarized the most techniques as a solution to prevent and mitigate the nightmare of Ransomware attack, which is the most critical attack in 2017. This attack has affect several large infrastructures in the world starting from the healthcare in Europe, and North America. If we survived the open position for the security developers and research till this time of paper writing, it shows massively increased the marked security consultant and developer in world wide. That indicates something really critical happen in internet security world and need immediate action against it.

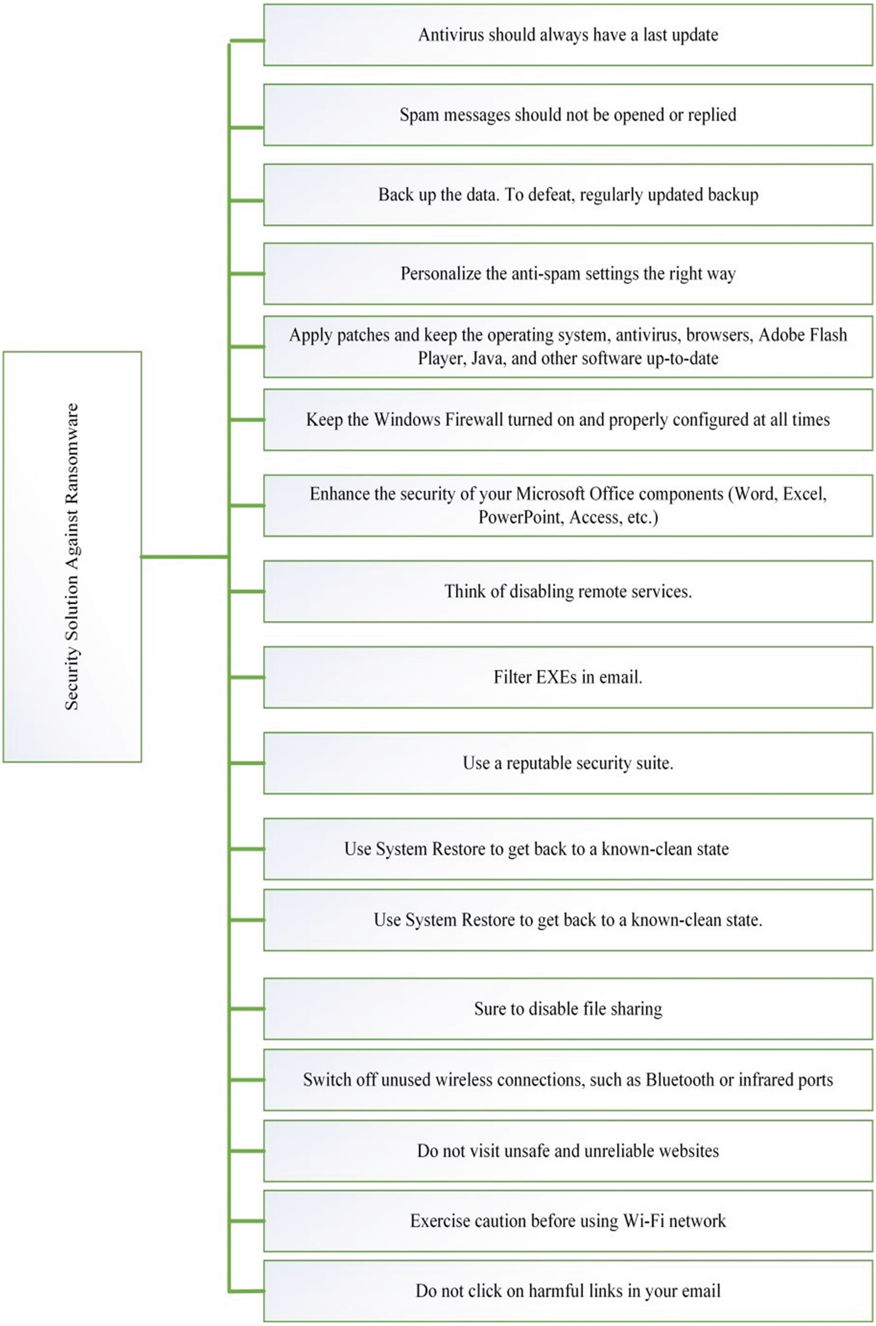

Fig. 6. Current security solution against Ransomware

4 Conclusion and Future Work

Automatic depiction and prevention security engines in not enough indeed to prevent and mitigate Ransomware attacks nowadays with ought colorization with qualifier from network security. Recent reports from defect verities of the network security companies faced a big challenge how to prevent these kinds of attack. Furthermore, hacker using alternative payments method such as bitcoin to do their crimes and need to rethink how to control and prevent their payments tools against these attacks the accrue a sensitive organization. In this paper, surmised the most critical works by other scholars to produce the roadmap for the academic and non-academics researches and developer to have a clear and intensive information from where to start to fight the battle of handsome attack. We have noticed that in 2017 was the highest and worst year in term of increasing non-control this attacks. The battle not finished yet, event in security work no one can won but at least we can temporary control it for some time still a new attack appears again in this world.

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The 10th International Workshop on Simulation and Modelling of Engineering and Computational Systems (SMECS-2017)

Power Management in Smart Grid for Residential Consumers

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Abstract. In this paper we have studied the power management for residential area. A proper load management brought fruitful results in term of Peak to Average Ratio (PAR) reduction and electricity cost. In order to achieve these objectives, we provide an energy management structure to perform scheduling on the basis of Genetic Algorithm (GA) and Fish Swarm Optimization (FSO). Time Of Use (TOU) pricing scheme has been used to calculate electricity cost. After experiments a noticeable difference has been found in the performance of our proposed algorithms GA and FSO. GA provides us better results in term of energy consumption and PAR reduction as compared to FSO. However, FSO performs more efficiently than GA in term of electricity cost reduction.

1 Introduction

Power management is a major issue now a days. In conventional power grid, there exist no proper plan to manage power consumption. Due to this mismanagement a large amount of energy is being wasted which may cause serious energy crisis in future. In these circumstances there exist a strong need of a well managed power control system. Smart grid meets all the challenges regarding power management. It also provides two way communication between consumers and grid station. Smart grid integrates communication technologies, computational abilities and a proper control system with existing conventional grid and enables two way communication between grid and consumers. Energy utility companies are always interested in profit increment with reduction in Peak to Average Ratio (PAR), however consumers wants to decrease electricity payments. Smart grid provides Demand Side Management (DSM) in an efficient way. Due to this content of smart grid, utility effectively create balance between demand and supply. Two main functions of DSM are load management and demand response. A proper load management brought fruitful results in term of reduction in number of peak power plants and electricity bill. Smart grid aims to lessen electricity bill, minimization of energy consumption and user com-fort maximization. To achieve

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these objectives, several DSM techniques and algorithms have been proposed in previous years. For instance, in [13], integer linear programming, mixed integer linear programming and mixed integer non-linear programming are used for electricity cost minimization. Similarly, in [4], authors use convex programming. In [5,6], integer linear programming and mixed integer linear programming are used to schedule the appliances. In this paper GA and FSO have been used for scheduling and have checked their effectiveness in terms of power consumption, electricity cost, user and PAR. For electricity cost calculation TOU is used. Rest of the paper is organized as follows. Section 2 briefly describes related work. Next, Sect. 3 explains problem statement and Sect. 4 elaborate system model. Simulations are discussed in Sect. 5. Finally, paper is concluded in Sect. 6 by pointing out the future work (Fig. 1).

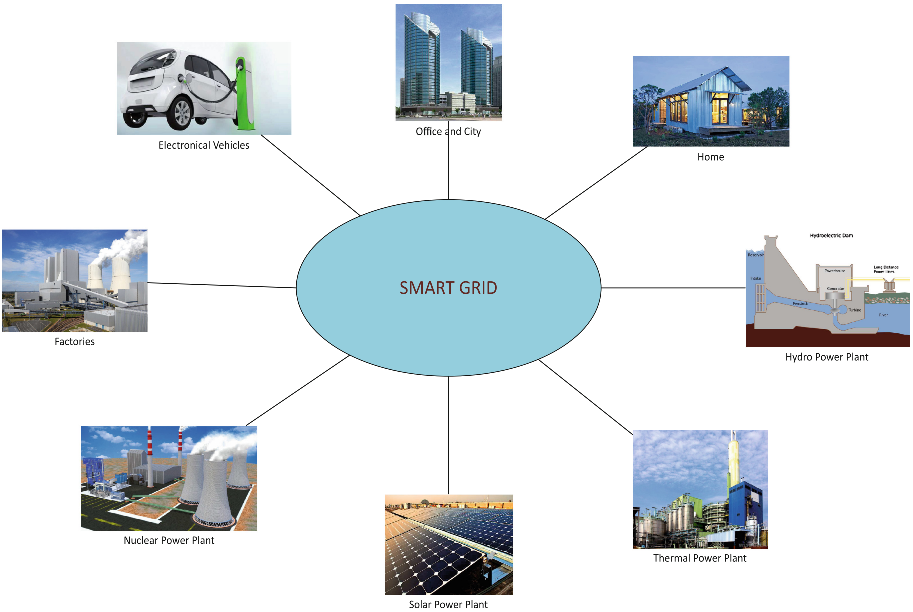

Fig. 1. System model

2 Related Work

Energy consumption and cost reduction remain a serious issue in traditional grid. To overcome these issues plenitude of scientific contribution has been proposed by many researchers around the globe. In case of smart grid, DSM is optimally accomplished by the production and application of different techniques and pricing schemes. Here we studied some of papers related to this space and categorized it on the basis of pricing schemes used in these papers.

Another model of DSM is introduced in presented in [11], which emphasizes upon minimizing the peak hourly load and deals with both the operator inclination and detailed necessities of each appliance in the household. The problem is solved by the application of an optimal technique known as integer linear programming technique. Time Of Use (TOU) is targeted for cost calculation. Simulations and results, based on single and multiple homes show that PAR is higher than daily average, balanced overall load and improves the performance of the power grid, attaining user satisfaction. The major lapse of the paper is the inconsideration of the waiting time. An effective Home Energy Management Controller (HEMS) model has been proposed in [12], which contain two types of appliances: real time appliances and schedulable appliances. They are interconnected with this model. Lower complexity is achieved by utilizing djikstra algorithm which impacts the scheduling of the appliances within limited hours. In order to attain a balance load according to PHs and OPHs TOU pricing scheme is used. Computational efforts are made to provide better results in contrast to the non-optimized schemes. DijCost min algorithm and sub-optimal algorithm are considered to evaluate the most efficient computational mechanism as these above mentioned techniques are only applicable for multiple homes. Recreations show the performance of the various proposed solutions have attained significant minimization in electricity cost and computational complexity. The limitation determined in this paper is it ignores the scheduling slots for a smaller population.

The author has scheduled the appliances in an efficient way in [13]. The appliances are classified into five sets based on operational time and power consumption. Load arranging algorithm is proposed that reins, operational time and the energy consumption level of smart appliances. Mixed Integer Linear Programming (MILP) is used to attain the main objectives which include reduction in electricity cost and energy consumption. For the purpose of cost estimation TOU is applied. To schedule the appliances Energy Management Controller (EMC) with MILP is integrated by the author. Results comes with successful achievements of understate consumer cost and load of the appliances, however there exist no proper plan to minimize PAR. In [14], an intelligent DSM is brought into discussion by authors which minimizes the electrical peak load and cost of electricity. Multi Objective Mixed Integer Linear Programming (MOMILP) has been explicated upon a set of appliances for the purpose of optimization. By using TOU pricing tariff electricity cost is estimated. Performance is calculated by six scenarios, focusing upon each household based on the proposed approaches. The simulations quantify the proficiencies for each house individually, overall management of the appliances gives us better results in term of cost, effective reduction in PAR and optimal scheduling for multiple homes, however it ignores the application of the proposed technique for smaller residential area. In real time pricing scheme, the pricing signal varies according to the usage of electricity on the consumer side. In [7], the authors have planned heuristic calculations centered energy management controller intended for a local location on a SG. Five heuristic algorithms GA, Binary Particle Swarm Optimization (BPSO), Bacterial Foraging Algorithm (BFOA), Wind Driven Optimization (WDO) and Global Wind Driven (GWD) are assessed to plan private loads concerning Peak Hours (PHs) and Off Peak Hours (OPHs) in and Real Time Pricing (RTP) environment, however enhancing User Comfort (UC) and reducing energy cost and the Peak to Average Ratio (PAR) in cooperation. The testing of these algorithms performs for a single home as well as multiple homes. Results comes about demonstrating that the proposed technique performs superior to the other heuristic algorithms. The electricity cost is lessened by these techniques, however, there still exist no proper plan of organizing appliances by using scheduling bits.

In [8], A multi-objective mixed integer linear programming is established on behalf of optimal energy usage in a smart home, making an allowance for an important adjustment concerning energy equivalent and an agreeable way of life. To check the proficiency of proposed algorithms, various recreations were performed under various situations utilizing genuine information. The results come in the form of decline in total working cost, energy use and also increase in user comfort level. Besides, this proposed model is not compatible with multiple homes and it require thermal energy sources. PAR is not discussed in this paper. Authors in [9], study the power setting up problem for built-up customers in the Smart Grid (SG). The challenges addressed in this paper include an optimal power consumption, scheduling of utilization in order to accomplish cost reduction and a desired compromise among the expenditures and the anxiety. In order to meet these objectives taguchi loss functions, Day Ahead Pricing (DAP) and flat price schemes are used respectively. The appliances are divided into two types with flexible starting time and flexible power rating with fixed running time. Simulations show a clear reduction in electricity cost. But enhancement in PAR is a major flaw of under contention paper.

A cost efficiency-based residential load scheduling framework has been introduced by the authors in [10], to achieve better residential electricity consumption while keeping the economic efficiency under consideration. Advance Fractional Programming is utilized for building up a heap planning calculation to achieve cost efficiency and furnishing with different utilization examples to investigate, In order to calculate electricity cost Inclined Block Rates(IBR) and pricing schemes is used by authors. Results depict efficient optimization of user comfort and overall reduction to cost, however the authors have not considered the effect of PAR and its significance. In [15], the author relatively assess the execution of home energy management controller, which is outlined on the premise of heuristic algorithms; GA, BPSO and Ant Colony Optimization (ACO). In such manner, Authors also present a generic architecture for DSM. In addition, issue plan is conveyed through Multiple Knapsacks Problem (MKP). PAR, user comfort, electricity cost and energy consumption are the key parameters used in this paper. For energy pricing, consolidated model of TOU and IBR is used. Recreation comes about show that each and every confined model for imperativeness association act totally to finish our challenges and exhibited as a smart response for broadening sound judgment for the augmentation practicality of SG. GA established energy management controller achieves more effectively than BPSO based energy management controller and ACO created energy management controller as far as a power bill lessening, crest to normal proportion minimization and user comfort level amplification. Efficient integration of RES is also one of the achievement of this work. But the enhancement in waiting time and ignorance of the installation cost of Renewable Energy Sources (RES) is still the limitation of under contention research paper. The researchers in [16], discuss the deployment of Energy Management System (EMS) in a Home Area Network (HAN) and its working in a single home unit, to meet the objective of electricity cost and PAR reduction. Applied optimal techniques include GA which is used for the scheduling of appliances based on the collaboration of RTP and IBR pricing scheme. Appliances are divided on the basis of their operations. Results depict that there exist a significant reduction in delay time and PAR. The user facilitation increases with reduction in daily electricity cost. However, this paper ignores the usage of waiting time and the possibility of those appliances which are being operated automatically in multiple time slots in a day.

A cost efficiency-based residential load scheduling framework has been introduced by authors in [8], to achieve better residential electricity consumption while keeping the economical efficiency under consideration. The authors have analyzed the effect of load shifting on cost with different households to attain optimized scheduling. Fractional Programming is used for developing a load scheduling algorithm to attain cost efficiency and providing with various consumption patterns to analyze, with the combination of IBR and DAP being integrated to work accordingly. Results depict efficient optimization of UC and overall reduction to cost, however the authors have not considered the effect of PAR and its significance.

3 Problem Statement

The main idea of this research comes from the fact that how to save energy? Energy resources are limited however the demand of energy is increasing rapidly due to enhancement of our daily needs. Which may cause serious energy crisis in future. In these uncongenial circumstances, their must exist some proper plan for the management of energy. Many scientists around the globe are trying to manage energy demand according to present energy resources. One the other side the utility companies are providing electricity on high rates and increasing their profit. In these situations, customers have to suffer in unfavourable environment. So we plan to manage the present power utilization according to increasing needs of energy. We aim to introduce a management plan which will be useful for both utility and customers. Our objectives include decrement in power consumption. This will also reduce the electricity cost which have to pay by the consumers. We also aim to enhance the comfort level of customers in return of low electricity rates. In following sections we propose techniques and strategies to manage demand of energy.

4 System Model

This research is based on power management problems and scheduling of electric appliances in order to manage energy consumption. Core objectives of this research includes efficient management of energy, reduction in electricity cost and maximization in user comfort level. In traditional power control system, a huge amount of energy is wasted due to the lack of a proper power management system. This phenomena may cause shortage of energy. Many researches around the globe are working in order to introduce new ways to save power collections. The best way to save power is to schedule energy consumption within the given energy resources. In this regard, a large number of new techniques have been proposed in order to schedule power consumption. The main idea of our scientific contribution based on these facts.

4.1 Fish Swarm Optimization

The FSO is a nature- inspired, meta-heuristic selection technique, emphasizing upon the behavior of fishes in terms of hunting their prey. The main approach of the FSO algorithm focuses upon the foraging and entrapment behavior of fishes larvae, indicating towards selection of the best prey and ensuring its retrieval. Moreover, FSO proves that it is able to give productive results as compared to others. The FSO algorithm has also evaluated majority of classical engineering problems employed, showing that this algorithm has advantages in solving complex problems on the basis of diverse search spaces. An example can be taken for the ship propellers, demonstrating the application of the proposed algorithm in solving real problems, illustrated in the form of the shapes of ships, with unknown search spaces as well. FSO is initialized with the different random walks of fishes in a specific search space.

4.2 Genetic Algorithm

The Genetic Algorithm is an acknowledged choice methodology which is focused on the human heredities. It utilizes the unsystematic pursuit heuristic approach to determine the obliged and unconstrained improvement inconveniences. For the most part, the practices studied in GA take after the standard survival of the fittest determined by Charles Darwin. In addition, GA is for the most part suitable for complex nondirect models where the position of the comprehensive most great arrangement is a testing undertaking. By and by, GA does not guarantee an optimal solution despite the fact that when it impacts the arrangement owed to the prospect nature for development of result. The affectation of GA begins with the chromosomes masses and recently new populace is painstakingly picked on the base of appropriateness esteem. In determination methodology, the wellness noteworthiness is appointed by computing the strategy with genomes. The better one is recognized by their wellness critical ness. Along these lines, two people are assigned from the choice technique in hybrid strategy. The chose one is as bits, which then experience periods of hybrid. Notwithstanding, the crossed bits should be the upgraded clarification rather than the ideal arrangement. Moreover, the proportion of the new people will have pretty much of their bits flicked or turnover with a roughly low prospect in change stage. The assurance is to support in the masses and compel indiscreet meeting.

5 Simulations

In this section the performance of GA alone and FSO alone is discussed in detail. Figure 2 shows a clear difference in load with unscheduled, GA scheduled and FSO scheduled. Load of scheduled appliances is approximately 20% less than unscheduled appliances. Figure 3 shows PAR for unscheduled and GA scheduled scheme and FSO scheduled scheme. The plot shows that PAR of GA scheduled is 5% less than FSA scheduled and 52.25% less in unscheduled. This PAR reduction will helps to improve capacity and efficiency of smart grid and will also help to achieve stability in power consumption. Figure 4 shows electricity cost and its differences between unscheduled, GA scheduled schemes and FSO scheduled scheme at the rate of 20%. In Fig. 5, it can be seen that the total cost increases by

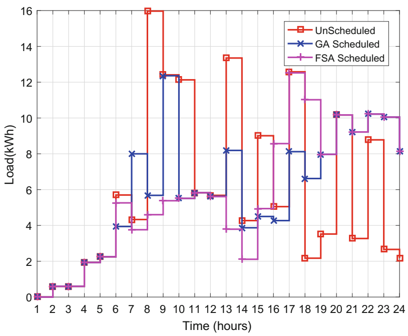

Fig. 2. Load

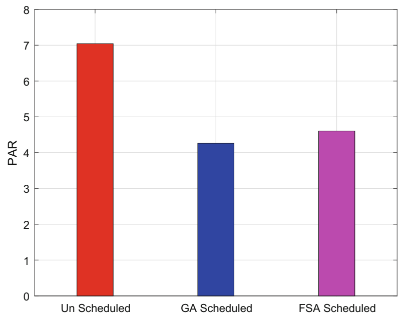

Fig. 3. Peak To Average Ratio

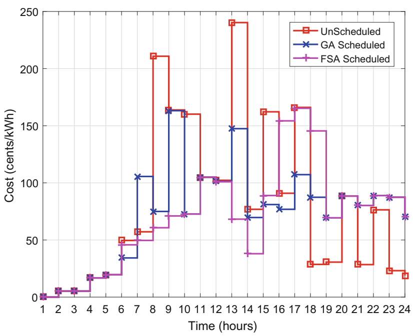

Fig. 4. Electricity cost

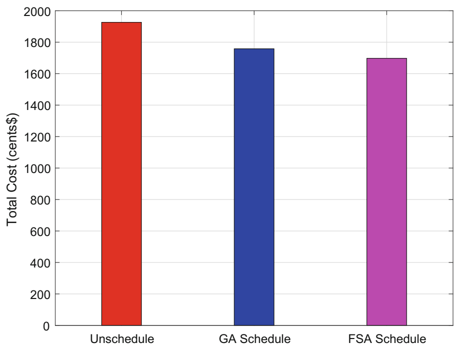

Fig. 5. Total cost

implementing GA and FSO. On the other side our proposed techniques enhance user comfort in terms of utility. So there is a clear trade of between user comfort and total cost. Figure (6), emphasizes upon the cost as the graph clearly illustrates a significant reduction with the application of FSO, meanwhile GA based scheduled cost calculated shows neutrality. Figures illustrate that there is FSA total cost is 5% less than GA, meanwhile cost of GA is 10% less as compared to unscheduled.

6 Conclusion

In this paper, we have presented power management architecture to save energy in residential areas. Reduction in PAR, electricity cost and energy consumption was the main objective of this paper. In order to meet this objective two meta heuristic algorithms GA and FSO have been used. TOU is used for the purpose of electricity cost calculation. Results shows the better performance of GA than FSO in term of reduction in electricity cost consumption and PAR. However electricity cost becomes low after implementing FSO. We decided to further reduce overall electricity cost in future.

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Demand Side Management in Smart Grid by Using Flower Pollination Algorithm and Genetic Algorithm

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Abstract. The introduction of Smart Grid (SG) in recent years provide the opportunity to the consumer to schedule their load in such an efficient manner that reduces the bill and also minimizes the Peak to Average Ratio. This paper focuses on scheduling the appliances in a more feasible and energy conservative way to satisfy both consumer and utility. In this paper, Flower Pollination Algorithm (FPA) is proposed to schedule the appliances in order to balance the time varying demand of consumer that is the basic aim of Demand Side Management (DSM). This paper emphasis on reducing the cost and Peak to Average Ratio (PAR) at same time. We used Real Time Pricing (RTP) tariff to calculate the consumer bill on the bases of real time energy consumption information. The results of proposed algorithm are compared with the results of Genetic Algorithm (GA), an existing technique to schedule the load consumption. The compared results show the significance of using this novel algorithm for DSM.

Keywords: Smart grid · Demand side management · Real time pricing · Heuristic techniques

1 Introduction

The increasing power demand makes it almost impossible for the traditional grid to efficiently fulfill the power requirements. Also the power losses in traditional grids make them inappropriate infrastructure. For these reasons the concept of SG is introduced to efficiently reduce the energy consumption and to manage the energy utilization in such a way that it satisfy both the consumer and the utility as well [1].

Replacing the whole traditional infrastructure with SG is quite impossible in reality, therefore, we incorporate the changes in the existing system to make it smart. The word smart can be defined as the system that is capable of computing,

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provide bi-directional communication and store the information for further use [2]. The main objectives of SG are load management and Demand Response (DR) [11]. The term load management means to mange the load in such a way that it satisfy the consumer's demand as well as it distributes the load evenly [11]. DR allows consumer to respond to the changes in the dynamic price models in order to manage their load requirement by keeping in view the aim of reducing cost [10]. Therefore, the main purpose of DSM in SG is to reduce electricity bill and PAR. Figure 1 shows the integration of SG in different real life scenarios.

The optimization of energy consumption in SG is achieved in past by using different optimization techniques such as Bacterial Foraging (BF), Binary Particle Swarm Optimization (BPSO), Genetic Algorithm (GA), Enhanced Differential Equation (EDE), Harmony Search Algorithm (HAS), Wind Driven Algorithm (WDA) and Ant Colony Optimization (ACO). Although these techniques performed well on the parameters of cost and PAR reduction, however, the room for improvement is always there. This fact motivates us to propose a novel algorithm for optimizing energy consumption.

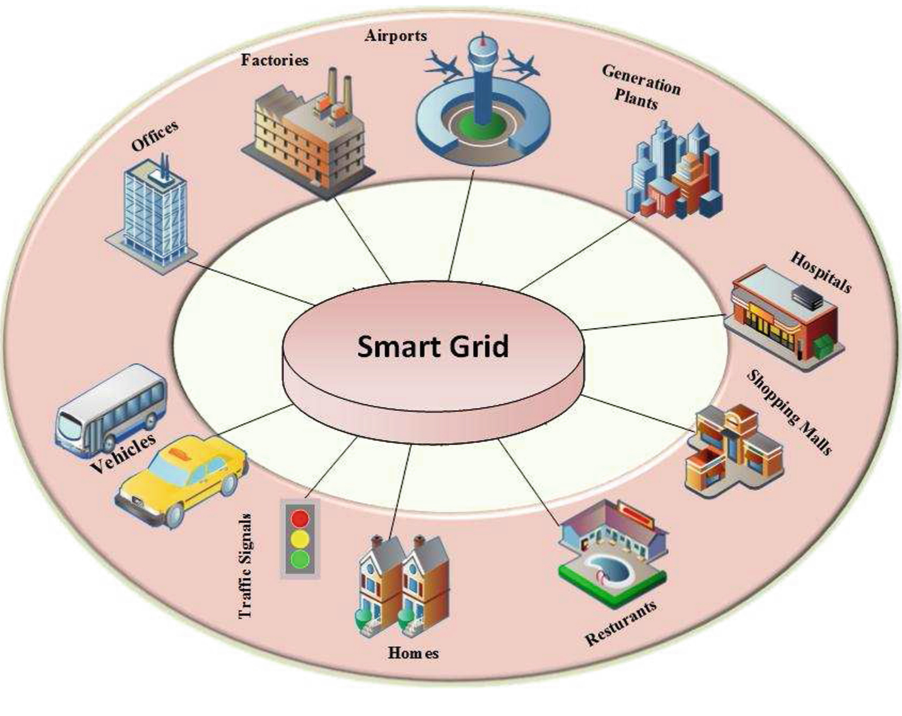

Fig. 1. Smart grid

In this paper we proposed the nature inspired FPA for DSM. FPA is an optimization technique which could be used in any field for getting optimal results. This technique mimics the behavior of flower pollination to get better results [3].

We used Rosen Brock formula for calculating the fitness of the randomly generated population. The flowers are pollinated either locally or globally by the birds and other insects. This behavior of flower pollination is copied to get local best and global best. We used Levy Flight function to decide the step size and dimensions for generating global population [4].

The appliances are scheduled by classifying them into two categories. The Manually Controlled Appliances (MCA) and the Automatically Controlled Appliances (ACA). The category of MCA includes those appliances that are manually handled and can be used at any time according to the user requirement. This category is not scheduled in the paper because the length and time of operation of these appliances is uncontrollable. ACA includes those appliances that could be controlled automatically and their length and time of operation is not variable. The ACA are scheduled in such a way that their length of operation is fixed for a range of time slots. The 24 h of a day are divided into 120 time slots of 12 min each.

Many different price tariffs are available for generating consumer bill time of use, inclined block rate, critical peak price and RTP. We adopted RTP tariff for billing. In RTP, per unit cost is calculated on the bases of load consumption. Hence, the per unit cost fluctuates with the fluctuating load consumption. The simulations performed in MATLAB are graphically presented to show the performance of our algorithm in the comparison of GA. The results of both the algorithms are evaluated on the parameters of cost, PAR, load, energy consumption and user waiting time. The rest of the paper is organized as follow: Sect. 2 briefly describes the related work, Sect. 3 contains the proposed model, Sect. 4 covers the results and simulation of the proposed technique. Finally the paper is concluded in Sect. 5.

2 Related Work

The state of the art work done in the field of SG is presented in this section. In [1], the author mainly concentrated on reducing energy consumption, cost and PAR. Renewable Energy Sources (RES) are also integrated by authors in the proposed scheme of fractional programming tools. The authors efficiently achieved the underlying objectives. However, cost minimization is not covered in the simulated results. Whereas in paper [2], the same issues are addressed by using cloud computing based Demand Side Management (DSM) system, in order to make it an open source for users. The simulated results show that the cost and PAR minimization is efficiently achieved by the proposed technique. However, User Comfort (UC) is not considered in simulations.

Author in [5], used hybrid GWD heuristic optimization algorithm for DSM in SG. Main focus of this paper is to schedule home appliances between peak and off peak hours while reducing the cost and maximizing the UC. The results show that proposed algorithm outperformed compared algorithms like GA, BF, WD and BPS on the parameters of cost, energy consumption, UC and PAR for single home. The paper could not present the comparative analysis of results of proposed scheme with other optimization schemes on the defined parameters for fifty homes. On the other hand authors in [6], used ToU and IBR as combined pricing tariff, in order to reduce the cost effectively. Automatically operated appliances were scheduled by using GA. Results explicitly show that this proposed scheme effectively reduced cost and PAR for the maximum of 10 residential users. UC and power consumption were not considered in this paper.

An optimal technique to schedule the power consumption in residential area is proposed in [7]. BPS optimization is used to schedule the appliances. ToU is used as pricing tariff in this paper. The results show a significant gain in cost optimization and PAR reduction whereas UC is compromised and the installation and maintenance cost of RES for third category users is not considered by the author. In paper [8], the author presented a Generic Demand Side Management (G-DSM) model for residential user. The author's main objective was to reduce PAR and cost and maximize the UC. GA is used to schedule the appliances and RTP is used as a pricing tariff in this paper. The results show an efficiency of 39 and 17 in cost and PAR for single user. Same parameters are reduced to 46 and 45 respectively in the case of 20 users.

The comparative analysis of GA, BPS and AC optimization techniques is presented in [9]. The author proposed the architecture of scheduling scheme by using GA with the consideration of RES and Battery Storage System (BSS). Hybrid pricing tariff is used that comprises of ToU and IBR. The results outperformed other schemes as compared to GA on the parameters like PAR, UC and cost. However, the execution time complexity is not considered. Also the idea of using BSS could not be effective in real life scenarios because of high installation and maintenance cost.

In paper [10,11], the authors addressed the issue of load balancing and load scheduling by using ToU and RTP as their respective pricing tariffs. However, in [10], an integer linear programming based optimization technique is proposed. Parameters of cost, PAR and UC are not explicitly addressed in this paper, whereas in paper [11], load scheduling and power trading were the issues addressed. The author used approximate dynamic programming to schedule the appliances. Results show that the proposed scheme smartly address the issues of scheduling and power trading. PAR and cost optimization is not explicitly mentioned in this paper.

Authors in papers [12,13] addressed the issue of normalizing the trade-off between cost and UC. In [12], appliances are scheduled to get the desired trade-off between electricity cost and UC. The shift able appliances are used under the categories of time and power shift able appliances. The results show that cost is reduced in mode 1, user comfort is maximized in mode 2 and in three both are almost at average level. The PAR fluctuation is ignored by Author in mode 2, where the main focus is to maximize user comfort that can result in increasing load on utility, whereas, in paper [13], the problem addressed by using multi objective evolutionary algorithm along with optimization technique. The results show that the reduction of cost and minimization of waiting time is achieved simultaneously by using the proposed technique. On the other side the effect on PAR is not considered explicitly.

In paper [14], authors presented a resource management technique by using stochastic model. The main idea is to tackle the unreliable nature of RES and electric vehicles to avoid blackout and provide a consistent and reliable energy supply even with the integration of RES and electric vehicles. The results in simulation section show that the achievement of author is in direct agreement to the problem statement of the paper. Some factors like financial cost of RES, execution time complexity and the trade-off between cost and UC is ignored by the authors.

3 Proposed System Model

The main purpose of SG is to manage user demands by using DSM. DSM is an efficient and reliable system to manage and control the SG working. This system has computational as well as communication capabilities that make the grid smart. Homes that consists of smart meter, Home Area Network (HAN) and Energy Management Controller (EMC) are known as smart homes. HAN acts as a bridge between EMC and appliances. All home appliances have a connection with EMC by using HAN. Any communication technology such as ZigBee, Wi-Fi, Bluetooth or wired protocols could be used to establish this connection. The EMC has a connection with smart meter as well. The users can enter their demands and requirement through an interface. These demands are then transferred to EMC, which performs the scheduling to manage and control the demands and load in order to provide a balance between both. The smart meter has to compute the bill for the user to keep him aware of his energy consumption pattern and the cost as well, so that user could make the changes according to his preferences. The smart meter has a connection with the SG to keep the system aware of user demands and also to get the information about changing per unit cost according to the tariff used. Therefore, it is evident that the connection between the SG utility and smart home is always bi-directional. In this paper we proposed a single home DSM system that has some x number of appliances. RTP is used as the pricing tariff for real time energy consumption. Figure 2 shows the Energy Management Model (EMC) used in this paper.

3.1 Classification Model

The scheduling is performed on daily bases and the appliances are scheduled on the bases of user requirements. The classification model emphasis on the division of time slots, operational time of appliances and on classification of appliances on the bases of their features. We classified the 24 h into 120 time slots, each hour into 5 slots of 12 min. This has been done in order to avoid the extra time utilization by those appliances whom required Length of Operation (LOT) is lesser than the slot given to them. In this classification we fixed the LOT of different appliances within the given range of slots. The next few paragraphs will explain the model of energy consumption and load categorization in detail.

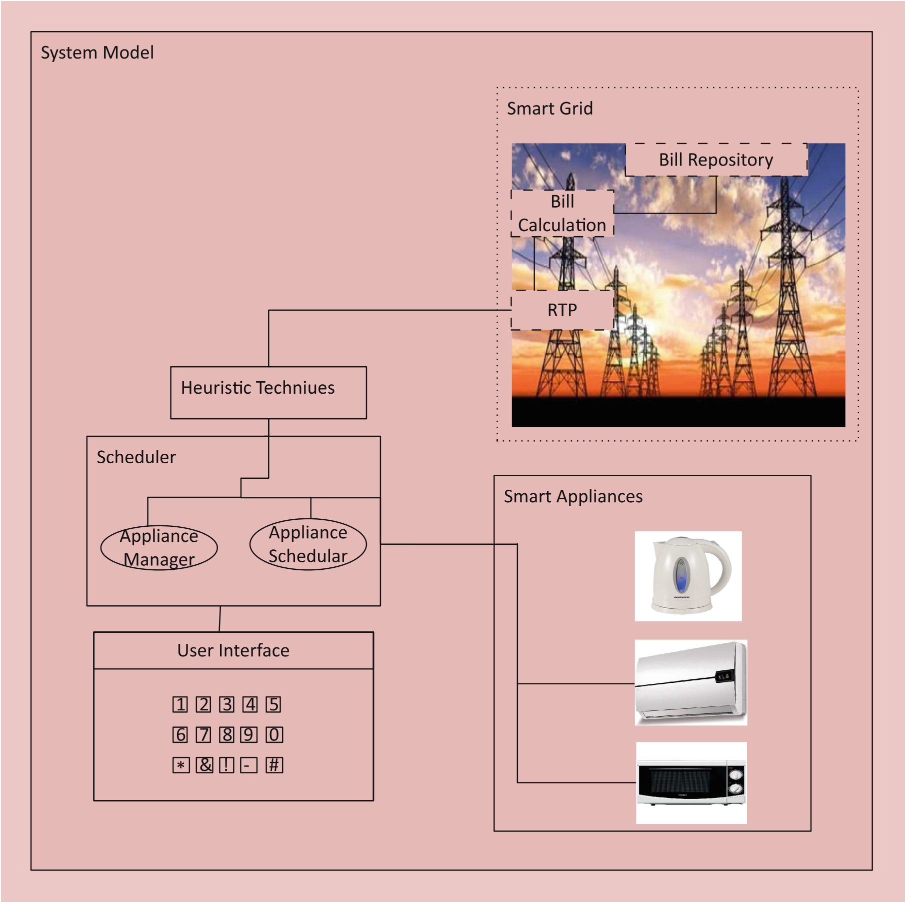

Fig. 2. HEM model

3.2 Energy Consumption Model

In proposed model we consider X number of appliances such that $X = (a_1, a_2, a_3, a_4, ...a_n)$ and T number of time slots such as $T = (t_1, t_2, t_3, t_4......t_{120})$. Overall energy consumed is denoted by E whereas, the energy consumed by one appliance is Ea and if we compute it on the bases of time slots used then it will become Ea(t). Therefore, we can write the total energy consumption of an appliance in all time slots can be written in mathematical form as: $Ea_1(t) = (Ea_1t_1, Ea_1t_2, Ea_1t_3, Ea_1t_4......Ea_1t_{120})$. Now we can write the equation for overall energy consumption as:

$$EnergyConsumption(x) = \sum_{t=1}^{120}(\sum_{a=1}^{X} E_a(t)) \tag{1}$$

3.3 Load Categorization Model

As our total load consumption is being divided among appliances used within the home. Therefore, our load categorization will be among them. In this paper we divided our appliances in to two sets named as ACA and MCA. In proposed technique we did the scheduling only for the ACA. As the operation of MCA depends on human desires, which is uncontrollable and can not be scheduled, therefore MCA appliances such as fans, television and lights are not scheduled in this paper. We denote the power consumption by x, the power rating by z and appliance status by y, which could be either 0 or 1. Therefore, the total power consumption by any particular appliance can be given in mathematical form as:

$$PowerConsumption(x) = \sum_{t=1}^{120}(\sum_{a=1}^{X} z_a^t * y_a^t) \tag{2}$$

where
y = 1 if appliance is ON
y = 0 if appliance is OFF

3.4 Price Model

Variety of different pricing tariff are in use which can calculate the consumer bill. We are using RTP as our pricing tariff. As this tariff computes the bill according to the real time price rates. Therefore, user will be well aware of on peak hours rates and off peak hour rate and will manage their consumption accordingly.

3.5 Heuristic Algorithms

The problem of uncontrolled energy consumption by the home appliances can be tackled by scheduling these appliances and by shifting the load from on peak to off peak hours. Therefore, in this paper two heuristic algorithms are used to schedule the appliances. Both the algorithms are adopted from nature inspired phenomenon. Both have their own characteristics and objectives. These algorithms are GA and FPA. The algorithm of our novel FPA algorithm is as follow:

4 Results and Simulations

To evaluate the performance of proposed algorithms, we performed simulations in MATLAB. The end results are then compared on the bases of performance parameters such as cost, PAR and waiting time. In this paper we consider the time slots of evening hours from 5pm to 11pm as peak hours whereas the time slots of morning hours from 7am to 11am are also considered as peak hours according to the most accepted statistical data available. According to the classification applied, the control parameters such as time and appliances are also classified. Appliances are categorized into the categories of ACA and MCA and

Algorithm 1. FPA for SG Scheduling

Initialization ($ttl.pop$,$ttl.slots$,D,EP,p,A,$Econ$)
Evaluate the initial PoP by using Rosen Brock fitness function
$J_{last} \leftarrow J_i$

for $avg = 1 \rightarrow 10$ **do**
  for $a = 1 \rightarrow A$ **do**
    for $t = 1 \rightarrow T$ **do**
      Generate random population by using upper and lower bound
    end for
  end for
  for $i = 1 \rightarrow max_{pop}$ **do**
    Evaluate fitness again
    if $Fitness_i < J_{new}$ **then**
      if $Econ_i < Econ_{new}$ **then**
        Update previous by new
      end if
    end if
  end for
  for $i = 1 \rightarrow max_{pop}$ **do**
    Update population by 0 and 1
  end for
  for $t = 1 \rightarrow T$ **do**
    Schedule the appliances with respect to LOT
    if $EP < D11$ **then**
      Off peak hour
    else
      On peak hour
    end if
  end for
  Update Population with minimum value
  for $i = 1 \rightarrow max_{pop}$ **do**
    if $rand < probability$ **then**
      keep within local search.
    else
      Generate new population in global search space.
      Calculate the fitness function of population.
    end if
  end for
  Update the population
end for

the scheduling is performed only on the ACAs because the operation of MCAs is uncontrollable. The 24 h of a day are divided into 96 slots of 15 min each. This unique division is performed to reduce the wastage of electricity when the appliance LOT is shorter than the allocated time slot. The classification followed is given in Table 1 along with the power rating of each appliance. The performance of both the algorithms measured on the bases of results achieved, is discussed in next few paragraphs along with the graphical representation of achieved results.

Table 1. Appliance classification

Appliances	OTI	LOT	Power *(kWh)*
Air conditioner	41–60	5	1
Air conditioner	61–85	5	1
Air conditioner	86–120	10	1
Electric radiator	1–30	5	1.8
Electric radiator	91–116	10	1.8
Rice cooker	1–25	2	0.5
Rice cooker	41–60	2	0.5
Rice cooker	71–90	2	0.5
Water heater	86–106	3	1.5
Dish washer	101–120	2	0.6
Washing machine	1–60	5	0.38
Electric kettle	1–25	1	1.5
Electric kettle	66–85	1	1.5
Humidifier	1–30	5	0.05
Humidifier	91–120	5	0.05
Clothes Dryer	70–90	5	0.8

Load consumption and load division within the given time slots is given in Figs. 1 and 2 respectively. The graph of load division shows that by using scheduling techniques we evenly divided the load over the given time period and also the load has been shifted from on peak to off peak hours. The graph shows that our proposed algorithms performed better than the unscheduled load. The load consumption graph shows that in all three situation the total load consumed is same and we did not compromised user comfort by reducing the load demand instead we scheduled load in a better manner.

The Fig. 3 shows the result of our proposed technique on the bases of PAR achieved. The bar graph clearly shows that the PAR of GA and FPA is far less than unscheduled power consumption. This contrast is because our proposed algorithms shifted the load from on peak hours to off peak hours in order to reduce the PAR. The comparative study of proposed algorithm shows that FPA results are more better than GA.

We used RTP as our pricing tariff that computes the consumer bill on the bases of real time unit cost. Therefore, the chances of high cost in unscheduled power consumption are quite high. The graph results in Figs. 4 and 5 also reveals the same reality. As the per unit cost in peak hours used to be high to discourage the users to consume energy in these hours and our proposed algorithms

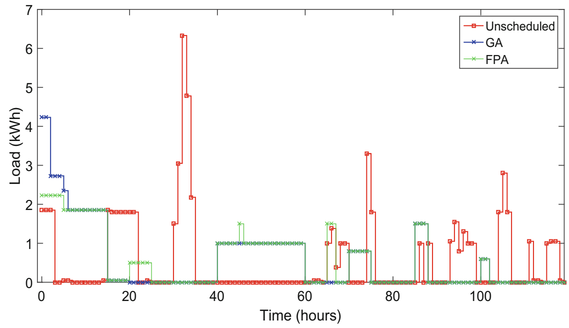

Fig. 3. Load distribution

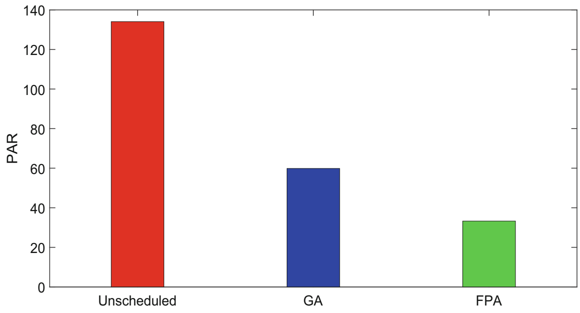

Fig. 4. PAR

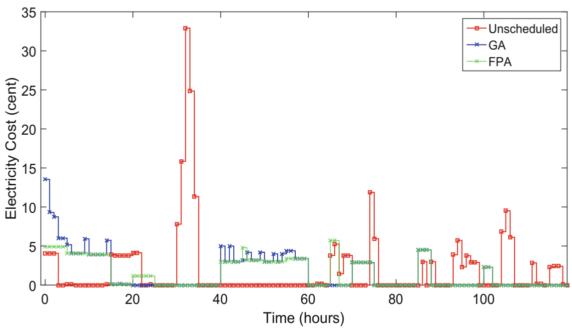

Fig. 5. Cost distribution

are already shifting the load from peak to non peak hours therefore, this will automatically reduce the cost. Comparing the cost of proposed algorithms show a slight difference between the performance of these algorithms.

The trade off between user comfort or waiting time and cost is obvious. When user has to wait to reduce the cost or because of the shift of load from on peak to off peak, then the compromise will be on user comfort. Our bar graph in Fig. 6 reveals the same fact. As we have seen in previous graphs that FPA performed better than GA on the parameters of cost and PAR, therefore its performance on this parameter must not be very good. Also in this graph we did not include unscheduled load as in unscheduled user do not have to wait in any case. They are free to use any appliance at any time, therefore waiting time will be zero in this case (Fig. 7).

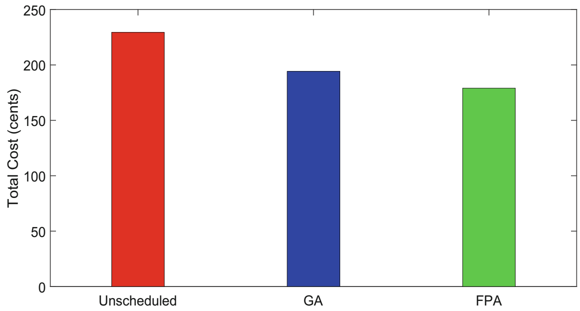

Fig. 6. Total cost

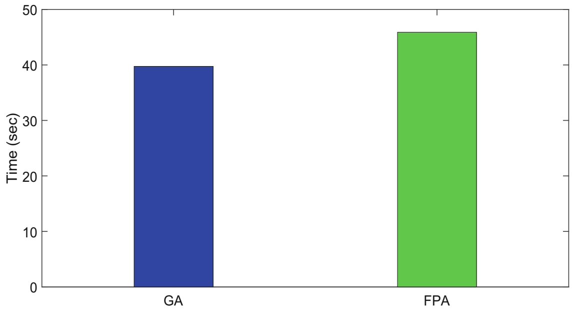

Fig. 7. Waiting time

5 Conclusion

This paper presented an EMC model to manage residential energy consumption. We avoided peak formation by shifting the load from peak hours to off peak hours. The RTP is used as pricing tariff to generate the consumer bill on hourly bases. We evaluate our proposed EMC model by using GA and FPA. The simulated results show that our proposed algorithms performed well on the parameters of PAR and cost reduction. The proposed novel technique based on FPA performed more better than GA on these parameters, while the waiting time of GA remains a slight better than FPA that shows the trade-off between user comfort and cost.

In future we will hybrid our proposed technique with one of the existing optimization techniques in order to improve our results and also to address other features such as user comfort. We will also incorporate reusable energy sources in our future work.

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Using Meta-Heuristic and Numerical Algorithm Inspired by Evolution Differential Equation and Strawberry Plant for Demand Side Management in Smart Grid

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Abstract. "Save Energy" is the cry of the day. Energy demand is increasing day by day, on the other hand Energy generation is decreasing, creating a gap between Demand Side Management (DSM) and Supply Side Management (SSM) leading to maximum Peak Average Ratio (PAR) formation. To overcome the gap between DSM and SSM and saving bill cost of the consumers we have designed a consumption scheduling technique for home area in DSM, using Enhanced Differential Equation (EDE) and Strawberry Algorithm (SBA). EDE and SBA schedule user's appliances intelligently and creates a daily optimal load balance for DSM and SSM thus providing advantage to both consumer and utility. Our proposed technique have not only focused PAR minimization but also User Comfort (UC) maximization, cost reduction, and waiting time minimization. Our simulation results verified that, we have obtain better results than other existing techniques.

1 Introduction

Different innovation have made the human life comfortable and easy. Among these innovation, Electricity is the one of the most valuable invention by science for the human life. It is generated from different sources like hydroelectric power plant, nuclear plant, solar plants, RES, etc. Electricity act like fuel for the vehicle of human life, without fuel vehicle cannot move, in the same scene Electricity is important for the human life. Electricity has been used in industries, homes, offices and other commercial places. It has become a backbone for these places. As population is increasing every day which requires more Electricity. This increase in population requires Electricity in order to meet their demands. To overcome this shortage utilities have started to educates their consumers to save energy, however new buildings are being constructed in government and public sectors. The problem is that, the Electricity consumption ratio is greater as compare to other economics sectors as discussed in [1]. The consumption

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ratio is different for different countries however 30–45% of global energy is consumed by buildings. According to [2], up to 56%, the energy consumption will be increased by the year 2010 to 2040.

It is found that use of bind Electricity is the main cause of energy crisis. To handle this problem, previously scientists have started working on finding other resources for the generation of energy like nuclear resources, natural resources which included sunlight, wind, coal etc. Beside this another problem occurred, load on the Grid increases during some hours of the day due to intensive usage of appliances. This type of situation is being observed seasonally, vary from country to country. To avoid load on the Grid, different pricing schemes have been introduced in the market like, Time of Use Scheme (TOU), Real Time Pricing Scheme (RTP), Critical Peak Pricing Scheme (CPP) etc. Through these schemes, the utility control load on the grid while providing some incentives to the consumer in the shape of cost or bill reduction. These schemes have these leading to user comfort. It is true that these schemes reduced load on the Grid, thus avoiding peak formation and also reducing bill of the consumer, however these schemes have completely ignored User Comfort (UC). By using Renewable Energy sources (RES), UC can be maximized and also by two way communication user can sell its excess Energy back to the utility helping in SSM [3]. However installation and maintenance cost of RES is not considered, which is very high. In [4], Energy consumption can be reduced up to 15%, when we schedule DSM consumption. Hence Focus of our work is to manage power consumption in DSM. DSM which is a key factor of SG, enabling the consumer to take better decision about his appliances usage and energy consumption. [5] When we efficiently schedule DSM we can achieve the following benefits: (i) Low Peak formation, leading to PAR reduction. (ii) Shifting load from on peak hours to off peak hours, decreasing load on SG. (iii) By allocating different time slot for each appliance according to user defined scenario, bill is reduced. Inspired from [6], we have proposed a power consumption scheduling system for residential area. Our system consist of EDE and SBA, while taking CPP scheme as a unit pricing scheme. The proposed system will decrease cost, PAR, and waiting time while it will increase UC. The system can be applied to the micro controller embedded in Smart Meter (SM), each appliance communicates with micro controller through Home Area Network (HAN). Through user interface of SM, the user can set plan for the usage of appliances, then the system generates consumption pattern defined by the user based on the pricing scheme provided by the utility (currently we have used CPP, however other pricing schemes can also be used).

Rest of the paper is organized as: Sect. 2 contains Related Work, Sect. 3 includes Problem Statement, Sect. 4 explains Proposed System, Sect. 5 consists of Simulation and Results, and Sect. 6 elaborates Conclusion.

2 Related Work

we have classified our papers into three categories, on the basis of the area they focussed on i.e. (i)consumer or demand side management, (ii) utility or supplier side management, and (iii) those papers who have considered both first and second area.

2.1 Classification

The above mentioned classification is explained below in detail:

2.1.1 Consumer or Demand Side Management

In [7], the author focuses on an offline scheduling problem in DSM, to manage power requests send by the consumer to the power grid controller. The grid controller has to schedule each request within the specified duration. The electricity or energy consumption cost is measured by a convex function of the load in each timeslot. The objective of the problem is to schedule all requests, in such away that for a specified time slot, we gain the minimum total energy cost. For the above mentioned problem the author has proposed a polynomial time offline algorithm. The algorithm first arranges the job in different arbitrary orders and runs each order following three steps. Next the algorithm maintains two invariants, i.e. (a) There is no legal-path in the resulting feasible graph. (b) Assures that for the consider job, the assignment is optimal. The algorithm also performs other steps like additional notation, correctness, and time complexity. In this paper [8] the author uses Day Ahead Pricing Scheme, supposing that electricity prices will be given by the supplier before one day. The author schedules power strategy for thee mode of operation, dividing appliances into two types. First type of appliance has fixed power and elastic start timing, while the second type has predefined working time and elastic power consumption. By this a user can control start time of the first type while power of the second one to reduce bill. The objective is to achieve a trade-off between discomfort and payments for residential users. The architecture of the system consist of ECS in smart meter, through HAN the service provider and user communicate to the appliances for send price signals and scheduling. From the proposed scheduling strategy of three different combination of two types of appliances, it can be observed that mode 1 performs well for cost saving power consumption. Limitation: Focus on DSM, not achieved user comfort, No description of Waiting time, utility I not considered.

2.1.2 Utility/Supply Side Management

This paper [9], deploy an online Energy Management Strategy (EMS) in Micro Grids (MG) for its real time operation. This scheme take into account the power flow and system operational constrains on a distributed network. Online EMS woks on the principles of Lyapunov optimization and problem is model as stochastic optimal power flow. Proposed algorithm uses more develop form of online algorithm because pure online algorithm is too simplified and is enough good to implement practically as compare to offline algorithm, which are too complex to implement practically. This algorithm make decision on the current available states of the system. It does not use any statistical prior knowledge, while managing real time energy. Micro grid sells extra energy to the main grid, when price is at peak and cost of using DERs is relative low. It enhances the efficiency of the micro grids making them to not only fulfil their local needs but also produce surplus energy to sell in the market or to the grid. This scheme is practical implemented in china province.

2.1.3 Consumer and Utility Focused

In [3], authors have presented an algorithm for EMC (energy management controller) to reduce the bills, PAR, waiting time and maximize system's efficiency along with UC. User interacts with the EMC through user interface and EMC is a little controller installed in the SM. The EMC sends user defined plan to the smart grid domain using WAN. Each smart home is equipped with SM. The author also integrates RES in home Energy management system. The proposed approach is not only for single home as well as for multiple homes. Electric price is calculated with a hybrid of two price signals i.e. RTP and IBR. To remove randomness in the selection of the new population and obtain much better convergence rate, a hybrid form of three heuristic algorithms GA, BPSO, and ACO is used. Problem formulation is done through MKPS. For this algorithm load is divided into three classes: (i) Fixed Appliances: whose load profile and LOT's start time and end time cannot be change. (ii) Shift Able Appliances: those whose LOT's start time and time can be change. (iii) Elastic Appliances: those whose load profile and LOT's start time and end time can be change. The system is able to do two way communication. There is a tradeoff between cost and user comfort so reducing the cost user comfort is compromised.

In this paper [10], a new mechanism for scheduling Smart Grids (SG) through using DSM scheme. A new hybrid pricing technique is implemented based upon repeated game model and Rubinstein-Stahl bargaining game. The system for which this mechanism is proposed consist of multiple selfish power suppliers, each has multiple consumers. We propose a new SG scheduling scheme that uses the DSM technique. To achieve effective SG management, we adopt a mixed pricing strategy based on the Rubinstein-Stahl bargaining game and a repeated game model. Also the proposed mechanism is applied in distributed foam, so that each user can set their appliances LOT and timing on a way to effectively minimize their bill and for the supplier side the load is shifted to off peak hours instead of on peak hours. According to the proposed mechanism there is no increase in predetermined power consumption amount. The attributes assumed for the proposed scheme are: (i) Ten consumers, each equipped with SM (ii) Ever consumer has NSA. (iii) Every consumer has SA. (iv) SM can change those appliances, whose power profile is changeable. (v) Total power demand is constantly generated compared to the predetermined demand. (vi) Each SA operate during its own defined time period. There are two cases considered in the proposed scheme: (i) When the estimated power amount is less than demand, in such case the supplier does produce more energy to fulfil consumer's need thus decreases supplier's efficiency. (ii) In the second situation estimated power amount is more than the consumer's demand. The supplier have to transfer this extra energy to other consumers, having energy crises.

From numerical result it is estimated that suggested scheme removes peak load. It also matches demand with supply. The numerical results show that the proposed scheme is effective for removing the peak load and matching supply with demand. Our game-based approach provides a better and effective performance, from the perspective of both consumers and supplier. The proposed scheme performs well, than other three previous SG scheduling techniques. In paper [11], the author uses scheduling and trading algorithm for the high penetration of RER's systems, in which each user is equipped with RER. User can sell their excess energy generation to other users or to the utility company. For a user it is more profitable to trade power with other users locally, users with excess generation compete with each other to sell their respective extra power in the market to their local users, to fulfil this purpose a game theoretic approach is own, in order to model interaction between users with excess energy or power. If the user sells the generation to the grid then the systems having high penetration of RERs, give rise to the voltage rise problem, which is a major challenge in integrating a large number of DGs in the distribution network. To remove the reverse power flow problem, it is good for the users to consume their generating power locally rather than injecting the excess power back into the grid. Approximate Dynamic Programing (ADP), has been used to schedule the operation of different types of appliances. From the results we can evaluate that power import for the system without ECC deployment and trading is larger is compare to system with ECCs and not selling. ECC shifts most of the load to low price time slots. Our proposed load scheduling algorithm reduces the average import energy to it minimum value, which is 820.2 kWh because of the trading among the users. The average electricity cost of the users for the system without ECC deployment and trading is doller 62.91. For the system with ECC deployment but without trading, this value is reduced to doller 54.73. Our proposed algorithm further reduces the electricity cost of the users to doller 40.37. Through this system, users are able to decrease their energy expenses by selling their excess generation to other users with a price higher than utility. Second, buyers may also benefit from the price reduction due to the competition between multiple sellers.

Paper [12], first describes architecture of the proposed EMC. The EMC consist of GH which receive information from DR, showing RTP electric price. The consumer communicate to HG through HAN by remote control devices. For the proposed scheme appliances are divided into two categories i.e. AOA and MOA. Each AOA operates automatically in most minimize cost, once it receive RTP signal, consumer does not need to control it manually. Although appliances operate in most efficient minimized cost but it increase PAR, which may affect the entire power system. To remove this problem, the author uses RTP combine with IBR. Also for EMC scheduler, GA scheme is implemented.

For GA population size is set 200, probability of cross over is kept 90%, and mutation rate is 2%. When generation reaches to 1000, evolution process stops.

AOA are taken 9, each appliance cannot operate more than 16 time in one day. One Time Slot (TS) equal to one hour is divided into 12 min, one hour is equal to 5 time slots. One day contains 120 slots, unit of LOT is these defined time slots, for example washing machine has LOT 46 then 4 TS will be required. The remaining two mints are ignored which may create errors. Mention system can also be applied for multiple consumers. By implementing this mechanism consumers are able to minimize their bill, waiting time and PAR while UC is maximized. This system don't take into account MOAs. It also waste remaining time of the TS.

In paper [6], the author deploy a mechanism for scheduling load consumption of appliances in home area load management, he divides the appliances into three categories i.e. Non-Shift-able Appliances (NSA), Time Shift-able Appliances (TSA), and Power Shift-able Appliances (PSA), however he proposes a mechanism for scheduling the power consumption of TSA and PSA. Proposed mechanism is able to schedule optimal operation time for TSA and optimal power for PSA. In this scheduling mechanism Smart Meter (SM) is the backbone of the system, communicates through HAN, which receives power pattern plan from the user and sends it to the controller for implementing the received plan. SM will control switching of TSA and power pattern of PSA. In this scheme the author considers seven appliances, among these seven appliances, fridge which is NSA operates twenty four hours consumes 0.12 kwh per hour, heater also belongs to NSA consumes 1 kwh, and along these when electric vehicle charger is also on which belongs to PSA consumes 01 to 3 kwh per hour, then the minimum peak load which is 1.22 kwh is gained though our proposed scheme using LDP technique. The proposed scheme fulfils both user preferences and individual appliance's power and time switching. The mechanism is first applied on single home then it is applied on multiple homes.

The flaws of this scheme are: (i) it does not consider or schedules NSA (ii) No price scheme is define (iii) Two way communication is ignored (iv) There is no description of waiting time.

3 Problem Statement

Our motivational factors are discussed below: (i) Load Balancing: Our system shifts load from on peak hours to off peak hours. By shifting load from on to off peak hours, load on the grid is minimized and problems like load shading is avoided. When load is balanced, this vanishes the gap between Demand and Supply. (ii) PAR Minimization: When consumers, use their high power rating appliances in off peak hours. Then there will be less chances of high PAR. (iii) Cost Minimization: Consumer's main objective is to reduce his/her Electricity bill, they want to pay less and consume more Energy. We have calculated minimum fitness functions for the cost reduction. (iv) UC Maximization: There is a trade-off among cost, waiting time and UC. They are inversely proportional to each other i.e. when cost is reduced, this will increase waiting time, which in turn will lead to discomfort of the user and vice versa. This paper have not only reduced cost and waiting time but also increased UC.

4 System Model

We have proposed a DSM optimization technique for energy scheduling in residential areas. DSM play an important role in energy consumption and also control activities of demand side users. Our optimization technique consist of Enhanced Differential Evolution (EDE) and Strawberry Algorithm (SBA). The proposed system's main objective are to schedule the DSM in HEM, so that the system intelligently mange the appliances in a single home to minimize bill cost and PAR formation thus giving advantage to SSM. It also reduces waiting time ultimately maximizing UC. The architecture of our system consists of single home (however this technique can be applied to multiple homes also), a set of seven appliances, which are categorized into three categories shown in Table 1. Non-shift-able appliances, whose power rating is fixed for each hour. Power shift-able appliances, whose power consumption pattern is changing. Time shift-able appliances, whose power is different for each time slot. Each appliance is equipped with sensors. Through these sensors the appliance can communicate with EMC through HAN. EMC is the embedded controller in SM, which monitors and controls the appliance. The EMC not only interact with the appliance, as well as with the end user though user interface. Through user interface, the user can set pattern of use according to pricing signal provided by the utility and also looking to his comfort. EMC receives pricing scheme from utility through WAN. For the simulation purpose, we have considered Critical Peak Pricing (CPP). In CPP electricity has high cost during on-peak hours, however cost at off peak hours is low and the utility encourage the user to use high power rating appliances in off-peak hours.

Table 1. Appliances categorization

Name	Type	User preferences and power requirements
Hob and oven	Non-shiftable	7 pm–8 pm
Fridge and freezer	Non-shiftable	24 h
Heater	Non-shiftable	9 pm–10 pm, 3 am–5 am (heater) hourly consumption: 1 kWh
Water boiler	Power-shiftable	Hourly consumption: 0–1.5 kWh daily requirement: 3 kWh
Electric vehicle	Power-shiftable	Preferred charging period: 8 pm–8 am charging power: 0.1 kW–3 kW daily requirement: 5 kWh
Washing machine	Time-shiftable	Operating 2 h, 1 kWh for the 1st hr and 0.5 kWh for the 2nd hr
Dish washer	Time-shiftable	Power: 0.8 kWh for 1 h, daily requirement: 0.8 kWh

5 Simulations and Discussions

In this section we have evaluated the results of the proposed system. The proposed system's code is run through Matlab software. Results are checked more than 15 times. The system has created the following results and plots, which are: electricity cost per hour is simulated in Fig. 1, EDE and SBA perform well than Unscheduled. Unscheduled have high cost of 330 Cent at time slot of 11, which is very high as compare to SBA and EDE, whose maximum cost is

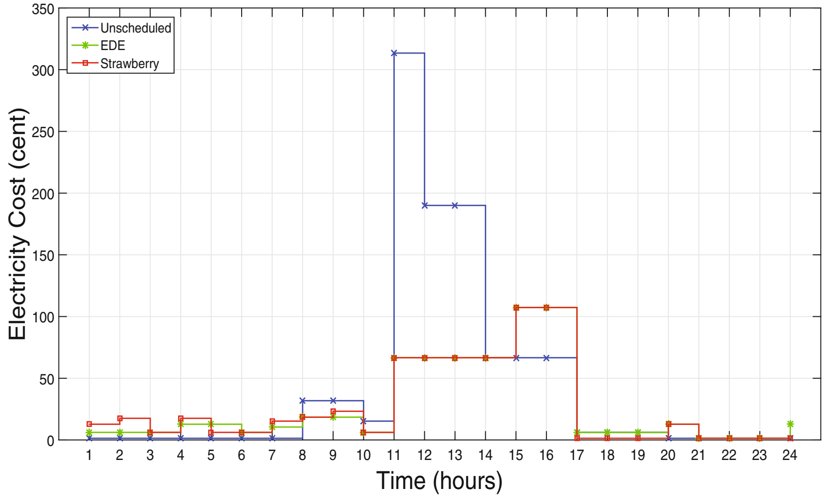

Fig. 1. Electricity cost per hour

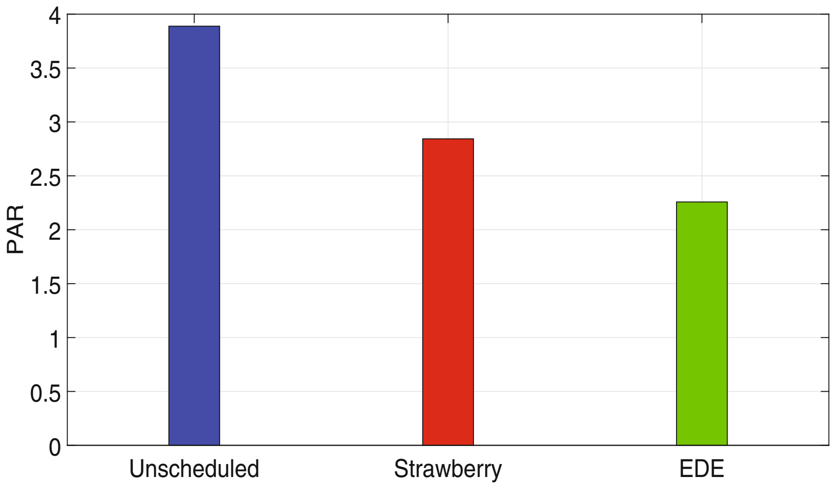

Fig. 2. Peak average ratio

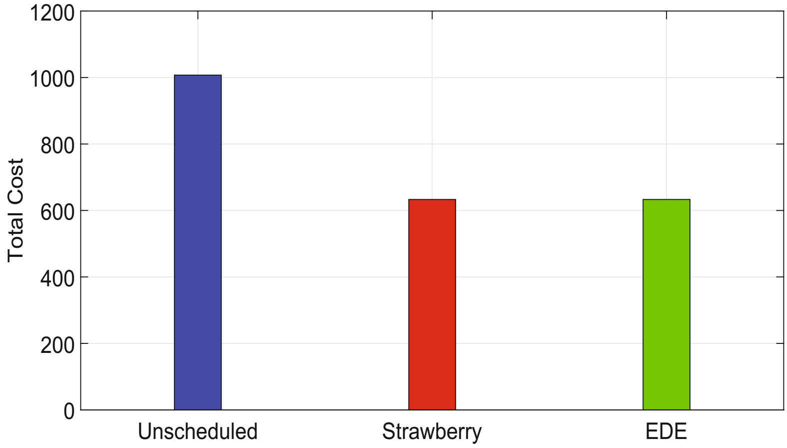

Fig. 3. Total bill cost

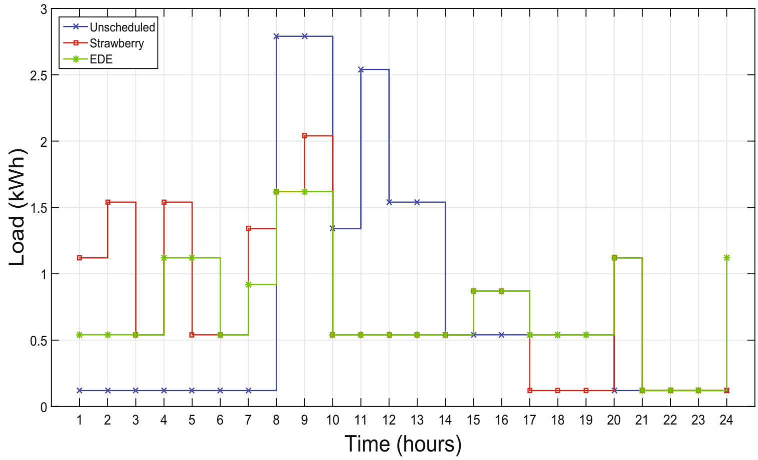

Fig. 4. Load per hour time

110 Cents per hour. It means that EDE and SBA, saves cost of the consumer during on and off peak hours. Figure 2, evaluate the PAR. SBA has the best result for PAR reduction, it has over come the problem of peak formation, which is the main cause load shedding. Figure 3, EDE has much better result than SBA and Unscheduled. EDE has reduced bill cost to 550 Cents, however in case of unscheduled and SBA it is 1000 and 700 Cents respectively.

Figure 4, shows that, maximum Average Load of 2.7 (kwh) is being generated by Unscheduled while SBA and EDE has minimum Average Load per hour.

6 Conclusion

In this paper, we proposed a scheduling mechanism to optimally schedule power consumption of appliances in residential area. We treated power scheduling as an optimization problem, to get an optimized solution. We used two optimization techniques i.e. EDE and SBA, while considering CPP as an energy measuring strategy. We succeeded, in achieving minimized PAR, bill reduction, and less waiting time.

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Genetic Algorithm and Earthworm Optimization Algorithm for Energy Management in Smart Grid

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Abstract. In smart grid several scheduling techniques have been proposed for load management in commercial, industrial and residential areas to minimize electricity cost, Peak to Average ratio (PAR) and provide user comfort maximization. Demand Side Management (DSM) is necessary for optimized results. Smart grid is a digital technology with two-way communication between the utility company and electricity consumers. Energy Management Controller (EMC) are used to maintain record of all appliances, operation time of appliances and cost which we have to pay for it. Smart grid motivates users to shift the load in Off Peak Hours (OPH) form Peak Hours (PH) through providing incentive in OPH. By this act consumers save money against load shifting from high price hours to low price hours. In this paper, Genetic Algorithm (GA) and Earthworm Optimization Algorithm (EWA) based schemes is proposed to minimize electricity cost and Peak to Average Ratio (PAR) while maximizing User Comfort (UC) via appliances scheduling.

1 Introduction

Traditional power systems are insufficient for future user demands such as stability, reliability and robustness. Many countries are facing problems which are arises due to the shortfall of electricity. Short fall of electricity is due to the wastage of power and improper use of electric appliances. Traditional power systems with traditional grids are using old ways of electricity generation, transmission and distribution which are wear out. Due to the arrival of science and technology electricity demand is increasing every day. Thus, a new system is required which can smartly monitors electricity issues and reduce demand pressure of electricity. Smart grid is a physical system having power system and information system which are connected to the different equipment's for smartly monitoring different activity of the users [1]. Smart grids have energy management controllers and some new technologies for communication, distributed distribution, distributed energy storage, smart metering and security to make the system reliable and robust. These smart tools and techniques are helpful to

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decrease the electricity cost and overcome electricity losses which are arises due to the traditional systems [2].

By using smart grids, the consumers of electricity can decrease electricity cost by scheduling the appliances in a time slot of OPHs with Real Time Electric Price (RTEP). Different schemes are introduced for the scheduling of electric appliances which helps to minimize electric cost [3]. The author achieves total power consumption for all electric appliances but he didn't introduce any scheme for a specific single appliance. Appliances are classified into interruptible and non-interruptible load to minimize electric cost in OPH when electric price is low [4].

Electric cost and peak demands are relative to each other. Electric price for the residential load vary time to time. Demand Response (DR) is the action through which energy demanded for the next hours and next days is estimated with respect to cost over time. Purpose of DR is not only to minimize electricity demand in peak hours but also prevent electric demand in off peak hours when electric price is low [5]. Demand side management in smart grids provide different functionality about electric demand control, infrastructure management and decentralized energy resources management [6]. Demand side management program inform load controller in electric market about the load scheduled and load reduction capabilities with respect to the time for next day. It schedules the load according to the user demand and estimate the electric cost [7,8].

Energy Management Systems (EMS) are introduced and installed for residential load management according to the DR in Energy Management Controller (EMC). EMC schedule power usage according to the user preference and price. EMC is installed in the smart homes and it controls the smart appliances through transmitting control signals via Home Area Network (HAN). Different power scheduling schemes and communication protocols are introduced for the smart appliances in the homes are introduced by using HAN [3,9,10]. Electricity load demand for residential and industrial areas are varies daily and seasonal between off peak hours and peak hours. Six techniques are used for daily and seasonal load management [11,12]. Peak clipping is used to reduce peak load by transferring load in off peak hours. Valley filling is load adjustment in off peak hours. Load shifting is mostly used technique for load shifting from on peak hours to off peak hours. Strategic conservations are used for load management by adopting different strategies to optimize load on daily bases and using distributed energy resources [13].

Demand side management controllers are used for minimizing electric cost, energy consumption, PAR and maximize user comfort [14–16]. Smart grids aim is minimizing total electric cost in the form of electric bill and total power consumption. Different demand side management techniques are introduced [17]. Evolutionary algorithms are used for residential, industrial and commercial load to minimize cost by using optimization techniques for load scheduling. Genetic Algorithm (GA), Binary Particle Swarm Optimization (BPSO) and Ant Colony Optimization (ACO) for load scheduling in cost effective manners [18,19]. Different GA based techniques with ACO and BPSO are proposed for minimizing

PAR and electric bill. It is used to minimize total aggregate load and cost [20]. In this paper, we are designing Smart Energy Management Controller for home area network where all appliances are connected and controlled. We are using two heuristic algorithms (GA and EWA) for a single home to get better solution. All Automatically Operated Appliances (AOA) appliances are schedules through GA and EWA. The purpose of this scheduling is to minimize electric cost and PAR. Simulation results are shown for both GA and EWA and their plots show their effectiveness and feasibilities for AOA.

Section 2 comprises of recent related work. Section 3 depicts the detail description of proposed model. Simulation findings and results are discussed in Section. Lastly, in Sect. 4, concluding remarks are presented followed by future directions.

2 Related Work

Energy Management System (EMS) for Home Area Network (HAN) by using Smart Grids, Smart Metering (SM) and make the appliances also smart by using different scheduling techniques. There are some integration of Renewable Energy Resources (RER) which can increase the stability of the whole system.

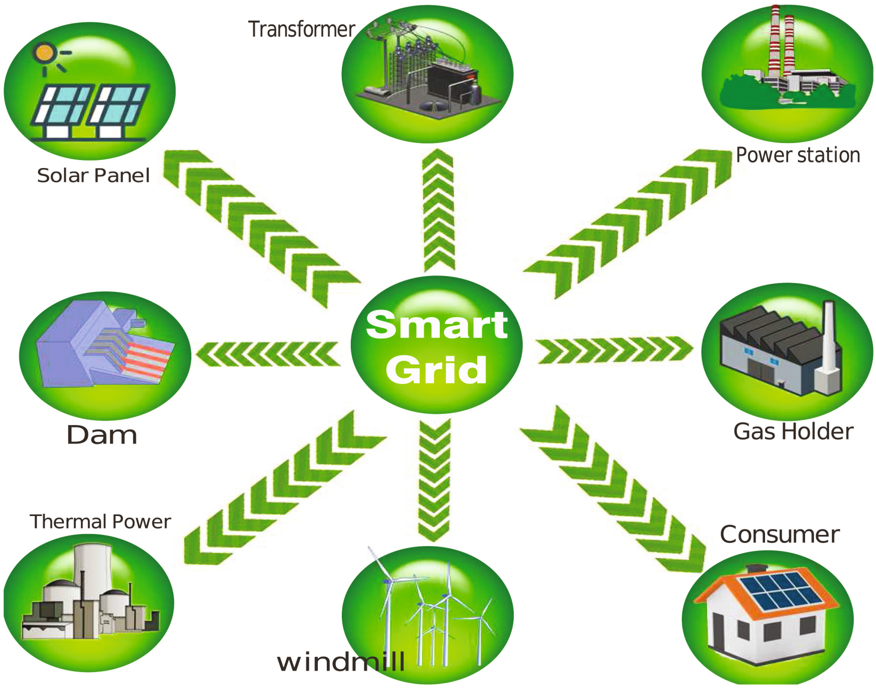

Fig. 1. Smart grid

The main objective of EMS has different parameters; Minimize electric cost, Minimize load in PHs, Minimize waiting time, Minimize delay and Maximize user comfort. Different techniques and models are proposed with the passage of time to overcome energy lacks and how available resources can fulfill desired needs of consumers. These techniques use different types of pricing schemes and different conditions which elevate users to avoid load in the PHs. Load will be shifted from PHs to OPHs (Fig. 1).

The Author managed the load in [1–4] is just discussing the Load that can be manage in such a way that it two-way communication between user and utility for next day energy required and they using RTP and IBR because RTP is much flexible and cost effective in [1]. Which main objectives are to minimize PAR, delay time and cost of electricity. In [2] the load is shifted to OPHs from PHs because electricity charges of PHs are much so when the load will be managed between PHs and OPHs then will also be reduced. In [3] data centers are created to manage the load where data is stored and analyses for the availability and demand for future. In [4] the author introduces the concept of thermostat which can switch off appliance when they exceed the desired limit which was compromised for the load in PHs. In [7] the author used Hybrid AI based optimization techniques based upon the BFA and GA for DSM in HAN.

RER are wind, hydro and solar based resources which are Integrated in the EMS for reliability and distributed for resources. Integration of RER will make the EMS more reliable and cost will also be effected and used do not totally depends upon the utility companies. PHs load does not affect electric cost because the RER based upon the wind, hydro and solar. In [2,3] the author manages the load for cost and PHs elevation but when RER are integrated in the EMS user comfort is increased because the user donot have to wait for the OPHs and user comfort of the energy management system is calculated in term of waiting time in [5,6,8]. And other aims of DSM are also achieved through this RER use however PHs cost will be same as OPHs due to the RER resources. In [5,6,8] use RER which can add user comfort in the form of waiting time minimization However, [8] there is two-way communication between the customer and utility. EMC first prefer RER electricity consumption for appliances and if that is not sufficient the utility resources are used. The RER electricity is more than the need then it will sell to the utility company.

Integration of resources make the system more reliable, stable and efficient while in [6] a new strategy is adopted through which energy of RER is stored and that will be used in the peak hours so by this mechanism the DSM can achieve PHs load as OPHs which can increase reliability, efficiency and make the system more stable. In almost all [1–5] the energy management and load management is based upon the PAR. Accumulative load is managed in such a way that maximum load will be below the PAR then there are some techniques through which load is managed by using PAR. In [2–5,7] the authors try to make the load below the PAR so when the load is under control the cost will also be managed. And estimation of future will also be depending upon the PAR value of EMC of whole system. The load will be PHs load or OPHs load we have to manage the load so it will be under the PAR limit. In [2,4] the author discusses the PAR minimization by using two schemes to make the load balance under the PAR of appliance i.e. Thermostat in [4] the author set a thermostat condition through which load is set under the PAR whenever any appliance can make the load above the PAR that appliance will automatically turned off and resume after some time when PAR load will not exceed the limit In [2] the author proposed the EMS in which Peak load for appliances are scheduled which predict the Thermostat set point which specify for the start time of Appliances. Purpose was to minimize peak load by an average.

3 Proposed Model

Demand Side Management (DSM) in smart grid mainly perform function like energy management and control demand of end users. The proposed system enable load management for single as well as multiple homes. SG offers two-way communication between consumers and utility. Through SG utility is aware of current usage of user. In our proposed work, we have two types of appliances; Interruptible, non-interruptible. Interruptible category contains appliances which have fixed energy/load and flexible usage time while interruptible appliances are those which have flexible load and fixed usage time. They cannot be interrupted during their working hours. Time of usage (TOU) is use for taking total early cost of consumed energy, TOU construct a block for particular hours. The energy price remains fixed for that hours (Table 1).

In addition to this we have used TOU as pricing scheme for calculation of bill. The main objective of all this study are: minimize the consumption of energy in order to reduce the electricity cost and reduction in PAR. The main focus is on the minimization of total cost calculated according to the Eq. 1 with PAR reduction (Table 2).

Table 1. Classification of appliances

Interruptible	Non-interruptible
Air conditioner^1	Electric kettle^1
Air conditioner^2	Electric kettle^2
Air conditioner^3	
Electric radiator^1	
Electric radiator^2	
Rice cooker^1	
Rice cooker^2	
Rice cooker^3	
Water heater	
Dish washer	
Washing machine	
Humidifier^1	
Humidifier^2	

Table 2. Power rating of appliances

Appliances name	Power rating (kWh)	Operating time (h)
Interuptable appliances		
Air conditioner [1]	1	5
Air conditioner[2]	1	5
Air conditioner[3]	1	10
Electric radiator[1]	1.8	5
Electric radiator[2]	1.8	10
Rice cooker[1]	0.5	2
Rice cooker[2]	0.5	2
Rice cooker[3]	0.5	2
Water heater	1.5	3
Dish washer	0.6	2
Washing machine	0.38	5
Humidifier[1]	0.05	10
Humidifier[2]	0.05	10
Clothes dryer	0.8	1
Uninteruptable appliances		
Electric kettle[1]	1.5	1
Electric kettle[2]	1.5	1

$$Cost = \sum_{t=1}^{24} \left(E_{Rate}^{hour} X P_{Rate}^{App} \right) \tag{1}$$

Equation 2 is Calculating the Total and and calculation of PAR using the Eq. 3 as in [5]

$$Load = P_{Rate}^{App} X App \tag{2}$$

$$PAR = \frac{max(Load_s)}{Avg(Load_s)} \tag{3}$$

3.1 Optimization Techniques

In our work, we used GA and EWA techniques.

3.1.1 EWA

The reproduction conduct of earthworms state multiple optimization problems, the reproduction steps of earthworms can be perfect by the following guidelines.

- Every earthworm have the ability of producing off springs and each earthworm individual have two types of reproduction.
- Every child of earthworm singular generated holds all the genetic factor whose length is equivalent to parental earthworm.
- The earthworm singular with the finest fitness permit on straight next generation, and cannot be altered by operators. This can be an assurance that population of earthworm cannot fail in the increment in generations.

Flow of EWA algorithm is as follows

Algorithm 1. EWA for SG scheduling

```
Step 1: Start Initialization. At first Set the counter generation t = 1
Set the counter of generation t=1
Set population as P of NP earthworm
Select the individual in search space randomly
Set the numbers of earthworms kept nKEW, maximum generation MaxGn, α as
  similarity factor, proportional aspect β, constant γ = 0.9.
Step 2: evaluation of Fitness. Set every earthworm aspect to its position
Step 3:
while till best solution is not achieved or t < MaxGen do
  sorting all earthworms according to the fitness value
  for i = 1 to NP (all earthworm) do
    Generate offspring xi1 through Reproduction 1
    Generate offspring through Reproduction 2
  end for
  Do crossover
  if i > nKEW then
    set the number of particular parents and the produced off springs (M)
    Select the N parents using method i.e. roulette wheel selection;
    Generate the M off springs;
    Calculating xi2 according to offsprings M generated
  else
    Randomly an indivisual earthworm as xi2
    Update the location of earthworm
  end if
  for j = nKEW + 1 to NP (earthworm individuals non-kept ) do
    do Cauchy mutation
  end for
  Calculate the population according to the newly restructured positions;
  t = t + 1.
end while
Step 5: Output the best solution.
End.
```

3.1.2 GA

Generic Algorithm is one of the most efficient algorithm among all heuristic algorithms, we have used GA for scheduling house hold appliances. Appliances are scheduled on the basis of user demand. GA works in the way to get maximum user comfort with optimized and minimum electricity cost. [2] Following are the steps involve in GA

Algorithm 2. GA for SG scheduling

```
Initialization
Generate population
Evaluate fitness function
Comparison of generated population with the maximum population
select two parents
cross over
mutation
evaluate fitness
Elitism
END
```

4 Simulation Results and Discussion

In this section, all the results of simulation are explained in detail. To manipulate the performance of our proposed techniques GA and EWA we do our simulation in MATLAB.

4.1 Cost

As graph shows that GA has low electricity cost as compared to the unscheduled and EWA because of shifting of load from ON to OFF peak hours. The maximum electric bill at 8 to 9 in aspect of unscheduled appliances is 59 cent per hour while at same time slots, EWA scheduled appliances shows the lower and on the other hand GA shows the best performance in order to reduce the cost to 3 cents. All the time GA shows better results we see as compared to EWA, because it shows somehow little uncomfortable results that GA and unscheduled shows most of the poor results. When elaborating the above graph GA shows a better performance throughout. It is high at start hour and low gradually. At 6 to 7 h EWA shows create a peak but is manageable and is very low than the unscheduled (Fig. 2).

Now according to the graph the electric bill is almost reduced to 35% by GA and 20% in EWA. Electricity cost was reduced more by GA because in some appliances we delayed the operation time, which was according the objective function that is designed. GA show the much better and smarter than others in aspect of electric cost (Fig. 3).

4.2 Load

In the above graph the load was maintained for GA and EWA scheduled appliances in 2 to 5 h. GA and EWA scheduled the appliances which shows almost

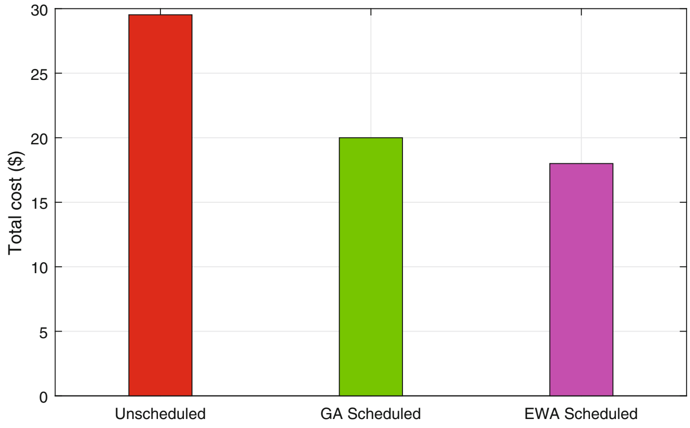

Fig. 2. Electricity cost

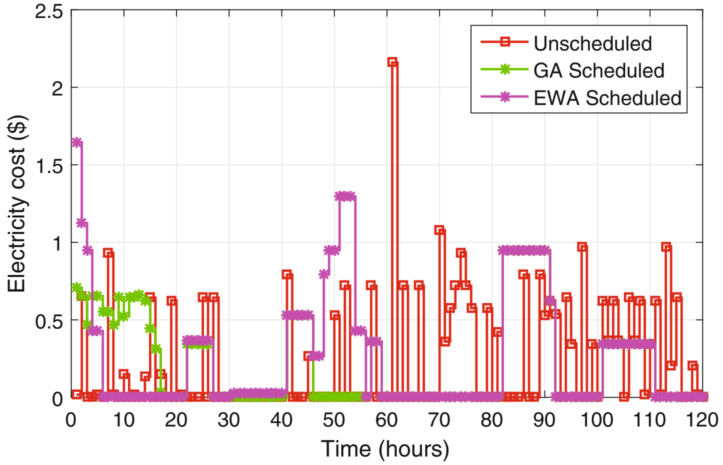

Fig. 3. Cost per hour

the continuous load at (1 kWh), Consumption of electricity of unscheduled appliances is bit higher than the GA. As compared to unscheduled, higher load is shown by EWA in same time slots. All these is because of shifting of load from on peak hours to off peak hours. In case of unscheduled appliances we can clearly visualize that the consumption was not smart, as in on peak hours load gets pretty much higher than any other hour slots because no smart technique was used. GA shows better consumption of electricity regarding to ON peak hours. While from 18 to 24 h, our EWA scheduled appliances and GA increased to 3 kWh which uses maximum load at these slots because of no threat of higher electricity cost so our interruptible appliances can use these slots as much they can. Electricity is used smartly by interruptible and non-interruptible appliances in aspect of OFF and ON peak hours by using the GA and EWA algorithms. Unscheduled of appliances cannot show the best energy consumption. The better arrangement of load is done by our proposed schemes and also the betterment is due to the classification of appliances in different categories. Overall the load of appliances in the 24 h is same throughout the day but we only schedule the appliances of in a manner that should efficient use of load in Peak hours in order to reduce our Cost and this is done by our GA technique (Fig. 4).

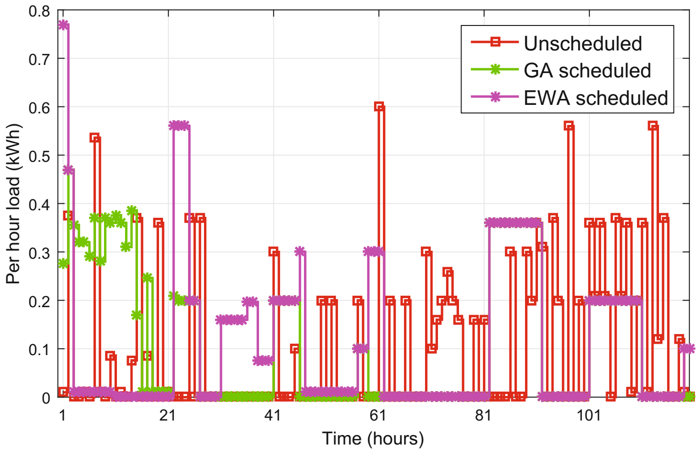

Fig. 4. Load in hours

4.3 Peak to Average Ratio

As PAR is concerned we have utilized our different techniques for optimization so that PAR was reduced which is beneficial to balance the power supply and demand. We just mislaid the fixed appliances because it has no such important role so we gave more priority to interruptible and non- interruptible appliances for PAR reduction. In the above given graph we can see that GA has scheduled the PAR load in which is decreased 50%. Similarly on the other hand EWA shows the same results for reduction in PAR as 40%. In order to avoid the creation of peak, TOU pricing scheme is used via giving information to user. GA shows almost better results than EWA that it gives the PAR reduction to 50%. In the unscheduled, the PAR is much higher because of no smartness technique are used. Performance of our proposed schemes were improved due to power capacity factor that causes utilities to fulfill the demand of consumers, resulting reduction in electricity bills. Unscheduled appliances show poor results that it doesn't tackles the peak formation problems while scheduled schemes were designed by GA and EWA in avoid to create peak and schedule the appliances for the 24 h (Fig. 5).

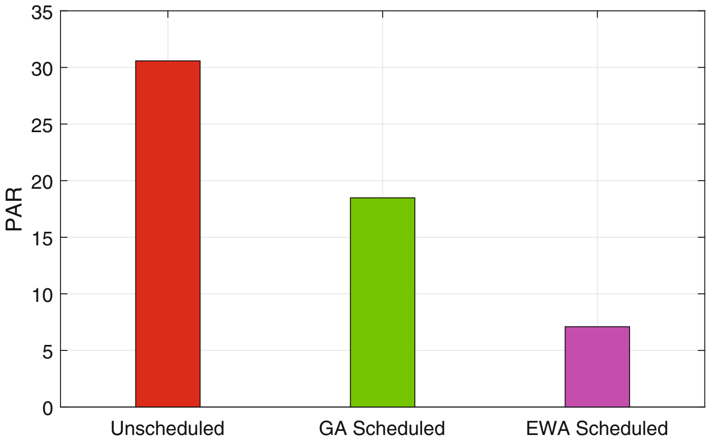

Fig. 5. Peak to average ratio

4.4 User Comfort

There is a tradeoff between electricity cost and the waiting time, if one is increasing then another decreases. Waiting time is almost same it is because we have achieved the electric cost and sacrifice the UC. We shift the load from ON to OFF peak hours for EWA and GA (Fig. 6).

Fig. 6. User comfort

5 Conclusion

In this work, we used energy management controller for AOA. AOA are scheduled according to the user requirements through our proposed technique using

GA and EWA under (TOU) signals residential consumers. Objective function of our proposed schemes which are reduction of delay time and electricity cost. PAR is main feature that is minimized and it is beneficial for the utility which make them stable and flexible. All the results of our proposed scheme using both GA and EWA are compared to the unscheduled results. The simulation results show that cost measured with GA and EWA are most optimized as compared to unscheduled cost. PAR of GA and EWA both are reduced as compared to unscheduled electricity consumption. Surely, the proposed GA and EWA based approach is reliable solution for energy management system in cost effective manner. In future, we investigate other scheduling techniques for cost minimization and maximize user comfort.

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Clinical Pathway Pattern Mining: Cleft Lip and Cleft Palate Case Studies

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Abstract. The treatment for cleft lip and cleft palate malformations required that specific treatments must be performed at a particular age of patients for at most 20 years from birth. Determining whether a patient treatment plan is followed, is highly important. Thus, Clinical pathway pattern mining is an essential tool to improve treatment plans for cleft lip and cleft palate patients. In this paper, we study clinical pathway pattern mining techniques to find a set of clinical pathway patterns. The proposed approach not only can discover patterns of medical activities, but also can provide the relation information between patient's age and standard's age of each treatment or medical activities. Moreover, this work also provides a method that can recommend eliminating unwanted result patterns for physicians.

1 Introduction

Cleft lip and cleft palate are facial and oral malformations that occur at very early stage in pregnancy. While a baby is developing, these disorders can cause feeding problems, speech problem, hearing problems, and frequent ear infections. Because of their early occurring, the cleft lip with or without cleft palate, can be diagnosed during pregnancy by ultrasound. Therefore, the treatment need to be planned and performed since prenatal stage due to the fact that some medical activities have a minimum age requirement or some other conditions have to go through in sequence. With these reasons, in some cases, patients who have these disorders may need treatment until adolescence and sometimes adulthood to be able to live normally as normal people.

Because patients with these disorders usually require a variety of treatments that need to be performed in a coordinated manner, the clinical experts recommend patients to receive treatment plan from cleft and craniofacial teams. In this study, with cooperation with Chiang Mai University Craniofacial Center, it was observed that a main problem of treatment was lacking continuity for many reasons, such as the patient who

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lived in a countryside area which can be very far from the center. The difficulty occurs since some of the treatments can be performed by countryside hospital nearby, but some critic treatment such as surgery must be performed by experienced and qualified physicians and health care provider from different specialties.

As the treatment requires the cooperation of multidisciplinary team of professionals, including plastic surgeon, pediatrician, speech therapist, nurse, ophthalmologist, dentist, otolaryngologist, orthodontist, prosthodontist and maxillofacial surgeon. Each department typically has approach to collect and maintain medical data individually even in the same hospital, thus this problem can cause confusion among specialties. For example, the dental department collect and store their medical data only in their specific document format, when a plastic surgeon needs dental data of the patient from the dental department they can only send their collected data which is their document. This process can take a lot of time and can cause misunderstanding because of the unfamiliar form of data. In addition to data diversity, there also have problems with treatment condition e.g. some patients need treatment from orthodontics department before appointment with surgery department, and some surgeries need to be performed before the patients can receive speech therapy but the transportation can be an issue. This scenario may delay receiving a dental care from the dentist and cause orthodontics even more delay.

The treatment plan for cleft lip and cleft palate patient is generally designed by clinical experts at the craniofacial center. Each patient may have a different plan according to their condition diagnosed by physicians. Each medical expert from the different craniofacial center may have different designing knowledge based on their experience.

In this paper, we study an approach for retrieving a set of clinical pathway patterns. Our work is based on the previous study by Z. Huang et al. [6, 7] which proposed an approach that can discover closed clinical pathway patterns and their time span between behavior in mined patterns. Our proposed work can discover patterns with regard to the patient's age relation of medical activities. Such discovery can help improving the treatment plan e.g. that gap of each treatment can be optimized [1–5]. The type of patterns, i.e. closed and maximal patterns, are also to be evaluated to see their effectiveness and efficiency by experiments.

The organization of this paper is as follows. Section 2 presents the basic definitions. The proposed approach is presented in Sect. 3. Our work will be evaluated by experiments in Sect. 4. Finally, Sect. 5 concludes the paper and gives the outlook to our future work.

2 Basic Definitions

Since the objective of this research is to retrieve the information from patient's treatment pathway which had performed differently depending on the patient's behavior. In order to discover the patterns, the data is firstly needed the transformation which the following concepts are required.

Definition 1. Clinical activity. A set of clinical activities that required in cleft lip and cleft palate treatment. Some of the activities may perform multiple times and some are not performed at all. It depends on patient's condition which diagnosed by the experts.

The clinical activities defined by the craniofacial center is shown in Table 1.

Table 1. All clinical activities provides by CMU craniofacial center

id	Age	Clinical activities
1	Newborn	evaluation for other anomalies
2	Newborn	feeding management
3	Newborn	on nasoalveolar molding or NAM
4	Newborn	micrognathia evaluation
5	3-5 months	cheiloplasty
6	3-5 months	on nasoform within 1 week after the operation for nasal collaspe prevention
7	3-5 months	on palatal obturator, if patients have cleft palate
8	6 months	hearing test
9	6 months	evaluation for otitis media
10	9-12 months	palatoplasty
11	9-12 months	oral hygiene
12	9-12 months	surgical treatment for otitis media with ET tube
13	2-5 years	speech therapy
14	2-5 years	oral hygiene
15	5-7 years	Velopharyngeal insufficiency evaluation
16	5-7 years	speech therapy
17	5-7 years	oral hygiene
18	5-7 years	evaluation for malocclusion
19	8-14 years	speech therapy
20	8-14 years	treatment malocclusion with orthodontic treatment
21	8-14 years	alveolar bone grafting
22	15 years	orthodontic treatment to prepare for jaw surgery
23	17 years	final cleft lip nose correction by opened rhinoplasty approach, if no malocclusion or maxillary hypoplasia
24	17 years	jaw surgery if mallocclusion or maxillary hypoplasia
25	> 17 years	final cleft lip nose correction by opened rhinoplasty approach

Definition 2. Clinical event. A clinical event is a clinical activity and age of patient when performing a clinical activity.

For example, a patient received alveolar bone grafting activity at 9 years old this clinical event is represented as

$$e = (alveolar\ bone\ grafting, 9)$$

Definition 3. Age standard. Every clinical activity has an age standard determined by the experts to recommend in what age, a patient should receive this clinical activity.

For example, alveolar bone grafting activity should be received at 8–14 years old.

$$Age\ standard_{avleolar\ bone\ grafting} = [8, 14]$$

It is shown that their lower bound and upper bound for this activity are 8 and 14 respectively.

Definition 4. Clinical pathway trace. A clinical pathway trace is a sequence of all clinical event that the patient has been performed. Each trace represents clinical pathway of one patient. Each clinical event can appear more than once and ordered by their receiving date if many events have performed in the same day it would be ordered by the activity ID as show in Table 1.

Definition 5. Clinical workflow log. A clinical workflow log L is a set of clinical pathway traces.

Table 2 shows an example of a clinical workflow log and the details which are recorded in the clinical tracking system. The full name of each treatment and its abbreviation is shown in Table 3.

Table 2. A clinical workflow log example of cleft lip and cleft palate patient

ID	Sequence
1	$\left\langle (o, 15.46), (j, 18.08), (u, 18.08), (w, 18.08), (j, 18.19), (w, 18.19), (m, 18.23), (j, 18.40), (w, 19.07), (w, 19.74), (f, 19.76), (w, 19.80), (f, 19.87) \right\rangle$
2	$\left\langle (i, 0.25), (j, 0.81), (m, 0.98), (h, 1.04), (j, 1.20), (j, 1.36), (j, 1.38), (j, 1.82), (m, 1.82), (j, 2.82), (j, 3.81), (m, 3.81), (j, 4.81), (j, 5.64), (j.5.90), (o, 7.90) \right\rangle$
3	$\left\langle (h, 0.56), (i, 0.56), (h, 0.69), (e, 1.20), (j, 1.20), (e, 1.22), (j, 1.22), (j, 1.37), (e, 1.53), (j, 1.53), (e, 1.99), (j, 1.99), (e, 2.75), (j, 2.75), (e.5.80), (e, 8.32), (j, 9.31), (u, 12.13), (u, 13.97), (u, 14.22) \right\rangle$
4	$\left\langle (j, 7.43), (o, 7.51), (m, 7.78), (w, 10.46), (w, 14.07), (f, 14.39), (o, 14.89), (f, 15.14), (o, 15.25), (f, 15.64), (u, 15.21), (u, 16.27) \right\rangle$

Table 3. Treatment name and its notation.

a: Evaluation for other anomalies b: Feeding management c: On nasoalveolar molding or NAM d: Micrognathia evaluation e: Cheiloplasty f: On nasoform within 1 week after the operation for nasal collapse prevention g: On palatal obturator, if patients have cleft palate h: Hearing test i: Evaluation for otitis media j: Palatoplasty k:Oral hygiene l: Surgical treatment for otitis media with ET tube m: Speech therapy n: Oral hygiene o: Velopharyngeal insufficiency evaluation r: Speech therapy	p: Oral hygiene q: Evaluation for malocclusion r: Speech therapy s: Treatment malocclusion with orthodontic treatment t: Alveolar bone grafting u: Orthodontics treatment to prepare for jaw surgery v: Final cleft lip nose correction by opened rhinoplasty approach, if no malocclusion or maxillary hypoplasia w: Jaw surgery if malocclusion or maxillary hypoplasia x: Final cleft lip nose correction by opened rhinoplasty approach

Definition 6. Clinical activity sequence. A clinical activity sequence is the sequence of clinical activities. Each activity can appear more than once. A sequence represents an ordered patient treatment by their receiving date. If many activities have been received in the same day, it would be ordered by activity ID showed in Table 1.

Definition 7. Sequence's support. A value that determines how frequent sequences occurred in database based on the number of sequences.

$$Support = \frac{sequence\ occuring\ times}{number\ of\ sequences\ in\ database}$$

Definition 8. Frequent pattern. A mined sequence that theirs number of occurrences in the database equals or greater than the sequence's support threshold.

Definition 9. Closed/Maximal sequential pattern mining. A frequent pattern S_a is said to be *closed,* if there is no other frequent pattern S_b, such that S_b is a super pattern of S_a and their supports are equal. A sequential pattern S_a is said to be *maximal,* if there no other sequential pattern S_b, such that S_b is a super pattern of S_a

Definition 10. Age different. An age different is a set of differences between activities.

For example, let $Age_{palatoplasty} = [1, 2, 3]$ is a set of age that patients in database recorded when they are receiving palatoplasty treatment and $Age_{alveolar\ bone\ grafting} = [8, 10, 18]$ is a set of age that patients in database recorded when they are receiving alveolar bone grafting treatment. Age different between these two treatments is

$$Age\ Difference_{palatoplasty\&alveolar\ bone\ grafting} = [7, 9, 17, 6, 8, 16, 5, 7, 15]$$

Definition 11. Temporal constraint. Let A be a set of clinical activities. A temporal constraint is denoted as $(a_1, [D^-, D^+], a_2)$ where $a_1, a_2 \in A$ are clinical activity name, and D^-, D^+ are the lower bound and upper bound of age difference between these activities.

For example, let $Age\ Difference_{palatoplasty\&alveolar\ bone\ grafting} = [7, 9, 17, 6, 8, 16, 5, 7, 15]$ be an age difference between palatoplasty and alveolar bone grafting activity, and let assume that their lower bound and upper bound are 5 and 17 respectively. The temporal constraint of these activities is

$$\theta = (palatoplasty, [5, 17], alveolar\ bone\ grafting)$$

Definition 12. Chronicles. A chronicle is a set of temporal constraints on a clinical activity sequence.

Definition 13. Clinical pathway patterns. A clinical pathway pattern is a pair of clinical activity sequences and their chronicles denoted as $\phi = (A, C)$, such that $A = (a_1, a_2, \ldots, a_k)$ is an ordered clinical activity sequence, and C is a chronicle on A such that for all pairs (a_i, a_j) of a satisfying $i < j$, there exists a temporal constraint $\theta_{a_i a_j} \in C$, where $\theta_{a_i a_j}$ is denoted by $(a_i, \left[D^-_{a_i a_j}, D^+_{a_i a_j}\right], a_j)$.

Definition 14. Pattern score. A pattern score is a value that determine how difference is the discovered pattern compared to the standard plan.

$$Pattern\ score = \sum_{i=0}^{k} Activity\ Error_i$$

where k is a number of clinical activities that appear in closed/maximal sequential pattern.

$$Activity\ Error_i = \frac{\sum_{j=0}^{n} |First\ receiving\ age_j - Standard\ Age_i|}{n}$$

where n is a number of patients who has been received that activity, and $First\ performing\ age_j$ is an age of this patient when receiving this clinical activity. The values can be initially set as follows.

$$\begin{array}{ll} Standard\ Age_i = lower\ bound, & if\ First\ receiving\ age_j < lower\ bound \\ Standard\ Age_i = upper\ bound, & if\ \ First\ receiving\ age_j > upper\ bound \\ Activity\ Error_i = 0,\ if\ lower\ bound & \leq First\ receiving\ age_j \leq upper\ bound \end{array}$$

3 Proposed Approach

In this section, we proposed a technique to discover clinical pathway pattern from the collected data in our clinical tracking system. The first step is to mine closed and maximal sequences. Closed [8–10] and Maximal [11] sequence concepts are very effective approach for the objective. Since the basic concept of frequent sequence is to only return an enormous amount of result sequences. In this paper we apply CM-ClaSP algorithm [10] for mining the closed sequences and VMSP algorithm [11] for mining the maximal sequences. Then, the chronicle sequences are determined from the result of the first step. Chronicle concept [12, 13] can help representing time-relation between two activities in a sequence. Such two steps are recommended by Z. Huang et al. [6]. The last process is to find which mined patterns are what the experts are interested. In this study, the experts indicate that they want to find patterns that is very different compared to the standard plan. The difference can be calculated by the score. The closed/maximal sequence mining algorithm, chronicle mining algorithm, and score computing algorithm is shown in Algorithms 1, 2, and 3 respectively.

4 Experiment

In this section, the proposed technique is evaluated on patient's data recorded from craniofacial data which has 465 rows representing activities of 29 patients. The data was firstly preprocessed into 29 clinical workflow logs. The evaluation is based on both effectiveness, the difference between the actual activities and treatment plan represented by score, and efficiency in term of running time.

All experiments were performed on a MacBook Pro with an Intel Core i5 2.9 GHz, 8 GB main memory running on macOS Sierra. The pattern mining were using SPMF software [14] and the chronicle generating and score calculating were implemented using Node.js.

Algorithm 1. Mining closed and maximal sequences

Pattern-miner(*L*,*minsupp*)
Input:
    L is a clinical workflow log
    minsupp is a minimum support threshold value
Output:
    closed is a set of closed sequences
    maximal is a set of maximal sequences

Steps:
    closed = CM-ClaSP(L,minsupp)
    maximal = VMSP(L,minsupp)
return *closed,maximal*

Algorithm 2. Mining chronicles

Chronicle-miner(*A,L*)
Input:
    A is a set of *closed/maximal pattern*
    L is a clinical workflow log
Output:
    Chronicles is a set of activities and their age difference
Steps:
    For each activity pair (a_i, a_j) in *A*, do
        $Age\ Difference_{a_i \& a_j}$ = set of difference value between a_i, a_j
        Chronicles ← $\{a_i, [\min\left(Age\ Difference_{a_i \& a_j}\right), \max\left(Age\ Difference_{a_i \& a_j}\right)], a_j\}$
return *Chronicles*

Algorithm 3. Pattern score calculating

Score-calculating(*A, Chronicles*)
Input:
    A is a set of *closed/maximal pattern*
    Chronicles is a set of activities and their age difference
Output:
    Pattern score is a set of score of pattern
Steps:
    For each *pattern* in *A* do
        For each activity a_i in *pattern*, do
            $Activity\ Error_i = \frac{\sum_{j=0}^{n} |First\ receiving\ age_j - Standard\ Age_i|}{n}$
            Pattern score += $Activity\ Error_i$
        Clinical pathway pattern ← *{pattern,pattern chronicles,Pattern score}*
return *Clinical pathway pattern*

4.1 Comparison Between Closed and Maximal Pattern Mining

The proposed technique is based on two concepts, closed and maximal pattern mining. The closed pattern mining by Huang et al. [6] was applied since its effectiveness. However, in our work, the duplication in the data was found and it can not be coped by the proposed method in term of the effectiveness by the experts' standard. Therefore, we also applied maximal pattern mining in our experiment to show which concepts given more satisfy result in this section.

The results in term of effectiveness and the efficiency are shown in Figs. 1 and 2 respectively. According to the result, in case the low minimum support is set, the maximal pattern mining algorithm can eliminate the number of result patterns better with less running time. This is because our sequential data of each patient are very different in term of length and activity variety.

4.2 Clinical Pathway Pattern Result Evaluation Score

In this section, we evaluate the score of the pattern to see whether the treatments are follow the plan. We count the number of clinical pathway patterns which their score is higher than 5 to see how well the proposed technique can indicate significant pattern when minimum support is set at most 0.200.

The result is shown in Table 4. It can be seen that the number of the patterns with high score (>5), stricter to the treatment plan, is not very different. However, when comparing between the high score and all scores, it can be seen that the maximal concept can eliminate the patterns with low score better and may lead to the more focused analytics further.

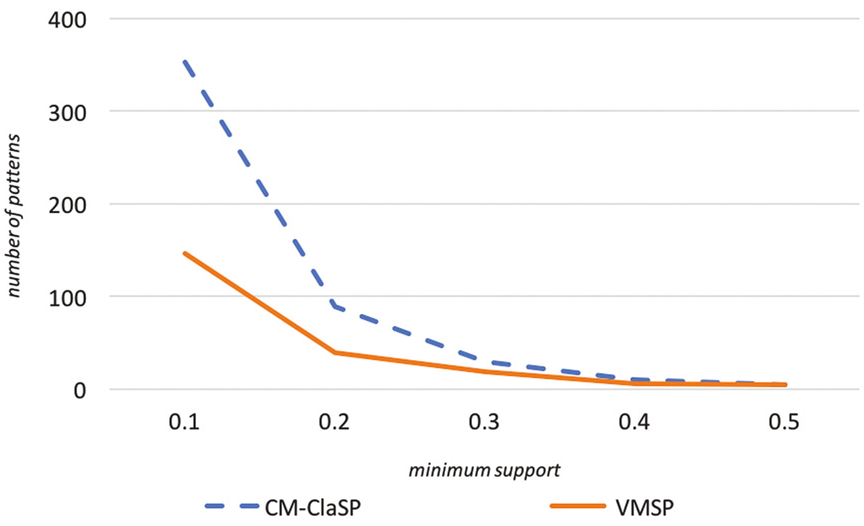

Fig. 1. Number of patterns discovered by the two pattern mining algorithms

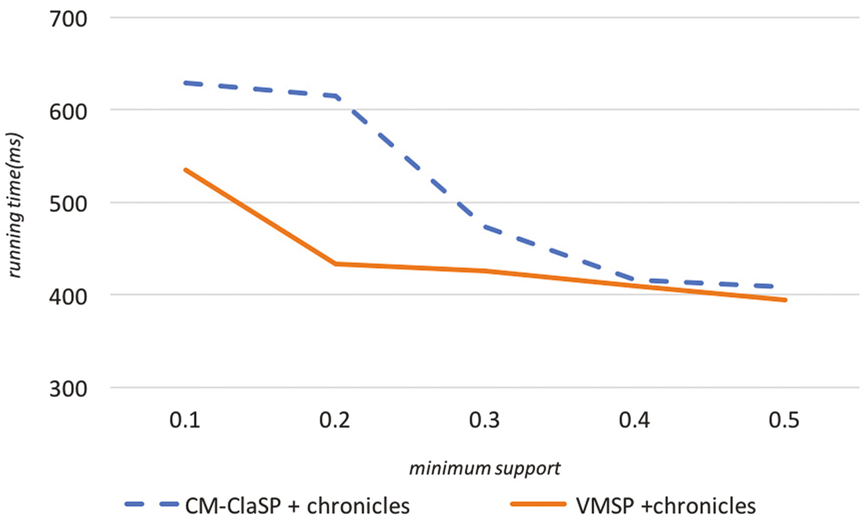

Fig. 2. Running time of the two pattern mining algorithms

Table 4. number of pattern with score >5 compare between two concepts

Minimum support	Closed, score >5	Closed, all score	Maximal, score >5	Maximal, all score
0.100	100	353	65	146
0.125	37	205	28	88
0.150	37	205	28	88
0.175	13	132	13	55
0.200	3	89	3	39

5 Conclusion and Future Work

In this paper, we presented the clinical pathway pattern mining method to find pattern that can improve the treatment plan and efficiency. The two techniques, closed and maximal pattern mining, are compared in term of effectiveness and efficiency. The experiments showed that the VMSP algorithm [11] which mines maximal patterns has less running time while the number of mined patterns is not very different. According to the experts' interest, the results from both techniques are useful, and similar. In our future work, we aim at investigating the prediction of treatment result and relation to the score.

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Design and Implementation of Division-Based Broadcasting Using NS-3

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Abstract. Due to the recent popularization of the Internet, continuous media data broadcasting such as audio or video have attracted great attention. Although continuous media data broadcasting can reduce the more necessary bandwidth than conventional on-demand delivery, waiting time from requesting data to playing it increases. In division-based broadcasting, many researches have proposed scheduling methods to reduce the waiting time. However, there are two problems in conventional evaluation environment using the computer simulation. First, since users need to modify the simulation program according to the change of evaluation situation, they can not accurately calculate the value of the evaluation result. Second, in conventional simulation program, it is difficult to evaluate the scheduling method considering the actual network environment. In this paper, to solve these problems, we design and implement the simulation environment using NS-3 network simulator in division-based broadcasting. By using NS-3, we can evaluate the scheduling methods considering various situations assumed in actual network environment.

1 Introduction

Due to the recent popularization of IP multicasts, such continuous media data broadcasting as audio or video are attracted great attention [1–3]. For delivering streaming data for webcasts, clients select programs and watch them. Since clients need to wait after making their selection before they can play, they become impatient and want to watch without interruption.

In IP networks, there are mainly two types of delivery systems: Video on Demand (VoD) and broadcasting systems. In VoD systems, the server start delivering data sequentially based on client requests. However, the available bandwidth increases in proportion to the number of clients, and waiting times under VoD systems increase. On the other hand, in broadcasting systems, the server repeatedly delivers the same data to many clients at a constantly available bandwidth. When clients receive data sequentially, waiting occurs between requesting and receiving the initial part of the data. In webcasts, many clients require many types of data from servers, and the size of each data becomes large.

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Many studies employ the division-based broadcasting technique, which reduces waiting time by dividing data into several segments and frequently broadcasting the precedent segments [4]. These scheduling methods make a broadcast schedule that considers the situation in actual network environments. Most scheduling methods in broadcasting schemes evaluate the waiting times in simulation environments. We need to evaluate them using scheduling methods in network environments.

However, there are two problems in conventional evaluation environment using the computer simulation. First, since users need to modify the simulation program according to the change of evaluation situation, they can not accurately calculate the value of the evaluation result. Second, in conventional simulation program, it is difficult to evaluate the scheduling method considering the actual network environment.

In this paper, to solve these problems, we design and implement the simulation environment using NS-3 network simulator in division-based broadcasting. By using NS-3, we can evaluate the scheduling methods considering various situations assumed in actual network environment.

The remainder of the paper is organized as follows. We explain the basic division-based broadcasting in Sect. 2. Related works are introduced in Sect. 3. Our proposed simulation environment is designed and implemented using NS-3 Network Simulator in Sect. 4. Next, we evaluate our proposed evaluation in Sect. 5. Finally, we conclude the paper in Sect. 6.

2 Division-Based Broadcasting System

2.1 Waiting Times in VoD and Broadcasting Systems

In webcasts, there are mainly two types of delivery systems: VoD and broadcasting. First, we calculate waiting times for VoD and broadcasting systems. Next, we explain waiting times for broadcasting data that are divided into several segments. The situations that cause waiting times in both systems are shown in Fig. 1. In the VoD system [5,6], the server starts delivering data sequentially based on client requests. Waiting times under VoD systems are roughly equal to receiving times. When the server repetitively broadcasts continuous media data, clients have to wait until the first portion of the data is broadcast.

In this section, first we present the procedure for calculating the waiting time in the case of broadcasting data without division. Next, we explain about the waiting time for broadcasting the data that is divided into several segments.

When the server broadcasts the continuous media data repetitively, clients have to wait until the first portion of the data is broadcast. For example, an example of broadcasting situation that the server broadcasts MPEG2 encoded music clip data using a 15 Mbps broadcasting system is shown in Fig. 2. When the consumption rate of data is 5.0 Mbps and the playing time is 7 min, the data size becomes $5.0 \times 7 \times 60/8 = 262.5$ Mbytes. In a simple method, since the server broadcasts the data repetitively without dividing it, broadcasting time is $7 \times 60 \times 5.0/15 = 140$ s. The minimum waiting time is given by the

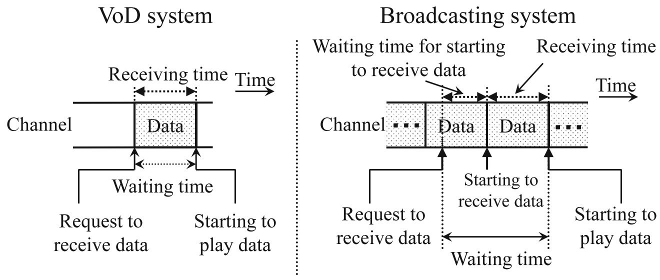

Fig. 1. Waiting time in VoD and broadcasting systems.

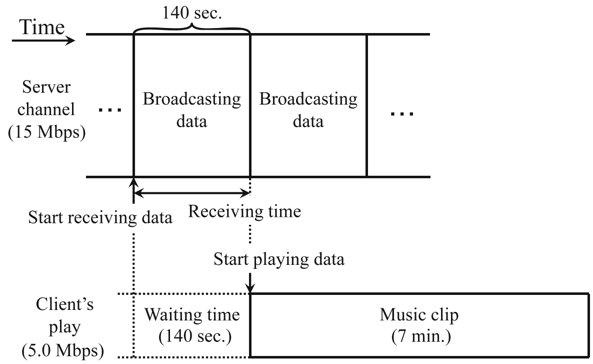

Fig. 2. Example of occurring waiting time in broadcasting.

client that starts receiving the data just before the start of the broadcast cycle. The minimum waiting time is 140 s that is the same as the time necessary to broadcast the data. The maximum waiting time is given by the client that starts receiving the data just after the start of the broadcast cycle. Since the client has to wait until the first portion of the data is broadcast in the next cycle, the maximum waiting time is twice of the broadcast cycle, $140 \times 2 = 280$ s. Since the distribution between the maximum waiting time and the minimum waiting time is uniform, the average waiting time is $(280 + 140)/2 = 210$ s. To reduce the waiting time, many methods employ the division-based broadcasting technique, which reduces the waiting time by dividing the data into several segments and broadcasting precedent segments frequently.

In the division-based broadcasting technique, since the data is divided into several segments, it is important to schedule segments without interrupting clients' continuous play. An example of division-based broadcasting technique is shown in Fig. 3. The example uses the Fast Broadcasting (FB) [7] method to explain the problem caused by heterogeneous clients easily. In the FB method, the broadcast bandwidth is divided into several channels. Bandwidth for each channel is equivalent to the consumption rate. In this case, the server uses three channels. Also, the data is divided into three segments, S_1, S_2, and S_3. When the total playing time is 7 min, the playing time of S_1 is calculated to be 1 min, S_2 is 2 min, and S_3 is 4 min. The consumption rate is 5.0 Mbps and the available bandwidths for clients are 15 Mbps. Bandwidth for each channel is $15/3 = 5.0$ Mbps, which is the same as the data consumption rate. The server broadcasts S_i $(i = 1, 2, 3)$ via broadcast channel C_i repetitively. Clients can store broadcasted segments into their buffers while playing the data and can play each segment after receiving them. In this case, when clients finish playing S_1, they finish receiving S_2 and can play S_2 continuously. Also, when finishing playing S_2, they finish receiving S_3 and can play S_3 continuously. In this case, since clients can receive broadcasted segments from their midstream, the waiting time is the same as the time needed to receive only S_1 and the average waiting time is 1 min.

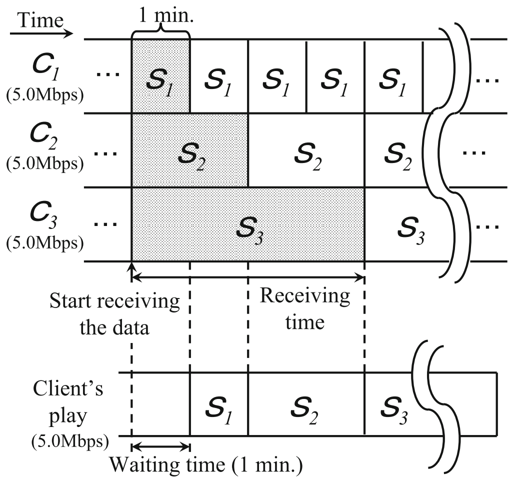

Fig. 3. Example of division-based broadcasting situation without interruption.

3 Related Works

Several scheduling methods to reduce waiting time for broadcasting systems are proposed. In these methods, by dividing the data into several segments and producing a proper broadcast schedule, waiting time is reduced.

In BroadCatch [8], the server divides the data into 2^{K-1} segments of equal sizes. The server broadcasts them periodically using K channels. The bandwidth for each channel is the same as the data consumption rate. By adjusting K according to the available bandwidth for clients, waiting time is reduced effectively.

In the Optimized Periodic Broadcast (OPB) [9], each data is separated into two parts. The server uses several broadcast channels and broadcasts each segment on each channel. When clients complete receiving the precedent parts of the content, they start receiving the rest portions of the data. Since clients can get the sub-segment data in advance, waiting time can be reduced. However, the bandwidth increases as the number of contents increases.

In the Hierarchical Stream Merging (HSM) [10], when the server broadcasts separated data via each channel repetitively, if clients complete receiving the data, the server merges the channel which the client receives. Since the method can reduce the necessary bandwidth, waiting time is reduced under the same bandwidth.

In the Heterogeneous Receiver-Oriented Broadcasting (HeRO) [11], the server divides the data into K segments. Let J be the data size for the first segment. The data sizes for segments are J, $2J$, $2^2J, ...,$ $2^{K-1}J$. The server broadcasts them using K channels. However, the data size of the K^{th} channel becomes a half of the data, clients may have waiting time with interruptions.

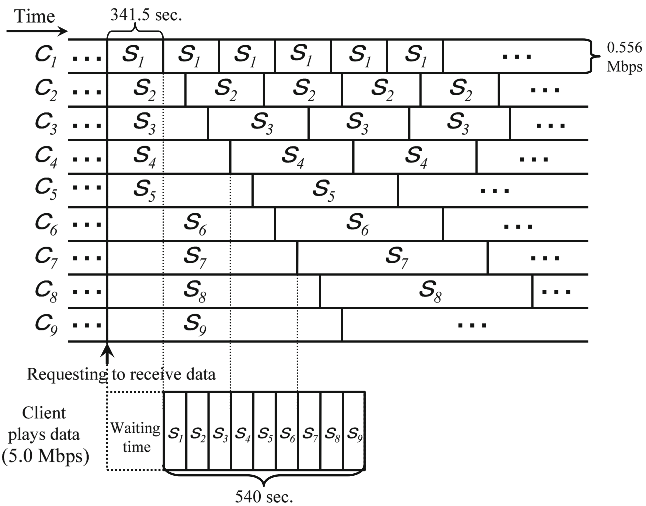

Fig. 4. Example of broadcast schedule under BE-AHB method.

In the Layered Internet Video Engineering (LIVE) [12], clients feed back virtual congestion information to the server to assist both bandwidth sharing and transient loss protection. LIVE can minimize the total distortion of all participating video streams and maximize their overall quality. Also, several researches study the reliable broadcasting in wireless network with packet loss probability [13,14].

In the Bandwidth Equivalent - Asynchronous Harmonic Broadcasting (BE-AHB) method [15], since the data are divided into several segments, segments must be scheduled without interrupting clients' continuous play. An example of division-based broadcasting is shown in Fig. 4. The example uses the BE-AHB method to easily explain the problem of interruption time. This example divides the data into nine segments, $S_1, \cdots, S_9$, and the total playing time of it is 540 s. Under the BE-AHB method, the playing time of S_1 is 37.9 s, S_2 is 42.2 s, and S_9 is 88.2 s. The consumption rate is 5.0 Mbps. The bandwidth for each channel is the same as the data consumption rate. When the available bandwidths for clients are 5.0 Mbps, the bandwidth of each channel is equally $5.0/9 = 0.556$ Mbps. Clients can play each segment after receiving it. While playing the data, clients receive the broadcast data and store them in their buffers. In this case, clients can play the data continuously until they have ended, even if they start playing them immediately after completely receiving S_1. When clients finish playing S_1, they have finished receiving S_2 and can play S_2 continuously. When they are finished playing S_2, they have finished receiving S_3 and can play S_3 continuously. In this case, waiting time is $37.9 \times 5.0/0.556 = 341.5$ s, which is the same as the time needed to receive only S_1. When the server does not divide the data, since the server broadcasts S_i by broadcast channels whose the available bandwidth is $5.0/3 = 1.67$ Mbps, waiting time is $180 \times 5.0/1.67 = 540$ s. Therefore, $(540 - 341.5)/540 \times 100 = 36.8\%$, which is shorter than the simple method.

4 NS-3 Network Simulator

4.1 Outline

Network Simulator Version 3 (NS-3) [16] is a discrete event network simulator implemented by the open source in network environment via Internet. The NS-3 is used by the simulation environments in many types of researches. In our paper, we design and implement the simulation environment using the NS-3. We constructed the virtual environment on Windows using VMWare Player.

In NS-3, users can design the simulation environment using the program called a scenario. By designing the scenario, users can evaluate the scheduling method in computer simulation considering many cases of situations assumed in actual network environment.

We explain the procedure of using the NS-3. First, users make the scenario by C++. Next, users design the network environment for simulation evaluation using Waf that is a python-based build tool.

In NS-3, users can easily modify the parameters in simulation environment. In addition, users can visualize the results of the simulation evaluation. For example, the NS-3 can make the on-line animation using PyViz [16].

4.2 Scenario

The NS-3 can construct the network environment and make the simulation evaluation using the scenario that describes the network information such as the available bandwidth, the number of channels, and the data size of the video data. In our proposed environment, the scenario mainly consists of three types of parameters such as nodes, a channel, and an application.

Node
The scenario in NS-3 shows the computer represented by a node. Eachnode has a *node* class by C++. The *node* class provides a method for managing computers in simulation evaluation. By setting the *node* class, users can add network devices, protocol stacks, and the function of applications, routers, switches, and computers on the network simulation.

Channel
The NS-3 selects one of two types of network channels to communicate between nodes. For wired networks, the NS-3 uses P2P channels or CSMA channels. On the other hand, for wireless networks, the NS-3 uses Wi-Fi channels or WiMAX channels.

Application
Generally, the software is classified into two types, which are the system software and the application software. The NS-3 uses user applications by the *Application* class and provides the method for evaluating the behavior of user application in simulation environment.

4.3 Example of Making Scenario

We explain an example of the program for the scenario that represents simple broadcasting. The procedure of the scenario program is shown below.

```
1. NS LOG DEBUG("Creating Topology");
2. NodeContainer net1 nodes;
3. net1 nodes.Create (2);// Setting n0, n1
4. NodeContainer net2 nodes;
5. net2 nodes.Add (net1 nodes.Get(1));
6. net2 nodes.Create (1);// Setting n2
```

Fig. 5. Example of scenario program for setting nodes.

1. Setting nodes in NS-3.
   Each computer for simulation environment is defined as a node. An example of a scenario program for setting nodes is shown in Fig. 5. In Fig. 5, users set three nodes n_0, n_1, n_2 respectively as a server, a client, and a router.
2. Constructing the simulation network by connecting nodes.
   An example of a scenario program for connecting nodes is shown in Fig. 6. In NS-3, users can set the available bandwidths of n_0 and n_1. In addition, users can set the network delay for delivering data in actual network environments.
3. Assigning the network address to the device.
   An example of scenario program for assigning the IP address is shown in Fig. 7. In NS-3, users can assign the IP address for the network environment used by simulation evaluation.

```
PointToPointHelper p2p1;
p2p1.SetDeviceAttribute ("DataRate", StringValue ("5Mbps"));// Setting bandwidth
p2p1.SetChannelAttribute ("Delay", StringValue ("2ms"));// Setting network delay
p2p1.SetQueue ("ns3::DropTailQueue");
NetDeviceContainer devices1;
devices1 = p2p1.Install (net1 nodes);// Setting link between n0 and n1
PointToPointHelper    p2p2;
p2p2.SetDeviceAttribute ("DataRate",StringValue("5Mbps")); // Setting bandwidth
p2p2.SetChannelAttribute ("Delay", StringValue ("2ms"));// Setting network delay
p2p2.SetQueue ("ns3::DropTailQueue");
NetDeviceContainer devices2;
devices2 = p2p2.Install (net2 nodes);// Setting link between n1 and n2
```

Fig. 6. Example of scenario program for connecting nodes.

```
Ipv4AddressHelper address;
address.SetBase (NET ADD1, NET MASK, FIRST NO);
Ipv4InterfaceContainer ifs1 = address.Assign (devices1);
NS LOG INFO ("Network 1: " ≪ ifs1.GetAddress(0, 0) ≪ " - " ≪ ifs1.GetAddress(1, 0));
address.SetBase (NET ADD2, NET MASK, FIRST NO);
Ipv4InterfaceContainer ifs2 = address.Assign (devices2);
NS LOG INFO ("Network 2: " ≪ ifs2.GetAddress(0, 0) ≪ " - " ≪ ifs2.GetAddress(1, 0));
```

Fig. 7. Example of scenario program for assigning IP address.

```
BulkSendHelper ftp ("ns3::TcpSocketFactory", Address());
ftp.SetAttribute ("Remote", remoteAddress);//Setting address
ftp.SetAttribute ("MaxBytes", UintegerValue (int(DATA MBYTES * 1024 * 1024)));
ApplicationContainer sourceApp1 = ftp.Install (net1 nodes.Get(0));
sourceApp1.Start (Seconds (SIM START+0.1));
sourceApp1.Stop (Seconds (SIM STOP -0.1));
```

Fig. 8. Example of scenario program for setting server.

4. Setting the server and clients.
   An example of scenario program for setting the server is shown in Fig. 8. In Fig. 8, when the finishing time is passed or the sum of delivering data reaches the threshold, the simulation environment is finished.

5 Evaluation

5.1 Evaluation Environment

We evaluated the scheduling method using NS-3 in virtual environment. The performance of computers in our evaluation is shown in Table 1.

Table 1. Measurement environment.

Computer	CPU	Intel® Core^{TM} i5-4590 CPU (3.30 GHz)
	Memory	8.0 Gbytes
	OS	Windows 10 Pro
Virtual environment	CPU	Intel® Core^{TM} i5-4590 CPU (3.30 GHz)
	Memory	1982 MBytes
	OS	Ubuntu 16.04

In the simulation environment of division-based broadcasting, we evaluate the waiting time using the scenario program on the NS-3 and the simulation program for evaluating the conventional simulation. The waiting time calculated by NS-3 is defined as a measured value. Also, the waiting time calculated by conventional computer simulation is defined as an ideal value. The ideal value of waiting time is a half of receiving time of S_1. The data size of S_1 is set based on the division ratio in the FB method. We compare the measured value and the ideal value based on the waiting time between the simple method and the FB method.

In the configuration of computers in the scenario by NS-3, the server and the client are connected with the wired network. The client receives the video data from the server via the router.

5.2 Waiting Time

The waiting time in the simple method is shown in Table 2, and that in the FB method is shown in Table 3. The channel bandwidth changes from 1.0 Mbps to

Table 2. Waiting time in simple method.

Bandwidth (Mbps)	Measured (s)	Ideal (s)
1.0	45.0	45.2
2.0	22.5	22.7
3.0	15.0	15.1
4.0	11.3	11.3
5.0	9.0	9.1

Table 3. Waiting time in FB method.

Bandwidth (Mbps)	Measured (s)	Ideal (s)
0.5	30.0	30.5
1.0	15.0	15.6
1.5	10.0	10.4
2.0	7.5	8.2
2.5	6.0	6.5

5.0 Mbps. The consumption rate is 1.5 Mbps and the playing time of video data is 1 min. The number of channels is 2, and the number of clients is 2.

In Tables 2 and 3, since the interruption time by the packet loss and the processing time between the server and the client occurs, the difference between the measured value and the ideal value is small. For example, in Table 3, when the available bandwidth is 1.5 Mbps, waiting time in the measured value is 10.0 s, and ideal value is 10.4 s.

6 Conclusion

In this paper, we designed and implemented the evaluation environment of division-based broadcasting on NS-3. In our proposed evaluation environment, by solving problems in the evaluation environment of conventional computer simulation, we can set the parameters assumed in actual network environment. We evaluated our proposed environment using NS-3 and calculated the waiting time using conventional scheduling methods.

In the future, we will construct the simulation environment for division-based broadcasting considering several types of clients.

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A Rare Piece Diffusion Method Using Rateless Coding on BitTorrent-Like Distribution System

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Abstract. In P2P content distribution systems, frequent join and leave operations of users make some content pieces extremely hard to be available. In the worst case, a certain piece is completely lost. Exchanging pieces in rarest-first manner can alleviate such a problem. However, since the pieces' rarities are calculated by each peer locally, globally rare pieces might not be sufficiently distributed. This paper proposes a piece diffusion method which accelerates the diffusion of rare pieces by applying rateless coding, which can recover data blocks from a sufficient number of encoded blocks. The key ideas of the proposed method are twofold; a piece rarity estimation based on cache statues of sender-receiver pair, and rarity-aware rateless coding for a small number of pieces. These strategies can prevent rare pieces from being completely lost with a small computational cost. Through computer simulations, we confirm that the proposed method can improve the download performance even when a large number of peers leave simultaneously.

1 Introduction

P2P distribution system is an effective solution for the large-scale content delivery because of its high scalability. In the system, users' terminals, called "peers," directly exchange their interested data each other. It can achieve high scalability with low costs in contrast to client/server systems, because transmission load is diffused over the entire system. When a user wants a content, the user firstly joins to a P2P network distributing the content. Then, the user exchanges the fragments of the content, called "pieces," with its neighbor peers. When all pieces are downloaded, the user completes the download process. Many users might stay in the P2P network and contribute the content distribution as so-called "seeder," while some users might leave the P2P network.

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Piece exchange strategies have a significant role in P2P distribution systems. If there is a rare piece that a few number of peers own, the other peers hard to complete the whole content. Moreover, in the worst case, the rare piece may be completely lost from the P2P network by the owners' leaves. BitTorrent [1], which is one of the most popular P2P distribution systems, uses "rarest-first strategy" in the piece exchange. According to this strategy, a peer preferentially downloads the rarest pieces within the pieces which the peer's neighbors own. As a result, the number of copies of every piece is balanced. However, Spoto et al. pointed out in [2] that the rarest-first strategy could not keep its distribution performance when the P2P connectivity is affected by the leave of many peers. Such events could easily arise in P2P video streaming systems. This performance degradation is caused by the fact that the piece rarity is calculated from the local information. Therefore, the piece distribution could not be uniform in the entire system, nevertheless pieces are uniformly diffused in a local network. This means some pieces could be completely lost when many peers simultaneously leave.

In this paper, we propose a piece diffusion method which accelerates the diffusion of rare pieces globally by applying rateless coding to deal with the above problem. Rateless coding is an erasure coding technique that generates an arbitrary number of encoded blocks from a fixed number of data blocks [3]. We adopt rateless coding for two reasons. The first one is that it can include multiple pieces' information with a similar rarity into one encoded block. As a result, globally rare pieces are preferentially diffused even when a peer cannot precisely estimate such rare pieces. The second one is its characteristic that the loss of specific encoded block does not affect the availability of original data blocks. In rateless coding, the decoding capability depends on only the number of received encoded blocks. Typically, a few percent more than the number of original data blocks can reconstruct original data blocks. Therefore, it can prevent a specific piece from being completely lost.

In order to effectively utilize the above characteristics of rateless coding, the proposed method consists of the following two functions; (1) estimation of globally rare pieces based on receiving statuses of both of sender and receiver, and (2) novel piece diffusion with rarity-aware rateless coding for a small number of pieces, which can make rare pieces available with high probability with a small computational cost. By these functions, the proposed method can effectively diffuse rare pieces and make them available with high probability even when users suddenly leave.

The rest of the paper is organized as follows. Section 2 describes the related work. Section 3 describes the detail of our proposed method, and Sect. 4 demonstrates the simulation results. Finally, Sect. 5 concludes this paper.

2 Related Work

In order to improve throughput and resilience to the leave of peer, some works [2,4–9] have proposed to apply data coding techniques to P2P distribution systems. In Avalanche proposed in [4], each peer exchanges coded blocks encoded by Random Linear Network Coding [10]. In this method, a peer re-encodes encoded blocks which have already received with linear combination of them using randomly selected coefficients, and sends it to the neighbors. When a sufficient number of encoded blocks are received, a peer can reconstruct the original blocks. In [4], simulation results have shown that Avalanche can achieve 2–3 times higher throughput than the case without Random Linear Network Coding. Meanwhile, PPFEED [5] improves the throughput by constructing the overlay network which is suitable for the deterministic Linear Network Coding. A P2P streaming system with rateless coding has also proposed in [6]. In this method, each peer decodes received encoded blocks once, and re-encodes them before sending. By this re-encoding, duplicate reception of the same encoded blocks is avoided, and as a result, throughput and resilience to the leave of peer are improved. In [7], Westphal shows that the combination of two transmission policies for the server: prioritizing newly joined peers and using a rateless code, can enhance the stability of P2P file sharing systems with selfish user behavior by mathematical analysis. RaptorQP2P proposed in [8] uses a rateless code technique, called RaptorQ code, at two-levels: file level and piece level. Simulation results in [8] show that RaptorQP2P can enhance downloading completion time compared with BitTorrent under the realistic peer online/offline patterns.

P2P distribution systems with rateless coding and network coding considering rarest-first strategy are proposed in [2,9], respectively. In these systems, a content is divided into pieces, and a piece is divided into blocks. In [2], each peer requests a rarest piece in the same way as BitTorrent. The requested peer generates encoded blocks from the requested piece using rateless coding. In addition, when a requested peer has no complete piece, the requesting peer confirms whether the requested peer has some encoded blocks. When it has some encoded blocks, the requesting peer requests it to send the encoded blocks. Thus, this system efficiently utilizes the network bandwidths. On the other hand, the system in [9] manages the number of neighbors' owning blocks per piece. When a peer requests a new block, it selects one of the pieces having the smallest total number of blocks among neighbors. Note that the total number of the blocks includes both of original data blocks and encoded blocks. Then, the requested peer generates encoded blocks from its owning blocks of the requested piece using Random Linear Network Coding, and sends them.

Our proposed method is similar to the methods in [2,9] in that they consider piece rarity. The major difference of the proposed method from the previous works is to generate encoded blocks from multiple pieces, rather than per-piece encoding. In particular, those multiple pieces are selected based on piece rarity calculated by multiple peers. This approach can improve the encoding efficiency and the reconstruction probability of complete pieces within finite duration, and efficiently diffuse the encoded blocks.

3 Rarest Piece Diffusion with Multi-piece Rateless Coding

In order to mitigate the performance degradation due to leaves of peers, this paper proposes a data diffusion method leveraging rateless coding for multiple pieces in BitTorrent-like P2P system. Our target P2P system consist of peers and "tracker," which manages join/leave of peers. Peers who have the complete file and upload it to other peers are called "seeders." On the other hand, peers downloading files by exchanging pieces with other peers are called "leechers." When a peer joins to the P2P network, it randomly connects peers based on the informed peer list, which consists of peers randomly selected by the tracker, until the number of connections reaches the minimum number. The informed peer list is also used to find another neighbor peer when a neighbor peer leaves. Each peer periodically selects some neighbors to upload a content file based on their upload contribution. Note that one of them is exceptionally selected at random to give slow peers an opportunity to download the content. To improve the distribution efficiency, a content is divided into some management units; "piece" and "block" (see Fig. 1). Piece is a unit of advertised data, and each peer informs its neighbor peers about its piece owning status. Each piece is further divided into blocks. Dealing with small sized block as a unit of exchanged data can effectively utilize network bandwidth. Each peer also exchanges piece owing status with its neighbors each other, and calculates piece rarities (as the number of neighbors who have a specific piece).

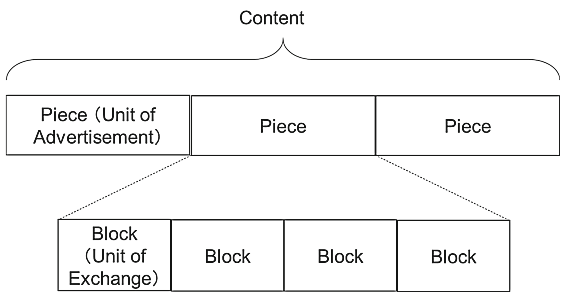

Fig. 1. Relation of content, pieces, and blocks.

The proposed method prevents rarest pieces from being completely lost by protecting rare pieces with rateless coding. In this method, multiple data blocks of rare pieces are encoded into one encoded block. Then, the encoded blocks are diffused one by one. Since rateless coding reduces the probability that any pieces are completely lost by leaves of peers, the proposed method improves the resilience to leaves of peers. This paper uses LT (Luby-Transform) code [11] as rateless coding for its simple encoding/decoding processes.

In order to effectively utilize rateless coding characteristics, the proposed method consists of the following functions; (1) rare piece selection based on receiving statuses of both of sender and receiver, (2) rarity-aware rateless coding for a small number of pieces, and (3) piece exchange to avoid duplicate reception of encoded blocks. In the following section, we describe the detail of each function.

3.1 Encoding Policy

The key feature of the proposed method is exchanging encoded blocks including multiple rare pieces instead of blocks of the rarest one. In rateless coding, an arbitrary number of encoded blocks $\mathbb{E}_{\mathbb{B}}$ are generated from data blocks $\mathbb{B}$, where $|\mathbb{B}| = k$. A peer can achieve k original data blocks when it receives slightly more than k encoded blocks. Since the loss of specific block does not affect the success probability of the decoding, rateless coding techniques can improve the resilience of the P2P network against the loss of information caused by peers' leaves. Moreover, a peer can also use encoded blocks of $\mathbb{E}_{\mathbb{B}'}$ to decode encoded blocks of $\mathbb{E}_{\mathbb{B}}$, when $\mathbb{B}' \subset \mathbb{B} \cup \mathbb{B}_O$ and $\mathbb{B}_O$ is the original blocks the peer already owns. This characteristic can absorb the difference between local piece rarities that each peer individually calculates.

When applying rateless coding to P2P system, there is a design choice regarding the range of encoding target; namely, using all pieces, selected multiple pieces or single piece as recovery target. The proposed method adopts encoding selected multiple pieces because of the following reason.

1. **Prevention from duplicate reception of encoded blocks**
   Limiting the number of pieces to encode can quickly reconstruct original blocks. Since the reconstructed pieces can be used to generate new encoded blocks, encoding selected multiple pieces can avoid performance degradation with duplicate reception of encoded blocks.
2. **Improvement of encoding/decoding efficiency**
   It is known that general rateless codes require more encoded blocks to decode them when less original data blocks (e.g. single piece) are used to encode [11]. On the contrary, when too many blocks (e.g. all pieces) are encoded, the decoding process requires a complex calculation. The proposed method can balance between the encoding/decoding cost and the overhead by selecting the suitable number of pieces for encoding.

3.2 Example of Proposed Piece Diffusion

Figure 2 shows the overview of the proposed piece diffusion method. In this example, Peer A requests pieces from Peers B and C. The requested pieces are selected based on their rarities. When Peer A decides to request piece 1 from Peer B, Peer A sends a request message for piece 1 to Peer B. Upon receiving the request message, Peer B selects the requested piece (i.e. piece 1) and the rarest pieces calculated by Peer B itself as the target of encode. Then, Peer B encodes the pieces into "encoded blocks," and send them to Peer A one by one. Upon receiving the encoded block, Peer A tries to decode it using original and encoded blocks that Peer A already has. Then, Peer A checks whether the already decoded blocks can reconstruct the corresponding piece. Note that the reconstructed piece may or may not be piece 1, since the encoded block includes information of multiple pieces. If any piece is reconstructed, the Peer re-calculates piece rarities and requests one of the rarest pieces. Triggered by the new request message, the Peer B also re-selects rarest pieces to encode.

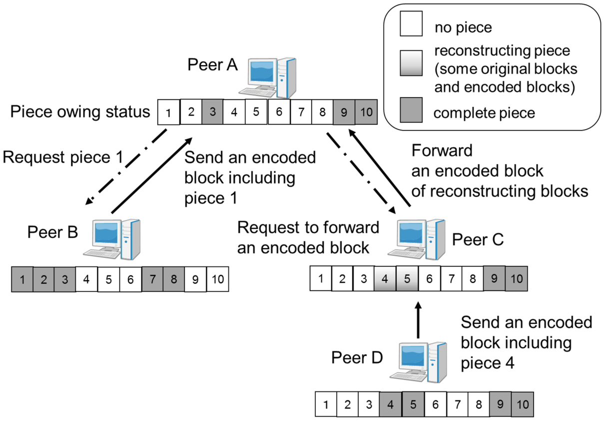

Fig. 2. Overview of the proposed method.

On the other hand, Peer C has no complete piece which Peer A needs. In such case, Peer A requests Peer C to forward encoded blocks instead of complete pieces in order to diffuse rare pieces' information and prevent the rare pieces from being lost. Although Peer A might not immediately use these forwarded encoding blocks in current piece reconstruction, those encoding blocks help to decode other encoded blocks in future. Upon receiving the forward request, Peer C randomly selects an encoded block to forward from among encoded blocks that Peer C is receiving from other peers (i.e. Peer D). Here, the forwarded blocks should include information of pieces the requesting Peer A does not have (e.g. pieces 4 and 5). In addition, Peer C excludes encoded blocks which have already been forwarded to Peer A from the candidates to be forwarded. By forwarding encoded blocks, peers can contribute to data diffusion, even when they have no complete pieces to send.

3.3 Selection of Encoding Candidate Based on Piece Rarity

The proposed method selects multiple pieces as encoding candidates based on the piece rarities calculated by both of sender and receiver. Piece rarities are calculated as follows. Each peer independently calculates piece rarities based on its neighbors' piece owning status. A piece owning status of a peer is advertised to neighbors in two cases: when the peer joins the P2P network, and when the peer completes a piece. Upon receiving the advertisement, neighbor peers update the piece owning status of the sender of advertisement. When neighbor peer or peer itself completes a piece, each peer updates the number of peers that have the piece. This number of owning peers corresponds to the rarity of the piece. Then, the pieces are sorted by their rarities in ascending order. This paper calls the sorted list as "rarity list."

Candidate pieces to be encoded are selected by sender based on the piece rarities. Let's consider an example that Peer A (receiver) requests new pieces from Peer B (sender). When N_R pieces can be requested simultaneously, Peer A selects several pieces up to N_R in order from the top of its rarity list. In this selection, pieces that Peer A has or Peer B does not have are skipped. When some pieces are assigned to the same rarity, Peer A randomly selects pieces among them. Then Peer A requests the selected pieces from Peer B. In the request message, piece IDs are included in ascending order of their rarities. Similarly, Peer B selects N_S rarest pieces which Peer B has and Peer A does not have, excluding pieces in the request message. These $N_R + N_S$ pieces become the candidates for encoding.

3.4 Piece Encoding Considering Rarity

The proposed method treats the pieces requested by the requesting peer (i.e. receiver) as the pieces which should be preferentially diffused rather than the pieces selected to encode by the requested peer (i.e. sender). In order to realize this distinction, the proposed method applies LT code-based Expanding Window Fountain Code (EWF code) [12], which enables to preferentially encode specific blocks to encoded blocks.

EWF code divides encoding candidate blocks by "window," and generates encoded blocks using rateless coding from data blocks within the window. In particular, this method uses multiple windows and provides encoders with different encoding parameters per window. For simplicity, however, the proposed method always uses two windows, namely window for receiver's selection and one for whole candidates. By including blocks which should be preferentially diffused into more windows, such blocks are encoded into more encoded blocks. As a result, the prior blocks are reconstructed more quickly than the other blocks.

Figure 3 illustrates the EWF coding in the proposed method. As mentioned above, the proposed method uses LT encoder in EWF coding. At first, Peer B initializes the encoding buffer with the pieces selected by the way of Sect. 3.3. In the initialization, the pieces selected by requesting Peer A, which has higher priority, are put at the head of the buffer. In particular, pieces are put in ascending order by their rarity. Then, the pieces selected by Peer B are put in the same way. After the initialization, Peer B applies windows $W = \{w_1, w_2\}$ to the pieces in the buffer. Note that when k_1, k_2 denotes the size of the window w_1, w_2, respectively, $k_1 < k_2$ is satisfied. Window $w_l (l \in 1, 2)$ includes the consecutive k_l pieces from the head of the encoding buffer. That is, these windows become larger toward the end of the encoding buffer as l increases. Moreover, window

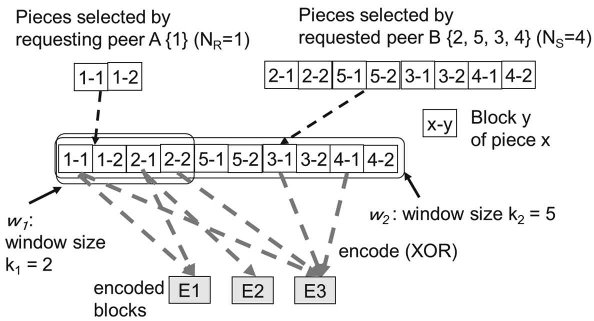

Fig. 3. Block generation considering piece rarity.

w_2 (i.e. window for whole candidates) fully includes window w_1 (i.e. window for Peer A's request). This window configuration makes pieces with higher priority to be included into more windows.

After the initialization, Peer B generates an encoded block. Peer B randomly selects a window from the window set W. When w_l is selected, the corresponding encoder e_l is used to encode the block. Then, e_l randomly selects the number of blocks to be encoded, d, according to a given probability distribution. In this paper, encoder e_l adopts Robust Soliton Distribution $\Omega(k_l, \delta_l, c_l)$ [11], whose parameters are as follows; k_l is the number of input blocks and equals to the window size of w_l, δ_l is the allowable failure probability of decoding, and c_l is the encoding parameter. After selecting d blocks from the blocks included in window w_l, the encoder e_l generates an encoded block by XOR operation of them.

Upon receiving a sufficient number of the encoded blocks, Peer A tries to decode them using both of the received encoded blocks and original data blocks which have been already decoded. When some original data blocks are reconstructed, Peer A checks if it can complete some pieces using the reconstructed blocks. If some pieces are completed, Peer A advertises that it has the completed pieces. Otherwise, Peer A continues to request the same pieces. Whenever the same pieces are requested, Peer B skips the initialization process and generates encoded blocks with the same configuration.

3.5 Avoidance of Duplicate Reception of Encoded Blocks

When some peers have no complete piece, such as newly joined peers, they have no choice but to forward encoded blocks in the decoding buffer. In particular, most peers have no complete piece immediately after the start of the content distribution. In such case, only the original seeder provides new encoded blocks, and the other peers just forward the received blocks to another peer. As a result, peers tend to receive duplicate encoded blocks from multiple neighbors.

To deal with the duplicate reception problem, it is important that many peers become to provide new encoded blocks as soon as possible. For this goal, the proposed method properly switches from the conventional rarest-first strategy to the proposed piece exchange with EWF coding. After joining, a peer requests pieces according to rarest-first strategy in order to quickly collect sufficient number of original pieces to generate encode blocks including new information. In this paper, a peer follows rarest-first strategy until the ratio of completed pieces exceeds threshold Th. When a peer completes more pieces than Th, the peer switches its strategy to improve the resilience of the P2P network against the leave of peer. In the second strategy, peers attempt to efficiently diffuse rare pieces by the proposed encoding method.

In addition, this paper also proposes the stochastic reselection of the encoding target to avoid making duplicate encoded blocks. We again suppose that Peer A requests encoded blocks from Peers B and C. If the selected N_R pieces for new request message to Peer B are the same as ones for the request message to Peer C, Peers B and C could generate encoded blocks from the same pieces. Although this makes Peer A decode the encoded blocks in a shorter time, Peer A tends to receive more duplicate encoded blocks from both of Peers B and C. Since the second strategy focuses on diffusing information of various pieces rather than quick piece collection, the peer re-selects other pieces as the encoding target with probability P.

4 Performance Evaluation

4.1 Simulation Environment

The proposed method was evaluated by our own developed simulator. In the simulation, the number of initial seeders is set to one. Peers arrive according to the exponential distribution with the rate of $\lambda_0 \exp(-\frac{t}{\tau})$ [13]. Note that λ_0 is the initial arrival rate, τ is the attenuation factor and t is the simulation time. The values λ_0 and τ are set to 10 and 50, respectively. The minimum and maximum numbers of the neighbor peers are set to be 10 and 20, respectively. We set the number of peers to which one peer can concurrently upload to be 4. Content size, piece size and block size are set to 16 MB, 256 KB, 16 KB, respectively. That is, a content is divided into 64 pieces, and a piece is divided into 16 blocks. We assume that each peer has the same transmission capability, and it can send 3 blocks per neighbor in one time unit.

The parameters of the proposed method are as follows. We set the number of windows L to be 2. Window sizes k_1, k_2 are given parameters. The default value of the probability that window w_1 is selected for encoding, $P(w_1)$, is set to 0.2. Robust Soliton Distributions Ω_1 and Ω_2, which are used by encoder e_1 and e_2, are $\Omega(k_1, 0.5, 0.02)$ and $\Omega(k_2, 0.1, 0.02)$, respectively. Threshold for switching piece request strategy Th and piece reselection probability P are set to 0.6 and 0.8, respectively. We also assume that a peer requests one piece per neighbor, i.e., N_R is 1. The number of candidate pieces selected by requested peer, N_S, is $k_2 - 1$. The scenario of peer's leave is as follows.

- All peers leave the P2P network according to the exponential distribution with the leave rate μ, regardless of being seeder or leecher.

- A certain ratio of peers simultaneously leave after 120 s from the start of the simulation. We call the ratio as "simultaneous leave ratio."
- When leecher cannot collect all pieces within 600 s, it gives up downloading the content and leaves.

4.2 Simulation Results

Under the above conditions, we observed the ratio of the peers who can complete download of the content, called "Completion Ratio," to evaluate the resilience to the leave of peer. We also evaluated the average downloading time of the peers who successfully download the content, called "Completion Time." Note that we excluded the simultaneously leaved peers in the calculation of Completion Ratio.

Figures 4, 5 and 6 show the basic evaluation of the proposed method. The values k_1 and k_2 represent the sizes of windows. The error bars indicate 95% confidence interval. Note that simultaneous leave ratio is set to 0.2. Figure 4 shows the sensitivity of the proposed method's Completion Ratio against threshold for switching piece request strategy Th. From the figure, we can see that Comple-

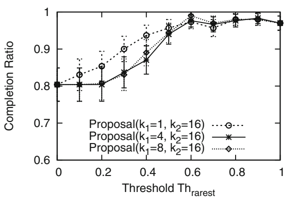

Fig. 4. Completion Ratio with various Th.

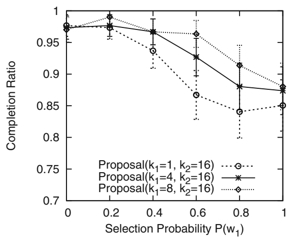

Fig. 5. Completion Ratio with various $P(w_1)$ (only simultaneous leave).

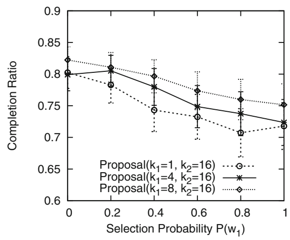

Fig. 6. Completion Ratio with various $P(w_1)$ (normal leave rate μ: 0.1%).

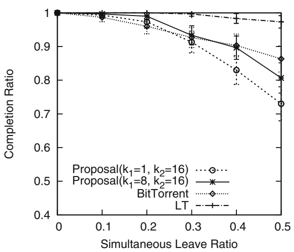

Fig. 7. Completion Ratio (only simultaneous leave).

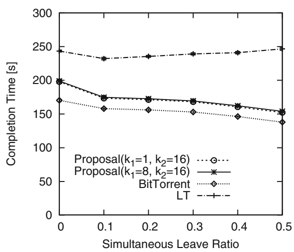

Fig. 8. Average Completion Time (only simultaneous leave).

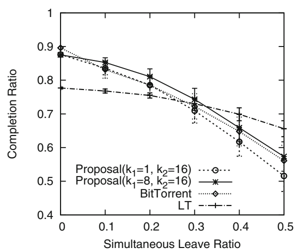

Fig. 9. Completion Ratio (normal leave rate μ: 0.1%).

tion Ratio increases with the increase of Th when Th is less than 0.6, regardless of window configuration. On the other hand, when Th is larger than 0.6, Completion Ratio slightly decreases with the increase of Th. This result shows that properly selecting pure rarest-first strategy and rarity-aware encoding strategy is fairly effective to improve the resilience to the simultaneous peer leaves. Next, we evaluate the variation of Completion Ratio of the proposed method as the window selection probability $P(w_1)$ changes. Figures 5 and 6 show the variation of Completion Ratio when only simultaneous leave occurs (i.e. $\mu = 0$) and peer leaves at leave rate $\mu = 0.1\%$, respectively. These figures show the tendency that large $P(w_1)$ degrades Completion Ratio and using large window w_1 can slightly improve Completion Ratio, regardless of leave rate μ. These results suggest that encoding many pieces into encoded blocks with large w_1 can improve the stability of the proposed method.

Figures 7, 8 and 9 show the comparison between the case using BitTorrent protocol (BitTorrent), the case using LT code to whole content (LT) and the case using the proposed method (Proposal). The error bars indicate 95% confidence interval. Figures 7 and 8 show Completion Ratio and Completion Time in the case without normal peer leave, respectively. Figure 7 shows that Completion Ratios degrade in all methods as simultaneous leave ratio increases. However, in most cases, LT keeps high performance in terms of Completion Ratio. This is because that LT's reconstruction capability depends on only the number of received encoded blocks, and the leave of specific peer does not affect Completion Ratio. However, Fig. 8 reveals that LT has worst Completion Time due to its overhead. On the other hand, Proposal makes most peer to complete downloading as well as LT without significant degradation of Completion Time, when simultaneous leave ratio is less than 0.3. In Proposal, a peer avoids the duplicate reception of encoded blocks. As a result, Proposal can achieve high performance in both of Completion Rate and Completion Time. However, when simultaneous leave ratio is larger than 0.4, BitTorrent achieves higher performance than Proposal. This is because that, in BitTorrent, more peers complete downloading before simultaneous leave of peers occurs than the other methods.

Figure 9 shows Completion Ratio when leave rate μ is set to 0.1%. Note that we omit Completion Time when $\mu = 0.1$ because any remarkable differences are not seen compared to the results in case of only simultaneous leave. Figure 9 shows Proposal slightly outperforms BitTorrent. On the other hand, LT degrades Completion Ratio. This is because that some peers cannot complete downloading before they leave, since LT takes a long time to reconstruct the content.

From the above results, the proposed method achieves high resilience to the leave of peer as well as LT, and high distribution capability which is slightly less than BitTorrent.

5 Conclusion

With the aim of establishing P2P distribution system with high resilience to the leave of peers, this paper proposed a novel data diffusion method leveraging rateless coding technique. In particular, the proposed method was designed to encode multiple pieces selected based on their rarity considering balancing between the encoding efficiency and the reconstruction capability of encoded blocks. The results of computer simulation demonstrated that the proposed method can improve the resilience to the leave of peers compared with the conventional piece exchange methods even when a lot of peers simultaneously leave.

As future works, we will investigate the throughput characteristics of the proposed method more deeply, and develop a parameter tuning algorithm.

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Models for Stream Data Distribution with Progressive Quality Improvement

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Abstract. Stream data distribution such as video delivery or sensor data delivery gets great attention due to the recent IoT (Internet of Things) trends. The stream data distribution with higher bit-rates than network capacities suffer long delay. One of the major approaches to shorten delay is decreasing the bit rates by removing a part of the data from data streams. The drawback is data loss and the data quality degrades. In this paper, we propose a novel approach that shortens delay relieving data quality degradation. In our approach, the data for quality improvements are distributed after distributing the lowest quality data. Thus, data quality improves progressively as time proceeds. We also propose some system models using our approach.

1 Introduction

Due to the recent development of sensing and communications technologies, IoT (Internet of Things) environments have attracted great attention. In IoT environments, various things like cameras and temperature sensors connect to the Internet and communicate with other things or computers. Most of these things act as sources of stream data. Stream data are series of data and generated continuously. For example, cameras record their surroundings and generate video stream data. Temperature sensors measure temperature values and generate sensor stream data. Stream data give much information continuously and so we can realize various applications such as pedestrian recognitions or environmental monitoring by receiving them. Receiving computers encounter the delay of data receptions from their generation or data loss if the communication bandwidth

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is insufficient since they should keep receiving stream data. To reduce delays or data losses for stream data receptions, many methods have been proposed.

In many cases, we can define several qualities for stream data. For example, one of the qualities for video stream data is resolution. Video images with high resolution include many pixels and are regarded as high quality data. Also, frame rate and color depth are the qualities for video stream data. One of the qualities for sensor stream data is sensing rate. Temperature values with a higher sensing rate can give more real time data and regarded as high quality data. The number of digits is also a quality for sensor stream data. The amount of the data generated in certain period is generally larger as the data quality improves. An appropriate quality of stream data is selected by applications managers since a higher quality stream data than the quality that is sufficient to provide applications services wastes the communication bandwidth. Therefore, conventional methods try to reduce delays or data losses under the situation that the quality of stream data is fixed [1–3].

Applications managers select the quality that is sufficient to provide services. In some cases, however, services can be successfully provided with lower qualities than that selected by applications managers. For pedestrian recognitions, image processing sometimes recognizes pedestrians with a lower resolution than the selected resolution. For environmental monitoring, abnormal weathers can be found with a lower sensing rate. If the quality of stream data is insufficient for services, services can be successfully provided by receiving a high quality data again. It is true that repetitive data receptions cause delay. But, the data quality generally progressively improves by receiving the additional data and combining them with the already received data. For example, resolutions of video images improve by adding the complementary pixels (multi-resolution coding). The sampling rates of temperature values improve by adding intermedial values. In such cases, we can further reduce delays or data losses by receiving stream data while improving the quality and finishing the reception when the service is successfully provided. However, conventional methods do not apply this progressive quality improvement approach.

In this paper, to apply the progressive quality improvement approach, we model stream data distribution with progressive quality improvement. In this approach, the data for quality improvements are distributed after distributing the lowest quality data. Thus, data quality improves progressively as time proceeds. The remainder of the paper is organized as follows. We introduce some related work in Sect. 2. We explain our proposed models in Sect. 3 and show some performance evaluation in Sect. 4. Finally, we conclude the paper in Sect. 5.

2 Related Work

Some methods to reduce delays or data losses for stream data distribution have been proposed. In [1], Zhang et al. proposed a method to reduce delays using peer-to-peer communication, i.e., the clients communicate with the server and also other clients. To find the client that has the unreceived data faster, a method to exchange the information of received pieces was proposed in [2]. Also, the authors proposed a distributed video processing system for stream data distribution in [3]. The system distributes the processing loads for the video stream data according to predetermined rules. However, these methods or systems assume that the quality of stream data is fixed. Our proposed approach in this paper improves the quality progressively.

For video or image data coding, some progressive coding algorithms have been proposed in [4–7]. These coding algorithms can decode the encoded data while improving the quality of the data. For example, the users can get the lowest resolution image data first and after that they can get a higher resolution image data by proceeding the decoding process. A heuristic caching algorithm based on the data sizes of objects is proposed in [8]. Our proposed approach in this paper is different from them in the point that we focus on the distribution of stream data. As coding algorithms, our approach can exploit them.

3 Proposed Models

In this section, we explain our proposed models. First, we explain our assumed system architecture.

3.1 System Architecture

Figure 1 shows an image of our assumed system architecture. In the figure, there are many data sources of stream data in the left side. The data sources generate stream data. These connect to a computer network such as the Internet and distribute stream data via the computer network. A processing computer is connected to the same computer network and receives the distributed stream data. The processing computer executes programs for analyzing the received stream data. The applications services are provided by the system. We used camera images as the data sources in the figure. But, we do not specify the types of data sources.

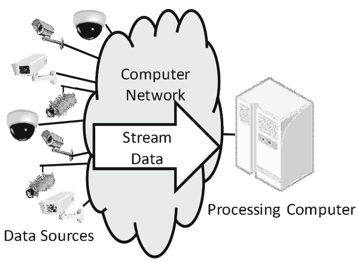

Fig. 1. Assumed system architecture

Figure 2 shows an image of our assumed data structure. There are three data sets in the figure. The data set 1 is the data for the quality 1. The quality is the lowest quality for stream data. For example, the lowest resolution video images for video stream data or the lowest sensing rate temperature values for sensor stream data. The data set 2 is the additional data for the quality 2. The processing computer can get the data for quality 2 by combining the data set 1 and the data set 2. The quality 2 is higher than the quality 1. The data set 3 is the additional data for the quality 2. The processing computer can get the data for the quality 3 by combining the data set 1, 2 and 3. Although the number of the data sets can be more, the quality 3 is the highest in this case as an example.

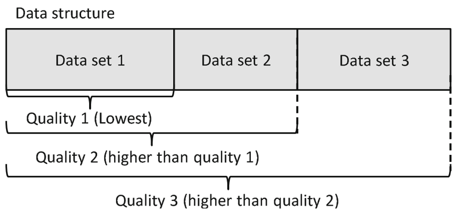

Fig. 2. Data structure

3.2 Progressive Quality Improvement

To show the idea of the progressive quality improvement, we first explain the stream data analysis under a conventional model. Figure 3 shows the communicating and the processing status under conventional model. In the figure, the time proceeds along with right. The left edge of the time line is the time to start nth cycle and the right edge is the time to finish nth cycle ($n = 1, 2, \cdots$). The time to finish nth cycle is the same time as the time to start the next process. The figure shows one cycle of the stream data distribution and the same time line continues until the data source distributes the data stream. The upper part of the figure shows the communicating status of the processing computer and the lower part shows the processing status. In the conventional model, the processing computer collects all data from the data sources in the first stage of each data

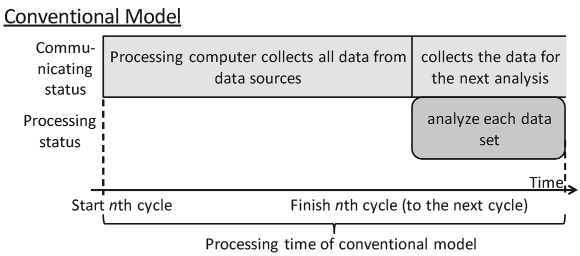

Fig. 3. An image of conventional model

distribution. The collected data include all data sets. After that, the processing computer analyzes each data set. While processing the analysis, the processing computer collects the data for the next analysis since the data sources continue to distribute the next stream data. The processing time in this model, i.e., from the time to start collecting data sets to the time to finish analyzing the collected data sets, is shown by the curly brace.

Next, we explain the stream data analysis under our proposed model. Figure 4 shows the statuses under our proposed model. In the proposed model, the processing computer collects each data set respectively in the first stage of each data distribution. After collecting data set 1 from the data sources, the processing computer analyzes the received data set 1. While analyzing the data set 1, the processing computer collects the data set 2. If the analysis of the data set 1 is insufficient to provide the service, the processing computer starts analyzing the data set 2 after collecting the data set 2. Same as the collection of the data set 2, the processing computer collects the data set 3 while analyzing the data set 2. In the case when the analysis of the data set 2 is sufficient to provide the service, the nth cycle finishes and the processing computer can start the next process. The processing time in this model is the sum of the time to collect the data sets 1 and 2, and the time to analyze the data set 2. This is shorter than that in the conventional model. Thus, the delay of the data processing can be reduced by the progressive quality improvement approach.

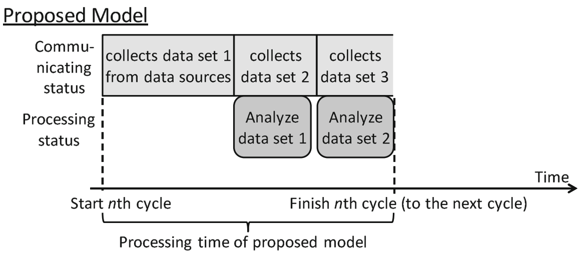

Fig. 4. An image of proposed model

3.3 Data Set Reception Models

In Subsect. 3.2, the processing computer collects the data sets sequentially without breaks. However, in practical situations, the processing computer cannot sometimes receive the data sets sequentially or encounters breaks depending on the network situations. Here, let $D(i)$ indicate the data set that the processing computer collects at the ith collection $(i = 1, 2, \cdots)$. For example, suppose the case that the processing computer collects the data set of that quality is q in the nth cycle. If it is required to analyze the next quality data set, $D(i + 1)$ is the data set of that quality is $q + 1$. If it is not and the processing computer starts the next analysis after analyzing the data set of the nth cycle, $D(i+1)$ is the data set of that quality is the lowest in the $n+1$th cycle.

Let $S(i)$ denote the data size of $D(i)$, $B(i)$ denote the average bandwidth to collect $D(i)$. $T_{gstart}(i)$ is the time to start the generation of $D(i)$ in the data source and $T_{gfinish}(i)$ is the finish time. $T_{cstart}(i)$ is the time that the processing computer starts collecting $D(i)$ and $T_{cfinish}(i)$ is the time to finish the collection and $T_{cfinish}(i) = T_{cstart}(i)+S(i)/B(i)$. If $T_{cfinish}(i)$ is later than $T_{gfinish}(i+1)$, the processing computer can sequentially collect $D(i+1)$ immediately after collecting $D(i)$ if necessary. Otherwise, the processing computer should wait for the generation of $D(i+1)$ and the delay of the collection lengthens. This is the same for collecting the lowest quality data in the next cycle after finishing receiving the data for a certain cycle. Therefore,

$$T_{cstart}(i+1) = \begin{cases} T_{cfinish}(i) & (T_{gfinish}(i+1) < T_{cfinish}(i)) \\ T_{gfinish}(i+1) & (T_{gfinish}(i+1) \leq T_{cfinish}(i)) \end{cases} \tag{1}$$

in case where the processing computer collects a higher quality data sets.

3.3.1 Processing Models

In Subsect. 3.2, the processing computer starts analyzing each data set after finishing receiving them. However, in practical situations, the processing computer can sometimes start the analysis while receiving data by using stream processing technique. Here, let $P(i)$ indicate the time to analyze $D(i)$. If the analysis time is proportional to the data sizes of data sets, $P(i) = aS(i)$. a is a coefficient to get the analysis time. Let $T_{astart}(i)$ denote the time to start analyzing $D(i)$ and $T_{afinish}(i)$ denote the time to finish the analysis. $T_{afinish}(i) = T_{astart}(i) + P(i)$. If $T_{afinish}(i)$ is later than $T_{cfinish}(i+1)$, The processing computer can continuously analyze $D(i+1)$ immediately after analyzing $D(i)$ if necessary. Otherwise, the processing computer should wait for the collection of $D(i+1)$ and the delay of the analysis lengthens. This is the same for analyzing the lowest quality data of the next cycle after finishing analyzing the data for a certain cycle. Therefore,

$$T_{astart}(i+1) = \begin{cases} T_{afinish}(i) & (T_{cfinish}(i+1) < T_{afinish}(i)) \\ T_{cfinish}(i+1) & (T_{cfinish}(i+1) \leq T_{afinish}(i)) \end{cases} \tag{2}$$

in case where the processing computer analyzes a higher quality data sets.

The delay time $Delay$ is given by the following equation.

$$Delay = T_{afinish}(i) - T_{gstart}(i) \tag{3}$$

The delay time depend on the collection schedule of the data sets.

3.4 Data Transmission Model and Methods

Figure 5 shows the structure of the data source. The data source consists of a data generator, a buffer and a data block selector. The data generator cyclically generates data. An example of the data generator is a sensor device. The data consists of one or more data sets and these data sets are recorded sequentially. Furthermore, each data set consists of one or more data blocks. Also we assume that the data sizes of these data blocks are equivalent to make the model simple. Data generated by the data generator is stored in the buffer temporarily. The data block selector selects one data block from the data stored in the buffer and transmits it to the processing computer via some communication channel.

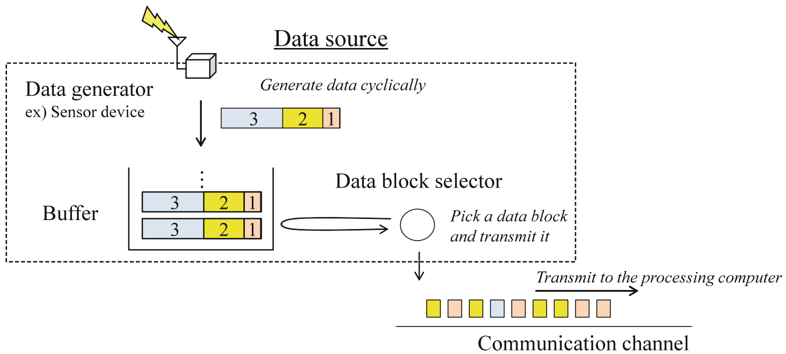

Fig. 5. The structure of the data source.

We propose the following four methods for the data selector to select a data block from the buffer: FIFO, round-robin, FIFO with data set priority, and round-robin with data set priority.

FIFO
: The FIFO method is typical and well known method. The buffer acts as a simple queue. The data block selector selects one data block in order from the head data block of the previously generated data and transmits it.

Round-Robin
: The round-robin method is also well known method. In the round-robin method, the data block selector selects one data block from the head data block of the buffer and transmits it. Then, the data block selector removes the selected data and re-puts it into the tail of the buffer. By this operation the data is sequentially rotated in the buffer every selection.

FIFO with data set priority
: FIFO with data set priority method is a combination method with FIFO and priority queue. The buffer works as a priority queue based on the priority of non-empty data set. If a data set becomes empty after transmitting a data block, the data block selector removes the data from the buffer, and re-puts it to the buffer again. Since the buffer is a priority queue, the order of the data becomes a preferable order based on the priority of the non-empty data set. The same priority data are stored on FIFO order.

Round-robin with data set priority

Round-robin with data set priority method is a combination method with round-robin and priority queue. The buffer works sigillary to FIFO with data set priority. In this method, the data block selector removes and re-puts the data which have the selected data block after every selection.

4 Performance Evaluation

We have investigated the performance of the methods described above by the simulation.

4.1 Evaluation Environment

We have investigated the delay time from the generation of data on the data source to the start of analyzing on the processing computer by a computer simulation. We simulated the transmission method described in the previous section. To make the simulation easily understandable, the delay time on the communication channel was assumed to be 0. Thus, the time that the processing computer can start processing can be the same as the time that the data source finished transmitting the data set. Therefore, we use the delay time until all data of a data set are transmitted at the data source as an evaluation index.

The simulation period includes 200 ticks (0–199), the former half 100 ticks (0–99) are the data generation period, the latter half 100 ticks (100–199) are the pause period. In the data generation period, one data is generated per every one tick. In the pause period, the data generation stops, and only the transmission of data in the buffer works. The data for evaluation consists of three data sets. The data set 1 (Highest priority) has one block. The data set 2 has three blocks. The data set 3 (Lowest priority) has 12 blocks. One data consists of 16 blocks. Under the simulation bandwidth of the communication channel, 10 blocks are transmitted per tick.

4.2 Evaluation Results

Figures 6, 7, 8 and 9 show the delay time of transitions for each method. The horizontal axis of the graph represents the elapsed time in tick count. The vertical axis of each graph represents the delay time in tick count from the data generation to finishing transmitting the data set in the data. Different data sets are shown by dotted colors.

In the FIFO method (Fig. 6), since the data blocks are transmitted in the order of generation, the delay time sequentially increases in the situation that the data blocks cannot be completely transmitted.

In the round-robin method (Fig. 7), since the data is sequentially rotated in the buffer, the data set near the head of each data (the data set 1 and 2) is transmitted earlier than the FIFO. On the other hand, since the data have no priority, the time to complete the transmission of the data set 3 is late.

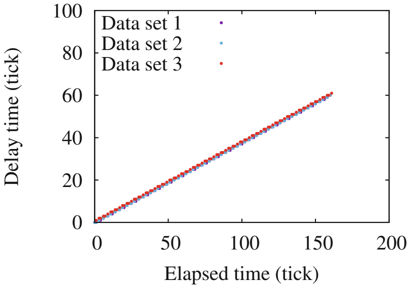

Fig. 6. FIFO

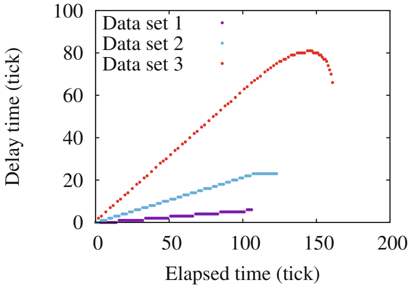

Fig. 7. Round-robin.

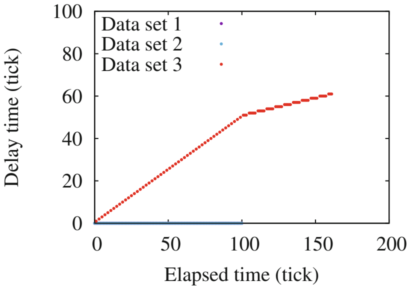

Fig. 8. FIFO with data set priority.

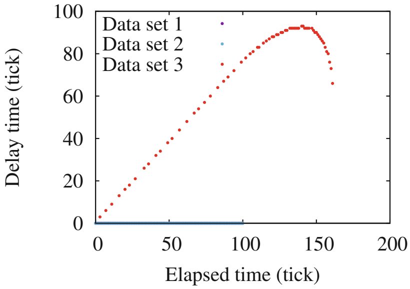

Fig. 9. Round-robin with data set priority.

In the FIFO with data set priority method (Fig. 8) and the round-robin with data set priority (Fig. 9), data set 1 and the data set 2 are transmitted with no delay. This means that the priority control works well. Comparing Figs. 8 and 7, the FIFO with data set priority finishes transmitting all data set earlier than the round-robin with data set priority method, since the blocks are transmitted sequentially in the order of their generations. The round-robin with data set priority method needs more time to finish transmitting since the data sequentially rotate in the buffer.

From above evaluation results, the FIFO with data set priority method is the best method in the evaluation environment.

5 Conclusion

In this paper, we proposed a novel approach that shortens delay relieving data quality degradation. In our approach, the data for quality improvements are distributed after distributing the lowest quality data. Thus, data quality improves progressively as time proceeds. Our performance evaluations show that our proposed model gives a shorter delay than conventional models in some situations.

In the future, we will propose more sophisticated methods using the progressive quality improvement approach and confirm the performance. Also, we will develop a stream data distribution system with our proposed methods.

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A Skip Graph-Based Collection System for Sensor Data Streams Considering Phase Differences

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Abstract. In the Internet of Things (IoT), various devices (things) including sensors generate data and publish them via the Internet. We define continuous sensor data with difference cycles as a sensor data stream and have proposed methods to collect distributed sensor data streams. In this paper, we describe a skip graph-based collection system for sensor data streams considering phase differences. Our method uses a phase shift to avoid the load concentration to the specific time.

1 Introduction

In the Internet of Things (IoT), various devices (things) including sensors generate data and publish them via the Internet. We define continuous sensor data with difference cycles as a sensor data stream and have proposed methods to collect distributed sensor data streams as a topic-based pub/sub (TBPS) system [1]. In our previous work, however, the loads to collect data are concentrated to the specific time by the combination of collection cycles.

Therefore, in this paper, we propose a collection system considering phase differences. In our proposed method, the collection time is balanced within each collection cycle by the phase differences, and the probability of load concentration to the specific time or node is decreased.

In the following, the addressed problems are described in Sect. 2. We describe our proposed system in Sect. 3 and its evaluation Sect. 4. Finally, we conclude in Sect. 5.

2 Problems Addressed

2.1 Assumed Environment

The purpose of this study is to disperse the communication load in the sensor stream collections that have different collection cycles. The source nodes have

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sensors so as to gain sensor data periodically. The source nodes and collection node (sink node) of those sensor data construct P2P networks. The sink node searches source nodes and requires a sensor data stream with those collection cycles in the P2P network. Upon reception of the query from the sink node, the source node starts to delivery the sensor data stream via other nodes in the P2P network. The intermediate nodes relay the sensor data stream to the sink node based on their routing tables.

2.2 Input Setting

The source nodes are denoted as N_i $(i = 1, \cdots, n)$, and the sink node of sensor data is denoted as S. In addition, the collection cycle of N_i is denoted as C_i.

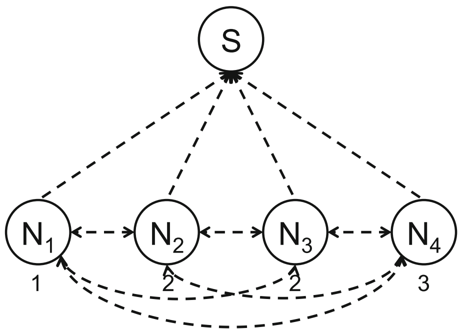

Fig. 1. An example of input setting

In Fig. 1, each node indicates source nodes or sink node, and the branches indicate collection paths for the sensor data streams. Concretely, they indicate communication links in an application layer. The branches are indicated by dotted lines because there is a possibility that the branches may not collect a sensor data stream depending on the collection method. The sink node S is at the top and the four source nodes N_1, $\cdots$, N_4 $(n = 4)$ are at the bottom. The figure in the vicinity of each source node indicates the collection cycle, and $C_1 = 1$, $C_2 = 2$, $C_3 = 2$, and $C_4 = 3$. This corresponds to the case where a live camera acquires an image once every second, and N_1 records the image once every second, N_2 and N_3 record the image once every two seconds, and N_4 records the image once every three seconds, for example. Table 1 shows the collection cycle of each source node and the sensor data to be received in the example in Fig. 1.

2.3 Objective Function

The communication load of S is L_0 and the communication load of N_i is L_i. The communication load SL of the entirety of the system is given by the following equation:

Table 1. An example of the sensor data collection

Time	N_1 (Cycle=1)	N_2 (Cycle=2)	N_3 (Cycle=2)	N_4 (Cycle=3)
0	✓	✓	✓	✓
1	✓			
2	✓	✓	✓	
3	✓			✓
4	✓	✓	✓	
5	✓			
6	✓	✓	✓	✓
7	✓			
...	...	...	...	...

$$SL = \sum_{i=0}^{n} L_i \tag{1}$$

In addition, the following fairness index (FI) is often used as an index for "equality" of specified values [2]:

$$FI = \frac{\left(\sum_{i=0}^{n} L_i\right)^2}{n \sum_{i=0}^{n} L_i^2} \tag{2}$$

where $0 \leq FI \leq 1$, and when $FI = 1$, $L_0 = \cdots = L_n$ and the loads of nodes are perfectly fair. It is indicated that the closer FI is to 1, the more the load is dispersed.

Another purpose of the present study is to disperse the communication load to the entirety of the system. Therefore, the objective function is SL and $1 - FI$, and the collection paths is determined to make these values minimum. In the present problem, the received sensor data stream can be sent to other nodes, and each node determines the sensor data to be sent.

2.4 Definition of a Load

The communication load of the source nodes and sink node is given as the total of the load due to the reception of the sensor data stream and the load due to the transmission. The communication load due to the reception is referred to as the reception load, the reception load of N_i is I_i and the reception load of S is I_0. The communication load due to the transmission is referred to as the transmission load, the transmission load of N_i is O_i and the transmission load of S is O_0.

In many cases, the reception load and the transmission load are proportional to the number of sensor data pieces per unit hour of the sensor data stream to be sent and received. The number of pieces of sensor data per unit hour of the sensor data stream that is to be delivered by N_p to N_q ($q \neq p$; $p, q = 1, \cdots, n$) is $R(p, q)$, and the number delivered by S to N_q is $R(0, q)$.

In the this study, the load with which one piece of sensor data can be received and sent per unit hour is normalized to 1, and the communication load L_r of N_r is given in the following equations:

$$L_r = I_r + O_r = \alpha \sum_{i=0}^{n} R(i,r) + \beta \sum_{i=0}^{n} R(r,i) \tag{3}$$

where α and β are loads with which one piece of sensor data is received and sent, respectively.

Figure 2 shows a case where $\alpha = \beta$ and the sensor data is collected directly from the source nodes in the example in Fig. 1. The figures in the vicinity of the branches are the number of sensor data pieces per unit hour of the sensor data stream. In this example, the sensor data stream is collected only from the sink node, and therefore, $R(0,q) = 1/C_q$ and $R(p,q) = 0$. Thus, $R(0,1) = 1$, $R(0,2) = 1/2$, $R(0,3) = 1/2$, and $R(0,3) = 1/3$. The load at each end is $L_0 = R(1,0) + R(2,0) + R(3,0) + R(4,0) + R(0,1) + R(0,2) + R(0,3) + R(0,4) = R(0,1) + R(0,2) + R(0,3) + R(0,4) = 2.33$, $L_1 = 1.00$, $L_2 = 0.500$, $L_3 = 0.500$, and $L_4 = 0.333$. In this case, $SL = 4.667$ and $FI = 0.617$.

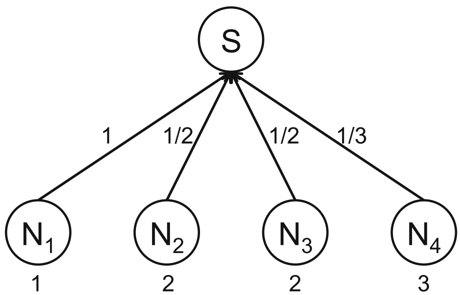

Fig. 2. A case of collecting the sensor data stream directly from the sink node

3 Skip Graph-Based Collection System Considering Phase Differences

3.1 Skip Graphs

In this paper, we assume the overlay network for the skip graph-based TBPS such as Banno, et al [3].

Skip graphs are overlay networks that skip list are applied in the P2P model [4]. Figure 3 shows the structure of a skip graph. In Fig. 3, squares show entries of routing tables on peers (nodes), and the number inside each square shows a key of the peer. The peers are sorted in ascending order by those keys, and bidirectional links are created among the peers. The numbers below entries are called "membership vector." The membership vector is an integral value and assigned to each peer when the peer joins. Each peer creates links to other peers on the multiple levels based on the membership vector. In skip graphs, queries are forwarded by the higher level links to other peers when a single key and its assigned peer is searched. This is because of the higher level links can efficiently reach the searched key with less hops than the lower level links. In the case of range queries that specifies the beginning and end of keys to be searched, the queries are forwarded to the peer whose key is within the range, or less than the end of the range. The number of hops to key search is represented to $\mathrm{O}(\log N)$ when N is denoted as the number of peers. In addition, the average number of links on each peer is represented to $\log N$.

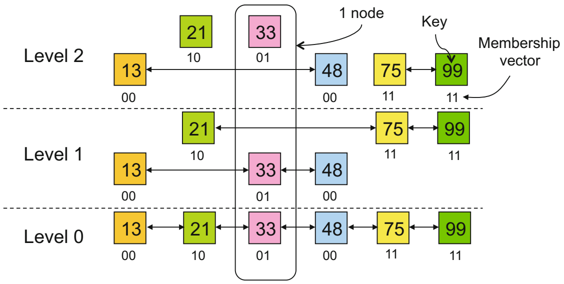

Fig. 3. A structure of a skip graph

3.2 Phase Differences

Currently we have proposed a large-scale data collection schema for distributed TPBS [1]. In [1], we employ "Collective Store and Forwarding," which stores and merges multiple small size messages into one large message along a multi-hop tree structure on the structured overlay for TBPS, taking into account the delivery time constraints. This makes it possible to reduce the overhead of network process even when a large number of sensor data is published asynchronously. Figure 4 shows an example of the data forwarding paths on skip graphs. In our previous work, however, the loads to collect data are concentrated to the specific time by the combination of collection cycles. In addition, the network traffic increases in the time that has high possibilities to collect data such as a common multiple of the collection cycles.

Therefore, in this paper, we propose a collection system considering phase differences. In the proposed method, the phase difference of the source node N_i is denoted as d_i $(0 \leq d_i < C_i)$. In this case, the collection time is represented to $C_i p + d_i$ $(p = 0, 1, 2, ...)$. Table 2 shows the time to collect data in the case of Fig. 1 where the collection cycle of each source node is 1, 2, or 3. By considering phase differences like Table 2, the collection time is balanced within each collection

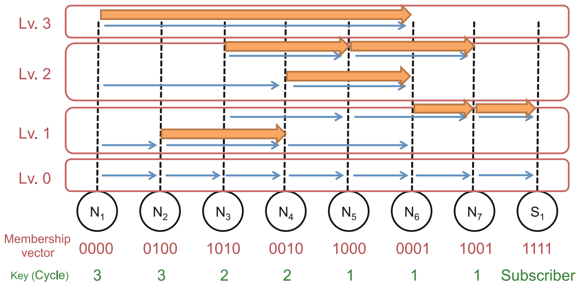

Fig. 4. An example of data forwarding paths on skip graphs

cycle, and the probability of load concentration to the specific time or node is decreased. Each node sends sensor data at the time base on his collection cycle and phase difference, and other nodes relay the sensor data to the sink node.

Table 2. An example of the collection time considering phase differences

Cycle	Phase Diff	Collect. Time
1	0	0, 1, 2, 3, 4, ...
2	0	0, 2, 4, 6, 8, ...
	1	1, 3, 5, 7, 9, ...
3	0	0, 3, 6, 9, 12, ...
	1	1, 4, 7, 10, 13, ...
	2	2, 5, 8, 11, 14, ...

4 Evaluation

In this section, we describe the evaluation of the proposed system in Sect. 3 by simulation.

4.1 Simulation Environments

Table 3 shows the simulation environments. We evaluate our proposed system in two environments by the combination of collection cycles. The number of the sink node is one, and the collection cycle C_i and phase difference d_i of each node is determined at random. In the simulations, we measure the number of nodes targeted to collect data from time 0 to 99 and compare the results with the case of not considering phase differences.

Table 3. Simulation environments

Env	No. of source nodes	Cycles
1	1000	1, 2, 3
2	1000	1, 2, ..., 10

4.2 Simulation Results

Figures 5 and 6 show the results of the number of the nodes targeted to collect data from time 0 to 99. The horizontal axis shows the time, and vertical axis shows the number of the targeted nodes at each time.

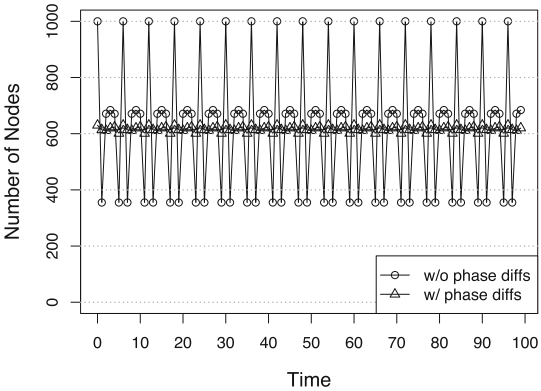

Fig. 5. Example of data forwarding paths on skip graphs

In the simulation environment 1 shown by Fig. 5, the case of not considering phase differences collects data from all 1000 nodes at time 0, 6, 12, ..., 96. This is because the collection cycle is 1, 2, or 3, and the lowest common multiple is 6. At other time in the case of not considering phase differences, the number of the nodes is extremely and constantly increase/decrease. On the other hand, the collection time is shifted by the phase differences in our proposed system, the number of the nodes is probabilistically equalized for each time if the phase difference of each node is determined at random. Therefore, the probability of load concentration is decreased. Also in the simulation environment 2 shown by Fig. 6, our proposed system can high balancing similar to the results in the simulation environment 1 while the case of not considering phase differences changes the number of the nodes complexly by the combination of cycles from 1 to 10.

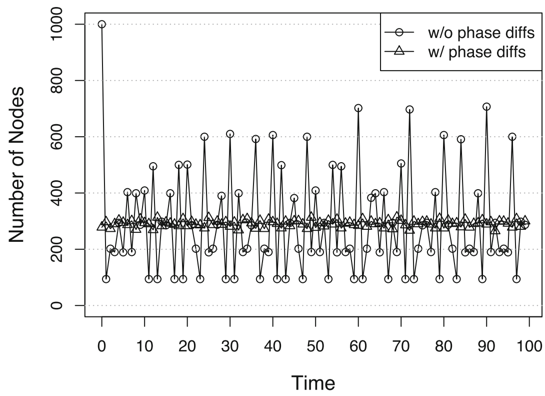

Fig. 6. Example of data forwarding paths on skip graphs

5 Conclusion

In this paper, we proposed a skip graph-based collection system for sensor data streams considering phase differences. Our method uses a phase shift to avoid the load concentration to the specific time. Our simulation results shows that our proposed system can equalize the number of the nodes targeted to collect data at each time.

Acknowledgements. This work was supported by JSPS KAKENHI Grant Number 16K16059 and 17K00146.

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Proposal of an Open Data Visualization System for Disaster Prevention and Disaster Reduction

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Abstract. In this paper, we propose an Open Data Visualization System for disaster prevention and disaster reduction at the time of natural disaster. We realized visualization of open data related to disaster prevention and reduction. Moreover, we realized visualization of real-time disaster prevention information handled by disaster control headquarters. We constructed this system as a Web application system. As a result, it became possible to provide the residents with application that do not depend on the terminal environment. In addition, we adopted responsive technology in the construction of this system.

1 Introduction

In recent years, there is growing interest in open data in countries around the world. In Japan, the National Strategy Office of Information and Communications Technology, Cabinet Secretariat shows three meanings to tackle open data. Currently, it is expected to create new values and create new services by mutual collaboration of various information such as big data and open data [1]. On the other hand, looking at the promotion of open data by basic municipalities, the mechanism of open data is not mature enough for local governments and local residents to feel the effect of open data. This is due to the lack of engineers and application development to utilize open data. In such situation, contests, workshops, ideathons and hackathons for promoting open data utilization have been held across Japan. In Japan, utilization of big data and open data in the disaster prevention/reduction disaster field is attracting attention. Disaster prevention and disaster reduction systems utilizing open data already exist. However, many of these disaster prevention and disaster reduction systems do not correspond to real-time disaster prevention information acquisition. In other words, it is difficult to acquire evacuation information, safety information, disaster information, etc. required immediately after the natural disaster.

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2 Purpose of Research

In this research, we construct the Open Data Visualization System for disaster prevention and disaster reduction at the time of natural disaster. We realize visualization of open data related to disaster prevention and reduction. Moreover, we realize visualization of real-time disaster prevention information handled by disaster control headquarters. As a result, residents can acquire real-time disaster prevention information such as lifeline restoration status in addition to open data information. In addition, we provide real-time information of shelters (food stock status information, daily necessities stock status information, and other notifications information) to residents.

3 System Configuration

The system configuration in normal times of this research is shown in Fig. 1. In normal times, this system configuration consists of the normal times database server that stores various open data, the normal times application server, the normal times user agent, and normal times data management agent.

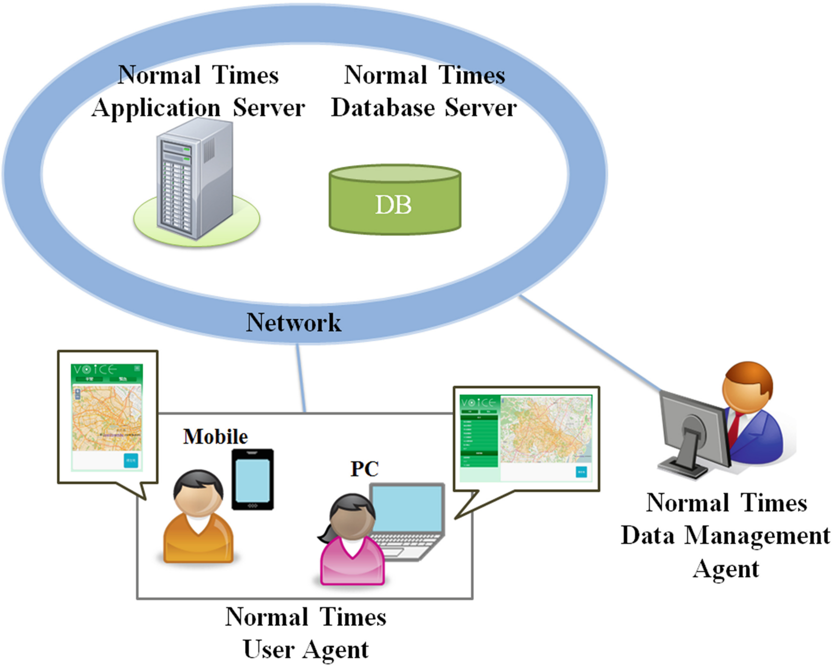

Fig. 1. System configuration (in normal times)

The system configuration in emergencies of this research is shown in Fig. 2. In emergencies, this system configuration consists of the emergencies database server that stores notification information from local governments and detailed information of each shelter, the emergencies application server, the shared folder, the emergencies user agent, the shelter agent, the local government department agent, and the emergencies data management agent.

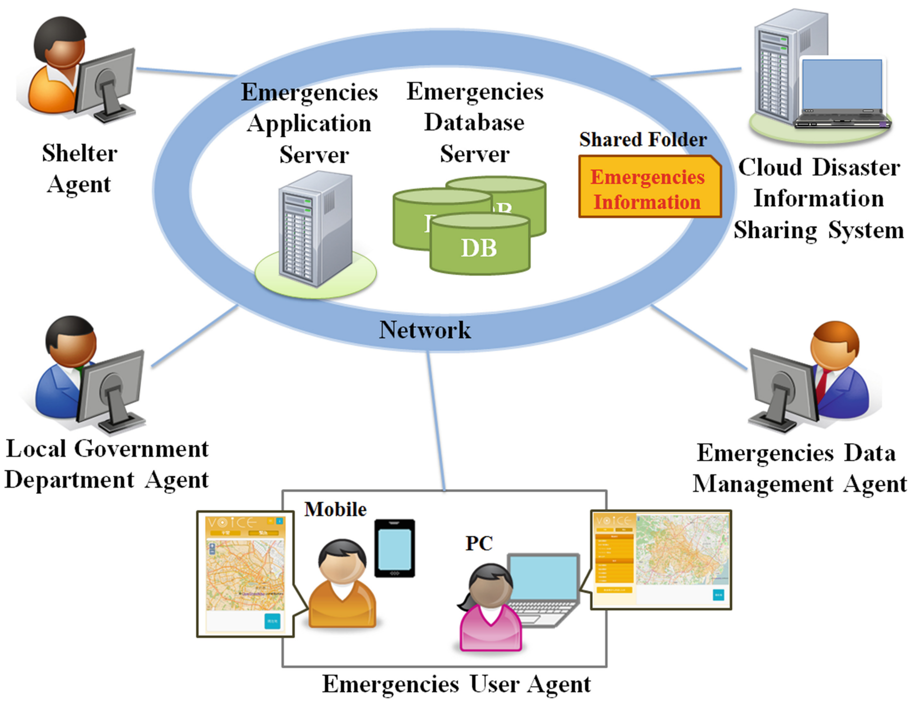

Fig. 2. System configuration (in emergencies)

4 System Architecture

The system architecture of this research consists of User Agent, Data Management Agent, Shelter Agent, and Local Government Department Agent.

The system architecture of User Agent is shown in Fig. 3. The User Agent consists of User Interface, Function Control Manager, Open Data View Manager, Basic Information View Manager, Local Government Message View Manager, Emergency Information View Manager, Asynchronous Task Manager, Shared Folder Access Manager, and Network Interface.

The system architecture of Data Management Agent is shown in Fig. 4. The Data Management Agent consists of User Interface, Function Control Manager, Open Data Update Manager, Administrator Account Edit Manager, Department Account Add Manager, CSV Import Manager, and Network Interface.

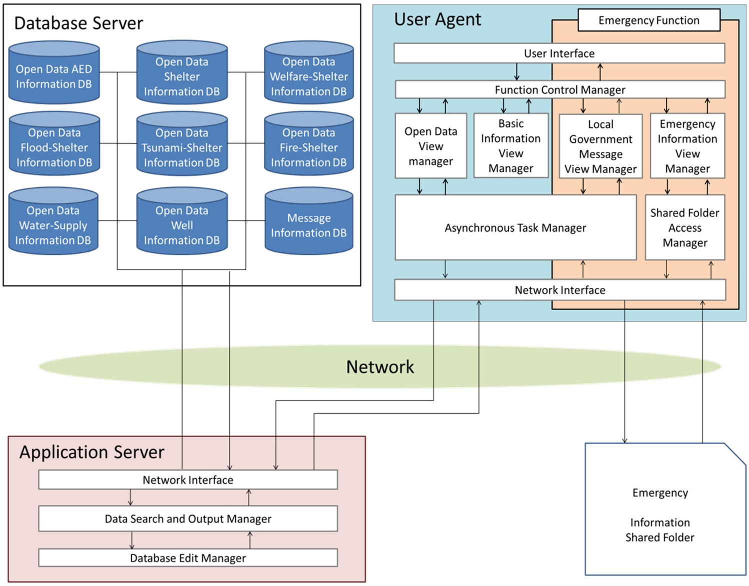

Fig. 3. System architecture of user agent

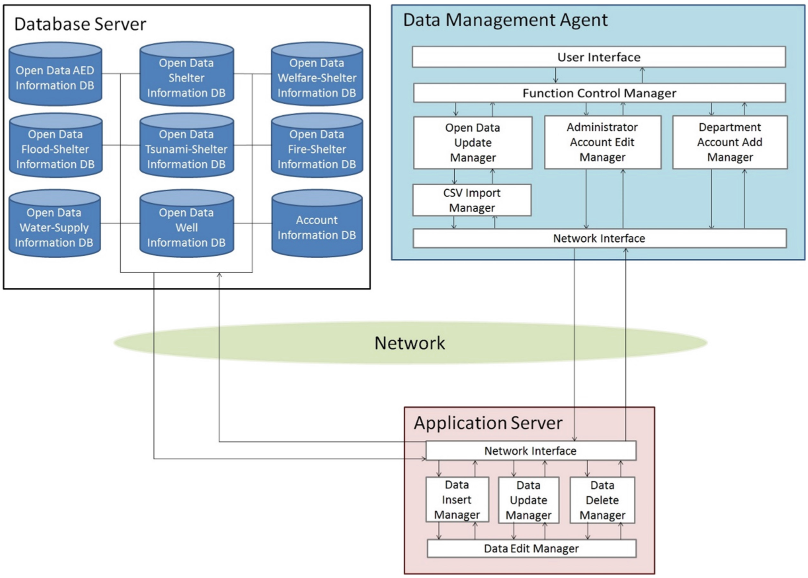

Fig. 4. System architecture of data management agent

The system architecture of Shelter Agent is shown in Fig. 5. The Shelter Agent consists of User Interface, Shelter Select Manager, Relief Supply Information Registration Manager, Relief Supply Information Update Manager, and Network Interface.

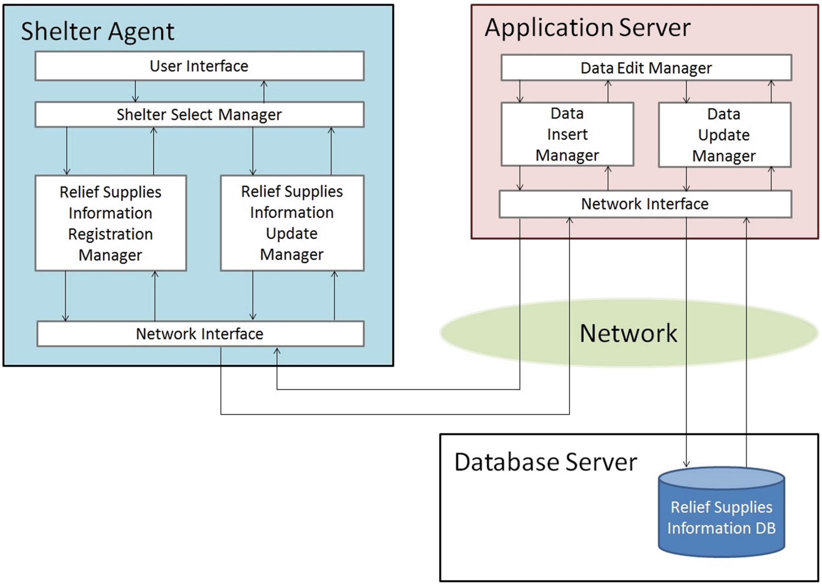

Fig. 5. System architecture of shelter agent

The system architecture of Local Government Department Agent is shown in Fig. 6. The Local Government Department Agent consists of User Interface, Function Control Manager, Local Government Message Registration Manager, Local Government Message Registration Update Manager, Local Government Department Account Edit Manager, and Network Interface.

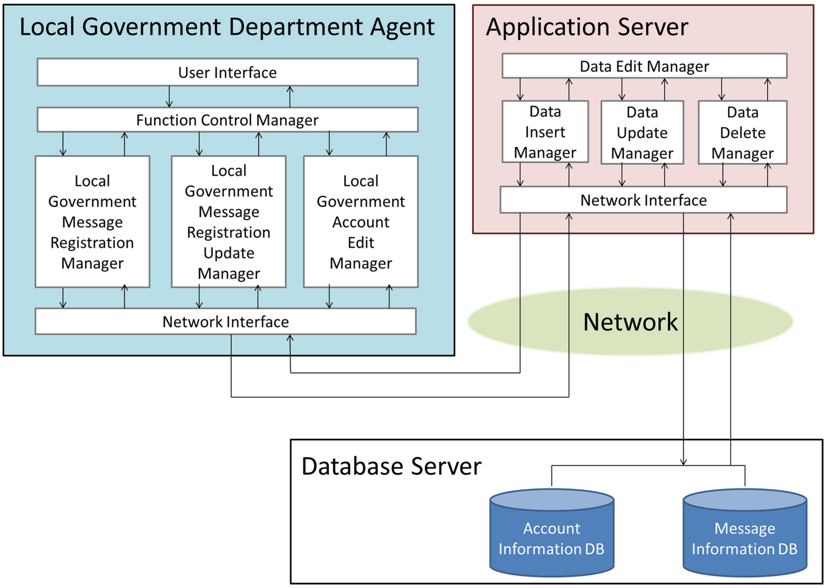

Fig. 6. System architecture of local government department agent

5 Prototype System

In this research, we constructed the open data visualization system "VOICE" considering switching disaster information in normal times and emergencies. In addition, this system adopted responsive technology. In normal times, VOICE visualizes open data provided by local governments on Web-GIS. On the other hand, in emergencies, VOICE visualizes disaster information provided by the disaster control headquarters in real time.

5.1 Designated Shelter Information Screen at Normal Times

The designated shelter browsing screen that visualized designated shelter information on the Web-GIS in normal times is shown in Fig. 7.

The designated shelter marks representing the location of the designated shelter is displayed. In this research, we adopted open data of Mito city, Ibaraki prefecture, to VOICE. Therefore, shelter data of 81 designated shelters located in Mito city are displayed on the Web-GIS. Facility name information and address information of designated shelters are associated with each designated shelter displayed on the Web-GIS. Therefore, the user can browse the facility name information and the address information of the designated shelter by selecting the designated shelter mark.

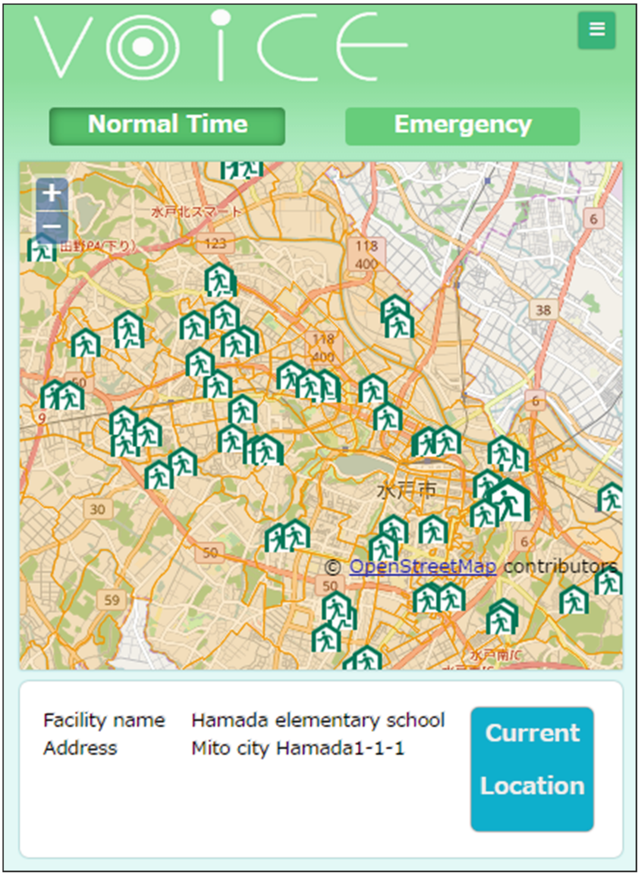

Fig. 7. Designated shelter information screen at normal times

5.2 Population Density Map Screen at Normal Times

The population density map browsing screen that visualized population density on the Web-GIS in normal times is shown in Fig. 8. The population density map data divided for each area is displayed. The areas with high population density are displayed in dark color, and areas with low population density are displayed in light color. Also, the user can confirm the current location information on the Web-GIS by selecting the “Current Location” button.

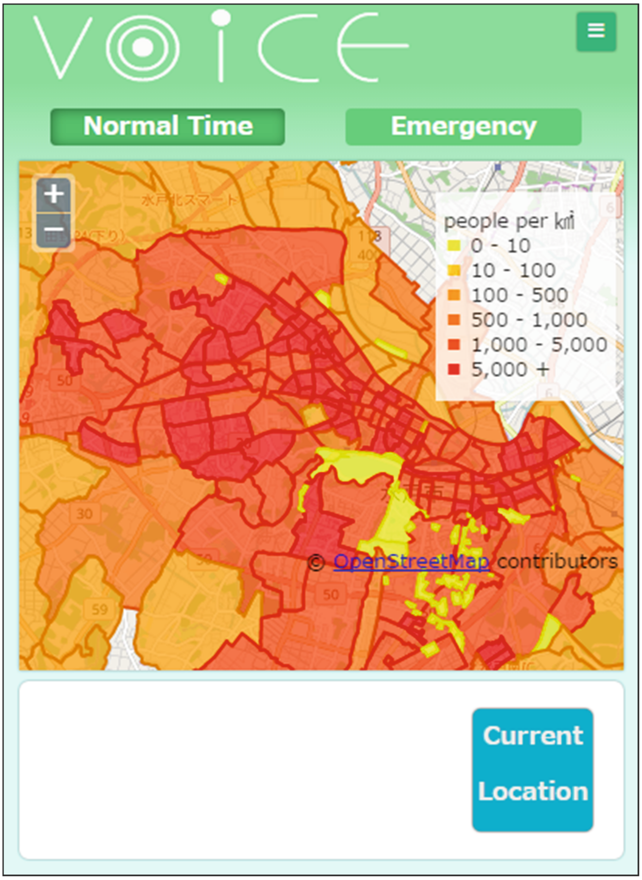

Fig. 8. Population density map screen at normal times

5.3 Lifeline Information (Water) Screen at Emergencies

The lifeline information (water) browsing screen that visualized water communication information on the Web-GIS in emergencies is shown in Fig. 9. The water flow and water failure data divided for each area is displayed. The lifeline (water) map is color coded into the following four colors. Therefore, the user can confirm the lifeline information of water communication at a glance by color-categorizing the supply status of water every area. In this research, we collaborated the "The Cloud Disaster Information Sharing System" [2,3] developed by Hirohara et al.

- Unconfirmed Area: Yellow Color
- Water Failure Area: Red Color
- Water Flow Test Area: Blue Color
- Water Flow Area: Green Color

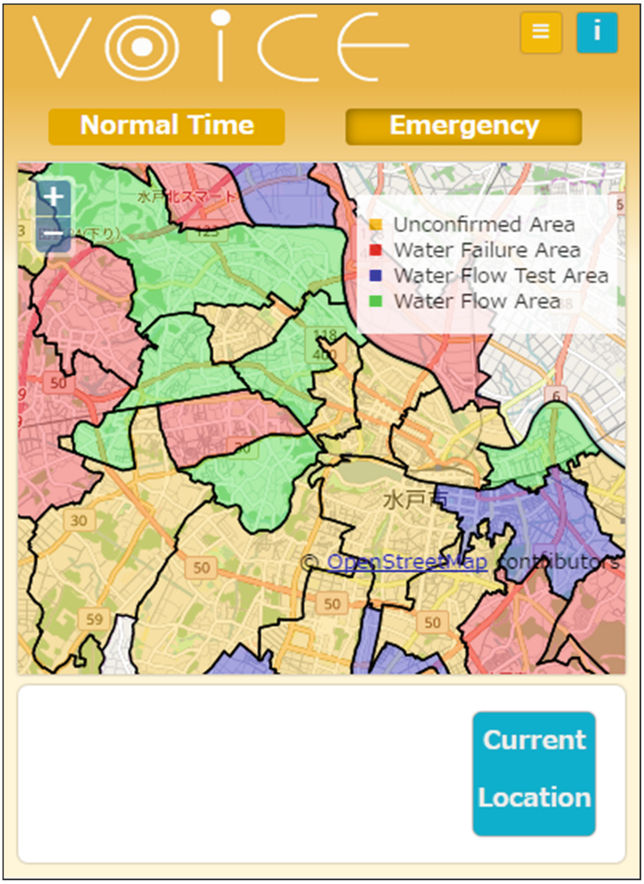

Fig. 9. Lifeline information (water) screen at emergencies

5.4 Temporary Shelter Information Screen at Emergencies

The temporary shelter browsing screen that visualized temporary shelter information on the Web-GIS in emergencies is shown in Fig. 10. The temporary shelter marks representing the location of the temporary shelter is displayed. Facility name information and address information of temporary shelters are associated with each temporary shelter displayed on the Web-GIS. Therefore, the user can browse the facility name information and the address information of the temporary shelter by selecting the temporary shelter mark.

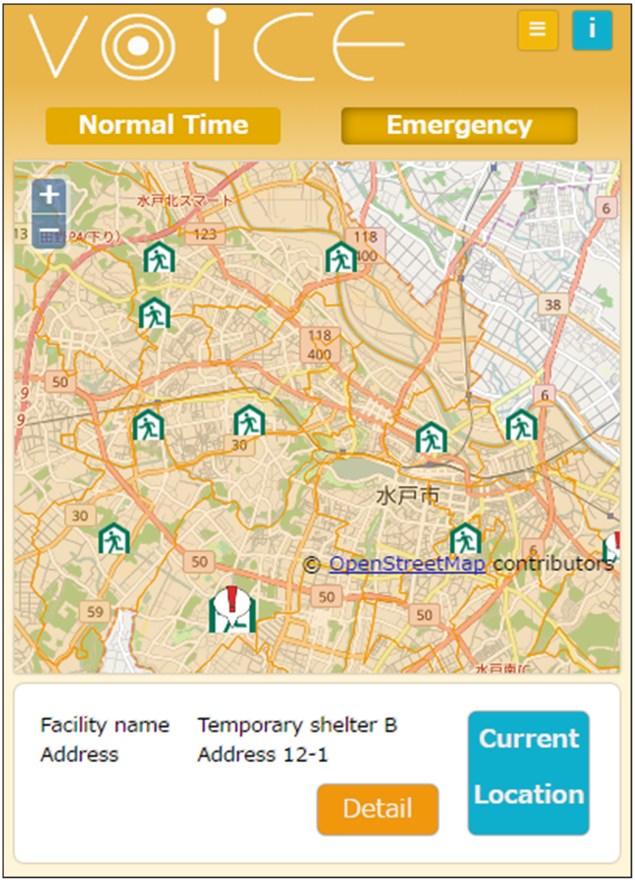

Fig. 10. Temporary shelter information screen at emergencies

6 Conclusion

In this research, we constructed the Open Data Visualization System for disaster prevention and disaster reduction at the time of natural disaster. We realized visualization of open data related to disaster prevention and reduction. Moreover, we realized visualization of real-time disaster prevention information handled by disaster control headquarters. In addition, we provided real-time information of shelters (food stock status information, daily necessities stock status information, and other notifications information) to residents.

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A Conceptual Framework for Developing an Information Retrieval for Healthcare Services

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Abstract. Treatment planning and treatment improvement for cleft lip and cleft palate patients need an accurate treatment estimation and treatment integration from several medical personals such as surgeons, orthodontists, and specialists. Thus, the patient data include different kinds of symptom and recorded data, including. long-term treatment, which can be complex and hard to understand. In order to search, monitor, and analyze these patient data, an effective approach is highly necessary. In this paper, a conceptual framework that facilitates the development of an information retrieval and searching suggestion for the electronic health record (EHR) is proposed, using the cleft lip and cleft palate as a case study. Specifically, it provides an essential mechanism that enables the information retrieval healthcare service to address the challenge of the accurate treatment estimation and collaboration from multidisciplinary team for developers and then build into the corresponding services.

1 Introduction

Cleft lip and cleft palate are obstinately congenital anomalies [1]. The anomalies can relate with multiple face organs such as a mouth, a nose, teeth, gum, palate, and maxillary bone. Treatment planning and treatment process improvement for the cleft lip and cleft palate patients need an accurate treatment estimation and collaboration from a multidisciplinary team. The team is generally composed of nurses, dentists, orthodontists, oral surgeons, otolaryngologists, geneticists, prosthodontists, speech therapists, radiologists, psychologists, feeding specialists, and plastic surgeons [2]. Usually, surgical treatments are begun immediately since a patient is born or at the childhood age. The patients then should obtain a very long continuation treatment (surgical and nonsurgical treatment), in which can be as long as 20 years [2, 3].

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From the nature of the treatment by multidisciplinary team, the types of recorded patient data can be variety, i.e. multi-user and multi-domain of knowledge of users. Moreover, the data could be recorded with multi-language including Thai language and English language. From the long continuation treatment, the members of multidisciplinary team can be changed. New team members must spend a lot of time to be familiar to the database. Searching the patient data with these characteristics is clearly time-consuming. In addition, results that return from searching might not be relevant for multi-user. Thus, the effective approach is highly necessary for managing the data in this environment.

Generally speaking, Electronic Health Record (EHR) consists of unstructured, narrative text and structured coded data [4]. EHRs are continuously being adopted to improve care such as quality of care, patient safety, and patient outcome measures, as well as reduce treatment errors [3, 5]. The retrieval of patient information tends to be a time consuming and error-prone in case of some or all relevant criteria are available in free text and not in a structured form [6, 7]. For example, a recent study that monitored the Norway's electronic patient record system reported that over a third of general practitioners gave up searching for patient information in the electronic system because it required too much time [8]. The information retrieval capability particularly for finding important information from free text patient care documents has only a little attention [5].

Even though, many information retrieval systems for EHR are implemented [9, 10], but the multi-languages searching is not investigated, especially for Thai language. In this paper, a conceptual framework that facilitates the development of a multi-language information retrieval and searching suggestion for the electronic health records (EHR) is proposed, using the cleft lip and cleft palate as case study. This framework addresses the varied needs of multidisciplinary users for accurately finding information in the documents.

The rest of this paper is organized as followed: Sect. 2 describes the proposed framework architecture. Each module of the framework is presented in Sects. 3–6. Section 7 concludes the paper.

2 *IRHS* Framework

The cleft lip and cleft palate medical data of patients are usually kept in EHR [3], generally referred as the cleft lip and cleft palate documents (CL/CP documents) because they contain both the structured data and unstructured data such as narrative text. CL/CP documents also contain a very long continuation medical data [2, 3]. Also, from the nature of the treatment by the multidisciplinary team, searching the patient data with multi-user, multi-domain of knowledge of users, and multi-language of data is clearly time-consuming. Last, but not least, free text searching of patient information from EHR can help users retrieve the past, related, or similar cases. The retrieval of "similar cases" may be of a great didactic and heuristic value for new users [6].

Figure 1 illustrates *IRHS* architecture. Essentially, it composes of five main components: (i) Query Formulation – that formulates the query string from user; (ii) Document

Indexing – that indexes term for describing the document corpus; (iii) Matching – that is the process of computing the similarity between documents and queries by weighting terms; (iv) Result Filtering – that filters out any irrelevant results by using user's conditions; and (v) Query Reformulation – that reformulates the queries by feedback and queries log for improving the final relevant result set. Details of these modules are provided in the following sections.

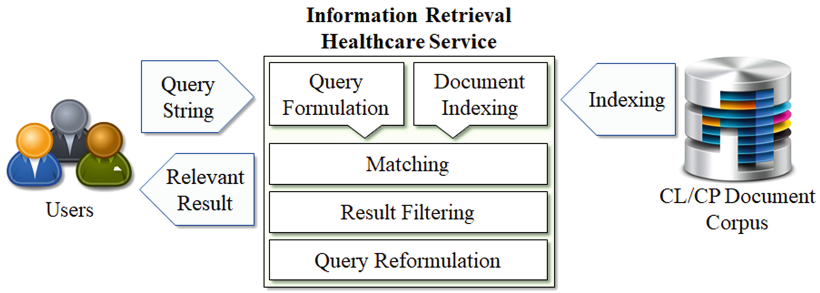

Fig. 1. The information retrieval healthcare service framework.

3 Document Indexing

This module consists of three components: word segmentation, stemming, and stop-word removal. The cleft lip and cleft palate document database were separated into two groups of the document indexing such as English language and Thai language. Each group is independent of consideration for indexing and matching module.

3.1 Word Segmentation

Word segmentation is the process of breaking a stream of text in documents up into words, phrases, symbols, or other meaningful elements. In Thai language and other Asian languages, word segmenting is nontrivial because there is no explicit inter-word delimiter [11].

The cleft lip and cleft palate documents are processed one by one. Their narrative text is tokenized into individual terms or words. For the Thai language documents, the LexTo services are used for word separation (www.sansarn.com/lexto/). This service is dictionary based approach with the longest matching technique.

3.2 Stemming

Stemming is the process of reducing related words to their stem, base or root form through affix removal. Its aim is to adapt different derivational or inflectional variants of the same word to a single indexing form [12]. Three approaches of stemming are generally used: dictionary based, rule based and n-gram based.

3.3 Stop-Word Removal

In information retrieval, a document is indexed by the frequency of its words. Statistical analysis of this process shows that some words have low frequency, while others have high frequency. However, the frequency does not dictate the amount of information carried by the words. For example, 'and', 'of', and 'the' appear frequently in the documents without significant information. This set of words is referred to as stop-words. Elimination of stop-words can significantly reduce the size of the indexing structure, speed up the calculation and increase accuracy.

4 Query Formulation and Query Reformulation

Figure 2 illustrates the query formulation and query reformulation modules. Query formulation receives the query string input from users. This input includes the user category such as nurse or dentist. The query string will be processed with the word processing as same as the processes in Sect. 3 (word segmentation, stemming, and stop-words removal). In addition, the query string inputs are translated to other language. This process helps user from the multidisciplinary teams to get more information in other language documents. For example, when user input query string in Thai language, the query formulation will translate to English language, and vice versa.

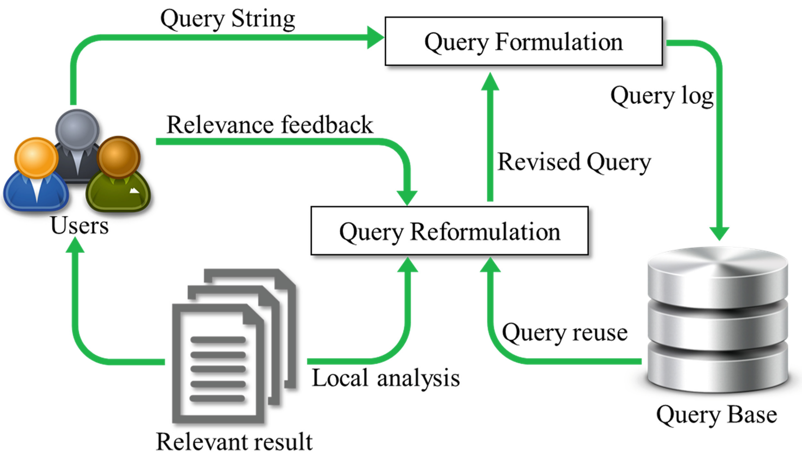

Fig. 2. The query formulation and query reformulation.

The output words are used for the matching module and keep in the query log which includes user category in the query base repository for the query reformation module.

The query reformulation analyzes information from four components: (i) the query reuse – that processes the similarity of the query string inputs and the query logs which keep in the query base repository; (ii) the local analysis [13] – that analyzes the appropriation between the relevant words and the relevant results which return from the matching module; and (iii) relevance feedback – that is ranked the relevant results by user.

After the query reformulation analyzes information from all components, the new terms of the query will be adding to the query formulation in form of the revised queries. The term weighting of relevant documents will be reprocessing. The weight of relevant documents will be increasing and the weight of irrelevant documents will be decreasing.

5 Matching

The matching module computes the similarity between documents which indexed from the document indexing module and query terms which process by the query formulation by TF-IDF weighting algorithm.

The TF-IDF weighting algorithm is often used in information retrieval and text mining [12]. This weight is a numerical statistical measure that is aimed to return how important between query words and indexed documents in the document corpus. The weight is also used in computing scores for ranking relevant documents. The TF-IDF value increases correspondingly to the number of times a word appears in the document but is often offset by the frequency of the word in the document corpus.

The retrieved documents from the matching module are used for the result filtering module in Sect. 6.

6 Result Filtering

Figure 3 shows the result filtering module. The number of retrieved documents which return from the matching module can be enormous. This module filters out any irrelevant results by using user's conditions, e.g., patient's age, patient's sex.

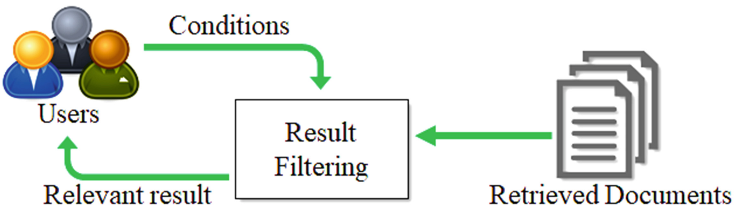

Fig. 3. The result filtering

7 Conclusions and Future Work

This paper proposes the conceptual framework that facilitates the development of *IRHS* for the cleft lip and cleft palate documents. Specifically, it provides an essential mechanism such as the query formulation, document indexing, matching, result filtering, and query reformulation that enables the information retrieval healthcare service to address the challenge of the accurate treatment estimation and collaboration from multidisciplinary team for developer and then build into the corresponding services. Future work is to develop such framework and make it publicly available.

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Adaptive Array Antenna Systems with Machine Learning Based Image Recognitions for Vehicular Delay Tolerant Networking

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Abstract. Although the V2V communication expects us to produce new applications of ITS, there are difficulties of the wireless connections in case of the vehicles such as the rapid movements or obstacles as well as the radio characteristics. This paper introduces the Delay Tolerant Network System with the Adaptive Array Antenna to realize the longer and stable wireless connections between vehicles, and the proposed methods consists of the adaptive antenna directions controls by using the machine learning based image recognitions for the assumed usages. Then, the prototype system and the experimental reports are discussed for the future studies in the paper.

1 Introduction

Although the V2V communication expects us to produce new applications of Intelligent Transport System (ITS) such as the driving safety system or the road surveillance system, there are difficulties of the wireless connections in the actual circumstances of the vehicles. First of all, if the automobiles use the high frequency radio band such as the IEEE802.11a/b/g/p for the high throughput communications such as the video streaming or the capture images, the transmission range becomes shorter in the case of non-directional antenna. The 100 m of the maximum range of IEEE802.11b is not enough distance to communicate each other. Secondly, the radio noise from the obstacles such as trees or buildings occurs when the vehicle runs in the roads. The network conditions are greatly influenced by these obstacles. Besides, the radio reflections by the car body is also great subjects for the realization of the V2V communication.

Therefore, this paper introduces the Delay Tolerant Network (DTN) System with the Adaptive Array Antenna (AAA) to realize the longer and stable wireless connections between vehicles, and the proposed methods consists of the adaptive antenna directions controls by using the machine learning based image recognitions for the assumed usages. Then, this paper especially deals with the prototype system of the image recognition

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methods based of machine learning in order to improve the vehicle recognitions, and the future studies are also indicated by the discussion of the implementations of the system.

In the followings, Sect. 2 deals with the related studies of the antenna directional controls for the vehicle-to-vehicle (V2V) communications, and the proposed image recognition methods with the Kalman filter in the antenna directional controls by AAA in Sect. 3. Section 3 introduces the proposed AAA system and Sect. 4 explains the prototype of the proposed methods. Finally, the conclusion and future study are discussed in Sect. 5.

2 Related Works

It is considered that the longer radio range of V2V communication is significantly important especially when vehicles move so fast and the high throughput is necessary for the communications such as the transmissions of video or image contents. Therefore, there are some previous studies to make the longer radio range by controlling the directional antenna.

The study [2] uses the directional antenna on the remote camera platform apparatus, and the direction is configured by the GPS location data from each vehicle. In the study, the GPS data is continuously observed in the vehicle, and the observed text data is transmitted to others by the 144 MHz amateur radio band which has longer wireless range. Then, the antenna angle is calculated with the current GPS location, and the remote camera platform is adjusted toward another vehicle. However, since the vehicles continuously move so fast, and since the vehicles themselves also change the angle along the roads, the quick controls of the apparatus and its calculations were future subjects for the stable network connections.

Another related work [3] is the usages of the Adaptive Array Antenna (AAA) for vehicles. The AAA is the antenna arrays with smart signal processing methods used to identify spatial wireless signals [3]. It calculates beamforming vectors in order to track and locate the antenna beam on the wireless nodes. The AAA generally uses the Beam Forming (BF) algorithm to identify the target nodes, and it is considered to be the effective methods for the V2V communication. The Digital BF antennas that consisted of multiple phased array antennas. When the wireless signal received at each element antenna, Beam-forming is proceeded in a digital processor. Next, both excitation amplitudes and phases can be accurately controlled [4]. However, this DOA (Direction of Arrival) Estimation algorithm usually use the rotational invariance techniques (ESPRIT) algorithms or Matrix Pencil method, and these algorithms have some subjects such as the complex or the convergence of the calculation process for the optical values.

Therefore, to realize the quick controls as well as the longer and stable wireless connection between vehicles, this paper proposed the AAA control methods with the image recognitions and the locational prediction function by the Kalman filter algorithm.

3 The Proposed Methods

Figure 1 is the system configuration of the proposed methods. The vehicles are connected by the DTN with wireless networks such as IEEE802.11b/n/p, and each vehicle equips the camera and the proposed AAA system for the sake of optimal antenna directional controls [1].

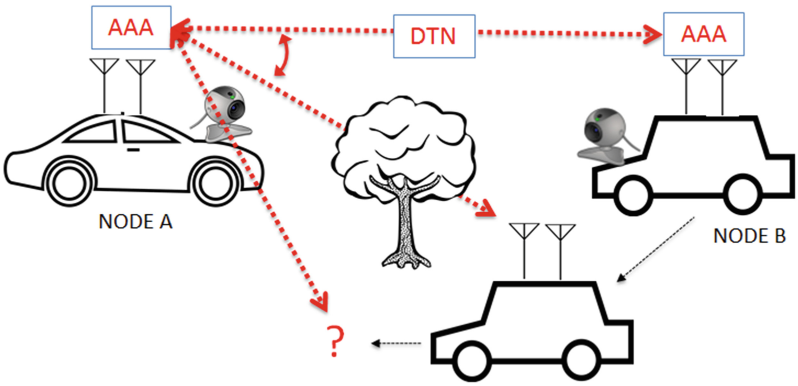

Fig. 1. The system architecture in the proposed methods. The target node B is captured by the camera of the node A, and the AAA is adjusted as way of the antenna directions toward the node B.

In the figure, first of all, each vehicle connected by the wireless connections based on the DTN. The DTN is the stored-and-forward typed protocol in the way that the node stores the data until the transmittable target node appears [5], and it is considered to be effective methods even if V2V communication [6].

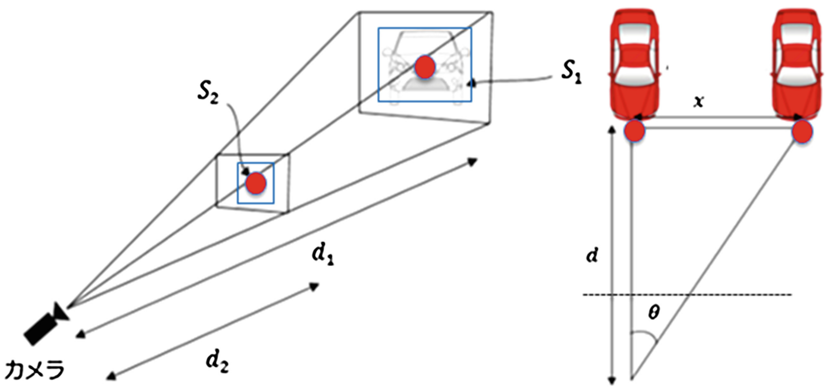

Fig. 2. The calculations of the antenna direction by the image recognitions. The total pixels of the captured vehicle image is used for the distance for the target, and the differential center point of the pixels is calculated for the direction for the target.

Secondly, the assumed vehicles equip cameras in order to capture the target vehicle images. Figure 2 explains the proposed process for the calculation of the target's direction and the angle [1].

In the left of the figure, the distance between the vehicles is calculated as the formula (1) by using the ratio of pixels and field distance.

$$d_2 = d_1 \sqrt{\frac{S_2}{S_1}} \tag{1}$$

Then, in the right figure, the angle is calculated as the formula (2) by using the differential pixels between the center of the image and the captured vehicle image.

$$x = d \tan \theta \tag{2}$$

Therefore, it is supposed that the proposed methods realize the quick calculation of the optimal angle for the AAA controls in comparison with the current DOA algorithm.

Finally, the predictional functions by the Kalman filter algorithm is introduce to the proposed methods in order to avoid the noise from the fast movements of nodes and the obstacles such as trees or buildings. The Kalman filter is one of the estimation algorithms that is mainly consisted of two phases such as Time Update and Measurement Update for the calculation of the prediction values [7, 8]. In the Time Update, formula (3) and (4) are carried out in order to update the current time and to predict the estimated values.

$$\hat{x}_k^- = A\hat{x}_{k-1} + Bu_{k-1} \tag{3}$$

$$P_k^- = AP_{k-1}A^T + Q \tag{4}$$

In the formulas, x_k is the estimate of the signal x, and u_k is a zero-mean (statistically) white (spectrally) random "noise" process with autocorrelation. A and B are matrixes which are numerical constants form observation values. Next, formula (5), (6), and (7) are confirmed in the Measurement Update in order to update observed values and adjustments.

$$K_k = P_k^- H^T (HP_k^- H^T + R)^{-1} \tag{5}$$

$$\hat{x}_k = \hat{x}_k^- + K_k(z_k - H\hat{x}_k^-) \tag{6}$$

$$P_k = (I - K_k H)P_k^- \tag{7}$$

Equation (3) is to compute the Kalman gain K_k. Equation (4) is to actually measure the process to obtain Z_k, and to generate an a posteriori state estimate by incorporating the measurement. Equation (5) is to obtain an a posteriori error covariance estimate.

Then, the antenna direction is controlled by the calculated values in order to realize the longer and stable wireless connection in the proposed method.

4 Implementations and Experiments

The prototype system as shown in Fig. 3 is implemented for the effectiveness of the proposed methods [9], and the machine learning algorithm is introduced in the prototype system in order to improve the efficiency of the image recognitions in this paper.

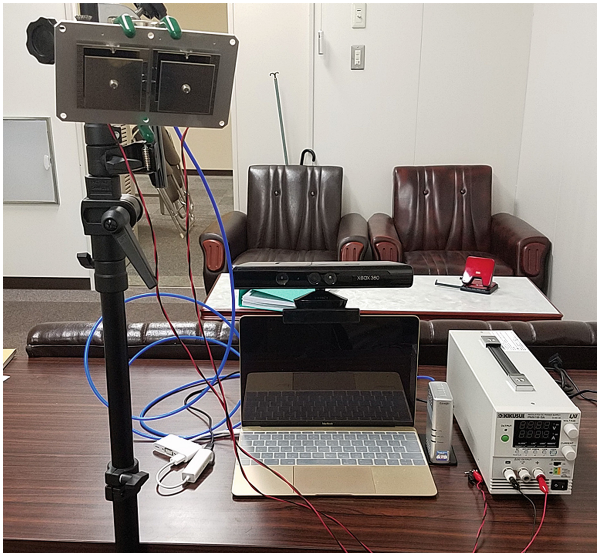

Fig. 3. The prototype system. Two antenna elements have the phase shifters that is controlled the given voltage, and it realize the quick directional antenna controls by the beam-forming.

In the system, Ubuntu 16.04 on the VirtualBox 5.1, OpenCV 2.4 [10], and Java 1.8.0 are introduced for the note PC, and the Machine Learning tracking API in the OpenCV is used for the image recognitions in this paper. Table 1 shows the details of the specifications in the system.

Table 1. The specifications of the prototype system

	Specification
Wireless interfaces	IEEE 802.11 b (2.4 GHz), DSSS
WiFi router	Buffalo WHR-HP-GN
PC	MacBook (Retina, 12-inch, Early 2015)
OS	Ubuntu16.04 on virtualbox5.1 in macOS X
API	OpenCV2.4.9 and Java 1.8.0
Antenna	Two antenna elements with the phase shifters
Voltage control	Kikusui PMX18-5A

The prototype system mainly consists of three parts that are the AAA, the camera recognitions, and the configurations of the voltage and data transmissions. Wen the target vehicle is captured by the camera, the vehicle is recognized by the machine learning API. In the previous system by the image thresholding in the OpenCV, there are problems about the accuracy of the image recognitions. Figure 5 is the captured image of the image thresholding method. As shown in the figure, it is supposed that there are some wrong image recognitions by the effects of the shadows or the sun light. Therefore, in this paper, the machine learning API is newly introduced in the system.

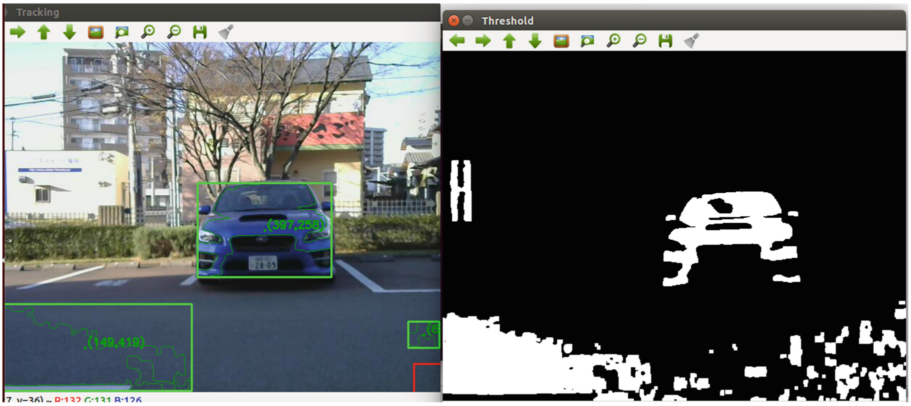

Fig. 4. The sample of the image recognition errors by the image thresholding method.

Therefore, the Data Learning (Haar-like training) API is used for the implementations of the image recognitions. Figure 5 shows the implemented process of the vehicle recognitions by OpenCV API. In the process, the positive images that is various type of vehicle's images and the negative images that is not vehicles are prepared for the machine learning. Then, the XML files of the learning data is used for the vehicle recognitions in the system.

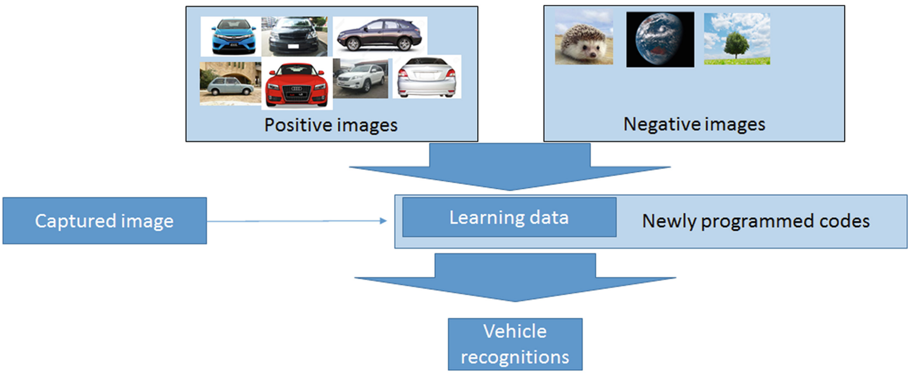

Fig. 5. The vehicle recognitions by the machine learning in the prototype system.

As the results, the accuracy of the vehicle recognitions seems to be improved as Fig. 6.

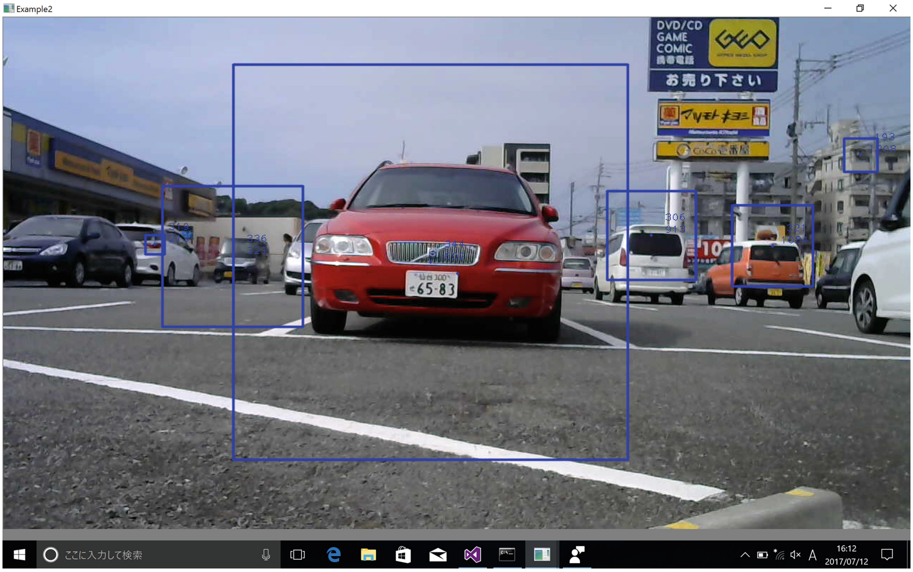

Fig. 6. The vehicle recognitions by the machine learning in the prototype system.

Although the effects of the vehicle colors or the lights are larger in the previous system, the new implemented system could capture the various types of vehicles as shown in the figure. Besides, the calculation periods of the image recognitions and the Kalman filter seems to almost same as the previous system, and the numeric field experiments are planning to the near future works.

5 The Conclusion and Future Study

Although the V2V communication expects us to produce new applications of ITS, there are difficulties of the wireless connections in case of the vehicles such as the rapid movements or obstacles as well as the radio characteristics. Especially, in the actual fields, the vehicles run fast and the obstacles such as trees might decrease the RSSI levels for the V2V communication.

Therefore, This paper introduces the Delay Tolerant Network System with the Adaptive Array Antenna to realize the longer and stable wireless connections between vehicles, and the proposed methods consists of the adaptive antenna directions controls by using the machine learning based image recognitions for the assumed usages. In details, the image recognitions with the camera is used for the estimation of the target directions, and also the prediction of the antenna direction is calculated by the Kalman Filter in order to make the longer wireless range and the stable network connection.

Then, the prototype of the proposed system is introduced, and the experimental results indicate the improvements of the vehicle recognitions by the proposed methods. Now, we are planning to additional machine learning to improve the efficiency of the vehicle recognitions by more positive and negative images for the machine learning, and the field experiments by the prototype system for the future studies.

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Evaluation of Multimedia Contents for Supporting Different Types of Self-learning

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Abstract. In recent years, information technology (IT) has been introduced to various educational fields. Thus, a students can study to play multimedia contents in anywhere and anytime. However, Japanese students spend short time on self-learning compared with other countries. Considering this fact, we propose a multimedia switching system to improve their learning time and understanding. In the system, multimedia contents are provided to reflect both knowledge and skills for keeping a self-learning time, motivation and understanding. The system is an educational content to switch their operation, media, quality reflected as a learning support functions. In this paper, we discuss about preliminary evaluation of the multimedia contents for supporting some types of self-learning.

1 Introduction

In recent years, the Information Technology (IT) has been introduced to many educational institutions such as digital teaching material, e-learning system, distance learning system and online courses. By using these system, the student can study anytime and anywhere [1, 2].

A digital teaching material is the electronic media constituting the content of learning items. An e-learning system is online workbook for self-learning to manage progress of study [3]. A distance learning system is consisted of remote communication tool and learning support tools to shorten the moving time. An online course is an online lecture using a video on demand service and video communication services. These systems can support efficiently preparation of lesson, self-learning and homework.

Many studies about education support system have been conducted to improve the effectiveness of lecture, practical training and experiments. In these studies, many educational methods and system are proposed to improve the self-learning [4], the management of learning history [5, 6], the active learning [7], problem/project based learning [8–10], the inverted learning and the problem based learning [11]. Also, the lecture video have been published on the Internet and used for different ways in classes [12–16]. However, these studies are not focused on student differences and abilities.

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In this paper, we present the implementation of the multimedia contents for supporting different types of self-learning.

This paper is organized as follows. We propose a new concept of educational multimedia contents and introduce a multimedia switching function in Sect. 2. Section 3 explains switching functions applying to education. We show implementations and preliminary evaluation of the contents in Sects. 4 and 5, respectively. Finally, Sect. 6 concludes the paper.

2 Educational Multimedia Contents

In general, the students have different abilities. For this reason, a learning support mechanism is important to narrow the differences of student abilities.

The multimedia is becoming popular as learning resource. The multimedia is spatio-temporally and semantically related with various types of media such as video, image, audio and text. In our multimedia educational contents, a multimedia switching function is introduced to switch types of media according to the student abilities as shown in Fig. 1. We assume that these contents are prepared by lecturer semi-automatically. The student abilities are considered as follows.

(L0) Lack of ability: Unable to understand basic terms and commonsense instructions in class.
(L1) Poor ability: Able to understand basic terms and commonsense instructions, but unable to use in class.
(L2) General ability: Able to carry out instructions with some explanatory diagrams.
(L3) Good ability: Able to carry out instructions with simple explanation

L0 student is required to improve basic academic ability before registration. L1 student is supposed to select both video and text contents. The student should study according to the program by playing video and text before a lecture. L2 and L3 students should select learning content as needed.

In the contents, each media includes the following information:

(M1) Video: Lecture video.
(M2) Image: Snapshot of important essentials for exercise or experiments.
(M3) Text: Textbook, operation guide, additional explanation and so on

These contents can be changed to other types of media during playing.

3 Construction Flow for Educational Multimedia Contents

The educational multimedia contents are constructed by 4 phases such as lecture phase, preparation phase, trial phase and improving phase as shown in Fig. 2. In the lecture phase, lecture is given from a lecturer. In preparation phase, each media is made from lecture video recorded during the lecture. In trial phase, educational multimedia contents consisted of each media are evaluated for their problems during in trial phase.

In improving phase, the text is revised for both misrecognition and supplement because insufficient explanation. After these phases, educational multimedia contents are released for practical use. But the phase goes back to previous phase when any problem occurs in each phase and practical use.

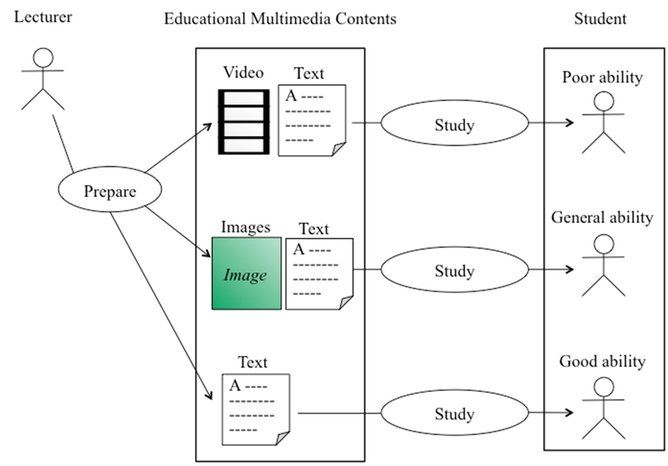

Fig. 1. Educational multimedia contents and multimedia switching functions.

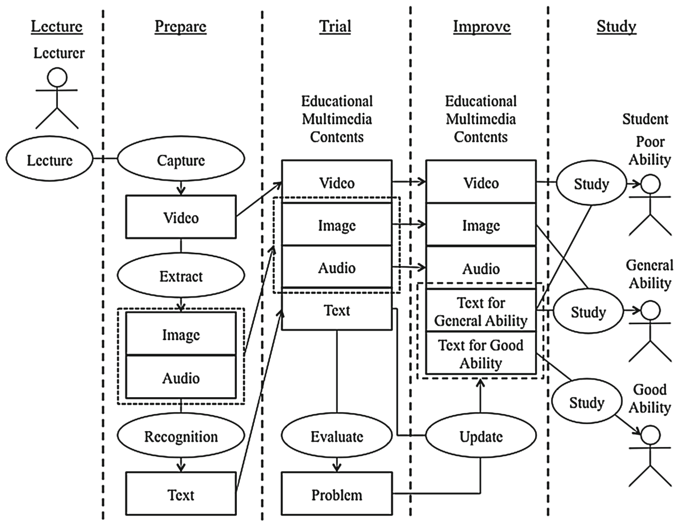

Fig. 2. Construction flow for multimedia educational contents.

We use some softwares to construct proposed contents. A lecture video is captured by a general video camera and desktop capture software as shown in Figs. 3 and 4, respectively. These videos are captured from an object oriented programing in a class. Figure 4 shows desktop capture software using by NVIDIA ShadowPlay. Adobe

Premiere Pro CS5.5 is used as extraction software for image optical character recognition and audio from the lecture video. The Adobe Premiere Pro CS5.5 is intended for character recognition. But the text needs to be revised manually in case of insufficient explanation as shown in Fig. 5.

Fig. 3. Lecture video captured from the real classroom.

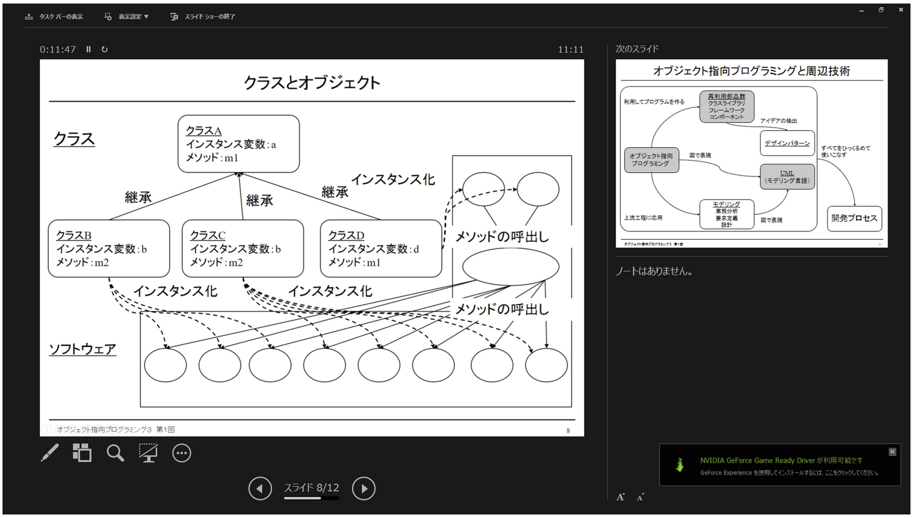

Fig. 4. Lecture video captured on desktop at object oriented programing exercise.

4 Implementation

We implemented our system on Web pages as shown from Fig. 6, 7, 8 and 9. For implementation, we used HTML5, CSS and JavaScript. The implementation has 4 types of user interface (Choice user interface, video user interface, image user interface and text user interface). When starting to play contents, a video user interface plays a video content as shown in Fig. 7. When any operation is carried out to the contents, the choice user interface is displayed on the Web page. The text user interface and image user interface are selected by pushing the button on the choice user interface as shown in Figs. 8 and 9. These interfaces are switched to the video user interface when there is not any operation. In order to switch to the video interface, this switching function monitors user operations by JavaScript "setInterval()" API, periodically. Each user interface can switch to another interface replacing objects such as media and its components in a html file. This mechanism and a part of html are shown in Figs. 10 and 11, respectively. An object can be updated by a document body on html. For this reason, the "innerHTML" property is used to rewrite by "<div id>" tag.

```
var synthes = new SpeechSynthesisUtterance('コンテナとは他のオブジェクトを格納する
オブジェクトです。コンテナと配列の大きな違いは？ひとつめは、格納するデータの
型をプログラム中で決めることができます。もう一つが、コンテナがオブジェクトな
ので、オブジェクトにはメソッドがいろいろと定義されています。例えば、push
front、 push back、とか、 pop front、 pop back、と呼ばれるような関数が、予め
各コンテナに、定義されています。そのコンテナには、いくつか種類があり、データ
の管理の仕方が違います。そのデータの管理の仕方に関してdepue、コンテナは、りょ
うほうこうからデータの追加と、削除ができる、キュー、と呼ばれるデータコードを
持ったコンテナがあります。');
```

Fig. 5. Example of recognized result (in Japanese).

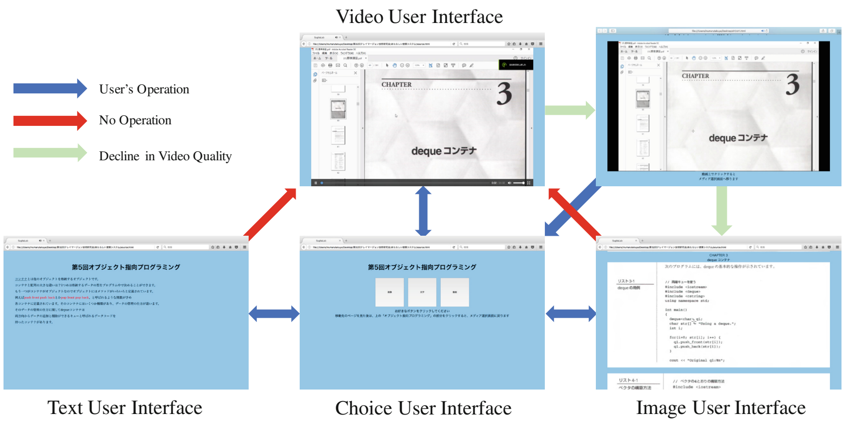

Fig. 6. Transition of user interfaces.

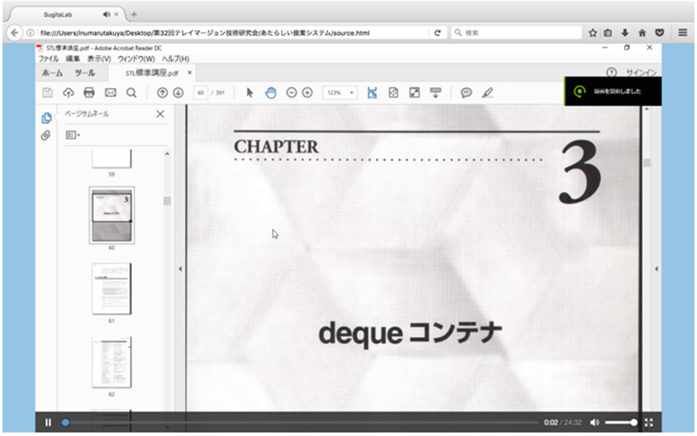

Fig. 7. Video user interface.

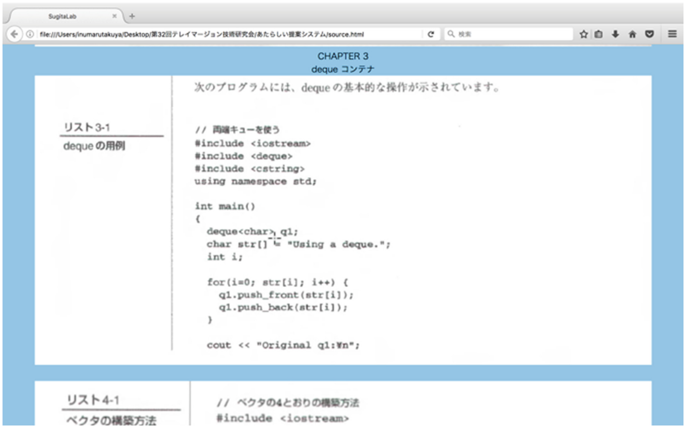

Fig. 8. Image user interface.

Fig. 9. Text user interface (in Japanese).

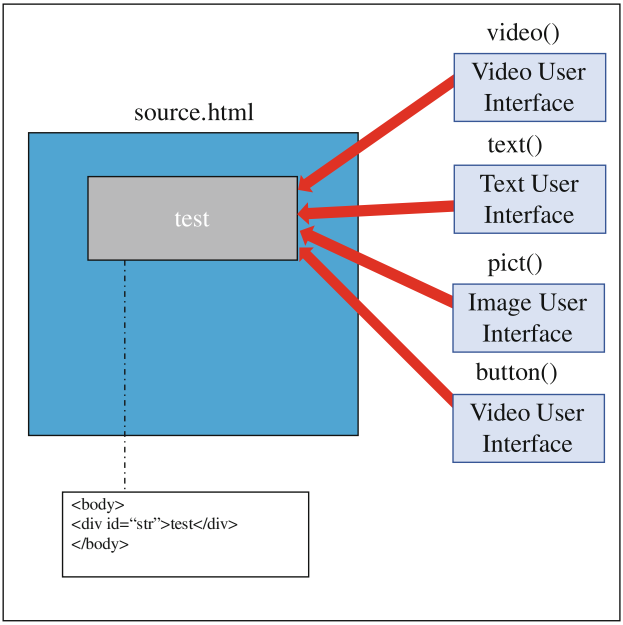

Fig. 10. Mechanism for user interface switching function.

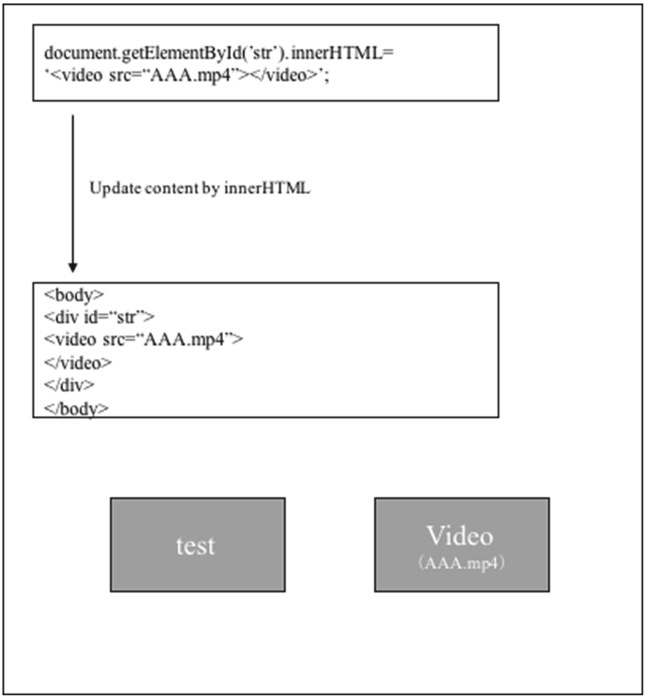

Fig. 11. Example of how to write by "innerHTML" property.

5 Preliminary Evaluation

We evaluated the implementation system by a questionnaire survey for playing the contents during 30 min. The questionnaire survey was conducted for 6 students, asking about the following questions:

Q1. Media contents understanding
Q2. Web browser easiness operation
Q3. Efficiency of learning (1:Poor, 2:Marginal, 3:Good, 4:Excellent)

From the results of the survey, the video user interface is the most understandable as shown in Fig. 12 and the chrome is the best browser for operating the contents as shown in Fig. 13. For efficiency learning, the students have answered to marginal as shown in Fig. 14. Considering these results, we showed improve our system as follows.

I1. Bugs in the user interface switching function caused by the differences of operations in the Web browsers.
I2. Optimizing the interval time for switching from the image contents and the text contents to the video contents.
I3. Overlapping of previous voices during switching to other user interfaces.

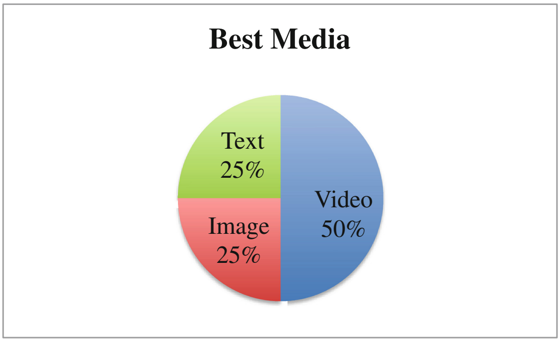

Fig. 12. Media contents understanding.

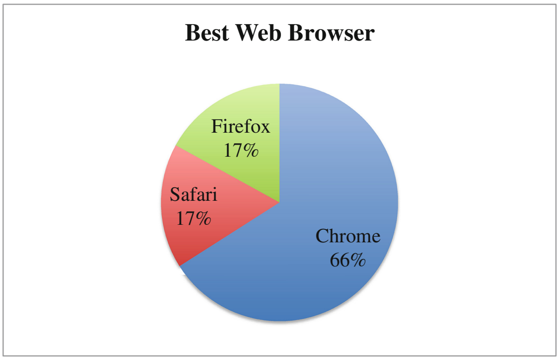

Fig. 13. Web browser easiness operation.

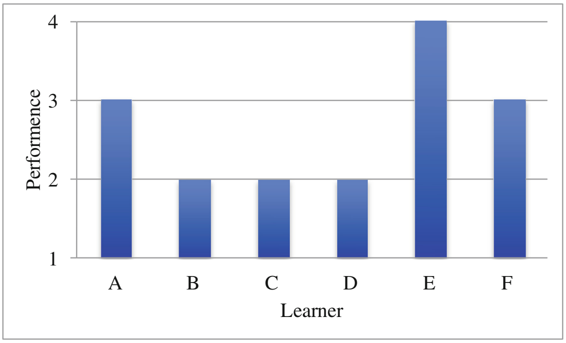

Fig. 14. Efficiency of learning.

6 Conclusions

In this paper, we presented the implementation of multimedia contents for supporting students with different abilities by providing appropriate multimedia contents. The implementation is running as Web pages and can switch 4 types of user interfaces (Choice user interface, video user interface, image user interface and text user interface) according to user operation and time. Also, we have constructed a self-learning content from a lecture video using video camera and desktop capture software. The videos are captured from an object oriented programing in a class. From the preliminary evaluation, the contents have some problems. Currently, we are improving the contents to reflect the results of preliminary evaluation. In the future, we will construct more contents and evaluate our implementation in real environment.

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Application of Fuzzy Ordinal Peer Assessment in Formative Evaluation

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Abstract. Peer assessment has been used for many years as a tool to improve learning outcomes but, only recently, it is becoming an increasingly used support also in students evaluation. Many approaches have been proposed so far to make peer assessment as reliable as possible even in case of incorrect or inaccurate evaluations proposed by students. Among these approaches, Fuzzy Ordinal Peer Assessment (FOPA) relies on ordinal evaluations (rather than cardinal ones) and on the application of models coming from Fuzzy Set Theory and Group Decision Making. FOPA has already demonstrated good results in in-silico experiments. To complement these results, in the work presented in this paper, we experiment the same model in a University context to support formative evaluation. Obtained results show better performance of FOPA with respect to competitor models and a general attitude of peer assessment models to approximate instructor ratings.

1 Introduction

Formative evaluation is a teaching method where *evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence* [1]. An important function of formative evaluation is providing students with continuous feedback, meaning that opportunities for feedback should occur continuously, but not intrusively, as a part of instruction [2].

A feasible way to approach formative evaluation either in classroom and within on-line learning environments is *peer assessment*. In peer assessment, students are required to grade a small number of their peers' assignments as part of their own assignment. The final grade of each student is then obtained by combining information provided by peers [3]. Peer assessment is able to economize teachers' time: an entire classroom can be graded in the time that it would take a teacher to grade just few submissions. Moreover, rather than having a teacher rush through each submission, students are able to take their time to correct just a small subset of them [4].

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The literature reports on many learning benefits connected to peer assessment like the exposure of students to different approaches, the development of their self-learning abilities, the enhancement of critical thinking, etc. [5]. This approach is also capable of easily scaling to any number of students (even in massive contexts like MOOCs) given that the number of assessors naturally grows with the number of students [6].

On the other hand, even if some studies suggest a good correlation between the results of peer assessment and instructor ratings in conventional classrooms and online courses (at least for specific, high structured domains), there is still a general concern on its use as a reliable strategy to approximate instructor marking, even in formative evaluation exercises [7].

To mitigate this issue, several corrected methods have been identified so far. In [8] it has been demonstrated that, asking students to provide ordinal feedback (e.g. "the report x is better than the report y"), allows to obtain better results with respect to asking them to provide cardinal feedback (e.g. "the grade of report x is a B"). Ordinal feedback is easier to provide, more reliable and overcomes the so called *bias problem* occurring when students grade peers on different scales.

Elaborating on these assumptions, in [9] a new ordinal peer assessment model named FOPA, based on *Theory of Fuzzy Sets* and *Group Decision Making*, has been defined. Experimental results with synthetic data (analyzed in the same work) have shown better performance of FOPA in the estimation of students' grades with respect to other peer assessment models. To substantiate this preliminary results, in this paper we experiment the same model in a real University context to support a formative evaluation exercise with classroom students.

The paper is organized as follows: the next section presents related work on peer assessment, Sect. 3 summarizes the defined FOPA model, while Sect. 4 illustrates the experimental setting and discusses the obtained results. Eventually, conclusions are summarized in Sect. 5.

2 Related Work

The main issue of peer assessment, when used as a tool to support formative evaluation, is represented by the lack of accuracy of grades proposed by students that may result in an erroneous feedback. Several approaches have been proposed so far to make peer assessment more reliable. *Calibrated Peer Review* (CPR) [10], proposes a calibration step to be performed by students before starting to assess other students' assignments. During the calibration step, each student rates a set of assignments that have been already rated by the instructor. The discrepancy between students' and instructors' grades is used to weight subsequent assessments.

In [11], three probabilistic models for tuning peer-provided grades are presented. Such models estimate the *reliability* of each assessor as well as her *bias* (i.e., a score reflecting the assessor's tendency to inflate or deflate her grade) based on the analysis of grading performance on special "ground truth" submissions that are evaluated either by the instructor or by a big number of peers. The estimated reliability and bias rate of each student are then used to tune proposed grades. A similar approach has been applied in [12], where a *Bayesian* model is used to calculate the bias of each peer assessor in general, on each item of an assessment rubric and as a function of the assessor grade assigned by the instructor.

In [13], the ability of an assessor student to correctly rate peer students is assumed to be dependent on the grade obtained by the same student. In other words, final grades to be assigned to students are obtained by weighting the grades proposed by their assessors on the basis of the grades received by the assessors themselves. Given that students' grades recursively depend on other students' grades, an iterative algorithm, named *PeerRank* is proposed for their calculation. In [14], the same model has been improved and applied in formative evaluation within a University course.

In [8] the authors have defined several probabilistic models for obtaining student grades starting from *ordinal feedback* provided by the peers rather than from cardinal one. An experiment with real students have demonstrated that the performance of such models is at least competitive with cardinal models for grade estimation, even though it requires less information from the graders. In [15], the authors have shown also that ordinal peer assessment is highly effective and scalable for student evaluation. They have defined a model for distributing the assignments among peers so that the collected individual rankings can be merged into a global one that is as close as possible to the real ranking.

3 The Defined Model

In a typical peer assessment scenario an *assignment* is given to n different students from a set $S = \{s_1, \ldots, s_n\}$. Each student elaborates her own solution (e.g. an essay, a set of answers to open-ended questions, etc.) generating a *submission*. Each student has then to evaluate m submissions (with $m \le n$) coming from other students. The assignment of submissions to assessor students is performed in accordance to an *assessment grid*: a Boolean $n \times n$ matrix $A = (a_{ij})$ where $a_{ij} = 1$ if the student s_j is asked to grade the submission of s_i and $a_{ij} = 0$ otherwise.

According to [3], a feasible way to build an assessment grid is starting with an $n \times n$ null matrix and initializing its elements basing on the following equation:

$$a_{\mathrm{mod}(i+j-1,n)+1,i} = 1 \forall i \in \{1, \ldots, n\}, j \in \{1, \ldots, m\} \quad (1)$$

where *mod* indicates the remainder after division of the first term by the second one. The obtained matrix is then shuffled in several iterations by randomly selecting a couple of rows (or columns) $i, j \in \{1, \ldots, n\}$ such that $a_{ij} = a_{ji} = 0$ and swapping them.

After having defined the assessment grid, each student is asked to rank submissions assigned to her. The partial ranks provided by each student are then used to build the overall ranking of submissions and to grade them accordingly. In the next subsections we analyze how this process is performed within a standard ordinal peer assessment model as well as within FOPA.

3.1 Ordinal Peer Assessment

In ordinal peer assessment, each student s_j is asked to define an *ordinal ranking* $\succ_j$ on the subset $S_j = \{s_i \in S | a_{ij} = 1\}$ of her assessees. Being s_k^j the generic element of S_j, with $k \in \{1, \ldots, m\}$, an ordinal ranking takes the following form:

$$s_{p(1)}^j \succ_j s_{p(2)}^j \succ_j \ldots \succ_j s_{p(m)}^j \tag{2}$$

where $p : \{1, \ldots, m\} \to \{1, \ldots, m\}$ is a permutation function. Equation (2) means that, according to s_j, the submission of the student $s_{p(1)}^j$ is better than that of $s_{p(2)}^j$, etc.

The ordinal ranking $\succ_j$ is undefined for elements not included in S_j so it is a *partial ranking* over S. The partial rankings defined by all students can be collected in a $n \times n$ *ranking matrix* $R = (r_{ij})$ whose generic element r_{ij} is the position of s_i in the ranking $\succ_j$ if $s_i \in S_j$, 0 otherwise. Starting from a ranking matrix, an *aggregation rule* is needed to compute a complete ranking over the whole set of submissions.

Several aggregation rules have been proposed so far by different researchers. A simple and effective rule is the classical *Borda count* [16] where the partial ranking provided by each assessor is interpreted as follows: m points are given to the submission ranked first, $m - 1$ points to the one ranked second, etc. Based on the assessment grid A and the ranking matrix R, the Borda score of any $s_i \in S$ can be calculated as:

$$Borda(s_i) = \sum_{j=1}^{n} a_{ij} \cdot \left(m - r_{ij} + 1\right). \tag{3}$$

The global ranking is then computed by ordering all the submissions in decreasing order of their Borda scores.

In [15], authors have demonstrated that Borda outperforms other, more complex aggregation rules like *Random Serial Dictatorship* and *Markov chain* inspired models, especially in case of imperfect grading (i.e. when partial rankings are not consistent to the ground truth). In [8], the authors have defined other peer assessment approaches based on models that represent probabilistic distributions over rankings, obtained from the models of *Mallows* [17], *Bradley-Terry* [18] and *Plackett-Luce* [19]. Such models have demonstrated better performance with respect to Borda also in case of imperfect grading and are also capable of detecting meaningful cardinal grades.

3.2 Fuzzy Ordinal Peer Assessment (FOPA)

In [9], an alternative ordinal peer assessment model named *FOPA* is defined. Applying this model, each student $s_j \in S$ is asked to define a *fuzzy ranking* R_j over the subset S_j of her assessees. Such fuzzy ranking is defined as a sequence:

$$s_{p(1)}^j \sigma_1 s_{p(2)}^j \ldots s_{p(k-1)}^j \sigma_{k-1} s_{p(k)}^j \tag{4}$$

with $k \leq m$. Terms in odd positions in the sequence represent elements of S_j while $p : \{1, \ldots m\} \rightarrow \{1, \ldots k\}$ is a k-permutation function. Terms in even positions belong to the set of symbols $\{\gg, >, \geq, \approx\}$ and define a degree of preference between subsequent terms in the sequence (with $\gg$ meaning "is much better than", $>$ "is better than", $\geq$ "is a little better than" and $\approx$ "is similar to"). Each submission appears at most once in the ranking so cycles are not allowed although partial rankings are admitted.

For example, let suppose that the student s_1 has to evaluate the subset of students $S_1 = \{s_2, s_4, s_5, s_6\}$. By proving the ranking $R_1 = (s_4 \gg s_5 \approx s_2 > s_6)$ she states that, according to her opinion, the submission of s_4 is much better than that of s_5 that, in turn, is at the same level of the submission of s_2 that, in turn, is better than the submission of s_6. The main advantage of this approach is that students not only order the submissions from the best to the worst but also express a degree of preference between them. Moreover, it mitigates the *bias* problem given that students provide relative evaluations that consider only a couple of submissions at a time.

According to [9], provided fuzzy rankings are then transformed in fuzzy preference relations, expanded to estimate missing values and then aggregated through ordered weighted averaging. From the aggregated relation, the global score $\phi(s_i)$ is calculated for every $s_i \in S$ and the submissions are ranked accordingly. The *cardinal grade* of each submission is then calculated by asking a reliable expert (e.g. the teacher) to grade the best and the worst submissions (i.e. the first and the last in the final ranking obtained through FOPA) and by normalizing the global scores according to these values.

Let g_{min} and g_{max} be the grades assigned to the best and the worst submissions, the estimated grade g_i for every $s_i \in S$ is obtained as follows:

$$g_i = \frac{(\phi(s_i) - \phi_{min}) \cdot (g_{max} - g_{min})}{(\phi_{max} - \phi_{min})} + g_{min} \tag{5}$$

where ϕ_{min} and ϕ_{max} are the global scores associated to the best and the worst submissions.

4 Experiment and Evaluation

To evaluate the capability of FOPA in supporting formative evaluation in comparison to the other peer assessment models discussed in Sect. 3, we have experimented them within a course on *Computer Skills for Education* of a M.S. degree in Pedagogical Sciences at the University of Salerno. In particular, the experiment was aimed at measuring at what extent each model is able to estimate the grade assigned by the teacher to every student based on imprecise ordinal feedback provided by students themselves. In the next subsections, we describe the experimental setting and, then, we illustrate and analyse the collected data.

4.1 Experimental Setting

The experimental set was composed by first year students taking part in a 20 h course on *Computer Skills for Education* aimed at developing basic competencies on computer architectures, computational thinking and coding. The course, that is part of a 5-year M.S. degree in Pedagogical Sciences, was held through traditional face-to-face lectures and exercises sessions.

The formative evaluation experiment was performed in classroom in two sessions, held in two different days of the same week, with 25 voluntary students. In the first session students have been asked to complete and submit a coding exercise while in the second session students have been asked to assess the submissions coming from a subset of their peers by providing a fuzzy ranking as defined in Sect. 3.

The peer grading task was performed in a blind mode in order that students do not know whom they are assessing. The same submissions have been also assessed by the course teacher to build the ground truth with which to compare the results coming from experimented peer assessment models.

4.2 Data Collection

A total of 11 students over 25 completed the first session by submitting a solution to the proposed exercise while the remaining 14 were not able to complete the task. For this reason, during the second session students were divided in two groups: the first including those that submitted their solution and the second including the remaining ones. Students of the first group (being considered more proficient) were asked to evaluate 5 submissions (over the 11 available) while students of the second group were asked to only evaluate 3 submissions.

To assign the submissions to assessors, two assessment grids have been generated: the first 11×11 grid involved students from the first group both as assessors and as assessees while the second 11×14 grid involved students from the first group as assessees and students from the second group as assessors. In both cases, Eq. (1) was applied to generate the assessment grid.

Only 17 students over 25 completed the second session by providing a fuzzy ranking: 10 coming from the first group and 7 coming from the second one. All provided fuzzy rankings were complete i.e. all assigned submissions were covered by them. The 11 submissions were also evaluated by the teacher in the range [0,30]. The provided fuzzy rankings as well as teacher assigned grades (true grades) are summarized in Table 1.

4.3 Evaluating Peer Assessment Models

We have applied FOPA and the other peer assessment models introduced in Sect. 3 on collected data both to demonstrate the effectiveness of ordinal peer assessment in the estimation of student grades and to compare the results obtained by each model with respect to teacher assigned grades.

The Table 2 shows, for each student, the true grade, the grade estimated by FOPA, those estimated by the models of *Mallow* (MAL), *Score-Weighted Mallows* (MALS),

Table 1. Students' provided fuzzy rankings and true grades assigned by the teacher.

Student	Assessees	Fuzzy rankings	True grade (0–30)
s_1	$\{s_2, s_4, s_7, s_9, s_{11}\}$	$s_4 \geq s_{11} \geq s_9 \approx s_7 \approx s_2$	18
s_2	$\{s_3, s_5, s_6, s_8, s_{10}\}$	$s_3 \geq s_{10} \approx s_5 \gg s_8 \approx s_6$	10
s_3	$\{s_1, s_4, s_6, s_9, s_{11}\}$	$s_4 \gg s_{11} \geq s_9 \geq s_1 \geq s_6$	24
s_4	$\{s_1, s_3, s_5, s_8, s_{10}\}$	$s_{10} \geq s_3 > s_5 > s_1 > s_8$	30
s_5	$\{s_1, s_3, s_6, s_8, s_{11}\}$	$s_3 \gg s_{11} > s_8 > s_1 \gg s_6$	13
s_6	$\{s_2, s_4, s_7, s_9, s_{11}\}$	–	18
s_7	$\{s_1, s_2, s_4, s_6, s_9\}$	$s_4 \gg s_9 > s_1 > s_6 \geq s_2$	10
s_8	$\{s_2, s_5, s_6, s_7, s_{10}\}$	$s_{10} \geq s_5 > s_2 \geq s_7 \approx s_6$	11
s_9	$\{s_3, s_5, s_7, s_8, s_{10}\}$	$s_3 \gg s_{10} > s_8 \geq s_5 \approx s_7$	18
s_{10}	$\{s_2, s_4, s_7, s_9, s_{11}\}$	$s_4 \gg s_{11} > s_9 > s_7 \geq s_2$	28
s_{11}	$\{s_1, s_3, s_5, s_8, s_{10}\}$	$s_3 > s_{10} \gg s_8 \approx s_1 \approx s_5$	26
s_{12}	$\{s_4, s_9, s_{11}\}$	$s_4 \gg s_9 \geq s_{11}$	–
s_{13}	$\{s_4, s_5, s_{10}\}$	$s_4 \gg s_5 \approx s_{10}$	–
s_{14}	$\{s_1, s_5, s_{11}\}$	–	–
s_{15}	$\{s_2, s_6, s_7\}$	$s_7 \gg s_2 \approx s_6$	–
s_{16}	$\{s_1, s_3, s_8\}$	–	–
s_{17}	$\{s_2, s_7, s_{11}\}$	$s_{11} \gg s_7 > s_2$	–
s_{18}	$\{s_2, s_5, s_{10}\}$	$s_{10} \gg s_2 \geq s_5$	–
s_{19}	$\{s_4, s_6, s_9\}$	$s_4 \gg s_9 \geq s_6$	–
s_{20}	$\{s_3, s_8, s_{10}\}$	–	–
s_{21}	$\{s_4, s_8, s_9\}$	–	–
s_{22}	$\{s_3, s_5, s_{10}\}$	–	–
s_{23}	$\{s_2, s_7, s_{11}\}$	$s_{11} \geq s_2 > s_7$	–
s_{24}	$\{s_3, s_6, s_8\}$	–	–
s_{25}	$\{s_1, s_6, s_9\}$	–	–

Bradley-Terry (BT) and *Plackett-Luce* (PL) as defined in [8], and the grade obtained using the Borda count defined by Eq. (3). While FOPA and the Borda count have been implemented in *Matlab*, we used the freely available *PeerGrader* software[1] for the MAL, MALS, BT and PT models.

Equation (5) is used to obtain cardinal grades from the scores associated to each submission. The performance of each model is measured both in terms of *Correctly Recovered Pairwise Relations* (PCRPR) and *Root Mean Square Error* (RMSE). With respect to PCRPR, as it can be seen in Table 2, all models rank the submissions in the same order reaching a 90% of similarity to the ranking made by considering teacher assigned grades. With respect to RMSE, the models behaviour ranges from a minimum error of 2.4, obtained by FOPA, to a maximum error of 2.9, obtained by Borda.

According to such results, we can assert that ordinal peer assessment is a valuable approach to support formative evaluation and is capable of estimating quite accurately

[1] www.peergrading.org.

Table 2. True grades compared to grades obtained with peer assessment methods.

Student	True grade	FOPA	MAL	MALS	BT	PL	Borda
s_1	18.0	15.7	16.0	14.6	14.7	14.3	12.0
s_2	10.0	9.8	9.0	11.1	11.5	10.8	14.0
s_3	24.0	28.0	27.7	26.9	27.1	26.6	25.0
s_4	30.0	30.0	30.0	30.0	30.0	30.0	30.0
s_5	13.0	15.6	18.3	15.9	16.2	15.1	17.0
s_6	18.0	9.0	9.0	9.0	9.0	9.0	9.0
s_7	10.0	11.0	11.3	11.9	12.2	11.7	14.0
s_8	11.0	14.1	13.7	14.9	15.1	14.1	13.0
s_9	18.0	19.6	20.7	19.7	20.3	19.9	18.0
s_{10}	28.0	24.1	25.3	23.6	24.4	23.7	27.0
s_{11}	26.0	23.5	23.0	22.0	22.5	22.1	24.0
Mean	17.9	18.2	18.5	18.2	18.5	17.9	18.5
PCRPR		0.9	0.9	0.9	0.9	0.9	0.9
RMSE		2.4	2.7	2.8	2.8	2.6	2.9

teacher assigned grades, at least in the considered sample. Only small differences can be appreciated with respect to the selected model. In particular, FOPA presents the minimum error but slightly increases the mean grade of the class with respect to teacher assigned grades. Instead, PL shows a slightly greater error rate but it maintains a greater fidelity with respect to the mean grade.

4.4 Additional Experiments

It should be noted that, while FOPA is able to fully interpret collected fuzzy rankings, the other models need to translate them into ordinal rankings before use. In particular, while Borda just interprets the $>$ symbol, MAL, MALS, BT and PT can also interpret the $\approx$ symbol (i.e. they admit ties). The symbols $\geq$ and $\gg$ within fuzzy rankings are so translated in the symbol $>$ before using them with methods different from FOPA. The $\approx$ symbol is also removed with Borda and an artificial random order is introduced between the adjacent symbols.

Given this difference, an additional experiment has been performed to investigate the behavior of FOPA when put under the same conditions of the other methods i.e. when using modified fuzzy rankings rather than the original ones. In such conditions, FOPA ended up with a 2.7 RMSE (with 0.9 PCRPR) so 0.3 points are lost with respect to the preceding settings. So, we can conclude that the contribution of fuzzy symbols is remarkable but not decisive in the estimation of teacher assigned grades.

Two additional experiments have been performed so far to evaluate how the models under examination perform with a reduced set of ranking strings. As said, students have been assigned to two groups, a first group including "more proficient" students and a second group made of "less proficient" ones.

The rows 1–3 of Table 3 show the results obtained by all peer assessment models by considering only fuzzy rankings coming from the group of "more proficient"

Table 3. Performance considering a subset of available fuzzy rankings.

Group	Measure	FOPA	MAL	MALS	BT	PL	Borda
1	Mean	19.1	17.6	18.7	18.9	18.7	17.9
	PCRPR	0.9	0.9	0.9	0.9	0.9	0.8
	RMSE	2.9	3.0	3.0	3.0	2.9	3.6
2	Mean	16.2	18.3	17.3	17.6	17.6	17.9
	PCRPR	0.8	0.6	0.7	0.8	0.8	0.6
	RMSE	4.7	7.8	4.8	4.7	4.8	8.7

students. With a lower amount of data available, all the models result in slightly higher error rates, while keeping the adherence to the teacher ranking almost unaltered. The consideration that can be drawn is that adding evaluations improve the peer grading process even in case of dubious reliability of the new evaluations.

The rows 4–6 of Table 3 show, instead, the results obtained by considering only fuzzy rankings coming from the group of "less proficient" students. As it can be seen, basing on a lower amount of data that, in addition, is of a worst quality, all models result in significantly higher error rates. In particular, Borda and MAL show the higher increase in RMSE (+5.8 for Borda, +5.1 for MAL) while BT shows the lowest one (+1.9). The adherence to the teacher's ranking also lowers drastically with values ranging from 60% to 80%. Nevertheless, also in this case FOPA shows the best performance.

5 Final Remarks

In this paper the results of an experiment aimed at introducing peer assessment as a tool for formative evaluation within a University course on *Computer Skills for Education* are presented. The performance of several peer assessment models in estimating the grades assigned by the teacher are measured and compared. Obtained results confirm that it is possible to estimate with a satisfactory degree of reliability student grades even based on imprecise ordinal feedback provided by students themselves.

The application of alternative aggregation models offers better results with respect to the classical Borda count. In particular, FOPA (the proposed model based on Fuzzy Set Theory and Group Decision Making) outperforms the other models in almost all conditions, at least in the limited framework of the performed experiment. The obtained results are so encouraging and suggest to extend the experience to other courses, both in Sciences and Humanities.

A weakness of the proposed approach is that the contribution of the introduced fuzzy symbols $\geq$ and $\gg$ is remarkable but not decisive to differentiate FOPA performance with respect to other models. One wonders whether using fuzzy numbers (maybe in form of linguistic labels) instead of fuzzy symbols can improve performance by better characterizing the uncertainty coming from students evaluation. This suggests to direct future research activities toward model improvement in this sense. Moreover, in [3, 6] it has been demonstrated that, weighting the grades proposed by assessor students based on their performance, can contribute in improving the reliability of final grades. To verify this occurrence also for ordinal peer assessment methods, we plan to introduce similar weighting techniques also in FOPA relying on *influence-based* fuzzy models like that introduced in [20].

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How RU? Finding Out When to Help Students

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Abstract. Understanding how students are feeling can assist Animated Pedagogical Agent (APAs) to provide helpful tailored support. However, eliciting their emotions is difficult. The research examined student's willingness to disclose their emotional feelings to the APA and whether being asked was disruptive or annoying. Nineteen high school students used a Virtual World (VW) designed to learn scientific inquiry skills. Emulating human behavior, the APA greets students by asking "how are you?" and provides an empathic response. However, students could ignore the empathic conversation and move on to a task-focused conversation. We found that students were willing to disclose both negative and positive emotions to APAs, on average once in every ten times they were asked. Furthermore, students preferred to reveal their emotions when they first met a character rather than in the subsequent meetings and negative feelings became stronger than positive feelings in repeated encounters.

Keywords: Animated pedagogical agent · Virtual worlds · Emotions

1 Introduction

Getting timely feedback and support during the learning process is important. A key benefit of an intelligent tutoring system is timely help [1]. This help could be provided by an animated pedagogical agent (APA), an animated lifelike character with teaching goals and strategies for achieving these goals in a learning environment [2]. A body of research exists exploring the potential of APAs to aid in the learning process and provide emotional support [3–10]. Moreover, the anthropomorphous features and social abilities of APAs elicit psychological responses from learners [11]. APAs can make the computer-based learning environment more interactive, engaging and efficient [12]. To identify the right time to support the student, the APA needs to distinguish between whether the student is deep in thought and working on the learning task at hand or stuck and disengaged. In the first case, an intervention would be disruptive and unhelpful.

This work is part of a larger project involving the design and evaluation of a Virtual World (VW) where secondary school students learn about science inquiry, ecology and biology through virtual hands on experiences. Students are able to collect data through navigation, observation and interacting with virtual humans and animals. In line with the pedagogical theory underlying our VW, known as productive failure [13], we do not

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want to tell students how to solve the problem but let them use trial and error to work out the answer for themselves. However, if they are unable to proceed, we want to step in and provide motivational and/or meta-cognitive assistance. Our VW and associated workbooks collect data on the educational progress of the student to inform meta-cognitive advice. However, we need some strategies to support their motivational levels.

In previous versions of this VW, we had implemented an APA who welcomed the student and orientates them in the VW. When the student wanted help they could use the phone symbol to "call" the APA. This approach relies on the student taking the initiative while the system is passive. Some researchers have used surveys, emoticons (e.g. [14]) or emotive aloud methods to elicit emotion. The timing of these requests may be linked to a timepoint in the activity, time-based at regular intervals or even random. In other research we are exploring the use detection of emotion via facial expression and behaviours such as navigation paths, log files and workbooks. However, in this paper we focus on an alternative human-like and proactive strategy delivered by the APA. We chose to emulate the human practice of asking "How are you?" to elicit one's emotional state. In the strategy, when a student approaches any of the main characters in the VW, the virtual human asks the students how they are feeling. However, we were concerned that students might find the request unhelpful.

Specifically, we wanted to see whether this strategy provided us with a means to find out the emotional state of the user so we could empathize with them, or to what extent the strategy could be used before it was ignored. To test our strategy, this study seeks to answer the following research questions:

Is a student willing to disclose their emotions to a virtual character in order to get empathic support?
If so, how often is the student willing to disclose their emotion?
When do students stop disclosing their emotion?

Following a review of related literature, we present our methodology, then results, discussion, limitations, future work and conclusions

2 Literature Review

In learning environments, affective and elaborate feedback has been shown to be an important factor to deliver motivation and performance in student learning [15]. APAs facilitate student learning by performing supporting roles in instructional environments. Moreover, the pedagogical agent provides an opportunity to simulate human, peer-like interaction [16]. Such social interaction is a key mechanism in computer-based learning [17].

2.1 Human-Computer Educational Support

The environments in which children learn have a significant impact on their learning and development. Positive teacher-student relationships have been found to have a powerful impact on students' achievement in the classroom in terms of educational, behavioral and social adjustment [18]. However research on anthropomorphic interactive agents revealed that proactive assistant behavior seemed intrusive [19]. Xiao et al. [19] conducted a between-subjects experiment with 49 university students who interacted with a 3D animated female interface during the given editing task. In three different conditions, three groups encountered either a proactive assistant, a reactive assistant or a manual. The first two groups were controlled using a Wizard of Oz technique. In the reactive condition, the assistant agent offered helped upon request whereas in the proactive condition the assistant agent also offered unsolicited help. In the last condition participants were given a manual with several printed pages containing information pertinent to the task. In terms of user performance, the study showed that there was no significant difference between the methods with or without an agent. However, Xiao et al. [19] argued that the task given to all groups was limited and straightforward so the results were acceptable at this stage. They conjectured that in a more complex learning classroom-based task the needs and benefits of having a spoken agent who helps emotionally and academically would increase.

2.2 Human-Computer Emotional Support

In addition to educational support, to help students emotionally, we need to assess the user's emotions. Early work in the field of affective human-computer interaction indicated that virtual characters were able to reduce negative emotions in users [20]. Several models of affect detection have been developed in virtual learning environments. Some researchers have utilized sensor-based physiological approaches employing technologies and equipment such as microphones, facial expression sensors (e.g. camera and webcam), conductance bracelet (i.e. skin conductivity sensor), pressure mouse and posture analysis seat to detect emotional behaviors such as facial expressions of the user, user's body posture, tones and dialogue acts and then give emotional support (e.g. [21, 22]).

Other researchers have used psychology-based theories such as the OCC theory [23] of emotional appraisal in learning environments to predict students goals based on their personal traits and behaviors (e.g. [24]). While virtual agents are now able to respond emotionally based on psychological theories [25], delivering emotionally supportive and appropriate responses based on the user's emotional state in learning contexts is still a difficult and under-explored question. For example, Castellano, Paiva [26] had mixed results with their empathic tutor. From the agent's point of view to convey empathetic support, requires exhibiting shared emotional responses, care for the users, and willingness to help them. Previous studies has shown that agents with emotional sensing capabilities are perceived as more caring, likeable and trustworthy than agents without empathic capabilities [27, 28]. Capability of expressing social cues are important for APAs such as sympathy for the user when they are sad or frustrated, encouraging the user when they are bored or anxious, giving compliments when they are satisfied or confident and mirroring the user's emotional states.

3 Methodology

We sought to address the research questions in the context of an actual school classroom where students were engaged in learning using the science inquiry virtual world introduced earlier. Providing authentic contexts is not easy and involves obtaining not only approval of our University's Human Research Ethics Committee but also subsequent ethics approval from the Department of Education in our state, the interest and commitment of a teacher and their head of department, relevance to the Australian national curriculum, written approval of the school principal, written consent of parents, scheduling of the study within appropriate classes, and coordinated set up of rented computers and other additional equipment loaded with the innovative technology. After some months of negotiation and preparation, we gained approval within a metropolitan-based girls-only comprehensive (i.e. range of academic achievers) public high school in October 2016.

Participants were invited by the Science teacher via sending information and consent forms to be signed by the parents. Nineteen girls attended a full-day 4-hour study conducted in one of the school classrooms that involved working through 5 different learning modules provided in an online workbook. Three of the modules involved use of our VW. Ten girls worked in pairs while nine girls worked on their own. This produced 14 sets of student data. This data includes navigation logs (mouse and key strokes), conversations and interactions data, workbook answers, academic abilities, student's personality and real-time videos and audios recordings of their face as well as interactions of the computer screen. As data collection covered the bigger project, we only report data and our findings relevant to the research questions presented in this paper. The form of their interaction with the VW is described below.

At the start, a virtual character provides orientation by introducing the problem that a fictitious animal species is dying out and seeks the assistance of the student to solve. Students then begin exploring the five locations in the VW for students to visit: Animal Counting Station, Hunting Ground, Research Lab, Village and Weather Station. Six interactive virtual agents, each with a different role, can be found at these different locations. Students collected information from the five locations by talking to the virtual agents. Each character has a list of seven to nine questions and a "goodbye" statement to indicate the end of conversation. Students will then answer questions in the online workbook. When the user approached a character in the VW, the character waved its hand as shown in the middle and right screenshots in Fig. 1 and asked about the users' emotional feeling by asking questions like "Hi, how are you today?" or "Hi, I have been expecting you. How's it going?" to convey empathic support.

For this study we modified the behavior of the virtual agents by allowing students to respond to the agents' "How are you?" questions either by expressing their feelings from multiple choices of answers (frustrated, interested, confused/stressed, confident/proud, bored or satisfied) or by avoiding giving an emotional response by choosing the option "Can I ask a question?" (See Fig. 1 right). These options came up in random order to avoid the same emotion being selected based on its position. We did not choose basic emotions such as happy or sad but emotions more commonly reported in academic contexts such as boredom, frustration, enjoyment, interest and confidence/pride [29].

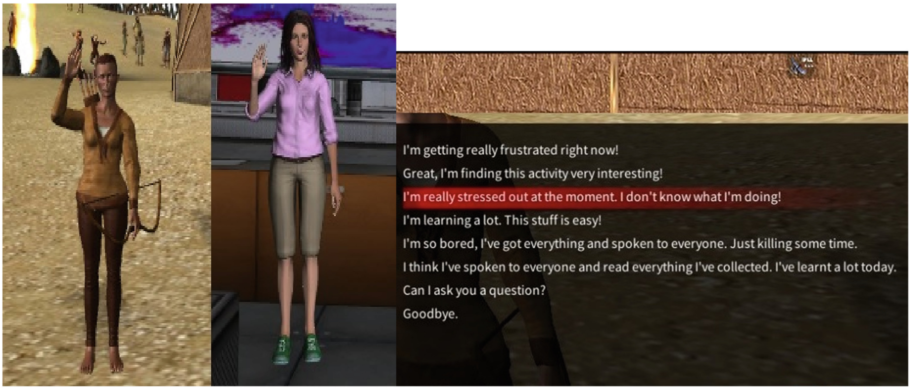

Fig. 1. Virtual characters (left) and Possible emotional responses (right).

In the design of these virtual characters our goal was to elicit the student's emotion but minimize interruption and to test how often students exercised the option of not expressing their emotional feeling. To make the conversation more human-like and to help the student reflect on what they were feeling, we also chose to use sentences to express the feeling rather than simply the word or emoticon. Talking to the character served two purposes in our study by providing; (1) empathic dialogue involving capture of the student's emotion with a corresponding supportive response; and (2) information about the virtual world including the virtual characters, animals and their activities. As a result, as students move around the island they will encounter characters multiple times and be asked how they are multiple times.

As shown in Table 1, 82 times in total students expressed their emotional feeling. In contrast, 819 times they preferred to ask a question about the VW. This indicates that on average only once for every 10 times they are asked "How are you?" they are inclined to say how they are feeling. The table also indicates that 52.4% of the time students had positive feelings (interested 31.7%, satisfied 12.2%, confident 8.5%) while 47.6% the feelings were negative (anxious 15.9%, bored 12.2%, frustrated 19.5%). Feeling 'interested' was the most selected emotional feeling. Furthermore, the feeling 'interested' was elicited 26 times from only 6 out of 14 groups of student/s. Moreover, feeling 'satisfied' was expressed 10 times from 8 groups. The number of groups experiencing negative feelings were 17 compared to 18 for positive feelings. Moreover, the number of times the negative and positive feelings were clicked was 43 and 39, respectively. Out of 14 groups of participants, 2 had declined to express any feeling to any character. The average number of groups that expressed each emotion was 6.

Figure 2 illustrates chronologically the number of times students expressed emotional feelings. The maximum number of times a character has been visited was 14 times. As shown in Fig. 2, on the first visit to a character, 12 different groups/students expressed their feelings, however as time passed and students visited the characters more, they were less likely to express their emotional feelings. The number dropped from 12 to 1.

Table 1. Elicited emotions in each group

Emotion	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	Freq	%
Anxiety	2	1	1			6	1			1		1	13	15.9
Boredom		1	2	1	3	1			1	1			10	12.2
Confidence			2	1	3	1							7	8.5
Frustration	12								3		1		16	19.5
Interest		8	3	7	3		2	3					26	31.7
Satisfaction		1	2	1	1		2	1		1	1		10	12.2
Total	**14**	**11**	**10**	**10**	**10**	**8**	**5**	**4**	**4**	**3**	**2**	**1**	**82**	**100**

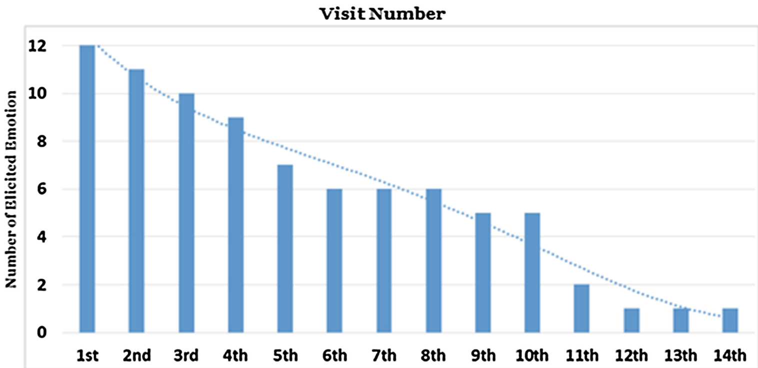

Fig. 2. The number of elicited emotions in each time meeting characters

Table 2 shows the different types of emotions at different times. The 1st half time refers to the first 7 visits to a character whereas 2nd half time applies to the last 7 visits to a character. 79% of all expressed positive feelings were in the 1st half and 21% in the 2nd half meetings. Among all expressed negative feelings, 69% were in the 1st half meeting and 31% in the 2nd half meetings. The result confirms the previous finding which students declined to propose their emotional feelings as time passed in the study.

On average, in the first half time 56% of the emotions chosen were positive (interest, satisfied, confident) in comparison with on 43% in the second half. This amounts for the negative feeling time were 44% and 57% respectively for the 1st and 2nd half meetings.

Figure 3 drills down further to reveal what particular emotion was expressed at their first to final meeting. We note that in the 12th, 13th and 14th times visiting a character the only emotional feeling was the negative emotion of frustration.

Table 2. Different emotions in different times

(a) Times per emotional feelings			(b) Emotional feelings per time		
Time/Feeling	Positive Feeling	Negative Feeling	Feeling/Time	1st half time	2nd half time
1st half time	79%	69%	Positive Feeling	56%	43%
2nd half time	21%	31%	Negative Feeling	44%	57%
Total	100%	100%	Total	100%	100%

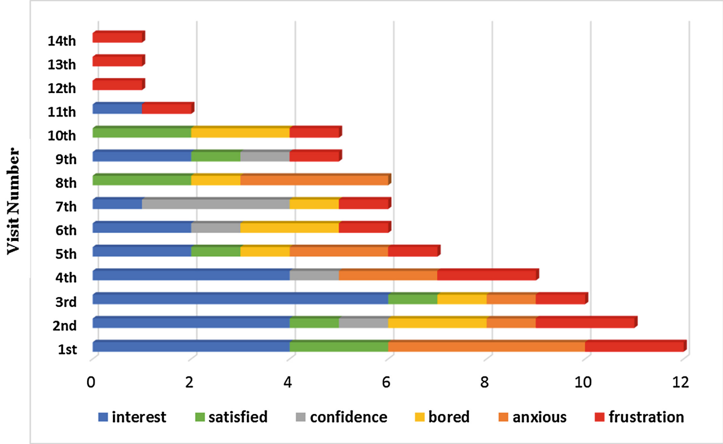

Fig. 3. Overall emotions weights in each time meeting characters

4 Discussion

The responses provided for students in reply to "How are you?" do not necessarily convey all possible emotions the students could be feeling. To design the students' emotional responses we have taken inspiration from the research around empathic APAs, particularly the work of Kim [14], Gwo-Dong et al. [5] and Villarica and Richards [30]. We sought to cover six key emotional states (interested, bored, confident, anxious, satisfied and frustrated) related to learning in a form of text that the user can click on to indicate what emotional state they are in. These sets of complex emotions are not completely disjoint. Students could also experience more than one emotional feeling at a time. From 14 groups of participants, only 2 groups did not respond to any of the characters' empathic questions. Thus, in answer to the first research question, we conclude that students are willing to disclose their emotions to a virtual character. Overall, students were willing to disclose both negative and positive emotions fairly equally (52% positive versus 48% negative). Thus, as the number of times participants expressed negative and positive emotions were not significantly different, we conclude that students would tell the character both negative and positive emotions.

To answer the second research question (“If so, how often is the student willing to disclose their emotion?”), we found that on average students expressed their emotion once in every ten times they were asked. Furthermore, they preferred to express their feeling more when they first meet a character and as they continued to respond there was an increase in negative emotions being expressed. This could be because of frustration of being repeatedly asked or frustration in not having completed their task yet. We did not gather data that would allow us to confirm either of these conjectures.

Finally, we answer the third research question, “When do students become annoyed or stop disclosing their emotion?” In the first half of meetings with a character, students experienced slightly more positive emotions than negative whereas in the second half meetings they felt slightly more negative than positive feelings. While the difference was not high, the increase in negative emotions could show that as time passed they got more annoyed with being asked or they found the task more boring or frustrating. To support this statement, there were only frustration emotions in the last three times meeting a character. According to Veletsianos [11] if learners consider a character to be inappropriate and annoying, they would not pay attention to it while completing the task (e.g. Clippy [31]). However, this did not seem to be the case, although the responses did get more negative over time, the users did not ignore the APA.

Regardless of the type of emotions revealed by students (negative/positive), as time passed they were disinclined to answer the empathic questions (74% responses in the 1st half and 26% in the 2nd half meetings a character). This indicates that asking empathic questions such as “How are you?” to elicit the student’s emotion is not critical to be asked every single time student meet a character unless if the character is meant to make a change into students’ negative emotional feelings. Therefore, as more character ask “how are you?” it becomes more annoying.

In summary, around one-tenth of the time, typically when they first met a character, students chose to engage in an empathic conversation. This is similar to [1] observation that students may interrupt the help offered by an APA to seek other help that is perceived as more useful. Heiner, Beck [1] indicate that interrupting an APA’s help by students could be the result of being bored, tired, lazy, impatient, or rude. Our empathic conversation was only limited to asking the student’s emotional feeling. As our goal was to keep track of emotional trend of the student during the task it was necessary to keep asking the student. However, while each character had a unique set of responses one for each emotion, the set did not change. The student may have come to realize the limited nature of the responses and thus chosen not to continue to express their emotion.

5 Conclusion, Limitations and Future Work

This work presented the effects of interrupting students for their emotional feelings by empathic APAs. We found that students are willing to disclose their emotional feelings to an APA. Furthermore, this work shows that students are more willing to express their emotion when they first meet a character rather than in the subsequent meetings.

The main limitation of this study is the number of participants and lack of male participants. There were only 14 groups of participants (19 students) in this study. We have conducted a second study at a coeducational (i.e. male and female students) high school to address this issue and collect more data that would allow us to build a comprehensive profile of the student (such as personality, attitudes to school and science). Also due to our concern about the appropriateness of being asked how you are every single time the user meets a character, in our second study we limited the greeting to only the first visit with a character. Thus this second study collected much less data on responses to the "How are you?" question and will focus on different research questions to be reported in a future publication after the data has been analyzed. Also to be reported in future publications is ongoing work to detect engagement from students' behaviours in the VW and associated online workbooks and to build a model to predict student engagement from the facial expressions and body postures recorded in videos collected in both of these studies. The use of behavioural and sensory data provided a more objective and less obtrusive measure for detecting emotion and when an APA should intervene. Other future work beyond the use of our current project with the Omosa VW could target different disciplines (STEAM) and learning modes (blended and full eLearning).

We want now to investigate firstly what happens when the APA is empathetic in a greater variety of ways and reacts more to the user's presumed emotional state. We are using an OCC based agent modeling tool for this work. Also we can use the learner model for effectively and consider why students may be visiting the same knowledge source repeatedly, then help them in their study.

If we do find that students start to interact more with such an agent, then we want to consider how much use is made by students of the advice and help she gives. To what extent would they trust the character? Would her interventions be useful or distracting so they are ignored? Considering that, in future we want to evaluate if the information delivered by our characters are credible. This paper is one step forward towards the goal of having empathic APAs as learning support in a VW.

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Principles for an Effort-Aware System

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Abstract. Learners require a certain effort to acquire a specific skill or competence. The invested effort can be affected by many factors as previous knowledge, abilities or time available for learning. The evaluation of the effort has been mainly related to cognitive science or instructional psychology due to the relation between effort and mental work. This paper focuses on how the effort can be estimated on e-learning systems. This information can enhance instructional process since teachers can analyze the total time learners invest on acquiring knowledge and they can adjust better the complexity of the course. The paper contributes on principles to design an effort-based system. Finally, a particular application to an intelligent tutoring system is performed.

1 Introduction

The effort on learning has always been a problematical indicator to evaluate students. The invested effort does not always imply that a skill has been acquired. Moreover, distinct effort is required for each learner and skill, but the effort and the acquisition of knowledge are somehow correlated. Different contributions have been proposed to tackle the problem. For instance, time spent studying can be estimated: student's self-reports [1], the period of the week (i.e. daily or weekend) [2], class attendance [3], consistent effort across semester [4]), time off task [5] or mental effort [6, 7], among others. All these contributions are based on student's perception or self-reports. Thus, the consumed time is approximated and error-prone based on student's opinion.

The interest for the invested effort is growing for the instructors' point of view. Currently, there are some methodologies or technological approaches to estimate this time but they are not used during the teaching process. The information is merely used as analytical data as another indicator of the instructional process. Consequently, there are many courses where the workload is disproportionate compared to the expected time the learner would have to invest and it is not taken into account during the assessment process. VLE (Virtual learning environments), MOOC platforms and e-learning systems have started to help instructors on this problem. Current systems log extensive information related to learner's actions such as submissions and learning resources usage, and this data can be processed to generate significant reports on learning analytics systems [8].

However, those systems are not always accurate on this information when the effort is performed out of the e-learning system. For instance, let us assume an assessment

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activity where the learner must write an essay. Mostly, the learner will use a word processor locally installed on her computer and the time spent on this task will not be recorded by the VLE system.

This paper aims to describe an approach to tackle this problem. Based on techniques related to timestamping, a system could be capable of estimating better the effort the learner spent on each task even in offline mode.

The paper is organized as follows. Section 2 introduces the effort-based timestamping approach to record learner's effort. Section 3 describes how this technique can be deployed on an e-learning system. A particular application is presented in Sect. 4 for an intelligent tutoring system (ITS). Finally, Sect. 5 analyzes the findings of a study case based on the ITS of the previous section, and conclusions and future work are summarized in Sect. 6.

2 Effort-Based Timestamping

Before explaining the design of an effort-aware system, this section describes the conceptual background.

In this paper, we define *effort* as the time the learner spent performing a task. A task can be anything related to the learning process such as reading the textbook, solving exercises, performing assessment activities. The unit of effort can be set to any unit of time (seconds, minutes, hours, …) depending on the interested granularity.

We define two modes for collecting effort: real-time monitoring and deferred monitoring. Let us describe each mode individually in the next subsections.

2.1 Real-Time Monitoring

In this case, the task is performed within the e-learning system, such as an online questionnaire or playing a video. In this case, collecting the effort is basically to monitor when the learner starts and finishes the task. Thus, the next tuple is defined following the standard defined for xAPI [9]:

$$< \text{actor},\ \text{action},\ \text{object},\ \text{context} > \tag{1}$$

where *actor* refers to the learner, *action* to the action performed (i.e. started, attempted, completed…), *object* to the resource or activity, and *context* to the date where the action has been done.

The previous tuple individually does not give any significant information. The tuples should be combined to obtain meaningful information. Assuming that we have two tuples

$$< \text{actor},\ \text{action\_start},\ \text{object},\ \text{date\_ini} >,\ < \text{actor},\ \text{action\_end},\ \text{object},\ \text{date\_end} > \tag{2}$$

where *action_start* refers to any action that indicates that the learner is starting the task and *action_end* to any action meaning that the learner has stopped performing the task; the effort can be computed as

$$\text{Total\_effort} = \text{date\_end} - \text{date\_ini} \tag{3}$$

Combining this information, the system can collect all effort related to an object for each learner. Figure 1 illustrates the output of a real-time monitoring. The figure shows an example of a task where the learner has worked during three slots of time. The effort is showed with respect a specific interval of time, e.g. a semester.

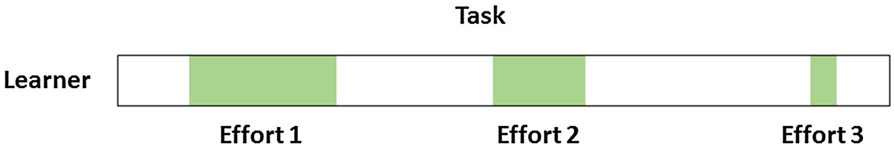

Fig. 1. Real-time monitoring

2.2 Deferred Monitoring

The previous model is the ideal case and the most efficient way to evaluate effort due to the system is tracking in real-time the effort. However, the learner is not always connected to the VLE. There are tasks where the effort is performed offline. Many tasks only require access to the VLE or e-learning system when the task is submitted, i.e. an activity in text format.

In this case, we propose a deferred monitoring where the effort is computed offline and submitted to the system at the same time than the task. There are simple solutions to add this information to the submitted task. However, this option requires some help from standalone or offline applications to keep track of the effort invested. In word processors, this help can be through a macro. In an ITS, it can be done by adding a module or plug-in.

Here, the same tuple format described in Eq. 1 can be used to store the effort within the task but with a particularity when the task is submitted. There is no need to keep track within the task the effort that has been already submitted. All the effort reported to the e-learning system can be removed from the offline task. Figure 2 shows an illustrative example of a deferred monitoring submission. Submission 1 informs about one effort produced continuously by the learner, meanwhile Submission 2 reports two efforts performed in two distinct intervals. As we can observe, Submission 2 only informs about effort non-yet reported to the system.

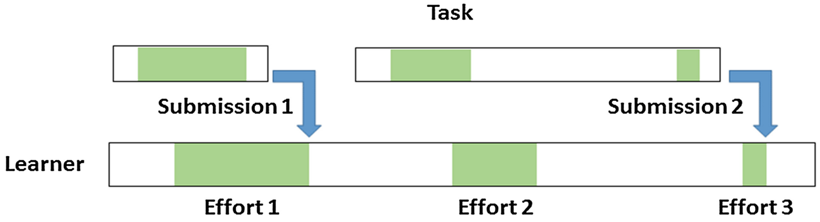

Fig. 2. Deferred monitoring

2.3 Learner-Aware Model

Previous monitoring modes assume that an individual learner produces the effort. However, the effort is not always from a unique one, i.e. a collaborative activity. Also, keeping track of the effort produced by all learners involved could help to identify plagiarism or enforce trustworthiness [10, 11].

For real-time monitoring, combining the effort of different learners can be simply done by knowing the learners involved in a collaborative task. For deferred monitoring, the logging of tuples works identical to Sect. 2.2 but tuples of multiple learners are kept within the task until it is submitted to the system. Then, the system will be responsible for merging the information. Note that, information such as the interaction among learners and parallel working on the task could also be known.

2.4 Pitfalls of the Model

Effort-based timestamping is not the most accurate model to approximate student's effort, but automatization is accomplished and self-records can be avoided. Compared to manual reporting, we consider a better model. However, many under-approximated or over-approximated records can be obtained. Some learners may not record some effort performed offline (i.e. not connected to the system) in both monitoring modes. Others may record out-of-task activities not associated with the current task.

Nevertheless, the outliers can be easily identified and normalized based on the average effort the learners invest in the activities. Several techniques can be used for outlier detection, [12, 13], even, a simple interquartile range (IQR) [14], among others.

3 Effort-Aware System

This section proposes an effort-aware system based on the two different monitoring modes described in the previous section. The system aims to be easily integrated into any VLE or tutoring system. The system is illustrated in Fig. 3.

The built-in modules specially designed for evaluating effort are described next:

- Effort client library: adaptation is required on standalone applications on deferred monitoring. The effort should be recorded in offline mode within the task. A library can be provided with a basic API to track the effort, although the adaptation should not be easy in some cases. Other approaches can also be applied. The design of a generic application to record effort similar to [15] could reduce the integration issues significantly. However, a manual start-of-art tool is not recommended since effort should be secured somehow within the activity to avoid manipulation before the submission.
- Online activity: In the online activity, the e-learning system is the responsible for tracking the effort. Most of the systems keep track on log files of the actions of the learner with the timestamp. Thus, this log files could be processed and the information related to the effort can be added to the online activity submission.

- Effort analysis: This module processes the received effort. The effort is extracted from the submission and it is further analyzed to obtain valid records. Different operations should be performed: (1) To compute effort based on the tuples described in Eq. 1; (2) to identify (different) learners and the activity involved in the submission; (3) to normalize in the case of outliers; and (4) to merge with stored effort. The complete process has to be thoroughly designed and we consider as future work.

The previous modules can be integrated into the submission workflow in custom VLEs or ITS without affecting the whole system. The next section introduces an example of an effort-aware intelligent tutoring system using the model described in this paper.

4 Study Case: Effort-Aware Intelligent Tutoring System

This section describes the adaptation of the intelligent tutoring system VerilUOC to an effort-aware system. VerilUOC [16] is a multi-platform GUI application for acquiring synthesis and analysis skills for digital circuits. Currently, VerilUOC is designed for first-year students on undergraduate courses. These students tend to have a weak background in the areas of computer architecture, electronics fundamentals and programming languages. In the context of VerilUOC system, the description of the circuits is performed graphically, not in Hardware Description Languages (HDLs), such as Verilog or VHDL, and the validation service using formal verification is embedded in the GUI application. Hiding the more complex aspects (HDLs and verification) increases the efficiency of the students and it allows them to focus on the learning concepts instead of technical aspects.

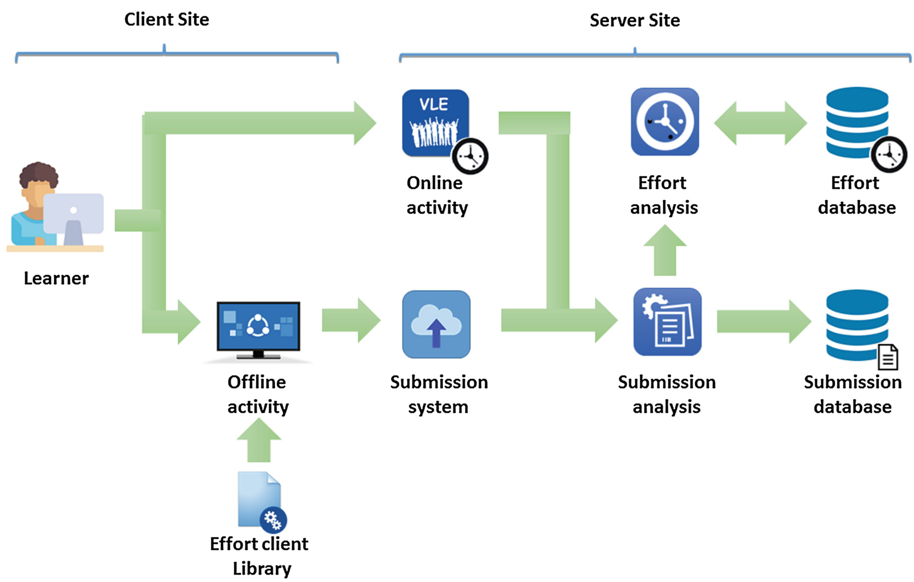

Fig. 3. Effort-aware system

This tool is currently used in the undergraduate course of Computer Fundamentals in the Bachelor of Computer Science at the Open University of Catalonia. Currently, VerilUOC has more than 150 exercises divided into four categories: tutorial, textbook, previous and current semester continuous assessment activities. Some learners are complaining about the tool. They feel overwhelmed with the large set of exercises and they claim that there is a significant overload in the practice part of the course. The initial objective of the tool was to have a large set of exercise but it was not mandatory to solve all of them. However, the course had incorporated some gamification rewards in the last editions to enhance engagement. Some rewards regarding extra points in the final score can be accomplished by obtaining badges and reaching the top score in a leaderboard based on the number of solved exercises. This gamification activity has increased the utilization of the tool but teachers were unable to evaluate the implications regarding effort. Thus, teachers decided to evaluate the effort based on the approach described in this paper.

Deferred monitoring was implemented based on the learner-aware model since VerilUOC is a standalone JAVA application where learners solve the exercises offline and, then, exercises are submitted and verified on the server side of the system. The exercises solved by the learners can be saved as files similar to a word processor. This feature helps students on their self-regulation by stopping and continuing the exercises at any time. The learner-aware model has been used to be able to analyze the plagiarism among students.

The tuple of Eq. 1 was used to store the effort estimation within the file. In the server site, the effort database has been designed to store the effort based on the next tuple:

$$< \text{learner\_id},\ \text{activity\_id},\ \text{owner\_effort},\ \text{date\_submission},\ \text{semester},\ \text{effort} > \tag{4}$$

where *learner_id* and *activity_id* identify the learner who performed the submission and the activity submitted respectively. *owner_effort* identifies the learner who performed the effort and *date_submission* and *semester* the timestamping information. Note that *learner_id* and *owner_effort* can be different. A file can be shared among learners and the latter will keep track of all learners who have contributed to the activity. Finally, the effort is stored in the last field.

Based on this tuple, the system is capable of identifying different efforts:

- The effort of the learner in the current semester: This is the real effort the learner has invested in the exercise. This effort is identified when *learner_id* and *owner_effort* are identical.
- The effort of the learner in previous semesters: This effort is identified when the *semester* field differs from the current semester. This information helps to keep track of repeater learners and effort between semesters.
- The effort of collaborators: This effort is identified when *owner_effort* differs from the current learner. This information is relevant to keep track of collaborations among learners.
- The effort of collaborators in previous semesters: It is identified similar to both previous efforts. This information aims to identify collaboration among learners between different semesters.

As explained in Sect. 2.2, when the exercise is submitted to verify its correctness, the effort is transferred to the server by using the following rules:

Rule (1) The own effort is transferred to the server and it is reset in the local copy of the exercise. Note that, the tuple is not deleted from the file, it is only set to 0. This helps to keep track of further collaborations among students within the current and different semesters.

Rule (2) The own effort in the previous semester is also transferred to the server and the local tuple is reset but not deleted. We assume that this effort is also the real effort of the user.

Rule (3) The effort of collaborators is annotated but the local tuple related to the other learner is not reset. We assume that this effort can be transferred by the owner at any time in the future.

Rule (4) The effort of other learners in previous semesters is also annotated and it is not reset in the local copy of the exercise. Similar to the Rule 3, we assume that the owner is the responsible for transferring the effort.

As we can observe, each effort-aware system can easily adapt the model to their objectives. There is no unique interpretation of the effort and there is no unique way to store it in the system. Here, the effort-ware system was focused on knowing the effort of the learner in the tool. Also, other information to detect plagiarism about learners and effort analysis on repeaters has also been considered.

Note that, the outliers' identification has not been yet resolved. Currently, the system stores the information as raw data since we are interested in answering the research question stated in this section: Are the learners investing the proper effort in the ITS described in the teaching plan of the course?

5 Findings

This section summarizes the analysis performed on Computer Fundamentals. Aforementioned, the research question is related to know whether the course is well designed regarding effort investment.

Computer Fundamentals is organized in three continuous assessment activities (CAA), a Final Project and a Final Exam. The scheduled effort for activity was estimated when the course was initially designed. During the past semesters, no modification was performed on the planned effort since instructors claimed that it was a correct distribution. The division in hours was 25, 37.5, 37.5 and 50 for the CAA1, CAA2, CAA3 and Final Project respectively. Note that, this effort encompasses study time of learning resources, the realization of assessment activities and problem-solving using the VerilUOC ITS. Thus, the hours invested in the ITS were estimated as 15, 15, and 25 for CAA2, CAA2 and Final Project; and an additional 10 h for each activity for non-assessment exercises in the ITS (i.e. 30 additional hours). Note that, exercises related to CAA1 are not included in VerilUOC.

In order to analyze the results, the effort of VerilUOC has been extracted individually for each assessment activity and aggregated by the complete course. Table 1 summarizes the results. The table shows the mean in hours, the median, the third quartile of the effort distribution and the maximum value Q3 + (1.5 * IQR) to detect outliers. Note that this value is considered the limit for a value to be considered an outlier based on the inter-quartile range statistical analysis [14]. The mean and the median are shown to observe the difference between the average value of all invested effort and the middle point of the effort distribution. As we can observe, the mean value is highly influenced by students that invest considerable effort. Although few students may produce these values, they impact significantly on the average. The median shows a relevant finding. Many students invest small effort in the ITS and the mean decreases over time on activities (i.e. the median in the final project is 2.6 h).

Table 1. Invested effort (hours) in Computer Fundamentals

	Mean	Median	Q3	Q3 + (1.5* IQR)	Planned	Overload	Outliers	Submitted
CAA2	7.3	4.0	7.0	12.8	15	[−11.0, −2.2]	12	208
CAA3	7.0	3.9	8.7	17.7	15	[−11.1, 2.7]	9	161
Final project	7.7	2.6	6.7	13.9	25	[−22.4, −11.1]	12	154
Total course	28.6	17.2	42	94.9	85	[−67.8, 9.9]	10	322

When these values are compared to the planned effort, we observe that the course looks well designed. Table 1 shows the planned effort and the overload effort computed as the interval [Mean – Planned, Q3 + (1.5 * IQR) - Planned] to detect whether there is study overload. We consider this range a good upper bound estimator of overload since it assumes the worst effort investments. If the outlier detector value is larger than the planned effort, we may assume that some students are unable to study the course properly within the scheduled time. Also, the table summarizes the number of outliers and the number of students who submitted each activity (the total number of students in the course is shown in the total course row). Only in CAA3, some students need 3 more hours to complete it assuming that Q3 + (1.5 * IQR) is the limit. In the total course, there is a broad range of effort investment from 17.2 h to 94.9 where 13 students (4%) needed more than the estimated 85 h and 10 students (3%) were considered outliers.

However, Computer Fundamentals has a significant dropout. Near the 50% of the enrolled students leave the course before the final exam. This behavior impacts in results summarized in Table 1 due to some students reported effort that does not contribute to pass the course.

Table 2 reports only effort from students who passed the course. The same information is summarized. The only difference is in the column *Submitted* where only students who passed the course and submitted the activity are considered. The objective of the table is to show the effort invested for students who passed the course. Relevant insights are detected:

- The effort in terms of mean, median and maximum value has increased compared to Table 1. This is an expected result. After excluding students who did not pass the course, the table shows that students who passed the course used significantly the ITS to practice and to learn the required knowledge.
- Similar work overload is detected in CAA2, CAA3 and Final Project when maximum values are analyzed, although fewer students were taken into account. We assume that students who did not pass the course mainly did not use the ITS.
- Significant effort is required through all the course when *Total Course* is analyzed. The median effort is nearly doubled. Also, after checking the lower bound value, we observed that at least 12 h are required to pass the course.

Table 2. Invested effort (hours) for students who passed the course computer fundamentals

	Mean	Median	Q3	Q3 + (1.5* IQR)	Planned	Overload	Outliers	Submitted
CAA2	8.4	4.4	7.0	12.8	15	[−10.6, −2.2]	10	120
CAA3	8.1	4.9	9.3	17.7	15	[−10.1, 2.7]	9	123
Final project	8.3	2.8	7.5	15.3	25	[−22.2, −9.68]	10	124
Total course	39.7	31.3	53.4	105.7	85	**[−53.7, 20.7]**	9	126

After analyzing these reports, we consider the course well designed regarding effort. Most of the students used the tool within the scheduled time. Some students required more time to complete the activities but this effort influenced positively to pass the course. Only one outlier student was detected who did not pass the course. We assume that the student left VerilUOC open when performing out-off-task activities.

6 Conclusions and Future Work

This paper has described how an e-learning system can be enhanced to analyze effort. A particular development to an existing ITS has been performed and the results have been used to analyze the work overload of the learners.

This application opens a broad range of applications. Effort-aware systems can be used to enhance learning, create more robust effort-based assessment models, create better adaptive systems and enforce trustworthiness on collaborative learning. Also, additional offline tasks, such as review other learning sources (web pages, books, papers) could also be taking into account in the future.

Finally, as future work, we will consider other cognitive aspects such as attention or engagement and the correlation with the effort invested.

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Applications of Distributed and High Performance Computing to Enhance Online Education

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Abstract. Modern online education (eLearning) needs are being evolved accordingly with more and more demanding pedagogical and technological requirements. On one hand, advanced learning resources, such as interactive video-lectures, 3D simulations, serious games and virtual laboratories are based on costly computational infrastructures. On the other hand, eLearning needs include supporting the latest learning methodologies and strategies, such as learning analytics, gamification and formative assessment, which require effective real-time processing and analysis of massive data as well as interoperability with external systems. However, these functional eLearning advances are especially frustrating when non-functional requirements are not met appropriately, such as scalability, performance and interoperability, having considerable repercussions on the learning outcomes as their lack impedes the expected learning flow. This paper presents an overview of the efforts tackled so far of using distributed computing for the enhancement of current eLearning by showing the approaches and the results achieved of some real applications of these technologies to real context of eLearning. The novelty of this approach is to combine the provision of complex and advanced software support to meet challenging functional eLearning needs with the benefits of providing powerful distributed and high performance computing to alleviate demanding non-functional requirements also to be met in this context.

1 Introduction

Modern and advanced eLearning needs are being evolved accordingly with more and more demanding pedagogical and technological requirements. Online learning environments no longer depend on homogeneous groups, static content and resources, and single pedagogies, but high customization and flexibility are a must in this context [1, 2]. As a result, current virtual educational organizations' needs involve extending and moving to highly customized learning and teaching forms in timely fashion, each incorporating its own pedagogical approach, each targeting a specific learning goal, and each

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incorporating its specific resources. These entire issues certainly represent a great challenge for current and future systems in the eLearning field [1, 3].

Furthermore, engaging online students in their learning process has been considered a key issue by the educational community due to the important positive effects in terms of increasing learning outcomes (performance) and satisfaction while reducing drop-out rates [4]. In order to increase student's engagement, online learning has been evolved from static contents to highly interactive, challenging, collaborative and personalized learning resources, thus providing students with high levels of empowerment and social identify within the eLearning context [5]. As a result, advanced learning strategies and methodologies, such as learning analytics, gamification and eAssessment, show a significant impact in terms of student's engagement and motivation [6]. However, when moving from small controlled tests to large scale deployments, a strong need arises of computational power to deploy and run these demanding learning strategies in real contexts of eLearning [7].

To sum up, most of eLearning technological approaches tend to focus only on the functionality of the system, while leaving out the "invisible" non-functional features, such as system performance, scalability, efficiency, interoperability and so on, which become highly demanding and crucial in this context [3, 7]. Indeed, these non-functional needs are especially frustrating when they are not appropriately met during the eLearning activity, which may considerably degrade the overall system performance, resulting in considerable repercussions on the learning performance as their lack impedes the normal learning flow. However, these non-functional features are many times purposely left out due to the complexity to be addressed and then deployed in real situations by using costly computational infrastructure [8].

To this end, the possibilities of using distributed and high performance computing technologies to specifically support real eLearning environments have been extensively explored in our previous research [7–11], leading to conclude that the features provided by these technologies form an ideal context for supporting and meeting the above demanding and complex needs of the eLearning domain. Indeed, it is proved the feasibility of distributed technologies to considerably enhance and improve the online learning experience. In particular, the use of High Performance Computing (HPC) and Cluster Computing is successfully applied for the purpose of efficiently processing large amount of data from learning activity log files [10, 11].

This paper presents an overview of the efforts tackled so far of using distributed and HPC for the enhancement of online learning combined with the results of some real-world applications. The main research question posed in this paper is whether we can meet the demanding computational needs of current eLearning. To address this question we combine the provision of complex software support to meet challenging functional educational needs found in eLearning in terms of increasing students' engagement, with the benefits of providing powerful computational infrastructures to alleviate demanding non-functional requirements also found in this context. The ultimate goal is to make eLearning stakeholders aware of the crucial role of the underlying computational support and help them select the best distributed computing scheme for the achievement of the educational goals in different eLearning scenarios.

To this end, Sect. 2 presents the main needs in current and advanced eLearning domain in terms of functional and non-functional requirements. Section 3 shows two real application examples of using distributed computing for eLearning, which are presented from the methodological and evaluation views. Finally Sect. 4 discusses on the main results shown and outlines future directions of this research.

2 Background

Current learning management systems (LMS) from educational institutions have evolved into complex ecosystems. These organizations' demands include cost-effective integration of legacy and separated learning systems, from different institutions, departments and courses, which are implemented in different languages, supported by heterogeneous platforms distributed everywhere and providing access anywhere anytime (mobile learning). Moreover, LMS infrastructures need to support the latest and advanced eLearning methodologies and strategies, such as learning analytics, gamification, formative eAssessment, and so on [6], which all require high-performance computational power for the software applications implementing these strategies to effectively be deployed and run in real situations, and eventually achieved their pedagogical goals.

Current needs found in the eLearning context include, among others, the following [9]:

- access from anywhere, on any learners' computer platform and any software,
- support for a growing load of learning resources, such as Virtual Labs, contents repositories and on demand video services and users who access these resources,
- transparent access of a huge variety of software and hardware learning resources,
- move to highly customized pedagogical models in timely fashion, each targeting a specific learning goal and incorporating its specific resources,
- process huge amounts of user interaction data from online learning,
- provide eLearning applications with advanced learning analytics services in terms user modelling, monitoring, prediction, e-assessment and security
- avoid central point of failure (decentralized) of LMS,
- eLearning applications are naturally scalable, fault tolerance and high performance.

2.1 Engaging eLearning Strategies

In this section, well-known and cutting-edge learning strategies in online education, namely learning analytics, gamification and eAssessment are briefly presented with the purpose to increase students' engagement in the learning process for effective learning to occur [4–6]. These strategies have in common the need to process large amounts of data collected from the user-user and user-system interaction in the LMS, thus requiring high computational power to manage massive interaction data and present the extracted knowledge in real time [10].

Learning Analytics
Learning Analytics (LA) for education appears from research about the processing, analysis and visualization of knowledge about the learning process [12]. This knowledge is gathered from large or very large data sets of events at different levels of abstraction, such as the interactions of students with LMSs, other students and instructors throughout the learning process [13]. Large-scale data collection, processing and analysis using suitable models and reasoning can improve the use of existing eLearning systems, as well as improving the system themselves [10].

In this sense, LA is built upon previous works in which the interactive processing of learning data has been exhaustively analyzed [12, 13]. There are many results and applications in education, such as providing effective assessment and automatic feedback to students; supporting instructors by monitoring and predicting student performance; modelling user profiles for content and process customization, according to the student needs, goals and individual skills; and for security for education [10, 11].

Gamification
"Gamification" is a term used to describe the use of game-based concepts and techniques outside recreational activities, with the goal of increasing the motivation of the participants and improving the results. The benefits of gamification are an increase in motivation and engagement, which can be applied in education or work-related contexts. In this sense, there are previous experiences where gamification techniques have been applied to both formal and informal learning scenarios [14].

Gamification offers a great variety of resources, such as rewarding mechanisms (scores, leaderboards, prices, achievements); progress logs ("to-do" and "done" tasks); social aspects (encouraging communication, reputation systems); feedback mechanisms and status notification (auditory or visual alerts) [15]. These gamification resources involve dealing with large data sets of great variety in type, format and size, and from heterogeneous data sources, thus first needing a costly normalization process for later data processing and analysis [11].

eAssessment
Assessment of online learning is a mature research field at present with a great impact on the learning process [16]. Building a consistent assessment framework involves to know how knowledge can be extracted from the formative activities. This knowledge can then be used for assessing and also for monitoring and scaffolding the learning process. For instance, by constantly showing cognitive assessment information about the online learning process, students can develop reflective and experiential learning skills by analysis and application, thus increasing engagement and motivation [6].

Driven by the students' interaction, a high amount of quantitative and qualitative information is considered and can be managed from on-line learning, which includes complex issues of the learning process (e.g., student well-being as well as self-, peer- and group activity evaluation),thus providing qualitative information about performance and behavioural aspects of the collaboration [17].

2.2 Distributed Computing for eLearning

Online learning environments must provide advanced enablement for distribution of both learning activities and the necessary functionalities and educational resources to all participants, regardless the location of both participants and resources. The aim is to enable the learning experience in open, dynamic, large-scale and heterogeneous environments, thus facing the main challenges in the development of LMS systems in terms of non-functional requirements arisen in this context [8, 9]. To this end, next we review some distributed computing schemes as suitable computational paradigms to meet these demanding eLearning needs.

Grid and Cloud for eLearning: Meeting compute-intensive educational needs
Grid and Cloud technologies are increasingly used for complex areas, which are computationally intensive and manage large data sets as well as promise scalability, enhanced availability and cost savings [9, 18, 19]. These features form an ideal context for supporting and meeting the demanding requirements of eLearning applications and, as a result, providing them with important benefits, such as wide geographical distribution of resources, transparent access to these resources, and so on. Further, the cloud can provide students and teachers with tools to deploy computing resources on-demand for lectures and labs according to their learning needs. The ultimate goal is to bring together personalized learning experiences with transparent, ubiquitous and on-demand access to distributed learning resources, all according to pedagogically sound approaches [1].

In addition, these technologies provide e-learning services, especially in scenarios where these services are computer-intensive (virtual worlds, simulations, video streaming, etc.), or are offered in a high-scale way, as in Massive Open Online Courses (MOOCs) [19]. In this context, Service-oriented architectures [7], and in particular Web services, play a major role due to the benefits that provide in terms of interoperability among heterogeneous hardware and software platforms, integration of new and legacy systems, flexibility of updating software, and so on [7, 9].

P2P technologies for eLearning: Building decentralized and scalable systems
Client–server systems, although the most popular approach to support Web-based LMSs, have many well-known drawbacks. In such systems, the shared resources are centralized on servers and users (clients) access them through request protocols. Everything is done at the server side while at the client side just an interface is needed. This brings important non-functional limitations, such as lack of scalability and fault tolerance, low performance and bottlenecks, as well as high costs in acquiring, developing and maintaining such applications [20].

In order to overcome these inconveniences, decentralized P2P networks are the most powerful alternative to client–server model to support virtual organizations. In a decentralized approach the client may act as a client and a server and thus becomes a primary "actor" of the system by contributing, managing and controlling the resources. This characteristic makes P2P networks very relevant for the development of eLearning systems and applications with important benefits, such as avoid central point of failure and bottlenecks and make eLearning applications naturally scalable, more efficient and fault tolerance (in comparison to centralized systems), etc. [20].

Cluster technologies for eLearning: Meeting data-intensive educational needs
In eLearning, it is reported that the lack of sufficient computational resources is the main obstacle to process large amounts of data in real time. Hence in real eLearning situations this processing tends to be done off-line in order to avoid harming the performance of the logging application, thus taking place after the completion of the learning activity which has less impact on it [10]. To this end, Cluster Computing is increasingly being used to reduce the overall, censored time in processing data by taking advantage of its large computing support. Several studies have been conducted to show that a distributed infrastructure can increase the efficiency of processing a large amount of information from group activity log files [11].

3 Research Methodology

In this section we present two real use cases of eLearning applications that use distributing computing to enhance ad improve the eLarning experience:

- Real-time user modelling in a virtual campus (learning analytics)
- Security in online learning based on trustworthiness (security)

Each of these applications is first motivated and then presented by following a research approach of development and evaluation in a real context of eLearning.

3.1 Real-Time User Modelling in a Virtual Campus (Cluster Computing)

3.1.1 Motivation

In distance web-based eLearning, the description and prediction of students' behaviour and navigation patterns when interacting with the Learning Management System (LMS) is a first issue. Indeed, a well-designed system's usability is a key point to stimulate and satisfy the students' learning experience. In addition, the monitoring and evaluation of real, long-term, complex, problem-solving situations is a must in this context. The goal is to describe and predict students' actions and intentions as well as adapt the LMS to students' features, habits, interests, and preferences in order to achieve a great stimulation of the eLearning experience.

However, complex processes involved in Web-based learning generate a great variety of type and formats of data usually stored in log files found, which are found in (i) ill-structured highly redundant form, and (ii) need to reduce and structure data for later analysis and extract knowledge. In addition, Web-based learning applications are characterized by a high degree of user-user and user-system interaction, which stresses the amount of interaction data generated. Finally, there is strong need for processing data in real time to have more impact in the learning experience. As a result, computational cost is the main obstacle to processing great amount and variety of log data in real time.

3.1.2 Approach

In order to deal with the above mentioned issues, we present a research approach for efficiently processing log files from web-based learning systems and applications. To this end, we first propose an algorithm for parallelizing the processing of log files. Then, we present several proofs of concepts to evaluate the computational results by using several distributed infrastructures. Finally we will interpret and discuss on the experimental results.

We have developed a simple application in Java, called *UOCLogsProcessing* that processes log files of the Virtual Campus of our university UOC[1]. We first conduct the processing of logs files sequentially. A PC with standard configuration is used for local sequential processing of daily log files (up to 15 GB) used for massive processing. As expected, results with one node are linear over time (see Table 1). Therefore, the time spent in processing large log files is too much for our purpose to process data in real time, thus we move next on a parallel distributed approach.

Table 1. Local processing of Log files (from 1 GB to 15 GB)

Size	1 GB	2 GB	4 GB	8 GB	15 GB
Time	197 s	413 s	817 s	1741 s	3076 s

The parallel implementation in the distributed infrastructures that we propose follows the master-worker (MW) [24] paradigm to parallelize the processing of log files, which is made up of master and worker peers:

- Master peers create and submit their requests.
- Worker peers assign Master requests to the available nodes and notify and send the results to the Master.

The main steps of the MW parallel algorithm to process a log file in our distributed infrastructures are as follows:

1. **[Pre-processing phase]:** UOCLogsProcessing counts the total number of lines of the log file, totalNbLines, and knowing the total number of parts to split the file off, nbParts, each peer node will receive and process a totalNbLines/nbParts of lines from the file.
2. **[Master Loop]: Repeat**
   (a) Read totalNbLines/nbParts lines from the original file and create a file with them.
   (b) Create a request and submit the partial file to the distributed infrastructure.
   (c) [Parallel processing]:
      (i) The request is assigned to a peer node of the distributed infrastructure.

[1] The Universitat Oberta de Catalunya (UOC) is located in Barcelona, Spain. The UOC offers distance higher education fully over the Internet since 1995. Currently, about 54,000 students and 3,700 lecturers are involved in 6,400 online classrooms from about 300 graduate, post-graduate and doctorate programs in a wide range of academic disciplines. The UOC is found at http://www.uoc.edu.

(ii) The peer node, upon receiving the petition, reads according to the petition's description, the part of the file it has to read via HTTP. The peer runs UOCLogProcessing functionality for processing the lines of the file, one at a time, and stores the results of the processing in a buffer.

(iii) The peer node, once the processing of the petition is done, sends back to the master node the content of the buffer. Until the original log file has been completely scanned.

3. **[Master's final phase]:** Receive messages (partial files) from slave nodes and append in the correct order the newly received resulting file to the final file containing the information extracted from the original log file.

We deployed our distributed approach of the MW paradigm to parallelize the processing of log files in a the nodes of the large-scale, distributed network PlanetLab platform (www.planet-lab.org), which is an open distributed computing infrastructure currently with 1353 nodes distributed in 717 different sites among universities, research centers or homes. The nodes are located outside a firewall and have to be visible from anywhere in more than one DNS.

3.1.3 Results

Table 2 shows the main results of log data processing in PlanetLab platform with different node configuration and data size, which are summarized as follows:

- By using a distributed infrastructure of up to 16 nodes, a considerable speed up is achieved in processing large log file data.
- For infrastructures larger than 16 nodes truly geographically distributed, such as PlanetLab, the speed up reduces with the increase in the number of nodes due to the significant communication time in receiving the chunk files and sending back the results to master node.

Table 2. Comparative log file processing with multiple nodes in PlanetLab platform

	500 MB	1 GB	2 GB	4 GB	8 GB	15 GB
1 node	61 s	121 s	269 s	557 s	–	–
2 node	36 s	76 s	153 s	430 s	1129 s	–
4 node	18 s	42 s	93 s	191 s	616 s	1325 s
8 node	13 s	28 s	63 s	126 s	324	821 s
16 node	10 s	23 s	47 s	101 s	271 s	529 s
24 node	8 s	22 s	46 s	92 s	251 s	481 s
32 node	8 s	21 s	43 s	82 s	242 s	458 s

Once the original log files have been processed and the results have been merged in well-structured form there exists an enormous reduction of the overall data up to 95% from 15 GB log file to resulting 800–900 MB (see Fig. 1). This allows a feasible storing of the processing results in a database for further analysis and knowledge extraction.

Fig. 1. Reduction of data after the original log line is processed.

Once data is processed, it is analyzed with some data mining methods suitable for extracting navigation patterns, such as K-means, Apriori and FPGrowth data mining algorithms and using the WEKA framework [21], thus extracting the association rules, such as those shown in Fig. 2. These association rules can serve for (i) monitoring and adapting the campus navigation to the students' needs, and (ii) predicting future actions of students based on navigation patterns.

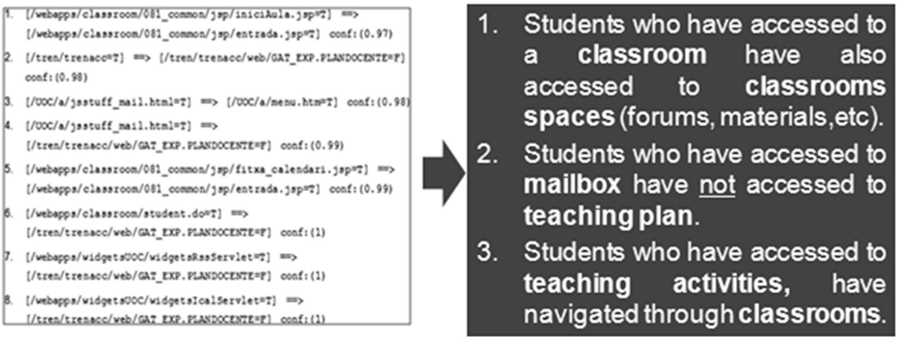

Fig. 2. Some rules found by FPGrowth of WEKA and their meaning.

3.2 Security in Online Learning Based on Trustworthiness

3.2.1 Motivation

Information security requirements have been generally considered and developed recently in distributed systems, such as Grid and cloud [22]. However, many security vulnerabilities are still reported in distributed LMSs and remain unsolved since eLearning services and activities are still designed and implemented without much consideration of security issues [23]. As a result, information security vulnerabilities may interfere in these activities, thus threatening and reducing the effectiveness of the overall learning process. Therefore, innovative security solutions are needed to overcome these limitations and support a secure learning process [11, 24].

To this end, a trustworthiness model is proposed based on a multi-fold assessment approach of online learning activities, which can meet security requirements of online learning process (see Fig. 3 and [11]). However, in order to provide effective and just-in-time trustworthiness information from the LMS, it is required a continuous processing and analysis of group members' interaction data during long-term learning activities, which produces huge amounts of valuable data stored typically in server log files. Moreover, modern eLearning activities demand a great amount of communication processes through a great variety of learning contents and tools, and many types of interactions. Therefore, because of the large size and variety of data generated daily in online learning activities, the massive data processing is a foremost step in extracting useful information, which requires computational capacity beyond that of a single computer [10, 11].

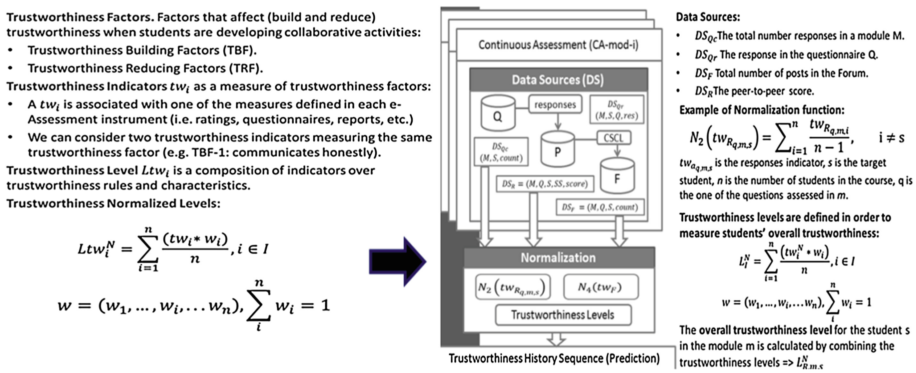

Fig. 3. A trustworthiness-based model for security in eLearning

3.2.2 Approach

With the aim to cope with learner's trustworthiness analysis and the building of our trustworthiness model (see Fig. 3), even in real time, we address here the need to alleviate the computational cost of massive processing of the large amounts of different type of data generated from different learning tools and LMS during long-term e-Learning activities. We consider in this context two types of log data coming from both the UOC Virtual Campus and the BSCW collaborative learning tool also used at the UOC to support online learning groups [11]. To this end, we propose a parallel approach for massive data processing supported by a distributed infrastructure that follows the MapReduce paradigm [25]. Therefore, we introduce first our MapReduce model on the normalization of different LMS log files, namely, BSCW and UOC. The results obtained will conduct our parallel implementation approach based on Hadoop and Cluster Computing presented next (see Fig. 4).

The MapReduce paradigm [25] works by splitting the processing into two stages, the map phase and the reduce phase, and each phase has key-value pairs as input and output (see Fig. 4). Therefore, we define the tasks in the map phase and those processed in the reduce phase, selecting the input and output keys for each phase. In this paradigm, the output from the map function could be processed by the framework before being sent to the reduce function. The Map phase takes as input a record stored into a log file; the key of this record is the offset in the file. When the map function receives the record,

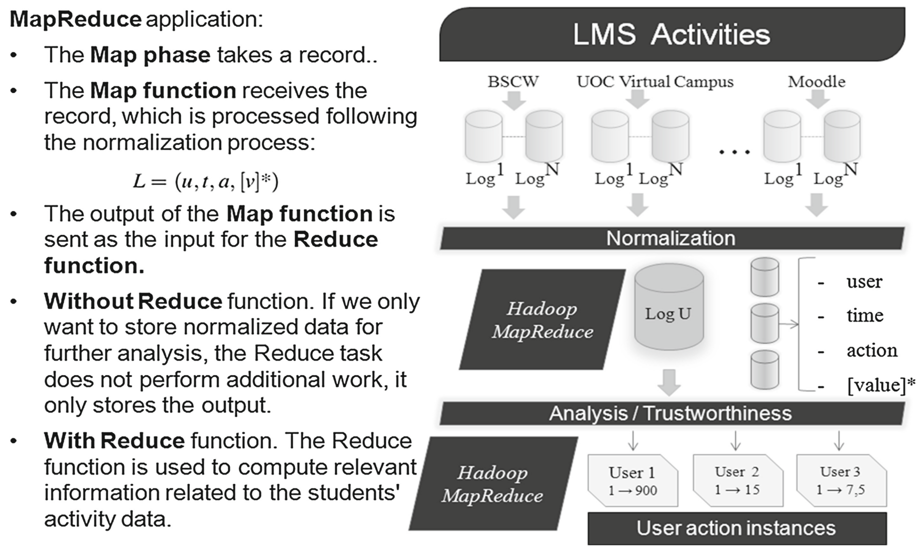

Fig. 4. Hadoop MapReduce processing approach

it will be processed following the normalization process and this output will be the input for the reduce function. For instance, the reduce function may be used to compute students' activity. In that case, one of the keys is the student, and the reduce function calculates the result of the parameter selected (e.g., number of documents created by the student, total session time, and sum of ratings).

The abstract model proposed supporting the MapReduce paradigm for normalization of LMS log files is then implemented in the parallel platform of Apache Hadoop (hadoop.apache.org). Hadoop MapReduce job is defined as a unit of work that the client wants to be performed [25] consisting in the input data, the MapReduce program, and configuration information. Then, Hadoop runs the job by dividing it into tasks of two types: map tasks and reduce tasks. There are also two types of nodes: job tracker, which coordinates the paralleling process, and several workers that perform the target work. Hadoop divides the input to a MapReduce job into fixed-size pieces and creates one map task for each split, which runs the map function for each record in the split. The implementation of map and reduce function deals with the different BSCW and UOC Virtual Campus log formats (see full details in [11, 24]). Once the logs are computed by the event extractor functions, the output is normalized following the model presented.

3.2.3 Results

Once the MapReduce applications have been developed, before running the jobs in parallel processing, network and distributed file systems are needed. Hadoop Distributed File System (HDFS) supports large data sets across multiple hosts to achieve parallel processing. HDFS is a block-structured file system based on splitting input data into small blocks of fixed size, which are delivered to each node in the cluster. We use HDFS as Hadoop MapReduce storage solution; therefore, some file system configuration tasks are needed, such as create user home file and define suitable owner, create MapReduce jobs input directory, upload log files, and retrieve results actions.

In Table 3, we can see comparative results of the battery of tests with multiple Hadoop nodes (i.e., 2, 4, 6, 8, and 10 workers) in our RDlab cluster (aggregated hardware resources are 160 physical servers, 1000 CPU cores, and 3 TBytes of RAM memory, 130 TBytes of disk space, and high speed network at 10 Gbit). Furthermore, additional file system integration processes were carried out by running Hadoop jobs over the open-source Lustre file system (http://lustre.opensfs.org), which is deployed in the RDlab (http://rdlab.lsi.upc.edu).

Table 3. Comparative MapReduce results.

Nodes	Log file size											
	1	10	50	250	100	500	1000	2000	4000	8000	10000	Speed up (%)
0	0	0	2	2	9	19	35	75	141	288	353	
2	14	14	15	14	15	29	44	77	141	280	339	4%
4	15	15	15	14	15	20	27	44	74	134	170	52%
6	14	14	16	15	15	15	25	38	64	117	151	57%
8	16	14	15	16	16	16	21	33	44	83	102	71%
10	14	22	15	17	16	21	16	33	37	72	83	76%

From this experimental study, we can see that the results do not grow linearly anymore. Moreover, by using a distributed MapReduce Hadoop infrastructure, a considerable speed up is achieved in processing large log file data as shown in Table 3, last column, (i.e., more than 50% for infrastructures with more than four nodes and more than 75% for 10 nodes). Regarding log file size, for too small values, the overhead introduced by the MapReduce framework, when sending the parts to the nodes and combining output data, is noticeable, and the framework control tasks spends too much time managing and distributing data. On the other side, values of the task size close to 3,000 MB considerably diminish this amount of time in comparison with the total processing time. Moreover, Reduce tasks spend too much time when the number of nodes is low.

4 Conclusions and Future Work

From the applications described in the previous section, we discuss here on the benefits of using powerful Distributed and HPC infrastructure to enhance eLearning and to what extend this paradigm comes to play a key role in this context.

The results of using our algorithm of Master-Worker running on PlanetLab platform show the potential for efficient processing of the UOC campus' log data, which generates daily 15–20 GB of interaction data coming from the interaction of 60,000 users. This data is stored in log files and is found in an ill-structured highly redundant form. Processing this information requires computational power beyond a single machine and demands a parallel approach. However, we need to consider the trade-off between the number of nodes used (i.e., level of parallelization) and the overhead caused by dividing the original log files into the number of nodes and then merging the processing results, as well as the communication cost (latency) of PlanetLab nodes, which are truly geographically distributed.

Moreover, we presented an innovative approach for modelling trustworthiness for secure assessment in online learning. The model allows for discovering how students' trustworthiness evolves into the learning system, which involves the processing of large amounts of LMS log data coming from different data sources, thus needing a costly normalization process prior the analysis of students' activity data. To this end, we proposed a complete MapReduce and Hadoop application for massive processing of LMS log file data running it into our RDLab Cluster. Although the overhead introduced by the MapReduce framework for small values is noticeable, when the task size is >1,000 MB the overhead time considerably diminishes in comparison with the total processing time. The results of the data processed by Hadoop MapReduce indicate that our trustworthiness model can tackle security breaches and enhance information security in e-Learning.

As ongoing work, we plan to conduct a further study by reproducing the same experiments in a different and powerful distributed and HPC infrastructure, such as the Centre of Distributed and High Performance Computing located at the University of Sydney (http://sydney.edu.au/research_support/hpc/) with aggregated hardware resources of 136 physical nodes, 4264 CPU cores and 6 TBytes of RAM memory. The goal of the study will be to confirm the gain in data processing from using a different distributed computing infrastructure, which can both reduce the data processing times and scale up our approach by adding further data sources from external tools of our virtual campus. We also plan to compare our MapReduce approach with Spark processing data streams framework (spark.apache.org) for faster processing of the large log data sets generated in our UOC virtual campus [26].

In future work we plan to present more real applications of distributed computing to eLearning by using different distributed computing schemes, such as P2P and Grid computing [20], in order to show evidences of the specific benefits of each scheme for a particular type of demanding problem found in the eLearning domain.

The ultimate goal of our research is to alleviate the cost of non-functional requirements when developing and using advanced tools and resources to engage students in eLearning. As a result, the demanding needs to scale up the number of students and tutors widely distributed everywhere are correctly met while interoperating with external tools and providing support for a growing load of learning resources in the current context of complex virtual educational ecosystems.

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Student Engagement Value (SEV): Adapting Customer Lifetime Value (CLV) for a Learning Environment

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Abstract. As a metric, Customer Lifetime Value (CLV) is important in business environments in order to prioritize customer value to the organization so that effort and resources can be effectively utilized based on the profitability of each customer. In an academic setting there is an equal interest to classify students based on their engagement, so that high performing students, weak performers who may likely be dropouts and the rest of the students in the spectrum can be clearly identified. In this paper we present a factor model for translating the CLV into a learning oriented Student Engagement Value (SEV), which defines an indicator of engagement. To analyze its utility we applied the SEV at the Open University of Catalonia, by setting an initial set of variables to calculate the SEV and calculate their values in a real context. The information provided for the SEV allows to perform personalized and relevant feedback and assistance to students.

Keywords: Student engagement · Customer lifetime value · Virtual learning environments

1 Introduction

Customer Lifetime Value (CLV) is a construct used by companies to identify profitable customers from the viewpoint of the company's cost of attracting, selling and servicing the customer (Kotler and Armstrong 1996; Berger and Nasr 1998). From a business' perspective a customer life-cycle consists of a series of transactions between the business and the customer. From a transition from product life-cycle to a customer life-cycle approach, businesses have made the marketing strategies more customer-centric and CLV is being used as an indicator of the profitability over the lifetime of customer (Jain and Singh 2002). Recently this customer-centric approach of business has grown and so has the importance of CLV in marketing research (Casas-Arce et al. 2017; Shih and Liu 2003).

From a corporate university point of view, the CLV can also be directly attached to the profitability of student enrollment in an academic institution. The students are the customers and the academic institution conducts its business by attracting students, providing paid degree programs as a product and making profits. However taking a further step inwards and away from a business model, we can see that a value such as CLV can also be an indicator of student engagement in their learning.

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Student engagement has been defined as the quality of student interactions with the learning activities and other components of their learning environment (Shernoff 2013) and a known contributor for academic success (Hughes et al. 2008; Ladd and Dinella 2009). As with customer life-cycle consisting of business transactions, a student life-cycle consists of learning related engagements between the student and the learning environment. At a macrolevel these can be administrative proceedings, registration and enrollments to more microlevel engagements such as reading a text or completing an assignment.

The goal of this research work is to propose a new compound indicator of the student engagement that takes into account information from multiple perspectives. The semantics and lessons learnt from the CLV in business will be used for creating the indicator. Therefore, in this paper we present a model for translating the CLV approach of measuring a customer's worth to a firm to measuring a student's worth in terms of engagement to the academic institution. We propose this Student Engagement Value (SEV) as an indicator to identify different levels of student engagement and thereby facilitate their learning in a personalized way. While we employ an online learning setting as a case study, our technique may also be adapted to blended or face-to-face learning settings if the factors and associated variables are identified accordingly for each situation.

This paper is organized as follows. Section 2 introduces the original factors utilized in the composition of CLV and in Sect. 3 we present their applicability in an academic context, providing our proposal of the Student Engagement Value (SEV). Section 4 explores our data collection setting and the initial pick for variables that allow to estimate the values of the factors we have defined. Then, Sect. 5 shows how the factors can be calculated from its variables, what should be taken into account in the calculation and how to group factors to focus on different analytical needs. Finally, Sect. 6 concludes the paper and presents the further work planned.

2 Customer Lifetime Value (CLV) and Associated Factors

The CLV has been defined in a variety of methods. One of them is as an aggregate indicator based on the underlying factors and a ranking system of customers based on the indicator (Hughes 1994) leading to customer segmentation and clustering. By aggregating multiple factors, it produces a composite numerical to denote a customer's value to the business. This numeral can then act as an indicator of the value of the customer for the future of the business relationship. In this section we present the original factors used as constituents of the CLV.

Recency (R). Recency is a factor that corresponds to the most recent time the customer did business with the firm. It is usually calculated by whether the customer made a purchase in the current month. The motivation behind this factor is that a customer who made a purchase recently is likely to call in and do business again (Bult and Wansbeek 1995).

Frequency (F). Frequency deals with how often a customer makes a purchase. It is based on the argument that customers who purchase frequently are more likely to purchase again and have a higher loyalty. In a typical scenario, the factor looks at whether the customer purchased every month.

Monetary (M). The Monetary factor deals with how much money the customer spends with the firm. It is based on the argument that the top spenders are more likely to buy again than customers who spend less.

Acquisition. Businesses have to bear high costs for customer acquisitions, especially in a market of competitors. Costs spent on marketing and advertising are typical acquisition costs.

Maintenance. The maintenance factor calculates the cost it takes to maintain a customer. It is usually related to customer service.

Retention. It refers to the probability that a customer remains loyal to a particular business and maintains the expected revenue as well as costs within a fixed period of time (Bauer et al. 2003). The costs spent on keeping customers engaged with the firm are the retention costs, and are usually lower than the acquisition costs.

Risk Costs. Risk cost deals with cost that the business firm has to bear for the potential risk, including loss adjustment expenses, risk control costs, transfer costs, and administrative costs.

Referrals. Referrals as commonly found in business models and marketing strategies, where customers bring in new customers to the business.

Discounts. Discounts are offers made to the customer from the business firm in ways of reduced prices or added services, to promote loyalty and thus making an impact on other factors such as frequency.

Churn. Two types of customers emerge in the churn factor, where one portion of them who are about to churn, where the frequent purchases has suddenly stopped and the other portion where the purchases had stopped a long time ago. Two of the biggest causes of churn are dissatisfaction with the service (14%) and resentment of an attitude of indifference by the marketer (68%).

A common CLV calculation is based on the Recency (R), Frequency (F) and Monetary (M) factors which is called the RFM method. For example, if the customer has made a purchase in the current month the value 5 (being the highest value) is assigned to R. Similarly, based on best possible values for F and M, the high ranking customers are given the value 555 and the lowest ranking customers the value 111. The CLV values between 111 and 555 will be indicators for all the customers based on their profitability. However certain other models of CLV calculation consists of more factors such as RFMTC method which adds on the time since first purchase (T) and churn (C) factors (Cheng et al. 2009). Also other methods exists such as WRFM (Weighted RFM) based on the conditions and characteristics of different industries (Stone 1975; Khajvand et al. 2011).

3 Defining Factors for Student Engagement Value (SEV)

As seen in previous section, CLV is quite customizable, allowing to adapt the metric to the necessities of any business, even to a corporate university. However, the factors used in businesses are not directly applicable at the university context, since there is no monetary purpose in the "university business" and the outcomes of universities are not profits, but something more difficult to measure. Therefore, the factors of CLV should be adapted before being applied to the university context.

We adapted the factors of customer valuation used in CLV to an engagement based student value. To do so we used information about the relationships that exist between students and the learning environment in terms of engagement. The adapted factors are the following:

Recency (R). In an academic setting, a student who engaged with the learning environment recently is likely to continue being engaged. As the CLV commonly uses a month as a time-frame for recency, we propose a week initially as a suitable timeframe for a student to engage in a learning environment. The reason is that a month is too much in the context of a subject, which has an average duration of 4 months. Therefore an example value we would use in the R factor is whether a student accessed the Virtual Learning Environment (VLE) in the current week or whether the student attempted a practice task in the current week.

Frequency (F). As the original F factor looks at whether the customer purchased every month, the adapted one deals with how frequently the student perform learning tasks. For example as the student accessed the VLE every week or the student posted in the forum every week.

Investment (I). In the case of Monetary factor that deals with how much money does the customer spends with the firm, we diverge towards a factor that deals more with *Investment (I)* from the part of the student: the time students spend in learning activities. As the original factor argues that the top spenders are more likely to buy again than customers who spend less, we argue that the more time the students spend in a subject it is more likely that they will continue investing time in their further learning activities and will perform more cognitive efforts. Some of the variables that can be used in this factor are the total number of access counts to the VLE, the total number of messages posted/read/responded in the forum or time spent in the VLE.

Maintenance (Ma). In an academic setting we translate this cost as the investment from the side of the teacher in order to maintain the students in the classroom, such as the number of messages sent to the notice board, the number of questions answered in the forum and the time taken to respond to students.

Retention (Re). Customer retention, or the cost of continuing to keep ahold of the customer is another factor that has to be translated indirectly in a classroom context. In an academic setting, dropouts are a common case where students leave the course during the semester due to various reasons such as lack of interest or capability. Therefore we allocate the retention costs in a classroom as the investment made on preventing likely dropouts. Variables such as number of messages sent to poor performing students or number of reminder messages sent regarding delayed submissions may be used in the calculation of this factor.

Referrals (Rf). We adapt the referral concept in a learning environment as a student invoking the engagement of another student by the way of interaction. For example, events such as, a forum post by a student receiving responses of other students, a student recommending a course or a subject to another student can be considered referrals in an academic context.

Discounts (D). The factor originally considered in CLV as discounts offered to the customer is also an indirect translation in an academic setting. As discounts are offers made to the customer from the business, we consider distinction or honors awarded to a student or credit awards based on prior courses in this factor we would define as *Awards (A)*.

Churn (C). In a classroom, the churn factor translates to likely *dropouts (D)*. The biggest causes of churn: dissatisfaction with the service and resentment of an attitude of indifference by the marketer which can be seen closely as dissatisfaction with the subject or indifference by the teacher. Data concerning when the student has last engaged in the learning environment provides an insight to the possibility of being a dropout or a likely dropout.

Performance (P). A factor not present in the business context, which is being introduced to calculate SEV is performance of a student in terms of grades. Throughout the semester, a student receives grades for continuous and summative assessment which are the variables used to represent this factor.

Risk Costs (Rc). Also as an approximation to the risk costs in a business, we have defined the risk cost of a student as whether they have completed the prerequisites for a subject or as the time lapse between since the prerequisites have been completed to the commencement of the course. Furthermore in certain subjects specific skills such as programming, modelling etc. can be useful. Whether the students possess these skills could also be a variable in student successfully engaging in the subject.

One of the original factors to CLV, acquisition costs of a customer has not been interpreted into the learning context. This is due to the fact that we focus on a learning environment where the students are already enrolled in courses, instead of a business model of an academic institution where prospective students have to be acquired through costs.

4 Data for Student Engagement Value

The previous section provides the basics to interpret and define the metrics of SEV. However, the calculation of each factor would differ greatly regarding the university analyzed and its data collection capabilities. In order to expand on our proposal of the

SEV model and define a possible implementation of its factors we used real data extracted in the context of the Open University of Catalonia (UOC). The UOC is an established Internet-based open university in Barcelona, Spain. Large bodies of students enroll in degree programs at UOC where all student learning and assessment is done online. Information about the learning process students do using the VLE and the track of the students in the VLE is used to populate a central data warehouse (Minguillon et al. 2016).

The data collection of our case study deals with the subject of Fundamentals of Programming, a mandatory 6 ECTS credit course in the first academic year offered to both the Telecommunication Engineering and Computing Engineering degrees at UOC. In Fundamentals of Programming course students make use of two learning spaces, the virtual classroom in the VLE as well as a wiki platform (xWiki) where they access the learning material. We have also implemented a student engagement capture module (Balasooriya et al. 2017) in the course where students leave a combination of cognitive and emotional engagement data. The data collected is the union of some data extracted from the data warehouse (such as the student forum activity, the teaching plan views, the library materials access and the connection patters of students at the VLE) and data collected by the student engagement capture module (such as behavioral data from the xWiki, video play events and tab clicks containing programming codes and algorithms).

We aggregated the collected data according to the SEV factors they help to explain, establishing a set of variables that can be used to calculate each factor value. Due to space constraints is not possible to describe the variables of all the factors here. Therefore, we present the most representative factors and assigned variables here.

Recency (R). In the case of UOC, we have collected data for a series of variables that represent recency in the learning environment. Table 1 represents our initial model for the R factor, based on the behaviors of students in the virtual classroom as well as the xWiki.

Table 1. Variables associated with the Recency (R) factor in SEV

Factor	Variable
Recency (R)	Recency of access to wiki, Recency of access to virtual classroom, Recency of engagement (leaving feedback), Recency of reading forum posts, Recency of writing forum posts, Recency of responding to forum posts, Recency of activity view, Recency of tool access, Recency of library materials access, Recency of LTI tool access, Recency of activity resource access, Recency of teaching plan view, Recency of video play, Recency of tab view

Similarly, the variables of Retention (Re) factor, presented in Table 2, focus in the effort required to guaranty the retention of the student: the time spent by teachers to trying to recover students who either dropout, may potentially dropout or fail.

Table 2. Variables associated with the Retention (Re) factor in SEV

Factor	Variable
Retention (Re)	Time spent on feedback to dropout students The number of messages sent to dropped out students The number of reminder messages (for delays) had to be sent to the student? The number of personalized messages sent to a student regarding poor performance

The factor of Risk Cost (Rc), see Table 3, have as variables a Boolean telling whether an student has fulfilled the prerequisites set for the subject (if not the risk of failure is higher), a numeric regarding the time spend until the student fulfilled the prerequisites (if a subject “Basics in informatics” is a prerequisite and was performed 10 years ago, there is risk that the student has forgotten about the basic concepts of the subject, resulting in a higher risk of failure) and a numeric that summarizes information of previous subjects (basically knowing whether student passed the related subjects and with what marks) in order to know how potentially well prepared the student is for performing successfully the current subject.

Table 3. Variables associated with the Risk Cost (Rc) factor in SEV

Factor	Variable
Risk cost (Rc)	The student has the required prerequisites The time lapse between completed prerequisite and the current enrolment The student possesses the technical knowledge required (in certain subjects)

Similarly, several variables have been associated to the other factors following the semantics of the SEV definition. For example the factor of Investment (I) takes into account the total access counts to the virtual classroom and the xWiki, total number of messages read, posted and responded in the forum etc., to represent the investment as a total.

5 Calculating the SEV

Once the SEV factors and the variables that represent the factors are defined it is possible to calculate the value for each factor. There is not a single way of calculating a factor, it would depend on how the subject is designed. For example, a subject may focus more on the learning material and forum activity rather than on the assessments. Then the variables related to the interaction and the learning material consumption should have more relevance in the calculation of the factor. To do so, we propose to assign weights in the calculation of the factors based on the contextual requirements. Teachers will define the value of the factors according to the characteristics of each subject. The final value of a factor therefore can be achieved by the following generic calculation, where *w* are the weights and *V* the variables to take in to account.

$$F = \sum\nolimits_{i=1}^{n} w_i V_i \Big/ \sum\nolimits_{i=1}^{n} w_i$$

For example, suppose the factor of Recency in the subject in consideration "Fundamentals of Programming". This subject does not have classical materials. In fact all materials are in the wiki and all the activities are performed in the wiki as well, which may be seen as the virtual classroom of this subject. Therefore, some of the variables that came from the data warehouse (such as "Recency of library materials access" or "Recency of access to virtual classroom") are of no use to the factor. Therefore, a weigh of 0 could be set to these variables in the Recency calculation. Visualizing the videos is very helpful, but there are few videos. Therefore, the "Recency of video play" is not a very relevant variable. Due to the importance of the wiki in this particular subject, the variable "Recency of access to wiki" should have the highest weight in the calculation of Recency factor.

Once the factor values are generated they can be ordered according to a pre-defined order such as the RFM. In our context, student engagement, we propose the following general model for SEV.

$$SEV\,(Student\ Engagement\ Value) = R.F.I.Ma.Re.Rf.A.D.P.Rc$$

Such a lengthy value could be too complex to make sense for human judgment. Also, not all factors are relevant in all contexts. The goal is to adapt the metric to make it usable and focused to each context. Therefore, the value of SEV can be calculated using different number of factors and classified into many different groups of interest such as, highly at-risk students, students that can be brought back to engage, students who need more feedback, High performing students who require less attention etc.

As an example, let us take the RFM equivalent of the SEV as RFI (Recency-Frequency-Investment). This value can inform about the students who engage the most and invest their effort in learning. An example value of 555 denotes a student who has recently used the VLE (the current week), and has used the VLE each week since the beginning of the course and has a very high interaction in the forum classroom (number of messages posted, read and responded, large number of teaching plan views, large number of video play events etc.). On the contrary, 111 denote the least engaged students. The rest of combinations can inform on students who lack on certain factors, such as in 552: a student who accessed recently, accesses frequently but invest less in the learning tasks. In that case teacher would have to try to figure out what happens (student is experimenting anxiety for example) and try to motivate the student to perform more learning activities.

Other methods of calculation extend upon this model where the factors of Retention (Re) and Maintenance (Ma) can inform on the students who require the highest and lowest costs from the teacher. The Dropout (D) factor can inform on the dropout students and a suitable combination of factors such as Investment (I) and Retention (R) can sort the students to distinguish likely dropped out students who have performed well but required higher costs from teachers (e.g. 545 or 455 etc.). Identification of such students can lead to better feedback and attention so that they may recover from their dropout trend.

6 Conclusions

The Customer Lifetime Value (CLV) has been a useful tool in order to strengthen the relationship between businesses and customers. By associating the semantic value of the CLV to the educational sector we have adapted its usefulness in an academic setting in order to classify student engagement, since it is a known contributor for student success. In the paper we proposed the creation of a metric, called Student Engagement Value (SEV) that allows to classify students according to their engagement. Several variables have been associated to each of the ten factors of the metric and a general formula has been provided to calculate the SEV factors and to aggregate them in order to address different analytical questions. The SEV metric will provide different values for each student; it has the potential to be a useful metric for the teachers to identify high performing students not simply based on grades but many other engagement factors, as well as the low performing students. It also offers the flexibly of combining, prioritizing and assigning weights based on contextual requirements in order to generate a series of useful indicators. The SEV can then lead to better feedback, attention and assistance to students so that the higher dropout rates that persist in education today can be reduced and rewarding students can be increased.

The variables considered in this work correspond to an online learning environment. Therefore, some may not apply to other environments and others would require to change its calculation formula. However, we believe that, at least, the proposed factors can be easily adapted to a blended or face-to-face classroom setting.

The work presented in this paper is preliminary, but promising. As further work we plan to implement a system that calculate the SEV in real-time and use the metric during the semester to see how its use may help teachers in their teaching and how the information it provides is useful to personalize the learning processes for each student. Thereafter, if the results are positive, we plan to deploy the metric at university level.

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Learning Resources Based on Analysis of Digital Newspaper Data

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Abstract. Digital newspapers are a source of information with very particular characteristics such as: they collect heterogeneous information on a wide variety of subjects, they can be considered truthful sources of information, generally their html pages have a regular structure, they are maintained permanently archived, they are quickly indexed by the main search engines, and the format of their URLs is regular, … This article describes a work developed in the context of a final degree project from the School of Computer Science at the Complutense University of Madrid. The objective of the work was to analyze the problems related to recover the information of an online newspaper, analyze which tools can be used to extract information, and how the retrieved information can be exploited in order to generate value-added services. To illustrate the results of this work, it has developed a prototype application in Python.

1 Introduction

Currently, Internet offers access to information in a simple and fast way. For this, it is enough to have a computer with an internet connection and a web browser. However, information retrieval faces essentially three problems [3]. The first problem [14] is relationed with the lack of an editorial authority to monitor the publications that are made on Internet. The second problem [2] refers to the low relevance of the information retrieved with respect to the search. Finally, the third problem [17] refers to the number of results recovered and the lack of indicators on which are the results that best fit the search.

Some of the above problems disappear or are minimized by using certain sources of controlled information such as online newspapers [8]. In this case, the first problem disappears, since the information published in an online newspaper is supervised and submitted to an editorial process [16]. This guarantees the quality of the contents both in terms of the presentation and the information reflected. However, the rest of the problems are still present to a greater or lesser degree. On the other hand, online newspapers present their own characteristics such as: they present heterogeneous information of very varied subjects, the html pages in each particular newspaper have a regular organization (they use the same structure and tags in their html pages, a set of concrete styles, they present the contents in a homogeneous way, …), the pages that make up the

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online newspaper are kept permanently archived (unless the newspaper disappears), they are indexed very quickly by the search engines, the format used in the urls of the pages follow a regular build, allow readers to add comments to the news (this facilitates automatic analysis of news content), and in general the news content is plain text inserted inside the html code [7].

This paper describes a work on retrieving and processing information from online newspapers, as well as the development of a web application that implements the main results and conclusions obtained.

The techniques of information retrieval and data analysis are a typical topic in artificial intelligence. One problem that arises when these techniques are taught in the university is to illustrate them with real examples. In this sense, the application implemented serves as a simple and quick source to obtain real examples (news from newspapers) to illustrate how algorithms of information retrieval and data analysis work, and the problems to apply them. In particular, it is useful to show the use of web scraping techniques, and the algorithm of sentiment analysis. In addition, each of the news items that are recovered from newspapers constitutes a learning object on which students can work to study the particularities of the news retrieved and how the different algorithms have been applied.

The article is structured as follows. Section 2 discusses the problem of the extracting information and some techniques available for it. Section 3 analyzes the sentimental analysis as a technique to process semantically information. Section 4 describes the requirements and architecture of the application implemented. In Sect. 5, it describes the functionality of the application. Finally, Sect. 6 discusses the results obtained and proposes future lines of work.

2 The Problem of the Extraction of Information

Online newspapers are websites made up of a large number of web pages interlinked. A distinctive feature of these pages is that a significant percentage of the information they store is represented by plain text, although the information could also be found in other formats such as images, videos, sound, or documents. Generally, online newspapers organize [4] the information into categories according to the type of information represented by the news: National, International, Economy, … Also, news of the same category are classified according to the importance they represent. This ranking is reflected in the order in which the news appears on the page, and in the fonts, style and sizes used to display the text of the content on the page [9]. For example, a news that constitutes an online newspaper headline will appear in the header of the page, the size of the text will be larger than the rest and it will have been used bold to highlight it. However, a less important news item will appear at a position below the page header, and the text will be smaller in size. This type of visual classification of the news forms part of the so-called newspaper style guide [10]. The guide describes all aspects referred to how to present the contents (fonts, font size, visual styles, structure type for the news), what kind of lexicon should be used, literary style … On the other hand, the news usually have some metadata associated or keywords that describe the information contained in the news. Also in some newspapers it is possible to find comments that readers add to the news.

In order to carry out the process of analysis of how to extract information from an online newspaper, a sample of several national newspapers was chosen in Spain: El Mundo and El País. Next, the content and structure of the html pages of each of the selected newspapers were studied, obtaining the following conclusions:

1. There are some common elements in newspapers regarding the categorization of news, and their positioning within the newspaper's web pages according to their importance. However, the sizes, fonts or styles used for each type of news are different in each newspaper. In addition, in many cases the name of the categories used is not the same although they have a similar meaning.
2. Most of the information that constitutes the news of an online newspaper is in textual format, so that the information found in other formats can be ignored.
3. The web addresses of the web pages that constitute the online newspaper are constructed following a regular structure in each newspaper. They usually contain references to the date of publication and the category of the news that contains the web pages.
4. Some newspapers add meta-information to the news within the web page. Usually, they are comments in html that are not visible to the reader and they are not displayed by web browsers.
5. The main elements of a news that can be used to extract information are: the category in which the news is classified, the keywords associated with the news, the styles, sizes and sources used to represent the text of the news, the comments that readers have added to the news, and the content of the text that forms the news.
6. There are major differences in style guides used in newspapers as there is no a standard on how news should be displayed on web pages.

Regarding the tools and techniques available to extract information, three techniques stand out:

- Regular expression processing [5]. It consists of using regular expressions to represent a search pattern, and then the pattern is used to make a repetitive search that extracts the substrings that match the represented pattern. For example, if it is considered a webpage containing links and we would like to detect such links. In order to do it, it possible to construct a regular expression that looks for and extracts the values of the links of the form: href = "http: //.+?". The regular expression looks for strings beginning with href = "http: //", followed by one or more characters ". +?", followed by another double quotation mark. The question mark added to ". +?" indicates that the smallest matching string is searched for. Finally, it is possible to add parentheses to the regular expression to indicate which part of the localized string you want to extract.
- Metadata processing [13]. Web pages are written in html which is a markup language. So, they can be processed as XML documents using processors such as DOM or SAX. In this sense, it possible to create a specific parser for the pages of an online newspaper, and to use the access and recovery methods offered by either type of processors in order to retrieve the information sought.

- Web Scraping Techniques [6]. They are frameworks that allow you to write a program that acts as if it were a web browser and retrieve the web pages. In addition, it offers other services such as [15]: (a) Methods that allow to examine the data of those pages to find certain patterns, (b) Methods that allow to transform of data without structure or semistructured in structured data that can be stored in a database for its later exploitation, (c) Automatic recognition of the structure of the data of a page, and (d) Interfaces to recover specific fields of information of a document avoiding the codification of these tasks.

The conclusions obtained were: (a) It is not possible to create a generic extractor of information for online newspapers that is adaptable to different newspapers due to the great differences of organization and representation of the information, (b) The techniques of web scraping are the tools more suitable to create an information extractor for an online newspaper since they facilitate the recovery of the pages of the online newspaper and its subsequent processing.

3 Sentimental Analysis

The sentimental analysis [1] is a technique to analyze a text semantically in order to categorize the text, to know what the text is about, to know the meaning of the opinion that it reflects (positive or negative), and to obtain the intensity of that opinion. Essentially, the technique is based on identifying the appearance of certain terms in the text to be analyzed and associating a numerical value. The information sought is obtained by comparing the value obtained with other reference values or by interpreting the value obtained. To implement it [11], in first place, it is prepared lists of terms that will be searched in the text. The terms of the list should be representative of the topic or concept being sought. For example, if the objective is to determine if a text is about education, then some terms that would be part of this list would be: education, teacher, student, lesson, etc. In addition to knowing what the text is about, it is also important to know whether the attitude described in the text is positive or negative. To do this, another list of terms that represent the positive or negative attitude is created (according to what is being sought). For example, some terms that would be part of a list of terms associated with a positive attitude would be: great, extraordinary, good, excellent, etc. Then, a numerical value is added to the terms of the lists (for example, a higher value is associated with terms more related to the concept sought or to terms that represent a more positive attitude). Once the lists of terms have been prepared, the analysis can be performed. Given a text and a list of terms, a counter is initialized to 0 and the words constituting the text to be classified are taken one by one, so that if a term appears in the list of terms, the value associated with that term is added to the counter. At the end of the process, the counter accumulates the sum of the values associated with the list terms that appear in the text. This value represents the intensity of the text with respect to the subject sought, the measured attitude, etc. With regard to how to use this number, there are several alternatives: use it directly, obtain a relative measure (for example to multiply the number of terms in the text by the highest possible score for a term in the list, and then divide the counter previously obtained between the value obtained with the multiplication), compare the value with the values associated with texts representative of it is being sought, etc. The disclosed technique can be improved by considering other aspects such as [12]:

- Interpret complex syntactic constructs (comparative sentences, negative or conditional sentences), sense of sentences such as irony, or identify mistakes made in writing the text.
- Interpret the opinion expressed in the text as for example sentences that affirm something positive by denying.
- Study the n-grams, digrams, trigrams, etc. that contains the text to refine the semantics associated with the text.

In general, the sentimental analysis is being used extensively in the context of social networks to know the opinion that have on a certain subject the users. For to it, it is used the generated information by users.

4 Requirements of the Application

The objective of the work was to create an application with the following functional requirements:

- It must allow the retrieval of news and content from online newspapers El Mundo and El País.
- You must offer a search engine about the content of the retrieved news.
- It should allow to select news according to various topics and analyze its content.
- It must allow statistical analysis regarding the news according to categories and words contained in the news.
- It should allow a sentimental analysis about the news retrieved. In this sense, it will allow uploading text files with lists of terms to use in the sentimental analysis.
- It must be implemented as a web application accessible from any browser.
- It must allow the search and recovery of news in particular about violence, economy and diseases.
- It should be easily extensible to other online newspapers. In this regard, for each online newspaper, a particular implementation must be performed that acts as a component within the main application.
- The databases used should be easily maintained.

The application has been developed in Python language using Django as a framework for web development and the specialized libraries: Beautiful Soup to carry out the web scraping on the contents of online newspapers, NLTK (Natural Language Toolkit) to perform natural language processing and PyMongo to manage a MongoDB database that stored all the information managed by the application.

With respect to the data model 4 collections have been defined in MongoDB to manage the information of the application:

- News collection. Store all information related to the news. It is formed by 5 fields: title of the news, newspaper from which the news comes, url of the news, content of the news and category to which the news belongs.
- Statistical_word collection: Stores data about the words that contain the news. It consists of 2 fields: word and counter that indicates the times that word appears.
- Search_word collection: Stores data about words that were searched for in the news. It consists of 2 fields: word and counter that indicates the times that word has been searched.
- Statistic_categories collection. It stores information about the categories with which the news are classified. It consists of 2 fields: category and counter that indicates the number of times the category is used in the periodical.

5 Functionality of the Application

The following section describes the functionalities of the implemented application:

1. Update the database of news. This functionality allows the user to update the MongoDB database in which are stored the news that are later consulted by the users, showing as result on the page some of the news retrieved (the source and title of the news are shown). The functionality consists of several phases. First, the database is cleaned, eliminating all news that is no longer available because its links have been deleted in the newspaper. Then, the online newspapers (El País and El Mundo) are consulted, all news is retrieved and finally the news are processed using Beautiful Soup (library Python for Web Scraping) in order to retrieve the information that is of interest for each of them and to store it in MongoDB. The news is stored categorized in MongoDB, using the category with which it is described in the newspaper. This functionality is accessible to the user from any page of the application, through a button called "Feed" that is in the left side menu of the application. In addition, in the left side menu, it appears links with the names of the categories, so that if it is clicked on one of the links, then it is generated a web page with a list of all the news in the database with that category associated (Fig. 1).

Fig. 1. Web page that shows news about science category.

2. Search for news. With this functionality, the user can search for news in the MongoDB database using a set of keywords provided by the user. Internally, Pymongo is used to access MongoDB and perform queries. As a result, a web page with a list with the news is returned. This functionality can be accessed from any application through the "Search" button in the left side menu, by filling in a text box with the search words (Fig. 2).

Fig. 2. Web page that shows the results of the search.

News analysis by topics. This functionality allows the user to search for news in the database containing certain words in the text and to obtain the intensity of the texts with respect to the concepts: violence, illness and economy. To perform the analysis a list of terms is used for each of the concepts, where each term has a value associated with it. The weight of the word searched in the text is then calculated (dividing the number of times each word appears between the total number of words that appear in the text). Then, using sentiment analysis, it is obtained the intensity of the text with respect to each of the concepts. As a result, a webpage is returned showing a news list where the weight of the searched words is considerable (default from 0.3). Besides, it is shown the intensity of the news retrieved with respect to the 3 concepts mentioned (in Fig. 3).

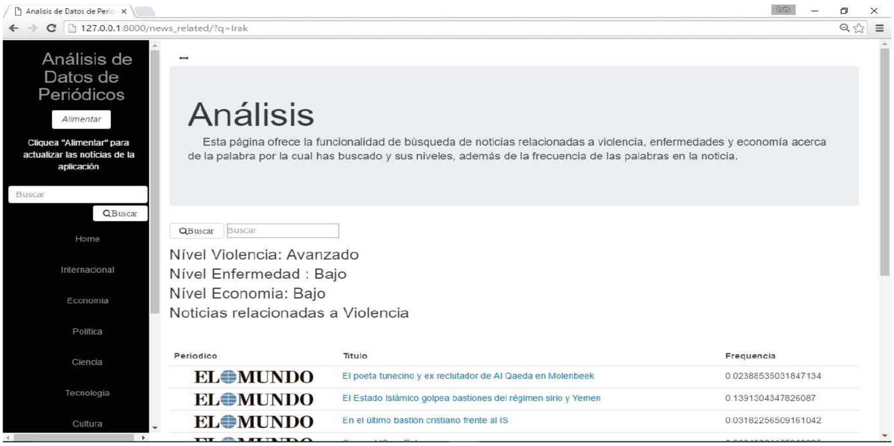

Fig. 3. Web page that shows the results of the analysis by topics.

3. Personalized analysis of news. This functionality allows the user to perform an analysis similar to that performed by predefined topics. To do this, the user uploads a text file containing a list of terms where each word has a value associated with it, and enters the words to be searched into the text. The operation is similar to the previous one, the weight of the words in the text is calculated, and the intensity of the text is calculated with respect to the list of terms provided using sentimental analysis. As a result, it is shown a web page with a list of news whose weight is considerable (default from 0.3) is displayed. In addition, the intensity of the news is shown.

4. Display statistical data. This functionality allows the user to view a web page that shows (Fig. 4):

Fig. 4. Web page with statistical information.

- The ten most searched words in the application (first column) and the number of times (second column).
- The news categories defined in the application (first column) and the amount of related news (second column).
- The 10 most popular words that occurs in stored news content (first column) and the number of occurrences (second column).

6 Conclusions and Future Work

The objective of this work was to analyze the feasibility of searching and retrieving news from online newspapers in a more refined way than searching for keywords. In this sense, the following conclusions have been obtained:

- The structure of online newspaper information is heterogeneous. In this sense, it is not possible to create a single tool that allows to process the news of any newspaper. The most optimal solution is to create particularized components to process each type of newspaper.
- The main differences that arise in newspapers are due to the way of organizing and representing the news, the language of styles and sources used to represent the importance or novelty of the news, the forms of the urls, the naming system used in the headlines of the news, and the categorization of the news (every newspaper uses a different categories).

- The web scraping technique allows you to efficiently manipulate the contents of a web page, facilitating the extraction of information from it.
- The sentimental analysis allows to make a basic semantic analysis of the contents that appear in a web page.
- On the other hand, the application developed has shown the possibilities in order to retrieve information from an online newspaper by combining the web scraping with the sentimental analysis. Likewise, its use has been illustrated in 2 specific newspapers (El Mundo and El País) and 3 types of specific categories (economy, violence and diseases).
- The retrieval and analysis of information from a newspaper is a real example that can be used in the teaching of Artificial Intelligence. This problem allows to illustrate to the students the difficulties that arise to recover information (ambiguity and imprecision of the information, semantics of the data, etc.), or the application of some techniques of recovery (web scraping) and analysis of information (sentimental analysis). And all this with the advantage of being able to experience it with real examples of an easy way using the application implemented.

The main lines of future work are to improve the application so that news can be downloaded, that the application is able to generate reports with calculated statistics and to improve the content analysis using more powerful computational linguistics techniques (it would be interesting to take into account the language of styles and fonts used in each newspaper). Finally, it is planned to add this environment as learning materials to show to students interactively a case study that makes clear the problems we face when analyzing online data, how to solve them and the results that can be obtained.

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An Adaptive Learning Approach Using a Full Engagement Educational Framework

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Abstract. This work presents an innovative framework with the aim to create full engagement for the learners on massive open online learning environments through a connectivist approach as an example of an adaptive learning experience. The proposed framework relies on the importance of creating engaging experiences before, during and after the finish of a course to increase learners' participation and reduce drop-out rates with the help of learning analytics. This work presents a compelling idea in the universe of MOOCs: It intends to expand the efforts of the learning design team to achieve pre and post-course engagement, where engagement take the form of an ongoing community of learners. This research provides results from the first successful experiences in two MicroMasters "Professional Android Developer", taught in English, and one specialization taught in Spanish: "E-Learning for teachers: create innovative activities and content" at the edX platform.

Keywords: Interaction analysis · MOOCs · Engagement · Adaptive learning

1 Introduction

Adaptive learning is a cornerstone of online learning environments, and this affirmation is particularly true as [1] recalls it as an educational method which uses interactive teaching devices to orchestrate the allocation of human and mediated resources according to the unique needs of each learner, but at the same time it is important to identify how the learner can be involved in the course from the beginning. This case is evident while managing massive online open courses (MOOCs). It is important to also notice the observation from [2], stating that the use of analytics in education has grown nowadays for four fundamental reasons that can contribute to the enhancement of adaptive learning approaches: (1) a substantial increase in data quantity, (2) improved data formats, (3) advances in computing, and (4) increased sophistication of tools available for analytics.

In this sense, taking into consideration the particular case of massive online open courses (MOOCs), it is possible to identify three phases related to the learner life-cycle in a MOOC: pre-MOOC, MOOC and post-MOOC, moreover, there are interesting studies in literature [3–6] about the use of learning analytics to identify the high drop-out and low approval rates from learners. In terms of learner engagement, Kuh et al. [7]

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defined the term as a two-fold condition. The first one is represented by the amount of time and effort learners put into their learning activities and self-study. The second component of learner engagement is represented on how the institution deploys its resources and organizes the learning activities in order to induce learners to participate in the proposed activities that lead to the experiences and desired outcomes such as persistence, satisfaction, learning, and finally, course completion and certification. Both components represent study fields based on the data analysis, but more important based on the context and progress of each learner. In the same line, there are studies in literature [8–11] that explore on different approaches to motivate and engage learners to be persistent and complete a course with a strong component of service-based architectures and cloud technologies used for learning activities. Nevertheless, it is not possible to find an online framework proposing specific actions to be performed to involve learners in all the phases of a MOOC (pre-MOOC, MOOC and post-MOOC) while at the same time perform learning analytics providing context-aware information based on each of the phases of a MOOC.

This work presents an innovative online framework with the aim to create full engagement for learners on massive open online learning environments. The proposed framework relies on the importance of creating engaging experiences before, during and after the finish of a course to increase learners' participation and reduce drop-out rates based on a strong component of learning analytics and providing context-aware information based on the actual status of the learner. Moreover, we are proposing an additional level of engagement based on the specific topic of the course, as an example it is possible to consider the case of a learners interested in a specific theme: "the Development of Android Applications". In this sense, the learner has an eager interest in the topic, the first level of engagement, then it is possible to identify the engagement in the course itself, this is related to the tasks, contents, and learning activities within the learning environment. For this, it is important that the learners are engaged at both levels, interested in the topic and the learning activities presented in the course. This work presents the first successful experience results from two "MicroMasters" specializations in the edX platform: "Professional Android Developer" and one specialization taught in Spanish: "E-Learning for teachers: create innovative activities and content". For this, the work is organized as follows: Sect. 2 presents a literature review related to virtual communities and MOOC frameworks. Then Sect. 3 describes the proposed Full Engagement Educational Framework (FEEF), complemented with a first validation of the proposal in Sect. 4. Finally, in Sect. 5 conclusions are presented with a lookout for future work.

2 Related Work

The creation of virtual communities around a common topic, but especially in the context of e-Learning, is a well explored topic in literature [12–15]. In this sense, the work by Barab [14] clearly identifies that there is an evident gap between a real community of learners and a group of individuals learning collaboratively, enrolled in a common virtual space but without a genuinely sense of belonging. It is interesting to mention the experiences from the “EdTechX: Educational Technology XSeries Program” and the “U.lab: Leading From the Emerging Future course” taught through the edX platform using external forums to enable different communication channels and a closer relationship with the learners. Overall, the learning experiences have been improved through the creation of a community of learners. In this sense, this concept is related to the term “communities of practice” that was introduced by Wenger as: *“… are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly*” [18]. Moreover, according to Hlavac [20] social communities can be classified into either Passion or Trigger Event Communities. In a Passion Community, people join because it addresses things that speak to their deep needs and ideals. In seeking community, they look to engage and interact with like-minded individuals, as well as hearing new information around this topic on the other hand Trigger Event Communities are related to specific events like the life of parents with kids or a specific holiday in the year. In this sense in order to create real engagement it is necessary to involve participants in real Passion Communities. This concept is particularly important in MOOCs because in general, a good amount of the participants of MOOC courses are professionals that are looking to update their knowledge and improve their career with specialized content. It is important to highlight that although the aforementioned courses used external forums and channels to improve the learning experiences, it is not possible to identify an on-going and *active community* before or after the end of the courses.

In terms of engaging experiences, the work by Malthouse and Peck [19], highlights that the most engaging experiences in media content that can be applied to a learning scenario are related to prepare content that fulfills and fits into the learners’ lives. The following concepts developed by [19] are related to the impact that a content in a course should evoke in a learner:

- The Talk About and Share Experience: A few examples in this concept are: “I bring up things I have read in the course in conversations with many other people”, “Reading the course content gives me something to talk about”, “A big reason I read this blog is to make myself more interesting to other people”, “I show things in the course to people in my family”.
- The Civic Experience: This idea is related with comments as the following: “Reading this course content makes me feel like a better citizen”, “Studying this course makes me more a part of my community”.
- The Utilitarian Experience: “I get good ideas from this blog”, “I learn how to improve myself from this course”, “It shows me how to do things the right way”, “This Web gives good advice”, “It helps me make up my mind and make decisions”, “The content makes me smarter”, “It looks out for my interests”, “It is convenient”.
- The Timeout Experience: “It is my reward for doing other things”, “It’s an escape”, “I like to go to this site when I am eating or taking a break”, “It takes my mind off other things that are going on”.
- The Feel Good Experience: “Reading this content makes me feel good about myself”, “When reading this content, I am worry-free”. [19].

Finally, In terms of online frameworks related to MOOCs, it is possible to find in literature interesting proposals for frameworks intended for educators to describe and design MOOC courses [21], to improve the learning outcomes in MOOCs based on different learning strategies [22], and a framework to take into account the accessibility in the different phases of a virtual learning project [23–25]. However, there are no proposals related to the different actions that need to be taken to maintain and increase the engagement in MOOCs while at the same time measuring, collecting, analyzing and reporting of data about the learners and their contexts in order to perform specific actions to enhance the learners' engagement.

3 Framework Proposal

The aim of the Full Engagement Educational Framework (FEEF) [27, 28] is to create a holistic learning experience that will last before, during and especially after a MOOC course is finished. This framework is composed of different strategies to identify specific target audiences in order to create engaging experiences through valuable and interesting content based. Moreover, the main idea is to move learners from each of the following groups: Potential Learner, New Learner, Low-Activity Learner and Active Learner with a strong use of learning analytics. The different strategies are planned to increase learners' activity and create a long-lasting relationship through *high content value* and a sense of belonging in an *active community*. The definition of the proposed Framework (FEEF), is based on three building blocks: The concept of the FEEF, the components and the expected results. In this section a proposed Case Study and the three building blocks will be presented.

3.1 Case Study

In order to identify each of the phases of the learner life-cycle (pre-MOOC, MOOC, post-MOOC), the use case of a participant enrolled in a course is presented. In the pre-MOOC phase, the learner was enrolled to the course two months before the beginning of the learning experience. During this waiting time several scenarios can happen, including a loss of interest from the learner in the course topics or the emergence of new time-consuming tasks that will hinder the participation of the learner in the course, leading to a potential drop-out. In this sense, it is important to mention the high amount of learners that enroll on a course and actually never log-in to start the learning experience. The second phase of the participation cycle is the learning experience within the MOOC, this phase involves the specific duration of the course and the different activities planned by the teaching staff.

The post-MOOC phase begins after the end of the course and it is important to highlight that nowadays a good part of the learners that are enrolled in MOOC courses are looking to improve their careers or learn new competencies to apply to a new job. It is interesting to mention that Jennings and Wargnier [16] explored on the so-called 70:20:10 rule [17]. This rule states that only 10% of relevant knowledge and expertise is acquired through formal training and education (e.g., MOOC courses), 20% through coaching and mentoring (e.g., from team-workers and bosses), and 70% via on-the-job learning, learning by doing, and other actual experience-building activities. This rule is well-accepted and used in the corporate training world, at the same time this could be interpreted that learners need to continue learning, apply the content of the courses in their jobs and get feedback from peers. This fact gives a potential opportunity to create a community from the participants of a course interested in a common subject. At the same time the idea to be part of a long-lasting and *active community* could engage participants after the end of a course. In summary, it is possible to create engaging experience about the topic of the course alongside the MOOC the activities and content included in the course itself alongside.

3.2 The FEEF Concept

The aim of the Full Engagement Educational Framework (FEEF) is to create an holistic learning experience. The proposal is intended to tackle the engagement in online courses with fixed cohorts with specific begin and end dates, but at the same time it is possible to be used with self-paced courses where there are no specific cohorts with begin and end dates, aspects that require special attention in order to give learners appropriate automatic or personal follow-up. This online framework is composed of different strategies to identify specific target audiences in order to drive engagement through valuable and interesting content. The online framework is enhanced with a strong learning analytics components that will provide context-aware information for an appropriate follow-up to the students based on their activity and performance.

3.3 The Components of the FEEF

The proposed Full Engagement Educational Framework (FEEF) is composed by the following components:

- An online community with open forums to discuss MOOCs topics and specific topics not tied to the MOOCs contents
- Production of edutainment content to create engaging experiences
- A blog to publish such *high value content* to targeted audiences
- Distribution of content to enrolled learners
- Distribution of at least 20% of the MOOC content as open tutorials
- Social media channels for content distribution to increase the reach to targeted audience beyond enrolled learners
- Specific segmentation of the different types of enrolled learners with the aim of providing targeted communication to take them to the next level of engagement and course participation

Figure 1 presents the process of the Online Framework, moving learners from the main categories: (potential learner, low activity learner and active learner).

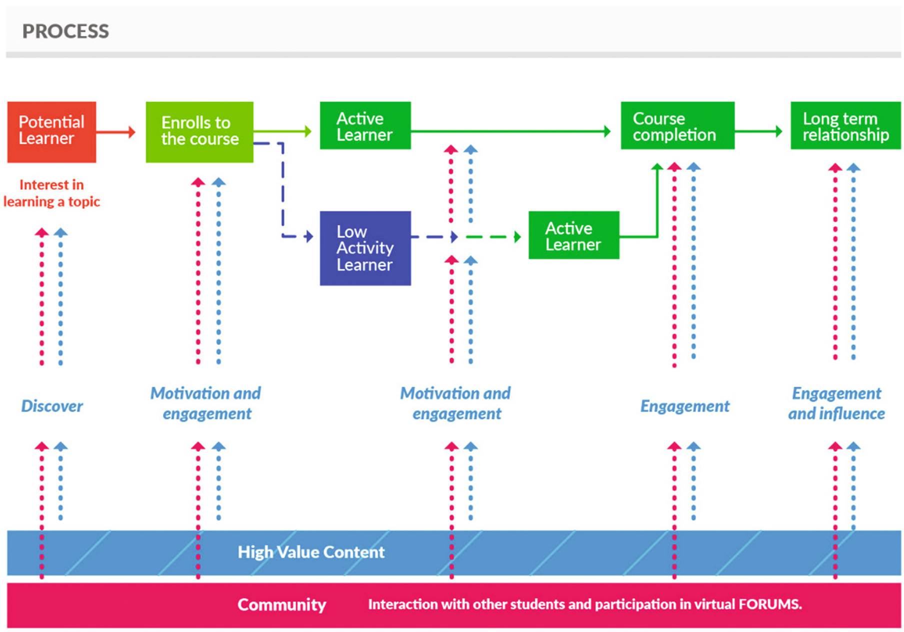

Fig. 1. Process of identified learner participation in FEEF

3.4 The FEEF Expected Results

The expected results from the Full Engagement Educational Framework (FEEF) are detailed as follows:

- Learning analytics related with the engagement perception and proper context-aware information to learners
- Identification of at least three main levels: potential learner, low to moderate participation, high participation
- Identification of the following stages: potential user stage, enrollment phase, pre-MOOC, becoming active user, MOOC, post-MOOC
- Generation of a sense of belonging materialized with the enrollment in the next courses of a proposed series of courses from the same institution
- Increased awareness and enrollment
- Generation of positive open influence on the Web in order to attract potential learners continually
- Maintain a long-term relationship with the learner, independently of her current engagement and participation level.

4 Framework Validation and First Results

The experiences presented in this work were prepared by University within the edX platform with two MicroMasters specializations “Professional Android Developer” and “E-Learning for teachers: create innovative activities and content”. This specialization has five courses and the first cohort had more than 30,000 enrolled participants. It is important to notice that both specializations are offered online with a series of courses with fixed cohorts with specific begin and end dates. However, even that there are fixed cohorts, the framework was prepared to be used with self-paced modality, a fact that allows to validate the framework through time and with different scenarios.

For the proposed innovative framework two engaging communities for each of the aforementioned specializations were prepared. The name of the communities are: Android Developers and e-Learning Masters. The communities, part of the full engagement educational framework, were prepared following the seven principles proposed by Wenger [26]:

1. The communities are designed for evolution with dynamic and updated content.
2. Facilities for an open dialogue between inside and outside perspectives.
3. Participation is encouraged at all levels, from starters to professionals.
4. The interaction was developed with public and private community spaces.
5. The communities have a focus on value.
6. There is a combination of familiarity and excitement.
7. The communities have a rhythm related to the publication of contents and interaction.

For this innovative framework, specific engaging actions were identified for each of the three phases of the learner life-cycle: pre-MOOC, MOOC and post-MOOC. The proposed engaging experiences are intended to take the participants from a very low interest in pursuing the course at a specific time, to an increased level of engagement that will enable the learner to gain real interest in the topic and invest more time to learn in the near future.

Related to the pre-MOOC and MOOC phases, the teaching staff part of the proposed educational framework prepared engaging and informative content to periodically send e-mail messages to keep the learners interested and informed even if they enrolled in the course three months before the start of the course and the high value content is sent through all the MOOC course.

For this full engagement educational framework a real community is built around each MOOC specialization. The aim is to create a community that persists after the learner finished the course through the post-MOOC phase. While nurturing a sense of belonging, sharing knowledge and increase skills, the community also serves as a place where participants can ask for help with real job questions and problems. The discussion forums are the heart of the community, thus all questions and answers are done through the community. The communities provide blogs, high quality content and videos related to the topic of the courses. It is important to mention that the community resides outside of the MOOC platform, but is fully integrated with it. In terms of the expected results from the FEEF.

For the particular case of the "Professional Android Developer" MicroMasters, the FEEF has proven to create long-lasting engaging experiences with an average of 12,000 weekly readers in the blog (http://androiddeveloper.galileo.edu). Specifically, using the PTAT (People Taking About This) metric, which represents the number of unique people that created a story about a page or on a page via different actions as the following: Like to page, Like to post, content sharing; Mentions, tags, event registration; Comments on the wall, retweets, answer to a poll. For the particular case of both blogs, the monthly average PTAT is 10,000. Reaching an average of 50,000 viewers per week, and with peaks of over 200,000 viewers per week.

Currently in the MicroMasters MOOCs the Active Learners are 20%. Furthermore, New Learners transitioning to Active Learners are 49%, and New Learners that become Low Activity Learners are 51%. Overall, it is possible to affirm that 40% of enrolled learners keep engaged with the Android topic independently of their level of progress in the MOOCs.

The Full Engagement Educational Frameworks has proven to create lasting engaging experiences move learners from being inactive to low activity to higher activity within the MOOC.

Additionally, it is important to mention that the discussion forums that are used during the MOOC course provide enhanced and easy tools to foster collaboration, and increase visibility of community leaders and major contributors, providing means for community recognition. Gamification instruments are introduced as part of this process. An important fact is that the community is fully open, and will remain open after the end of the course so the learners are able to browse through it without login, and also is possible to participate into it without being member of a MOOC in order to create a live and growing community to enhance the post-MOOC phase. Actually for the common configuration of MOOCs, the discussion forums represent and internal learning activity, but the idea is to open the access to general topic discussion forums to all participants so that the content and contribution will not be lost at the end of the course, even the enrolled learners are not able to review the discussion forums again for the expiration date of the courses, in this sense it is important to provide an open space to involve learners, potential and future learners and public in general to make use of the interesting discussions and questions resolutions of topics of general interest. At the same time, internal forums to discuss particular aspects of the course and methodology will be taken into account.

5 Conclusions and Future Work

Nowadays the MOOC movement brings together thousands of learners around a common topic for a short period of time. However, the learner's experience may last up to three to four months since the enrollment, creating a long waiting time that could be enhanced by creating engaging experiences. On the other hand, for self-paced MOOC courses the learners are starting the learning experience every day, and they could feel alone or without attention if they do not get the appropriate follow-up. In the particular case of the both aforementioned MicroMasters, the first editions were performed as a self-paced course, but now the courses are having fixed starting dates, with small time-outs in order to have cohesive groups. In the particular case of specializations with more than three courses, it is convenient to define a specific deadline in comparison of a self-pace modality.

This work presents a thought-provoking work to evolve the MOOC conception to a wider scope through the use of engaging experiences within an external community. This work proposes a Full Engagement Educational Framework (FEEF) in the context of virtual learning but especially for MOOCs. The definition of the proposed Online Framework (FEEF), is based on three building blocks: The concept of the FEEF, the components and the expected results. The FEEF is based on the use of communities of learners, active interaction and *high quality content* to motivate the learners to start, finish and approve a MOOC course, while at the same time giving the learner the opportunity to be part of a strong and long-lasting community, a *Passion Community*.

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Design of a Microlevel Student Engagement Data Capture System

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Abstract. Student engagement is a known contributor to student success. In the ever increasing channels for online learning, both engagement and success has been seen to struggle particularly in the STEM subject areas where dropouts are high and grades are lower. Student engagement has been known to be measured in lengthy questionnaires at the end of a semester, whereas we propose and design a microlevel approach to timely capture student engagement that adds the cognitive and emotional dimensions to the more widely used behavioural engagement data. In this paper we present a data capture design we have carried out to re-design the conventional method of retrospective and lengthy engagement questionnaires into a more dynamic, timely method that uses micro-surveys at strategic points in a virtual learning environment using a newly developed data capture module. We discuss our findings based on a pilot study carried out at Universitat Oberta de Catalunya, Spain.

Keywords: Microlevel student engagement · Engagement analytics · Data capture module design

1 Introduction

One of the biggest problems in higher education, particularly in online learning platforms today is the high rate of student dropout (Griffith 2010). Combined with the lack of student success in Science Technology, Engineering and Mathematics (STEM) education, this presents a severe problem towards filling the quota of critical thinkers and problem solvers the modern economy requires (Fredricks et al. 2004; Kennedy and Odell 2014). In online learning, the self-regulatory environment typically found in the traditional classroom falls away and it becomes the student's responsibility to engage with the course (Shernoff 2013). Student engagement has been a well-research area of interest when it comes to understanding learner behaviours and the relationship between engagement and success (Kuh et al. 2011; Shernoff and Schmidt 2008; Ladd and Dinella 2009). Engagement in learning refers to the behavioural, cognitive and emotional manifestations of motivation (Skinner et al. 2009) and it reflects the students' interaction with the context (Fredricks et al. 2004). Engagement is also tightly bound with the environment it occurs in as well as the individual (Fredricks and McColskey 2012). While the conventional understanding of student engagement comes from retrospective data

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collection at the end of a semester using lengthy questionnaires administered to the students, research has also shown retrospective judgments strongly differ from real-time experiences (Goetz et al. 2016) and also the engagement survey approach has been unsuitable particularly in computer science subjects (Sinclair et al. 2015).

In this sense, a re-thinking of measuring student engagement for the purposes of understanding of how students behave, think and feel in their learning in a timely and actionable manner is required. With the increasing amount of data captured from Virtual Learning Environments (VLEs) today, research has moved on towards Learning Analytics (LA) in order to construct better prediction paths towards student success as well as the development of dashboard systems for feedback and visualization and Recommender systems that support students with achieving goals (Erdt et al. 2015). However much of the research that focus on LA tend to look at behavioural data although behaviours do not reflect the entirety of student engagement. Students' subjective perceptions, as opposed to mere behavioural indicators becomes critical (Appleton et al. 2006; Garcia and Pintrich 1996). Separate research has also been carried out that measures the cognitive aspect of learning (Schraw and Dennison 1994; Zhu 2006) and emotion capture in online platforms (Boekaerts et al. 1995; Feidakis et al. 2012) apart from the purely main behavioural analytics side of LA (Pardo et al. 2017). However in reality these factors not isolated process and are dynamically interrelated within the students (Fredricks et al. 2004). The combination of all three provides a richer characterization of students as well as an opportunity to test for interactive and additive effects on one another (Fredricks et al. 2004). While the conventional engagement surveys measure the three dimensions of engagement together, their weakness lies with the retrospective nature of data collection and a macro-view of the learning process, being unusable in a dynamic learning environment. Our research (Balasooriya et al. 2017a) has introduced a framework of microlevel student engagement (MSE) to acknowledge the challenge of engagement in online learning as well as the requirement of microlevel engagement data, which can work as an accessory to the conventional macrolevel engagement survey method. It presents an opportunity to improve on the quality and timeliness of the data.

In this paper we describe how our engagement data capture process has been designed to divert from the conventional retrospective questionnaire approach to cater a more online-ready generation of learners. For this purpose we look at the literature on student engagement measurement in Sect. 2, and the stages of how we approached a microlevel design, from identifying learning components in the VLE, creating micro-surveys, creation of survey templates to the development of a MSE data capture module is described in Sect. 3. We discuss the implications of our approach, preliminary results and the limitations in Sect. 4 as well as the future modifications based on our findings, ending with the conclusions in Sect. 5.

2 Measurement of Student Engagement

Student engagement surveys have been and still are the common approach to measure student reported data on their engagement in schools and universities. A major characteristic of these instruments is that they collect data at the end of a study semester or a year, making the self-reported data retrospective (Pintrich et al. 1993; Crick et al. 2004; Kuh 2009). While comprehensive and lengthy, they are capable of covering a larger macrolevel scope of engagement, including extracurricular activities, student-faculty relationships, supportive campus environment etc. The typical length of these questionnaires can be as high as 70–100 questions per student. They are also clearly partitioned so that behavioural, cognitive and emotional engagement dimensions are clearly distinguished. Prior research such as the work done by Fredricks and McColskey (2012) and Henrie et al. (2015) have attempted to collect and classify a large number of engagement survey instruments. While the origin of many of these instruments have been paper-based in face-to-face classroom settings, online versions are also being utilized.

The National Survey of Student Engagement (NSSE) uses over 100 questions, to capture a broad set of data from active and collaborative learning tasks to student-faculty experiences (Kuh 2009). Surveys such as the Confidence and Doubt Questionnaire (CDQ) focuses only on the emotional dimension of learning (Boekaerts et al. 1995) by using smiley faces as a measurement of emotions. Surveys such as the Metacognitive Awareness Inventory (MAI) (Schraw and Dennison 1994) focus on the cognitive aspect of learning exclusively. Furthermore, other instruments focus not directly on engagement but motivation, such as the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich and De Groot 1990). Henrie et al. (2015) observe that out of 113 engagement studies surveyed 77% was operationalized from a behavioural engagement perspective. Some cognitive and emotional indicators were utilized in 43.4% and 40.7% of the studies respectively. Furthermore 43% of the studies only used one dimension and only about 21% contained all three engagement dimensions. These numbers show encouraging opportunities for strengthening the multi-dimensional engagement measurement, as some researchers argue that the term ‘engagement’ is only valid only if multiple components are present (Fredricks et al. 2004).

In student engagement studies, the main approach to measure engagement has been student self-reported data. Self-reported data reveals a higher level of information which is not directly observable such as the cognitive and the emotional engagements and is harder to infer from system-level log data (Fredricks and McColskey 2012). There is critical value in subjective perceptions of students as opposed to simple objective data on student behaviours (Appleton et al. 2006). Although in a retrospective student engagement survey the self-report method can be easily used, a microlevel adaptation of the method should be carefully approached due to the fact that self-reports can be intrusive to the students at a microlevel. A challenge also remains as to how a traditionally designed paper based large survey translates into a series of online micro-surveys by means of usability and a visual design. Therefore in the next section we describe the stages of how we redesigned the self-report data collection method for a microlevel engagement data capture in online learning settings.

3 Designing a Microlevel Data Capture of Engagement

In this section we present the steps we took in our research design. Our case study was carried out at the online Open University UOC, where all student learning and assessment is done online. In order to test our initial approach of data collection, we used an action research methodology (Susman and Evered 1978) to carry out iterative test rounds in order to improve based on the results. As a pilot study we selected the Fundamentals of Programming course offered to undergraduate students at UOC, a mandatory course in the first academic year. The pilot study was a performance test for our data capture module design as well as its usability in a real setting. The data submission was not made a mandatory part of the classroom activities since we aimed to test the organic level of data accumulation, however we presented the students with the advantages of providing the data since it would help the teachers to understand their perception on different components of the subject and would act as a feedback source.

3.1 Identifying Components of the Learning Environment

In a typical course-based VLE, courses contain various components such as virtual classrooms, a teaching plan/syllabus, multimedia based learning resources, learning/practice tools, assessment modules and communication channels such as noticeboards and forums. A VLE can also contain internal links to academic services such as virtual libraries, student-faculty communication channels or access to more information. From a learning point of view, our focus in this study is the learning-related engagement inside a course. Many institutions record the logs of each of these components which reflect student activity on a daily basis, such as number of page views, number of video-play events, navigational data inside the virtual classroom, academic grades, among others. However as noted in Sect. 2, a majority of engagement data collection instruments focus only on the behavioural dimension. As we utilize self-reports in order to integrate the cognitive and emotional engagement dimensions, we have to specifically identify which components of a VLE is suitable for, or valid for this purpose.

In Fig. 1 we present a generic structure of the VLE and its components as identified from our case at UOC so that we can define the points of interest for the data collection. In the 'Learning Resources' subset in the figure, we notate various sections and components of the xWiki pages such as the objectives, summary, examples, exercises etc. As mentioned earlier, we use these components as focal points of engagement where timely data can be acquired. For example, the behavioural dimension of engagement is already captured by the UOC data-mart when a student accesses a page or views a video. However the dynamic cognitive and emotional processes perish as soon as the activity concludes and are not captured by a survey at the end of the semester. Therefore we identify these locations where such dynamic and timely data should be captured.

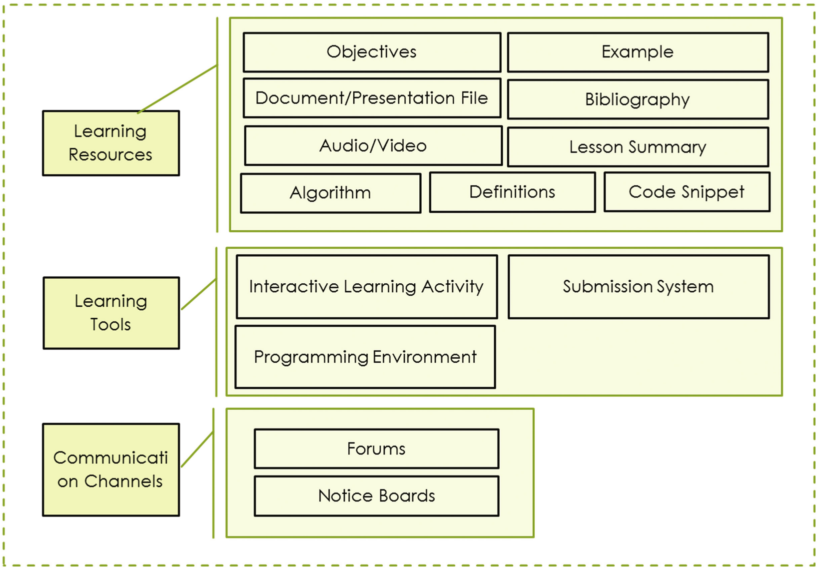

Fig. 1. Components present in the Fundamentals of Programming course VLE

In this course the major component of learning occurs in a wiki platform (xWiki) where the learning resources are hosted. Therefore first iteration of the module test was based on the student engagement with the xWiki platform and the learning resources in it. In addition the students also access the campus VLE where they have to download the assignment activities and use the message forum and class notice board.

3.2 Defining Engagement Micro-Surveys

Breaking down a longer and larger-scope engagement questionnaire into a series of micro-surveys comes at a cost. Much of the macrolevel variables such as extracurricular engagement has to be trimmed in order to fit the microlevel focus of the instrument. Therefore in our study we have selected only the engagement with learning tasks as they correspond directly to the microlevel activities the students carry out in-class such as watching a video or reading a text. This is one of the main reasons why we emphasize that although MSE is an essential set of data, it works best as a component of a larger whole of student engagement measurement.

Short forms that use as low as 1 item to 3 items of academic data capture has been recommended as a reasonable alternative in cases where longer instruments are not suitable (Gogol et al. 2014). In our study where self-reported data is required in situ, we utilize this approach in order to minimize the intrusiveness of the instrument. We have limited the number of questions to a maximum of 3 but mainly keeping the regular number of questions to 2 per survey. Another decision we have made in this approach is to not prompt both cognition and emotion based questions unless they are essential in the context in order to keep the instrument shorter and directly applicable. For example we focus on the cognitive side more in a task of watching a video or reading an algorithm and omit the emotional data such as if it makes the student happy, whereas we omit the cognitive side when we focus on a task where the measurement of emotion holds more value. In some tasks we measure both aspects simultaneously. Table 1 shows variations of the use of cognitive and emotional survey items.

Table 1. Variations of the capture of cognitive and emotional data in context

Component	Cognitive	Emotional
Example	The example has been easy to understand	–
	The example clarifies the concept well	–
Lesson content	–	I'm interested in the lesson contents
Lesson summary	The lesson has been easy to follow	I'm satisfied with the number of examples

The survey questions are answered in the ordinal format of 1–5 Likert scale with an additional option of 'not sure'.

3.3 Creating Templates

Having created the micro-surveys, we format them as a web template so that they can be invoked on demand inside the VLE. These templates are HTML pages that contain the web form and are designed for each of the learning component types in the VLE as identified earlier. Figure 2 shows one such template for a scenario where a student is learning a programming algorithm. In multi-lingual contexts, templates can be created in any language and the module is capable of retrieving it based on the end-user language.

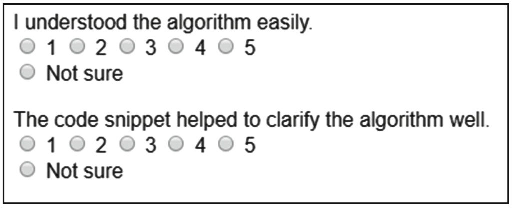

Fig. 2. A template that contains questions on algorithm understanding

Template creation separates the surveys from the main VLE platform and therefore it is flexible to develop various templates for various components and simply invoke them. Different institutions can collect context-specific data and still analyze engagement dimensions. In a simplified way, this architecture is illustrated in Fig. 3 below.

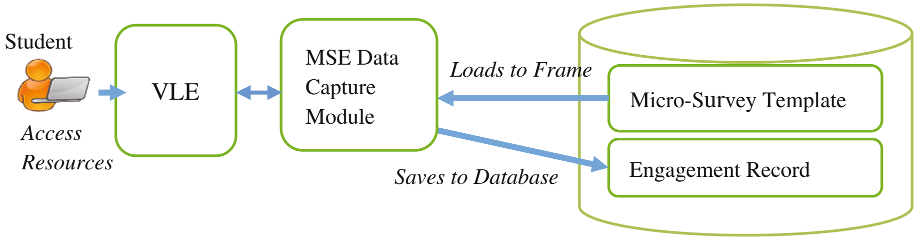

Fig. 3. Loading the question templates to the VLE and capturing engagement data

3.4 Data Capture Module Design

User experience design (UX) and the interaction design were design considerations put into the development of module. Based on inspiration from online platforms which prompts for user feedback, we opted to use a sliding window from the right hand side of the page where a button would be visible in order to open it. A larger reasoning behind this was to allow the students to take their time with the learning task without being forced to input data from an intrusive popup screen which would disrupt their work. When the data was input, the feedback window would be closed automatically. In Fig. 4 we can see the layout of the data capture module in-line with the learning task, in this example the objectives for a lesson.

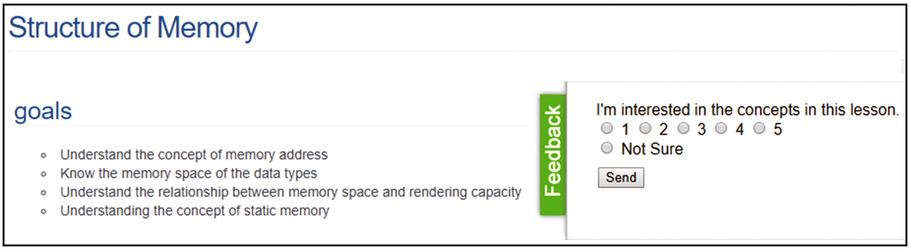

Fig. 4. The layout of the data capture module in the objectives section of a lesson

The module was created using JavaScript and HTML/CSS and the code block for the slide-in box, it was placed in each of the locations in the xWiki as identified earlier. Attribute values were sent as parameters in order to fetch the required question template, for example if the question template for a lesson objectives was needed, a parameter 'objectives' was coded into the attributes in that location. In this way the data capture module can be integrated in any desired location simply by placing the code block and changing the required question template. Furthermore the content language was also captured from the page so that the corresponding question templates can be automatically selected. The user ID was also captured from the session in order to anonymize it and store it for analytics purposes. Due to its implementation simplicity, the module can be integrated in any HTML based platform in order to invoke the data capture module.

4 Discussion, Limitations and Future Work

In our study we have attempted to redesign the student engagement data collection process by focusing on a microlevel of engagement rather than the retrospective method. Using the data collected at UOC in the Fundamentals of Programming course we have received data from 50 students during the pilot study which makes up around 25% of the total number of enrolled students. However with the number of dropping out students throughout the semester we believe that the approach is a promising method of understanding the classroom context in a more dynamic way. One of the opportunities we have identified in increasing the response rates is to incorporate the MSE data submission part of the continuous assessment process (Balasooriya et al. 2017b). Our data have shown capable of producing valuable information such as interest levels that students show (part of emotional engagement) in the ongoing lessons as illustrated in Fig. 5. Such microlevel results are currently not generated in the conventional engagement research.

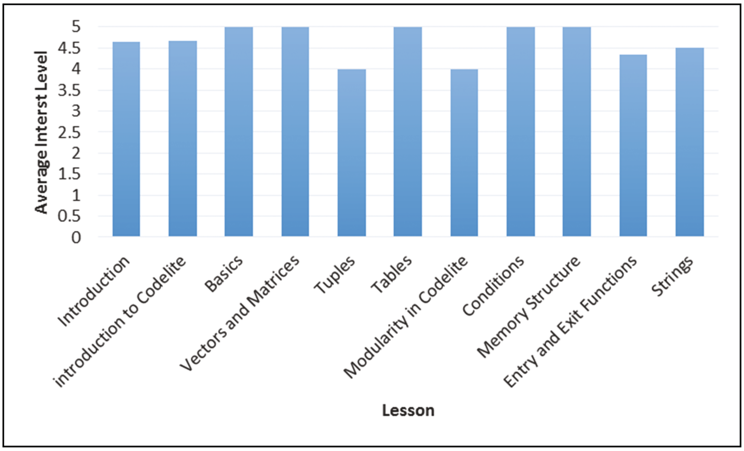

Fig. 5. Average student interest levels in lessons

We have also produced results regarding the average cognitive and emotional engagement levels in each lesson, each resource type etc. Such a dynamically produced set of information has the potential to inform on the strengths and weaknesses of the ongoing teaching methods or the learning resources and helps pinpoint to exact locations where students are having difficulties.

However one of the weaknesses of our initial approach has been the lack of organically provided self-reported data on engagement. Based on this knowledge, our second iteration is being planned in which we aim to test multiple possibilities such as making the data submission part of the continuous assessment process or redesigning data capture module with easier access by reducing any extra action by the students. Further work is needed to be carried out in order to integrate the rest of the components of the VLE so that more MSE data is collected.

5 Conclusions

Student engagement has been an essential research component towards understanding student success. Particularly in STEM education and online learning settings the need for higher success rates has always been in demand. While retrospective data collection on student engagement and a macrolevel approach has always dominated the student engagement research methods, more and more dynamic data produced from online learning platforms has pushed for the need for a timely and a better understanding of ongoing student behaviours, cognitions and emotions. Therefore in our study we have looked at the design of a data capture method in online learning environments where timely data can be captured not only at behavioural and system-log level, but also from self-reported data on cognitive and emotional engagements. We have designed and developed a data capture module in order to integrate them in VLEs by focusing more on a microlevel of learning. Our initial results show that MSE data has the potential to inform about the students in a richer way, providing more opportunities for teachers and institutions to support them and redesign their own approaches to teaching.

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Voting in Distributed Revision Control Systems

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Abstract. In a distributed revision control system (dRCS) such as git, the clear divide between developers with commit rights and outsiders prevents the system from being used in projects where the content is contentious, such as political documents. We design and implement a framework that does allow a large number of users to establish a consensus current state of a repository by voting on commits.

1 Introduction

In a traditional revision control system, the access rights are binary: Either you are a developer and thus can modify all branches at the central repository, or you are not, and thus have no rights to modify anything. Distributed revision control systems (dRCSs) allow finer control since every user can have their own repositories, containing their own (or common) branches. When a user wants to get the newest state in a dRCS, they have to decide which of the forks they prefer. In many software projects, one of the forks is the *de-facto* primary fork used by almost everyone, and just like in traditional revision control systems, is only writable to a few chosen developers. At most, some branches are off-limits for some developers, or automated checks are performed to ensure that code fulfills minimum standards.

Sometimes, additional *code review* systems are in place. Some, such as the git-appraise project [1], even work in a distributed fashion. Oftentimes, the barrier placed by the code review system for new code to be integrated into the repository is just social; developers are supposed to await agreement before committing the changes, but are not hindered by the access control systems. More advanced code review systems may require a quota, say 3 developers, and/or passing of automated tests.

This design works reasonably well for uncontroversial software where most, if not all changes are unobjectionable. We would like to bring the features of dRCS – namely censorship-resistance/decentralization, traceability of changes, and cooperation – to political drafting (for instance, of a party manifesto, a constitution, or a tax plan) where discussions are heated and some users may want to obstruct the process.

One could easily allow any political collaboration in existing dRCS by restricting every party or individual user to their own branches. However, such

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a dRCS would just manage the multitude of opinions instead of producing any consensus. We define consensus as **one current version** of the document.

This version and its history of all changes which contributed to it form the **dynamic master branch**. While users can still see other branches and work on their own branches, the dynamic master branch provides a common consensus. Its newest commit forms the state of the repository that new or non-involved users see by default.

Therefore, we propose an extension of dRCS which allows a large set of active users to democratically vote on what the current newest version in the system is.

Explicit votes are already recorded in code review systems. We propose to record votes within the dRCS itself. The major contribution of our paper is an algorithm that determines how to calculate the dynamic master branch given a graph of commits and votes on them, and an implementation of this algorithm with the git dRCS.

Our motivation of political drafting does not preclude software or any other projects using dRCS from profiting from the approach. While a radical departure from current organization, the dynamic voting enables a much lower barrier when selecting active developers, as a single bad apple cannot destroy or significantly impede the project's progress. Additionally, we theorize that voting does scale better than existing code review systems with a larger project size.

The rest of this paper is structured as follows: After relating to similar areas of research, we start by outlining an attacker model and the basic design parameters before we delve into the assumptions and utility functionality we require. The main contribution of our paper consists of describing a set of properties that should apply to all voting systems in dRCS, and then describing an algorithm which fulfills these. We also explain how we implemented the proposed algorithm. We finish with conclusion and outlook.

2 Related Work

There is a huge body of research about secure electronic voting [2], most of which is orthogonal to this paper; we strive to apply voting to dRCSs.

As already mentioned, code review systems function similarly to what we want to achieve. However, code review systems focus on improving quality instead of picking which way a repository should evolve. As such, both the voting schemes and the integration of content is not present in the feature set as described by Bachelli and Bird [3].

The voting system we present bears similarities with proxy/delegation voting; Instead of voting on delegates who determine an end result, our users' votes on versions determine the end result. Proxy/delegation voting is a research branch of its own.

3 Attacker Model

In contrast to a regular dRCS, where all users are collaborating peacefully, we assume that some users act if not outright maliciously, then at least vehemently in defense of their political views. In addition, agents of the status quo will want to shut down *any* discussion, either by outright denial of service[1] or by flooding the dRCS with nonsensical, offensive, or similarly inappropriate content.

As such, we must design the voting scheme so that it resists any attacks. In particular, we assume that users may engage in, among others:

(1) Spamming the system with meaningless content.
(2) Offering a large number of alternative suggestions.
(3) Riding a popular suggestion by proposing a change that inverts the original meaning, and optionally introduces the content the attacker preferred.

In our analysis, we focus on the security properties of the algorithm and not a real-world project implementation. Thus, we exclude a number of attacks, namely:

- Temporary denial-of-service (flooding) attacks, i.e. those which focus on CPU or network usage.
- Attackers preventing the good users from communicating, for instance in order to suppress votes. We assume that all messages between the good users get through.
- Attacks against cryptographic primitives.
- Attacks against software implementations of the algorithms.
- Attacks against hardware and software platforms.

4 Assumptions

We assume that we can defend against the basic forms of spamming by imposing a user quota (say, 100 MB). Networks nodes can also choose to omit content that has no chance of being selected for inclusion in the dynamic master.

4.1 PKI

In order for quota and voting to be meaningful, we must be able to prevent Sybil attacks. In Peer-To-Peer networks, Sybil attacks can often be defended against by proof-of-work or clever distribution of responsibility. This may very well work to ensure file size quotas: for instance, we could require completing a puzzle whose difficulty is equated to a certain total file size per user.

Unfortunately, our application has a much lower tolerance against Sybil attacks: In a small project with 100 active users, even 20 votes will regularly be decisive. At the same time, having 20× the computing power/memory bandwidth/disk space of the least-powered user is well within the reach of any attacker. Therefore, proof-of-work-solutions cannot be applied here.

[1] A dRCS is uniquely able to resist DoS attacks, since it can in principle work via sneakernet, and thus thrive even when Internet access is completely censored.

Therefore, we assume that some PKI that certifies the identity of all users. In principle, even a web of trust (as long as it is offering protection against Sybil attacks) would work: Every node just ignores content and votes by users it does not trust. However, in order for the consensus to be universal, i.e. the dynamic master being the same for all users, it is necessary that trustworthiness is a global property.

Therefore, in the following, we assume a very simple PKI in which a central certificate authority certifies the identity of all users. Notably, the CA only needs to certify identity, not beningancy.

4.2 Graph-Based dRCS

In this paper, we focus on graph-based dRCS such as git and mercurial. This is opposed to centralized systems such as subversion, which are very easy to censor, and patch-based systems such as darcs, which pose their own unique challenges. In such a graph-based dRCS, every change leads to a commit, which has a number of predecessors, forming a DAG:

- Commits without parents are *root commits* created at the start of a project. Most repositories contain just one root commit, but this is not necessary.
- Since root commits are rarely perfect on the first try, commits with 1 parent are the norm; they build upon their parent commit.
- Commits with more than one parent are merge commits, which combine the contents of the parents. The content of a merge commit may be calculated automatically, with human intervention, or a combination of both.

As opposed to patch-based dRCS, the choice on what to display is simple: The commit comes with its current state (no computation necessary). Its history can be determined by exploring the DAG. Thus, we just have to select one commit.

Votes are being stored and distributed alongside the commits. One can vote for a specific branch by voting for the current newest commit in that branch. We assume at that there is at least some non-malicious path between all honest users, which prevents vote suppression attacks. Crucially, being a simple set, votes can be merged quite easily. For now, we assume a vote consists of a simple digital signature of `I vote +1 on commit b728c31`.

5 Vote Counting Properties

In this section, we lay out the fundamental properties any sensible voting system in a dRCS must fulfill by listing a number of test cases.

Our voting system must deal with unique challenges. Since new commits are not only added more often than many users will vote, but are also expected to win with regularity, we need a way to transfer existing votes to new commits. In addition, as opposed to a normal election, where there are usually only a couple of sensible candidates, a repository can easily contain hundreds or thousands of commits.

Whenever we compare two commits, all else being equal, the pick must simply be the commit with more votes. Since we engage in a form of approval voting, we only need to compare the absolute number of votes. Figures 1 and 2 show the simplest cases: two commits with the same ancestor node, or two root nodes. Nevertheless, we predict that most new commits are born out of existing ones, and thus most repositories only have one root commit - after all, that's what we commonly see in existing graph-based dRCS repositories.

As shown in Fig. 3, we must compare all commits in the system. Since an attacker can chose between suggesting their changes as one commit or a very long chain, both variants should be equal. An algorithm must not walk the graph and decide which child to pick on each step without considering the grandchildren. This property avoids that the algorithm becomes stuck in a local maximum. Due to attackers being able to control their point of branching off from the line of the previously most popular commit, any attacker can easily create such a local maximum.

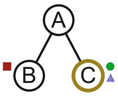

Fig. 1. Property 1a: Commits with more votes win...

Fig. 2. Property 1b: ... irrespective of whether they have a common root node.

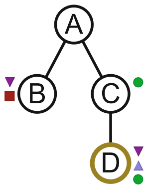

Fig. 3. Property 2: Point of branching is irrelevant.

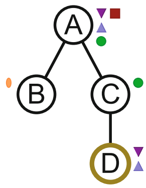

Fig. 4. Property 3: Newer votes win against older ones

Figure 4 shows another important property that any voting system must fulfill: When a user votes for a newer version of a commit, the old vote must not be regarded when comparing with other descendants of the commit that was originally endorsed. If votes for a commit would also count for all descendants, users would be unable to ever rescind their support for a commit or subgraph of commits, since after a while presumably a small change from *every* non-malicious user has been merged in.

At the same time, we may want votes to count for descendant commits as well. Granted, to ensure that we have a democratic mandate, we can select the commit with the most individual votes (B in Fig. 5). However, if some users only rarely vote on the general direction of the work, their votes are likely to spread over multiple commits (the newest or most prominent ones at the time of voting) of the branch they prefer, and thus should be combined.

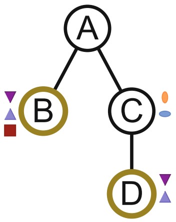

Fig. 5. Option: In this scenario, it is feasible that either B or D are selected, depending on the algorithm.

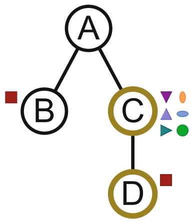

Fig. 6. Property 4: The algorithm needs to balance accepting new content and avoiding spam or unfounded changes.

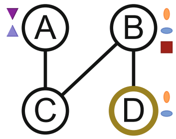

Fig. 7. Property 5: A merge should be valued no higher than the highest of its parents. This is just one simple example.

Any algorithm needs to balance two conflicting goals:

On the one hand, we most definitely want to update to commits that have a larger number of votes on them than their descendants have. Otherwise, we would be stuck in perpetuity with an extremely popular commit, remaining unable to gather enough votes for simple typo fixes.

On the other hand, we should not blindly accept any changes. For instance, in Fig. 6 only one out of the six users that voted for the previous commit C has voted for the successor C. This could easily be the attempt of an attacker who did not like C to stealthily reintroduce the content B nobody else liked.

This balances likely needs to be user-configurable, among a continuum including:

- The most popular commit overall without any regards to recent additions, for instance for a binding resolution.
- A conservative approximation of the current state, only hopping forward if a significant number of users (say, 30 or 50% of the users active in the last 30 days) votes for a commit.
- The current state of the development, but excluding likely attackers – or just less-malicious users simply changing something out of the blue.
- The bleeding edge of content - oftentimes useless, but somebody has to vote on these new changes too.

A clever algorithm may also dynamically modify its threshold depending on how different the changes are - if $C - B$ is just one small correction (and not inserting or removing a negation), it is probably safer than if the difference amounts to deleting almost everything and then inserting huge new portions of content.

We can require a more stringent approach when it comes to merges, as outlined in Fig. 7: If merges would inherit the votes of all parent commits, then an attacker would simply insert a merge commit purporting to merge *all* commits, but in reality introducing the attacker's preferred version. For this reason, a merge commit must not be ranked higher than an equivalent commit following one of the parents.

6 Vote Counting Algorithms

The trivial voting algorithm is simply picking the commit with the most votes. If multiple commits have the same number of votes, pick the one with the highest distance to a root node. This algorithm has a number of advantages:

- It is very easy to compute.
- The algorithm works with any voting system - every commit is simply an independent candidate. However, that would ignore the actual structure of a dRCS.
- Provided the majority of users does indeed vote for one commit, is very resistant against attacks; an attacker must compromise or convince a large number of users.
- Viewed as a simple vote between all commits (completely disregarding commit history), this algorithm implements a binding referendum.

However, there are major disadvantages:

- The majority has to consense on which specific commit to select.
- Once a large number of users has voted, it is very hard to advance the state. This is reflected in the failure to fulfill properties 3 and 6.

6.1 Recursive Algorithm

Therefore, we propose another vote counting algorithm – named *recursive* – which fulfills all of the previously listed properties:

1. Let the initial current node C be a virtual node without any votes whose children consist of all root nodes.
2. If C has no descendants, return C.
3. For each descendant commit of C, calculate the number of unique users who voted for it.
4. Let C' be the commit with the highest number of votes as calculated in step 2.
5. If the abort criterion is reached on C', abort the search. C is the winner and will be displayed by default.
6. Set $C = C'$ and continue in step 2.

Possible abort criteria depend on the number of unique users who voted for a commit or any descending commits:

- Falling short of an absolute number of votes, e.g. 3. While this rule is quite easy to understand and implement, it does not scale with the project size.
- Falling short of a percentage of the number of people who voted in total, e.g. 10% of active users.
- Falling short of a percentage of the number of people who are eligible to vote, e.g. 5% of users registered with the PKI. This option requires distribution of PKI numbers and is thus not optimal in the cases we aim for.

- Abort if the number is less than a percentage of the number of people who voted in the previous year[2]. To avoid manipulation of commit dates, the effective date of a commit is calculated as the maximum of the described time and the maximum of the effective date of all its preceding commits, and can never exceed the current time. If an attacker forges commit dates to be in the future, they are clamped to the current time, so the attacker might as well use the current time in the first place. If an attacker forges commit dates to be in the past, for instance in an era where only very few users are active, they can only descend from commits during that era. Since only few users were active during the era, those commits are unlikely to be picked by the algorithm.

Setting the abort criteria to abort-always results in the aforementioned trivial algorithm, so this is in fact just a generalization.

This algorithm fulfills all mentioned properties:

Properties 1 and 2 are fulfilled by the basic construction, namely step 1 and its sibling step 4, both of which look for the node with the most votes. Property 3 requires that newer votes win against older ones. By looking at the descendants of the highest-scoring commit, this property is embedded into the algorithm, provided the abort mechanism does not trigger. Property 4 is reflected by the abort criterion. Property 5 is given, since we only enter a merge commit from the ancestor commit with the highest score.

6.2 Other Approaches

With the *include-descendants* variation, in step 3 of the above algorithm, we could calculate the set of users who voted for the commit or one of its subcommits. Since any predecessor then includes all the votes of its descendants, this is not even harder to calculate; at the ith step, we only have to consider nodes with distance i to the root node, and only those children of the best-scoring commit or commits in the previous steps.

However, this has an important side effect: Two minority factions could form a coalition, of which *one* version would be picked. For instance, in Fig. 8, neither the circle nor the 4+-gon faction have an absolute majority. By simply composing all their proposals from a common ancestor, they could ensure they win if the *include-descendants* variant is being used.

On the other hand, *include-descendants* accumulates votes over a longer history, which can be beneficial as well, since it prevents an organized group which is able to focus on one single commit from overtaking a drawn-out discussion. In Fig. 9, the polygons are outnumber the ellipses and E seems to be a natural pick, but since the polygons never reached consensus on one commit, they would still lose.

[2] Or any other timescale.

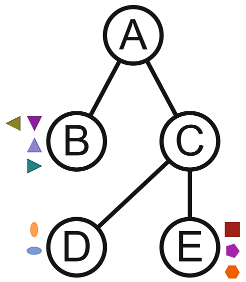

Fig. 8. If all three proposals B, D, E would be presented individually, B would win. However, by going from a common ancestor, E wins here with the *include-descendants* variation, but not with the simpler *recursive*.

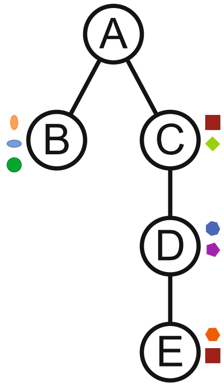

Fig. 9. 5 users have voted for E or its predecessors, but the *recursive* algorithm would pick B (3 users) nevertheless.

We also considered a number of setups which we discarded. In this section, we want to document one obvious one with significant disadvantages:

Negative votes would greatly simplify the abort mechanism, since we could simply abort if the score becomes 0 or lower. Malicious commits by attackers can simply be flagged down by the community. However, this allows active users to vote twice: Once for their preferred and once against all other versions. Reasoning over subtrees can also become much more complex.

7 Implementation

We have implemented an extension to git which realizes voting as described in this paper. For the commits themselves, we do not change the existing repository structure, maintaining backwards compatibility. You can download the complete source code our implementation at https://github.com/hhucn/git-vote/.

8 Conclusion and Future Work

We have presented how it is possible to determine the current state of a dRCS by voting. In particular, we worked out properties that must hold for all dRCS voting systems and presented an algorithm that fulfills them, as well as an implementation thereof with the git dRCS.

In this paper, we concentrated on the effects of voting on the commits and their DAG, just assuming that a **PKI** is given. Dedicated voting systems such as Citivas [4] enable additional desirable features such as anonymity or coercion-resistance. However, as long as the voting system allows votes on multiple "candidates" and enables us to trace votes by the same user – although not necessarily identifying which user this is in real life – it can be used here as well.

We simply assumed that every user could access every vote, since votes would eventually find their way through a DTN, even if some users suppress them. However, this is not necessarily the case; if an attacker can encircle their target and filter only votes for their cause, they can create a false impression of consensus. One approach to defend against that would be the use of a blockchain for the votes: Since the difficulty of achieving new solutions can be made to never decrease, a node could become suspicious if the number of blocks does not match the expected network speed.

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Analysis of Frameworks for Building IaaS Cloud Using by Cloud Computing Providers

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Abstract. A lot of companies are considering to use some cloud services and move their infrastructure into the cloud. This opens up many possibilities for providers of cloud services and IaaS (Infrastructure as a Service) services. From this reason, smaller service providers have to build their own cloud which will be offer the same capabilities like cloud services from large service providers (Microsoft Azure, VMware's vCloud Air, Amazon Web Services and others).

This article describes benefits of using IaaS clouds and available frameworks on market, includes and describes some frameworks for building IaaS cloud, which can be offered to customers via self-managed portals and tools. There is mainly described the Azure Pack solution from Microsoft, the vCloud Suite solution from VMware and possibilities of free open-source software platform OpenStack.

Keywords: IaaS · Cloud · Microsoft · VMware · OpenStack

1 Introduction

Companies are forced nowadays most effectively spend with their means, and in recent years there has been a great process of streamlining and improving the efficiency of funds spent on IT environments, services and infrastructure [1, 3].

Traditional IT previously worked as the company owned all their IT infrastructure and take care of it yourself or with the help of service companies. Such an environment has been very conservative, inflexible and inefficient [4].

One of the trends of recent years is the disengagement from the physical IT environment and use environment of providers, when companies rent computing power in cloud provider's data centers and more efficiently spend money [3].

This efficiency is based on an assumption that has been repeatedly demonstrated, the operation of data centers and the physical hardware is one of the highest IT costs, thus mainly the physical hardware acquisition and workforce, which has to take care of hardware, software and facilities. Other benefits of using infrastructure service providers includes cost model change. Costs are spread continuously and does not need to have a high expenditure on the purchase of hardware and software at the beginning of the investment. Another benefit is using of continuous and flexible response to the need for

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physical resources and real purchasing only the effective use of resources or even paying only for the computing power actually consumed.

1.1 Cloud Computing

Cloud Computing is a model, which is based on the Internet principle and providing services and computer technology over the Internet and customer accesses their services via the Internet and pay regular fees to cloud service provider, either on a subscription or consumed computing environment basis (typically processor time, operation memory, data storage, software licenses, etc.) [12, 18, 19].

Cloud environment should be properly dimensioned and correctly built to meet the characteristics that should be properly constructed typical cloud infrastructure and therefore it was really a cloud. Such properties include [1, 10, 11]:

- Self-service provisioning and operation on demand by the customer;
- The ability to access via the Internet from anywhere and from any device;
- Utilization and separation of resources among several customers;
- Scalable and flexible environment and the possibility of capacitive extension, either on side of the customer and side of the provider;
- Minimal input costs for customer for service building and configuration;
- Measurement of services and billing.

For the cloud computing area is also important transition of IT functions between the traditional IT solutions to providing IT as services.

In the last few years, the provision of IT has been changed mostly to delivering IT as a service, when a customer orders the service and then pay for it. This concept is called Anything as a Service (XaaS), where for anything can be put almost any service, not just IT service. Between basic IT and cloud services and cloud solutions from XaaS concepts belongs [7, 14]:

- Infrastructure as a Service, when the infrastructure is provided as a service and the customer rent this infrastructure to build its own IT infrastructure and take care yourself or can even rent some service supervision;
- Platform as a Service, when a customer rents ready runtime environment, a typical example is the Microsoft Azure Services, where customers can rent, e.g. database instance and there has its own data;
- Software as a Service, when entire software is provided as a service for user and a typical example is Office 365.

These cloud services differ mainly in layers, which are administered by the provider and by customer. Each such type of service has its own different uses and properties, and according to the characteristics advantages and disadvantages.

1.2 Infrastructure as a Service

Infrastructure as a Service Cloud is a service, which provides virtual machines, storage and network resources. These resources can be managed by cloud's customers and they can deploy their own operating systems, applications, tools and others or they can use any preformed templates from provider [4, 6]. These resources should be centrally managed and built with respect to be built with cloud computing requirements, which are defined in Chapter 1.1 and providers can use preformed solutions for building of IaaS cloud or they can create their own solution or use some a ready solution and add additional functions [8].

For this article propose, should be defined a framework for building Infrastructure as a Services solution. This Framework should offer a solution for building virtual infrastructure, be multi-tenant solution for more costumers and offer self-service portal for management, billing and reporting [2, 17].

Infrastructure as a Service consist these parts: compute, which delivers computing resources (virtualization platform), storage, which delivers places for data storing, networking, for network interconnecting virtual and physical networks [14].

2 Problem Definitions

As described in Chapter 1, the use of cloud services business provides benefits for these companies and thereby opens the demand for services providers.

On the market there are several major worldwide cloud service providers and products, for example Amazon Web Services (AWS), Microsoft Azure [14], VMware vCloud Air [23], Google Cloud Platform [7], Rackspace [20] and more.

These companies are true leaders, but there is still enough space in the market for smaller companies, which can offer better conditions for customers, linkage with other services, superior customer support and implementation options and much more. But smaller local companies can also offer's equivalent service using the tools that are available on the market that can be deployed in a production environment and for their use also offer Infrastructure as a Services cloud solution [3].

This article deals with the possibilities Infrastructure as a Services platform for creating cloud services, which can then be offered to customers by cloud service providers, mapping options from virtualization platforms leaders: Microsoft and VMware, as well as the possibilities of using open-source OpenStack technology.

Company Microsoft offers a framework called Windows Azure Pack, which in conjunction with Hyper-V virtualization and System Center, can provide partial opportunities this company offers its products and Microsoft Azure cloud platform.

In contrast, company VMware offers VMware vCloud Suite, offering the possibility of creating a vCloud environment based on VMWare's virtualization and also offers other tools that can be used for creating cloud environment and its management.

The created cloud solution does not necessarily serve for cloud service environment and providers, but larger companies can also build such a cloud and use within your enterprise to benefit from a private cloud model.

3 Frameworks for Infrastructure as a Service Cloud

Companies that want to offer Infrastructure as a Service solution, thus offering infrastructure services to their customers, such a solution must build a cloud and there are several ways in which such a company may issue. Might use some ready-made solutions from companies that offers such a solution or build a whole solution on open-source tools. Another option is to use a finished solution which is possible expand by yourself, thanks to its openness [3, 7].

Microsoft offers a framework which is called Windows Azure Pack (further WAP) and which is based on the Hyper-V virtualization platform and System Center, which serves primarily for the management and automation infrastructure [3, 22]. WAP is based on product Microsoft Azure and offers similar services, such as cloud services, public cloud this company and WAP is opened for further expansion using open Application Programming Interface (API) and companies can develop services that it is possible to customers through their portal to offer WAP [24].

Additionally, Microsoft is currently developing a new product called Azure Stack, which will offer even more options, than now offers WAP and which will offer services for Microsoft Azure from Data Centers of cloud service provider [13].

In contrast, VMware has a ready solution for the creation of IaaS Cloud, which is called VMware vCloud Suite, a suite of tools you can use to create and manage a cloud environment, which is also available to customers [9, 23]. VMware vCloud Suite is built on virtualization platform called vSphere and vRealize Suite Cloud Management Platform suite, which helps with managing and automatization of this cloud. This product is based on the other VMware's product vCloud AIR, the public cloud and VMware to offer customers service public cloud.

Another options for creating IaaS cloud solution and other components is using other products or tools, for example OpenStack, Apache CloudStack, OpenNebula, HPE Helion Eucalyptus, but some of these solutions are based on OpenStack.

This article deals mainly with technologies from Microsoft and VMware, thus tools Windows Azure Pack and VMware vCloud Suite.

4 Windows Azure Pack

Company Microsoft offers Windows Azure Pack (further WAP), which is built on Windows Server, System Center on instruments and is based on the same foundation of Microsoft's public cloud product - Microsoft Azure [15, 24].

The basic building component includes Windows Server, thus mainly virtualization platform Hyper-V and other services such as DHCP and DNS server, Active Directory Domain Services, Federation Services, Certificate Services, and more.

Another important part of tools of the System Center family are Virtual Machine Manager, for virtualized solutions deployment and management, and Operations Manager, for measurement and usage of the services in WAP.

An important component is the Service Provider Foundation, which provides services and connectivity to ensure the Infrastructure as a Service Cloud for a set of WAP.

This component provides management portals and binding via API interfaces to other infrastructure components, namely Windows Server and System Center.

Environment management is possible via Admin Portal, which offers the ability to manage and configure through a Web interface that public cloud. But for the next administration are available and the need for individual components and interfaces - especially console tools from the System Center family. The solution includes Customer Portal, which customers access to the leased funds, have the ability to deploy and manage services, for example, connect to each virtual machine.

Furthermore, even the SQL server that is hosting the database needed for the WAP.

Among the services, which features are included in WAP, are:

- Web sites, which can be used for creating a Platform as a Services, which can be integrated with many open source applications and tools (e.g. ASP.NET, PHP, DropBox and many more);
- Virtual machines, which offers self-service deployment and management of virtual machines, which can run Windows or Linux based operating system, including server or client operating systems;
- Virtual Networks, for creating network infrastructure and network connection to existing different infrastructure;
- Service bus, which enables reliable asynchronous messaging between applications, when sender needs to ensure that messages will be delivered;
- Database, which enables us to offer customers access to an existing SQL and MySQL databases for their applications.

Thanks to large number of API's, WAP can be more developed in-house or expanded to other third-party tools and can be more customizated.

5 VMware

VMware vCloud Suite is a package of products that serve to create a platform and cloud solution using Infrastructure as a Service. VMware's products which are included in VMware vCloud Suite are [23]:

- ESXi, which is VMware's virtualization platform (hypervisor);
- vSphere, which is used for ESXi server managing and environments;
- vRealize Operations, which is solution for managing of operations and capacity and configuration management of the solution;
- vRealize Automatization, which is solution for automation and self-service of the entire provisioning managed and deployed services;
- vRealize Business, which provides resource management and reporting.

On the figure there are a few elements, which are helping with creating whole solution [23] and these elements are vCenter Operations Management Suite, which includes vRealize Operations, Automatization and Business, vFabric Application Director, which helps with creating some templates of services, which will be offered via a portal to customers, vCloud Director, which allows construction of different cloud services in data center and offer customers a variety of parameterized, vCloud API, which is opened interface based on protocol REST (Representational State Transfer), which allows development and customizations and creating of additional services, vCloud Connector, for bulding hybrid cloud solution and connection to private or public cloud environments across multiple clouds, vCenter Orchestrator, which helps with automation of the entire environment, in terms of operations and in terms of service provisioning.

In this solution there is for customers routinely generated virtual data center (VDC), which is a logical grouping of computing resources and storage and within that VDC then the customer has the option to create their own virtual servers and other services. All the services that offers customers specific vCloud are called vApps, which may include, for example, simple or complex server system or application and these service templates are located in place, which is called vApp catalog and users have options to choose which vApp can be installed into your virtual data center [23].

In order to enable access to the same resources multiple customers or entities there can be created organization, what is collection of users and groups, and are used to separate one customer access only to its organization and its systems.

6 OpenStack

A relatively new open-source OpenStack platform also offers opportunities for cloud service providers [5, 16]. OpenStack is cloud computing platform that supports all types of cloud environments and aims to implement a single, massive scalability and rich feature set collaborating and experts from around the world.

Basic OpenStack architecture consist compute component, network component and storage. These services are connected via OpenStack Shared Services [15].

OpenStack offers the possibility to use in many areas, e.g. to provide High Performance Computing (HPC), for using in the fields of IT as a Service, Big Data, providing network topologies and services and many other areas.

For the area of Infrastructure as a Service can be OpenStack used to create a similar environment offering Microsoft and VMware as a commercial product, saving costs for these products, but this is reflected in the cost, which the state will build solutions based on OpenStack, because OpenStack as such offer no ready-made solutions and is rather an open framework for own development. OpenStack is a collection of several projects that have open APIs and that working together. These projects include for example [5]:

- Nova for compute management and communication with virtualization platform;
- Neuron for virtual a physical network management;
- Heat for cloud orchestration;
- Horizon for creating self-service portal for management;
- And many others.

OpenStack is most often used with KVM virtualization platform, but also can be used with VMware's ESXi, Microsoft's Hyper-V or Citrix Xen.

7 Comparison and Collaboration

Both solutions deliver a similar solution for building Infrastructure as a Service Cloud, but Service Provider can develop own services, which can be used with collaboration with these solutions or delivered via portal to customer.

The comparing and the decision to implement solution should be based primarily on the knowledge and the architecture of the current solution and state and comparison should be also targeted to virtualization platform, because it is core point of decision. Each of these solutions is based on the individual tools of both companies and the following Table 1 various tools are shown that are primarily used in the solution.

Table 1. Both company technologies and solutions

Area	Microsoft	VMware
Virtualization	Hyper-V	vSphere ESXi
Virtual machine management	System center virtual machine manager	vCenter Server
Monitoring	System center operation manager	vCenter Operations Management Suite
Self-Service	WAP or app controller	vCloud Director
Service management	WAP or system center service manager	vCloud Automation Center
Automatization	System center orchestrator	vCenter Orchestrator
Monitoring	System center operation manager	vCenter Operations Management Suite
Protection	System center data protection manager	vSphere Protection Manager

Microsoft's Windows Azure Pack
The advantages of WAP belong:

- A simple link to other Microsoft's technologies and systems;
- The well-known environment like in Microsoft Azure;
- Simple connection to the Microsoft Azure;
- Windows Azure Pack is more opened for development of extensions;
- Windows Server license for hosted operating systems are included;
- Suitable for Microsoft's virtualization.

In contrast, the disadvantages are:

- Some limitation in network virtualization and software defined networks;
- Only basic services are included;
- Less customized for customers;
- Development of this product has been stopped, because will be replaced by Microsoft Azure Stack product in the coming months.

VMware vCloud Suite

The advantages of VMware vCloud Suite belong:

- VMware vCloud Suite is more sophisticated complete solution for creating Infrastructure as a Services Cloud;
- Suitable for VMware's virtualization;
- High level of customization for customers;
- A networking can be expended and more complex thank of implementation of VMware NSX technology.

In contrast, the disadvantages are:

- More expensive for basic solution and deployment;
- Solution can get expensive because Windows licenses are not included.

As the advantages and disadvantages of both solutions clear, Windows Azure Pack is technically simpler and cheaper but less complex and VMware is more complex but expensive for basic deployment, but it can be said, that when company uses Microsoft's virtualization and tools (System Center), company should use Windows Azure Pack, and when company uses VMware's virtualization, that VMware vCloud Suite should be used, because these implementations will be cheaper and there will not be not implement some new and not verified technology for company.

8 Conclusion

In this article were presented solutions of the two companies, which deal with virtualization and deliver IT services and systems - Microsoft and VMware, and their frameworks - Microsoft's Windows Azure Pack and VMware's vCloud Suite.

Both of these companies offer tools or products, which can be used for creating an Infrastructure as a Service Cloud and cloud services that offer customers. These products are primarily based on instruments and other products of these companies, but are also established and based on public cloud services, which both companies offer - Microsoft Azure and VMware vCloud AIR.

In the article, the two products are compared and outlined deployment options and their potential use, whether in the area of creating a cloud that subsequently the company will be offered as a Cloud Service Provider to external customers in the area of cloud computing to create a company that will offer this cloud to internal customers. But both models are essentially identical.

The article also discussed possibilities of using open-source OpenStack, which offers the possibility to create a public cloud. OpenStack has also been described as a possible solution that combines parts of solutions from Microsoft and VMware.

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Orchestration and Automation of NVF

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Abstract. This paper explains how to handle automation of Network Function Virtualization. There is an increase of popularity of moving out from legacy hardware networking devices to virtual network appliances. Vendor's goal is to virtualize their physical products so these products can be used in cloud environments. There are also community projects like OPNFV. In our work we propose to way how to automatically orchestrate these Network Function Virtualization devices.

Keywords: NFV · VNF · SDN · Network automation · Configuration management

1 Introduction

Nowadays there is a transformation in datacenter networking for usage of new technologies in virtualization of networking devices. In past the innovation of networking was slower than in other IT fields [5]. It is not rare to have completely virtualized datacenters. The next step was virtualization of networking. There have been a lot of noise around SDN (Software Defined Network) which has multiple definitions and on one hand stands for tunneling traffic from virtual machines through legacy hardware infrastructure. On the other hand stands for configuring physical networking devices by protocols like OpenFlow. However it does not solve some scenarios. With cloud virtualization of both operatings systems and networks there is also evolution of orchestration and you can spin up whole virtual infrastructure with virtual machines, virtual storages and virtual networks. But there is one key subject that is missing in this puzzle and it is NFV (Network Function Virtualization).

Network Function Virtualization, which was first mentioned in ETSI [9], and it stands for transormation of networking functions into virtual appliances. NFV is new area and it is still under development and one of the key domains are automation, management and orchestration of virtual networking functions. It is not a problem to spin up virtual machine that should be used as firewall between two virtual machines. However there is a problem with automatic configuration of this appliance to do what is required. Lots of vendors and wide community mean lots of approaches for NFV. Each vendor tries to create his own virtual copy of their physical device.

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Goal of this thesis is to propose solution for orchestration of simple networking functions that can be used in cloud environments. The infrastructure for NFV will be based on cloud platform OpenStack and SDN solution OpenContrail.

2 The Need for NFV

This section describes why there is a need for Network Function Virtualization. Traditional networking devices like routers, switches, load balancers and firewalls are one purpose boxes which do not scale very well and are configured by standard interfaces. Networking infrastructures which consist of tens or hundreds of these devices. Management of this size of infrastructure can be painful and there is a space for mistakes [3] (Fig. 1).

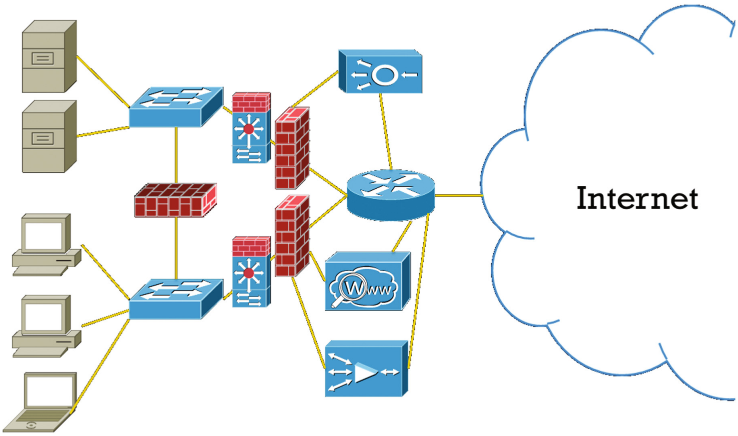

Fig. 1. Traditional networking infrastructure [4]

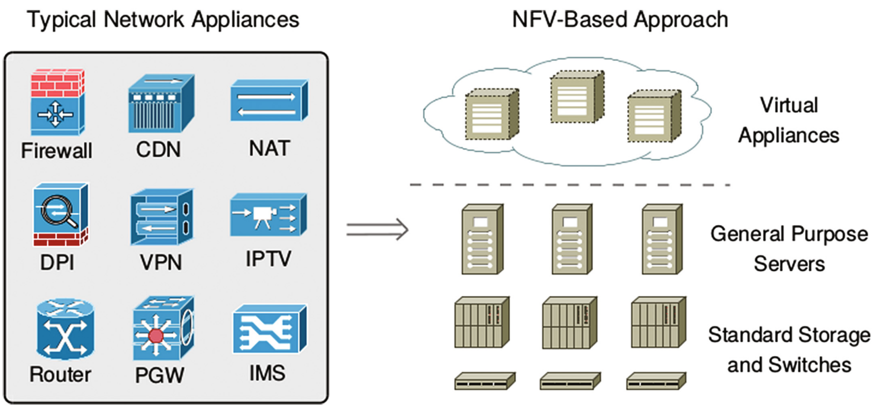

Fig. 2. Virtualization of networking functions [4]

Because of this not so flexible approach concept of NFV appeared. Whole idea is based on separating software functionality of networking devices from hardware [1] (Fig. 2).

The key components of NFV can be separated into three main parts:

1. Network Function Virtualization Infrastructure (NFVI) which stands for all hardware and software resources that are needed for creating environment for VNFs.
2. Virtual Network Functions (VNFs) are specific implementation of networking functions.
3. Management and orchestration of NFV (NFV-MANO) which is responsible for managing software and hardware resources in whole infrastructure [7].

Abstraction of software from hardware enables to use standard physical servers which are already used for company applications also for NFV. This helps with:

1. Lowering of costs - decrease of buying dedicated physical devices. Servers can be used for multiple purposes.
2. Faster Time-to-market.
3. More flexibility by scaling based on customer needs.
4. Lowering operational costs.

3 Requirements for NFV

There are many factors to consider what NFV can be chosen. Other decision has to be made for choosing NFVI. This chapter focuses on these factors.

One of the factors is availability for usage and testing. This can be in form of opensource, trial license or proof of concept. The next factor is compatibility with x86 platform so it can use traditional servers as hypervizor [2]. NFV solution should be also compatible with user virtualization platform e.g. KVM, VMware, Hyper-V... The last is integration with used NFVI which will be described in following lines.

The decision of choosing the right NFVI is as important as choosing the right NFV solution [6]. One of the factors might be openness of the NFVI solution. The other really important factor is having good option of automation of VNF like Heat in OpenStack project. The last but maybe one of the most important is support of SDN because SDN and NFV goes together hand to hand. Type of the SDN will be result of what features, like Service chaining, may be used. Two platforms that can be used as Infrastructure for NFV are VMwate vCloud Suite and OpenStack. Because we care about openness of solution, the OpenStack is used for this thesis purposes.

4 Test Cases for VNF

There are typical use cases of specific virtual functions, VNF (Virtual Network Function), under NFV framework.

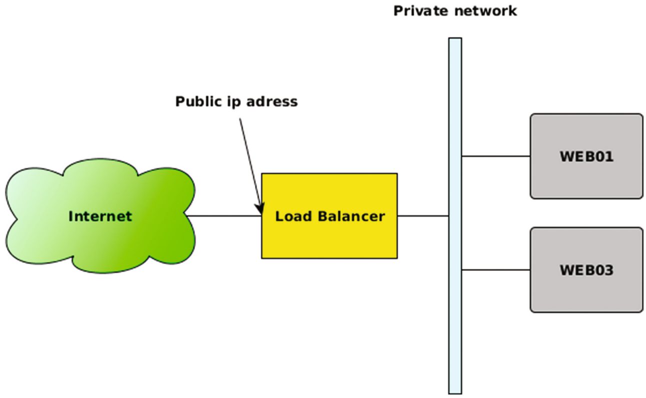

Fig. 3. LBaaS scenario

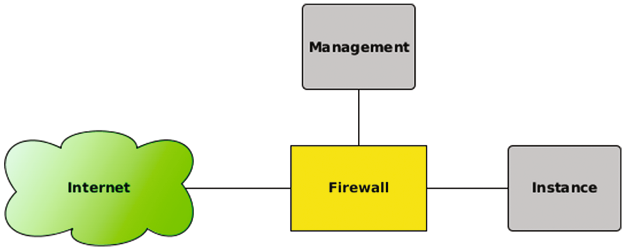

Fig. 4. FWaaS scenario

4.1 LBaaS Scenario

One of key networking functions is load balancing. The need for smarter load balancing is even increased with cloud and autoscaling [13]. When the new virtual machines are spinned up, the load balancer pool should be updated as well [8]. Lets assume typical topology for load balancing in cloud. There are two virtual networks, one for public IP addresses and second for private pool (Fig. 3).

4.2 FWaaS Scenario

Other Virtual Network Function is FWaaS (Firewall as a service). This VNF can be used for example to secure connection between private and public network or between two private networks. We can consider simple scenario where user wants to create virtual instance with internet access (Fig. 4).

5 Implementing VNF

5.1 Implementing FWaaS

In this section will be described orchestration template for FWaaS. The NFVI (Network Function Virtualization Infrastructure) in our thesis will be

OpenStack. The orchestration in OpenStack is handled by module called Heat. NFV is handled in OpenContrail by resource named Service instance [10]. This is special type of instance which is put between networks and do operations to the traffic between them. It is possible to use multiple service instances between two virtual machine. This ability is called Service Chaining [11]. The typical Heat stack for FWaaS can looks like example on following lines. Lets show only the most important parts.

The Heat stack consists of:

1. Virtual instance which will be used for VNF testing - connection to the Internet.
2. Private network for testing virtual instance and for one interface of VNF.
3. Service instance firewall VNF definition with three interfaces where left stands for public network, right for private network and management for access.
4. Policy to allow traffic to service instance.

First there has to be Service template definition. This will create generic template which defines specific parameters that can be modified during Service instance creation. In this example there is Service template which enables configurations like of availability zone, which interfaces can be configured, mode of the Service instance or static routes.

Listing 1.1. Service template

```
service_template:
    type: OS::Contrail::ServiceTemplate
    properties:
      name: test-fw-template
      service_mode: in-network-nat
      service_type: firewall
      image_name: { get_param: template_image }
      service_scaling: True
      availability_zone_enable: True
      ordered_interfaces: { get_param: ordered_interfaces }
      flavor: { get_param: template_flavor }
      service_interface_type_list:
      { "Fn::Split" : [ ",", Ref: service_interface_type_list ] }
      shared_ip_list: { "Fn::Split" : [ ",", Ref: shared_ip_list ] }
      static_routes_list:
      { "Fn::Split" : [ ",", Ref: static_routes_list ] }
```

Next thing to define is Service instance which uses Service template described above. There is specified availability zone, Service template, scaling, interfaces, etc.

Listing 1.2. Service instance

```
service_instance:
  type: OS::Contrail::ServiceInstance
  depends_on: [private_subnet_1]
  properties:
    name: { get_param: private_instance_name }
    service_template: { get_resource: service_template}
    availability_zone: { get_param: private_availability_zone}
    scale_out:
```

```
        max_instances: 1
    interface_list: [
        {
            virtual_network: "auto"
        },
        {
            virtual_network: {get_param: public_net}
        },
        {
            virtual_network: {get_resource: private_net_1}
        }
    ]
```

The last thing to show from Heat template is Contrail networking policy. Lets allow everything from both directions and apply Service instance to this policy.

Listing 1.3. Contrail network policy

```
private_policy:
  type: OS::Contrail::NetworkPolicy
  depends_on: [ private_net_1 , service_instance ]
  properties:
    name: { get_param: policy_name }
    entries:
      policy_rule: [
            {
              "direction": "<>",
              "protocol": "any",
              "src_ports": [{"start_port": -1, "end_port": -1}],
              "dst_ports": [{"start_port": -1, "end_port": -1}],
              "dst_addresses":
              [{ "virtual_network": {get_param: public_net}}],
              "action_list":
              {"apply_service": [{get_resource: service_instance}]},
              "src_addresses":
              [{ "virtual_network": {get_resource: private_net_1}}]
            },
      ]
```

5.2 Management of Fortigate VM

In this subsection will be described real case of using Fortigate firewall as a VNF appliance. How is virtual machine deployed by Heat templates was shown in previous subsection. The automatic configuration of Fortigate VM is done via management API [12]. For instance we need configuration of networking interfaces:

Listing 1.4. Fortigate interface configuration

```
config system interface
edit port1
set type physical
set vdom root
set mode dhcp
```

```
set defaultgw disable
set allowaccess ssh ping http https
end
```

The next configuration step is enabling NAT on interface from port3 to port2 so virtual machines from private network can access the Internet.

Listing 1.5. Fortigate NAT configuration

```
config firewall policy
edit 1
set srcintf port3
set dstintf port2
set srcaddr all
set dstaddr all
set action accept
set schedule always
set service ALL
set logtraffic all
set nat enable
end
```

These sets of commands can be loaded into the device by following Python script which shows how to load interface configuration. Loading of NAT configuration is analogous.

Listing 1.6. Script for loading configuration

```
from pyFG import FortiOS
import sys
if __name__ == '__main__':
    f = open('fortios_intf.txt', 'r')
    candidate = f.read()
    f.close()
    d = FortiOS('fortigate', username="admin", password="fortigate")#,
    vdom='test_vdom')
    d.open()
    d.load_config('system interface', empty_candidate=True)
    d.load_config(config_text=candidate, in_candidate=True)
    config_changes = d.compare_config()
    d.commit(config_changes)
    d.close()
```

6 Conclusion

We have managed to do the first steps in orchestrating Virtual Network Functions. This approach of using orchestration templates together with configuration tooling can be used for creating and operating virtual appliances with specific networking function in OpenStack and OpenContrail environment.

We created simple python script which uses configuration commands for Fortigate firewall to demonstrate that it is possible to automatically prepare virtual instance for specific networking tasks like using NAT for traffic that originates from private network.

This approach is still using vendor specific configurations. We plan to expand automation and configuration to be vendor independent and to be able to orchestrate multiple different VNFs.

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NoC-Based Thread Synchronization in a Custom Manycore System

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Abstract. This workshop paper presents an efficient hardware support for thread synchronization in a customized manycore system developed within the MANGO H2020 project. The solution relies on a distributed master and on a lightweight control unit on the core side, using hardware-level messages and thus avoiding memory accesses. It supports multiple barriers for different application kernels executed simultaneously. The results for different NoC sizes provide indications about the reduced synchronization times and the area overheads incurred by our solution.

1 Introduction

The increasing need for resource- and power-efficient computing over the last decade has stimulated the emergence of compute platforms with moderate or high levels of parallelism, like GPU, SIMD, and manycore processors in a variety of application domains [1,2,5,10]. In particular, manycore systems are based on a considerable number of lightweight processor cores typically connected through a Network-on-Chip (NoC) [3,20], providing a scalable approach to the interconnection of parallel on-chip systems. In fact, on-chip connectivity has been attracting much interest during the last years, also including recent developments at the physical technology level [6,8]. While early NoCs, like the Epiphany mesh-based interconnect [13], used a flat cache-less memory model, caching and related coherence management has become a crucial feature in today's NoCs needed to improve performance and preserve programmability in manycore systems. Examples of modern manycore solutions include an integrated 80-tile NoC prototype architecture, based on an on-chip 2D mesh topology, proposed by Intel [12], and the Tilera TILE64 processor [11], based on three-wide VLIW compute cores with 64-bit instruction words as well as a scalable 2D mesh network with support for coherent shared memory, where each core can directly access any other cache through the interconnect. The Tilera NoC infrastructure in fact provides five different networks for different uses, including one dedicated to memory transactions. Being targeted at parallel applications, these systems are expected to provide some form of support for thread synchronization, e.g. *barrier* primitives. Existing solutions use a variety of hardware- or software-based

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techniques. The work in [7] describes some synchronization algorithms implemented in software, that rely on a message passing infrastructure and different NoC topologies. In [21] the authors implemented a dedicated G-line net dedicated to barriers. This solution is limited to ASIC architectures and requires a wire for each tile. In [22], the authors support thread synchronization in a packet-switched manycore NoC by relying on two types of links.

This work presents an activity developed in the context of the *MANGO: exploring Manycore Architectures for Next-GeneratiOn HPC systems* H2020 research project. As part of the manycore architecture exploration carried out by the project, the authors developed a customizable GPU-like core used as the compute element in a configurable NoC with support for coherent shared memory. The manycore system is tested on a large-scale FPGA platform developed by MANGO, where hardware reconfigurability is mostly used for emulation purposes, although FPGAs could also be chosen as the final acceleration technology for certain classes of workloads [4,9,14,16]. This workshop paper specifically explores the adoption of a distributed and NoC-based synchronization mechanism. At the heart of our approach is a distributed synchronization master inspired by the directory-based coherence protocol. Relying on the distributed approach as well as the lightweight three-staged synchronization client on the core side, the proposed architecture can support multiple synchronizations for different application kernels running concurrently. The paper describes the main insights in our approach, the resulting architecture and the way it handles multiple synchronizations concurrently, as well as the advantages of the distributed mechanism.

The rest of the paper is organized as follows. In Sect. 2 we summarize previous techniques for supporting barrier synchronization in manycore architectures. In Sect. 3 we describe the baseline manycore system as well as the synchronization hardware introduced by this work. In Sect. 4 we describe the implementation of the barrier function, while in Sect. 5 we evaluate it with a synthetic benchmark both in a central and distributed configuration for different NoC sizes.

2 Related Work

Barrier synchronization is a common primitive used to separate in time different phases of a parallel application. Efficient support for barrier synchronization in manycore systems is of paramount importance because of its role in parallel code. Culler and Gupta in [19] address this problem for shared-memory multiprocessors. They present a software solution, which relies on hardware atomic instructions and memory coherence. The solution uses a lock variable and a counter keeping track of all the cores that have hit the synchronization point. Indeed, the literature offers various software-based barrier solutions. Hoefler and Rehm [7] present a study on software barrier algorithms combining both shared memory and message passing techniques. The authors implement typical barrier synchronization algorithms, such as Butterfly and Combining tree, and analyze message overheads and the required memory for each of them. The results in [15] show that software barriers, even when based on hardware message passing, incur considerable overheads causing NoC resources to stay underutilized, unlike hardware barriers. As a consequence, many NoC-based techniques have been proposed in the last years. In [21], the authors implement a hard-wired barrier mechanism called G-line net. Each core has a dedicated wire connected to the barrier master. Synchronization is established as soon as each core asserts its line. This technique uses multidrop connectivity and the S-CSMA collision detection in order to provide a flow control mechanism (EVC), enhancing performance in terms of latency and power consumption. Such a solution does not require memory accesses, and provides fast synchronization compared to software solutions. However, the approach may lack scalability and supports only one barrier at a time. The authors of [18] propose a communication unit in a NoC-based system, relying on a barrier controller and a communication unit that enable synchronization operations. The control unit is integrated into a general NoC switch and communicates with a centralized master located in the network. The paper proposes an efficient control mechanism, but it still relies on a centralized master resulting in limited scalability. Similarly, [17] introduces a synchronization architecture, called the Synchronization State Buffer (SSB), which is a small buffer attached to the memory controller of each memory bank. It records and manages the states of active synchronized data units to support and accelerate word-level fine-grain synchronization. The SSB solution has been implemented in the context of the 160-core IBM Cyclops-64 chip architecture. The authors of [22] propose a novel thread synchronization technique relying on packet-switching mechanisms in a NoC-based manycore system. The interconnection system provides two physical links used in the protocol in order to avoid deadlocks. The work introduces a synchronization-operation buffer (SB), which enqueues and manages the requests issued by the processors. The mechanism uses a spin lock implementation, requiring a constant number of network transactions and memory accesses per lock acquisition. Note that the approaches described above do not support concurrent barriers if different application kernels are running in separate sub-regions of the manycore system.

3 Architecture

The proposed synchronization mechanism has been integrated in the GPU-like accelerator core being developed within the MANGO H2020 project. The core comes with a NoC-based manycore architecture, as shown in Fig. 1, where each tile includes a hardware multi-threaded SIMD processor. The system provides a distributed coherent L2 cache and hardware coherence support based on a directory protocol. The main idea behind our solution is to provide a distributed approach inspired by the directory-based system. Our architecture aims to eliminate central synchronization masters, resulting in a better message balancing across the network. Combining a distributed approach, hardware-level messages, and a fine-grain control, the solution supports multiple barriers simultaneously from different core subsets. Coherence does not affect the overall performance, since

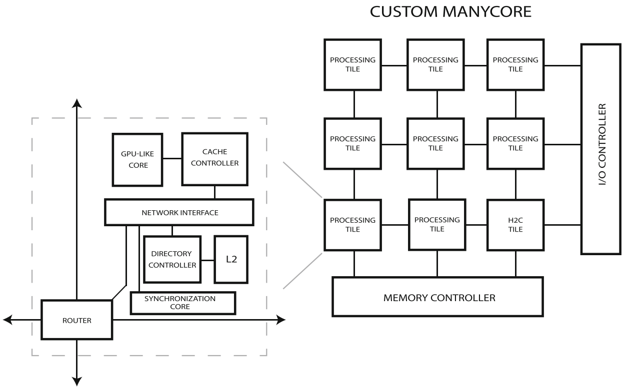

Fig. 1. The custom manycore system addressed by this work.

the system provides a dedicated virtual network exclusively used for synchronization. Below we describe the main components of the proposed synchronization hardware.

Boot Setup. The Boot Setup module is in charge of initializing every structure involved in a barrier synchronization. It sends the `Setup` messages in the initialization phase, then sets and updates the barrier counters in the involved Synchronization Core. When an application kernel requires a synchronization, it specifies the barrier ID and the number of cores involved. The Boot Setup module steps into the Service state where it gathers all this information and selects a synchronization master. Then, when the network is ready, the Boot Setup initializes the chosen Synchronization Core by sending suitable messages through the NoC, conveying the barrier ID and the number of cores involved. From this point onward, the designated Synchronization Core becomes the synchronization master of this barrier, and it will handle all the synchronization messages from the involved cores.

Synchronization Core. The Synchronization Core is the key component of our solution. This module acts as the synchronization master, but unlike other hardware synchronization architectures, it is distributed among all tiles in the manycore. As explained above, the Boot Setup module selects a specific Synchronization Core based on the barrier ID set by the user. In this way, the architecture spreads the synchronization messages all over the manycore. By using this approach, the synchronization master is no longer a network congestion point. Figure 2 shows a simplified view of the Synchronization Core. The module is made of three stages: the first stage selects and schedules the `Setup` and the `Account` requests. The selected request steps into the second stage, which strips the control information from the message. In the last stage, the stripped request is finally processed. If it is a `Setup` request, the counter is initialized with the number of involved threads. On the other hand, if the request is an `Account` message, the counter is decremented by 1. When the counter is 0, all

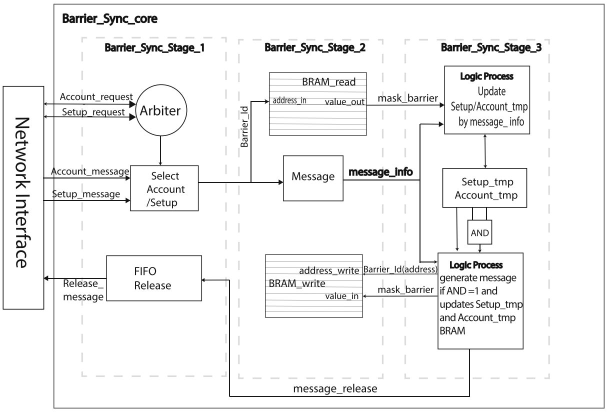

Fig. 2. Overview of the synchronization core.

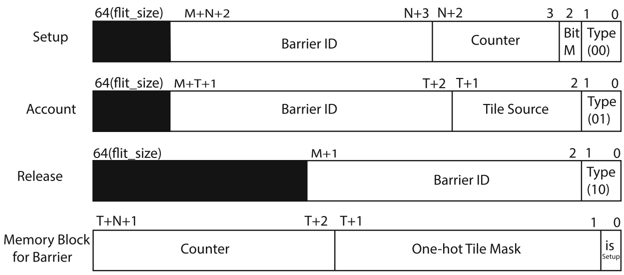

Fig. 3. Synchronization messages, 64 bits each. The `Setup` message is sent by the Boot Setup module in order to initialize the chosen synchronization master. It encloses the unique barrier ID and the number of threads to synchronize. The `Account` message is sent to the master, when a thread hits the barrier from the core side. The `Release` message is sent by the synchronization master to all the involved cores when all the `Account` messages are collected.

the involved cores have hit the synchronization point, and the master sends a multicast `Release` message reaching all of them. Refer to Fig. 3 for the format of the synchronization messages.

Barrier Core. The Barrier Core manages the synchronization on the core side. Each thread in a processing core can issue a barrier request through a specific barrier instruction introduced into the processor ISA. When a thread hits the synchronization point, the Barrier Core sends an `Account` message to the Synchronization Core, and stalls the requesting thread until a `Release` message from the master arrives.

An example of synchronization. Assume we have a manycore with 16 tiles: 14 processing tiles, one tile for the host interface, and one tile connected to the memory controller. The programmer executes a parallel kernel that involves the

14 processor tiles. As a first step, a core sends a `Setup` message to the chosen synchronization master, containing a counter value set to 14 and the unique barrier ID. The synchronization master is chosen by a simple module operation on ID: $T = ID \bmod TileNumber$. The Synchronization Core, located in tile T, receives those values and initializes a counter, that will be assigned to this specific barrier from this moment onward. The most significant bits of the barrier ID locate the tile that manages that ID, as in a distributed directory approach. On the core side, when a thread hits the synchronization point, the Barrier Core in its tile sends an `Account` message to the master in tile T and freezes the thread. As soon as the master receives this type of message, it decrements the respective counter. When the counter reaches 0, all the involved cores have hit the synchronization point, and the master sends to each of them a `Release` message by multicast. When receiving the `Release` message, the Barrier Core releases the thread and resumes the execution flow.

4 Implementation

In addition to the hardware, this activity also relied on the LLVM-based compiler developed within the MANGO project for the GPU-like core. We extended both the back-end and the front-end in the compiler in order to provide a C-level support to synchronization. On the back-end side, the processor ISA has been extended with ad-hoc instructions. On the front-end side, an intrinsic operation has been added, called `__builtin_nuplus_barrier_core(Id_Barrier, NULL)`. The synchronization components rely on a private virtual channel added in the system, which routes all synchronization messages. The baseline system already provided virtual channels but, as observed above, the hardware coherence support tends to flood the network infrastructure with data and coherence messages, and could easily impact the synchronization mechanism performance. On the core side, when a barrier instruction is decoded, the control unit waits until

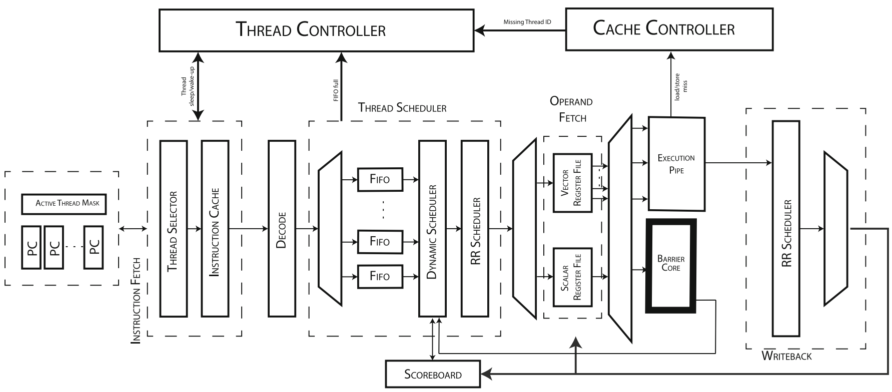

Fig. 4. The microarchitecture of the GPU-like core and the barrier functional unit.

all previous instructions are committed, then it stalls the requesting thread, and fetches the barrier into the Barrier Core module in the execution stage (see Fig. 4). This component sends an `Account` message to the designated Synchronization Core, and waits until a `Release` message arrives. We integrated the Boot Setup component in the Host Interface tile, which is normally used for communication and for booting the manycore system. An arbiter selects the proper component in the Host Interface tile depending on the commands coming in through the interface. The Synchronization Core has been integrated at the tile level, as shown in Fig. 1. It is connected to the Network Interface of the processor tile and dispatches messages on the synchronization virtual channel. Below we will compare the performance of our distributed solution with a centralized master approach that allocates the Synchronization Core only in Tile 0.

5 Evaluation

In this section, we will evaluate the performance of the proposed solution in terms of clock cycles and area overhead. Next, we will compare the presented solution with a standard synchronization mechanism based on a centralized master. We will not compare our work with any software approach [22], since the proposed solution does not require memory accesses or atomic instructions, and thus incurs a significantly lower latency. A useful feature introduced by our solution is the support for multiple barrier synchronizations from different application kernels being executed simultaneously on different subsets of cores.

Simulation. For timing evaluation, we run the system with different NoC sizes by using a cycle-accurate simulator. The architecture has been successfully synthesized on a Xilinx xc7a100tcsg324-1 FPGA with two different versions of the synchronization master: a standard centralized configuration and our distributed approach. Table 1 summarizes the resource requirements of the two approaches for different NoC sizes. We observe that the areas occupied by the Barrier Core and the Boot Setup are constant, since those modules are not influenced by NoC parameters such as the number of tiles or specific topologies. The distributed approach incurs area costs increasing with the number of tiles, although it can support a larger number of barriers, which can involve selected sub-groups of threads, with a resource overhead distributed uniformly across the tiles.

The proposed architecture and the centralized solution are simulated in the same environment with the same parameters. Both run the same kernel made of a barrier setup performed by Core 0, followed by a call to the synchronization intrinsic provided by the compiler, as explained in Sect. 4. The time performance is evaluated by averaging out the synchronization times of all the involved threads. Each core has been equipped with a 64-bit performance counter which is initialized when it detects a barrier operation, and stopped when the release message from the master is received.

Synchronization of the whole manycore. As a first experiment, we run a kernel which involves all processing cores instantiated in the manycore. We compare

Table 1. Comparison of the resource requirements of the synchronization hardware

	Barrier core	Boot setup	Centralized synchronization core			Distributed synchronization core (*per tile*)		
			2×2	4×2	4×4	2×2	4×2	4×4
LUT	69	16	257	324	572	185	207	268
Flip-Flop	56	17	369	520	786	321	420	567

Table 2. Time of a single synchronization operation involving all cores

NoC size	Centralized	Distributed
2×2	26	26
4×2	72	72
4×4	74	74

Average clock cycles per thread

Table 3. Time of multiple independent synchronization operations taking place concurrently.

NoC size	Centralized	Distributed
2×2	26	26
4×2	164	135
4×4	263	216

Average clock cycles per thread

the approach based on a centralized synchronization master with our distributed solution. Table 2 summarizes the clock cycles required by the synchronization for different NoC sizes. As observed, the two approaches reach the same results, due the limited size of the network and the absence of concurrent synchronizations.

Synchronization with concurrent kernels. The proposed architecture supports multiple barrier synchronizations from different application kernels being executed simultaneously on different subsets of cores. The maximum number of distinct barriers supported is $N/2$, where N is the number of threads instantiated in the system. In the experiments below, we compare the number of clock cycles needed to synchronize all the subsets, running the maximum number of supported barriers in parallel. We assume that the developer parallelizes the kernel on sets of consecutive tiles.

Table 3 summarizes the results of our study. The centralized solution lacks scalability, even for small NoC configurations, and the final count is highly dependent on the position of the synchronization master. Our approach requires the same clock count for the smallest NoC, but results in improved scalability as the

NoC size is increased. Furthermore, our solution does not rely on a fixed master, as this is chosen based on the barrier ID, hence by the user or possibly by the compiler.

6 Conclusions

This workshop paper presented the synchronization hardware added to the GPU-like custom manycore accelerator being developed within the MANGO H2020 project. The proposed solution relies on a distributed master and on a light-weight control unit on the core side, providing a synchronization mechanism through hardware-level message exchange without any memory access overhead. The proposed solution supports multiple barriers for different application kernels executed simultaneously on different subsets of cores. The results collected for different NoC sizes provided indications about the area overheads incurred by our solution and demonstrated the benefits of using a dedicated hardware synchronization support. As a long-term goal of this research, we aim to explore the implications of different NoC topologies as well as the impact of the positions of concurrent masters when multiple kernels are run in different subsets of cores.

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A Methodology for Social Networks Analysis and Mining

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Abstract. Social networks analysis is an emerging trend among scholars and researchers in the last years. A great number of companies are interested in social networks data mining. Data gathered from Facebook, Twitter or other social networks result to be very attractive in many application fields, like economics analysis, sentiment analysis, and politics analysis and so on. In our work, we focused on the analysis of the content of textual information obtained from the social media. Our investigation is finalized to extract hot topics in social network. We considered, as case study, reviews obtained from the social network Yelp.

1 Introduction

Nowadays, social network information are precious for many application fields. For example information gathered from social network are used by so-called "social media marketing" to organize an advertising campaign: companies can reach a bigger number of stakeholders and create a more modern concept of advertising, quicker, immediate and sometimes matched with catchy hashtags.

Important information that analyst are interested in, regarding how people feel about an event occurred in their lives or around them. It has been proved [20] that the use of emoticon or hashtags can identify the sentiments people feel: the use of these forms of communications are the easiest way to share them on the net. This led researchers and scholars to extend the study of sentiment analysis to the digital world, mining information through forums, blogs, social media, in order to understand how the people react to and event (i.e. a new law, terrorist attack and so on).

In literature, there are many tools and projects designed to perform different kind of analysis [3,4].

In our work, we focused on the analysis of the content of textual information obtained from the social media: through our investigation, it is possible to extract hot topics in social network. We considered, as case study, reviews obtained from the social network Yelp.

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1.1 Text Mining Procedures

Effective and efficient access to domain relevant information requires the ability to automatic process and organize the information especially if these are contained in huge repositories of data [6–9]. The most used approaches in Big Data processing are based on the graph algorithms, parallel and distributed architecture.Some Big Data infrastructures deal with Apache Hadoop [25] software for data-intensive distributed applications, based in the MapReduce programming model and a Distributed File System (Hadoop). MapReduce job splits the input dataset into independent subsets that are dealt with map tasks in parallel. This step of mapping is then followed by a step of reducing tasks. These reduce tasks use the output of the maps to compute the result of the job. Some open source tools for Big Graph mining are proposed, as Pegasus, a big graph mining system built on top of MapReduce.

It allows to find patterns and anomalies in massive real-world graphs [19,29]. Another Big Data Mining initiative is Apache a scalable machine learning and data mining open source software based mainly on Hadoop and a collection of hardware, software and design patterns for managing very fast large-scale data at very low cost and using BIDMat an interactive matrix library that integrates CPU and GPU acceleration.

For what concerns the text analysis, Morphosemantic approaches similar to the one proposed here have been already proposed for many languages and applied to the medical domain. Works that deserve to be mentioned are Pratt on the identification and on the transformation of terminal morphemes in the English medical dictionary; Wolff on the classification of the medical lexicon based on formative elements of Latin and Greek origin; Pacak et al. on the diseases words ending in -itis; Norton e Pacak on the surgical operation words ending in -ectomy or -stomy; Dujols et al. on the suffix -osis. Between the nineties and the 2000, many studies have been published on the automatic population of thesauri, we recollect among others Lovis et al.,that derives the meaning of the words from the morphemes that compose them; Lovis et al. that identifies ICD codes in diagnoses written in different languages; Hahn et al.that segments the subwords in order to recognise and extract medical documents; and Grabar e Zweigenbaumthat uses machine learning methods on the morphological data of the thesaurus SNOMED (French, Russian, English). Several works focused the problem to the definition and the implementation of a comprehensive architecture for information structuring, while the work is dedicated to resolve the issue of ensuring semantic interoperability of different entities by mapping the content of different corpora on a set of shared concepts.

For what concerns the decision support system in literature they are usually categorized in two typologies, Knowledge-based and non-Knowledge-based [14,23].

Rink [27] proposes a method for the automatic extraction of medical concepts and relations from electronic medical reports. Medical concepts are extracted with supervised machine learning algorithms [15,18,24]. Several knowledge sources are used for feature extraction: a semantic role labeller, a POS tagger, a phrase chunk parser, WordNet, Wikipedia and the General Inquirer lexicon. Doan [17] introduced an automated system to extract medications and related information from discharge summaries. The researchers developed an integrated system adapting some existing NLP tools. In order to proper model data, several approach have been proposed [5,21,22]. Moreover, to efficiently process huge amount of data, several approach regarding hardware implementation of data processing tools are developed [2].

Moreover, in the field of data protection, in [11–13] authors proposed infrastructures devoted to protect intellectual property installed on the FPGA by means of partial dynamic configuration.

2 A Social Network Analysis Methodology

The predominant approach to analyze social network is the graph theory, even though it is largely debated. This theory derives from the studies of Euler and provides us a way for studying Networks of any kind. In social networks the single user or groups of users are represented as a point and their relation are represented as lines. The data obtained from these graphs are then recorded in matrix form, in this way we can study directly the data without drawing the graph, that helps a lot when we are facing large social network data sets. To the lines connecting points in the diagram we can assign a direction in order to determine which point influence the other and to that influence we can also assign a value to represent the strength of that relation.

2.1 Text Analysis Tools

2.1.1 TaLTac

TaLTaC (Trattamento automatico Lessicale e Testuale per l'analisi del Contenuto di un Corpus, Lexical and Textual automatic processing for analyzing the Content of a Corpus) [28] is a software able to perform on documents and data written in natural language operations like: Text Analysis, Text Mining and Corpus Analysis. It has been developed in Italy from the conjunction of the University of Salerno and University "La Sapienza" of Rome. The first task to do in our environment is creating a "Work Session", which is the file that is going to contain all our information, then we build the "Corpus", our main object, which will be analyzed with various instruments and operations. The Corpus is then divided in two parts: fragment and section. Each Corpus can contain more fragments and sections. One of the main functions of TaLTaC is the extraction of significant information from the Corpus (Text Mining), such task uses endogenous and exogenous resources: the former is composed of the number of fragments and the categorical variables which can be associated to the text in order to identify fraction of the corpus logically related. Thanks to this kind of resource TaLTaC is able to perform a "Specificity Analysis". The exogenous resources are lists which contain the frequency of a term or lexical unit, thanks to these lists the software is able to identify peculiar language of the text.

2.1.2 Gate

GATE (General Architecture for Text Engineering) [26] is a open source free software which excels at Text Analysis. The first version was written in the mid-1990s and it has reached currently version 8. The main resource of this program is ANNIE (A Nearly New Information Extraction System), which provides a lot of information extraction techniques such as the English Tokeniser which splits the text into annotations of type Token or the POS Tagger that assigns to every token an annotation that describes its characteristic (i.e. NNP for Proper Noun in singular form) and more. The Gate software is a family made up of:

- an IDE, Gate Developer
- a web app, Gate Teamware
- a framework, Gate Embedded

2.2 The Methodology

In order to achieve a fine analysis of our data we applied different types of operations.

2.2.1 Text Pre-treatment

This is the first process to be applied on text, in order to obtain a clear analysis in the successive processes. It is made up of the following phases.

Normalization: This phase allows to remove any data duplication and it normalizes the writings of names, acronyms and other entities. In order to achieve these goals we have to execute various tasks:

- Change apostrophes into stresses (for the words that is needed), in order to determinate the right word;
- Label words/sequence of words so that they can assume the right meaning and are not mistook with others expressions (i.e. a name can be mistaken for a noun, Rose or rose);
- Change of capital letters into lowercase for the words that are not labeled, if one is labeled we need to analyze what the label says: if it is a name (of person, of a city or a general proper name) then it will keep the capital letter, in other cases it will not.

Correcting Spelling Errors: This phase consists of comparing a misspelled word with the system dictionary in order to correct and analyze it in the right way.

2.2.2 Lexical Analysis

Lexical analysis analyzes the segments of the Corpus (a segment is a sequence of graphic forms separated by a strong divider). A segment can be easily be defined by choosing a set of dividers (i.e. punctuation such as "." , ";") and then separating the sentences between these elements. Once we obtained our segments we can estimate various analysis parameter such as the IS index: this measures the level of absorption of the segment regard the single elements which it is made of. Other important operations in this part of the analysis are the Tagging, which links to every word a description of the grammatical or semantic characteristics [16], and the Lexation which identifies the sequence of words defined during the pretreatment as one unique entity. Last we define the Corpus' key words by studying the repetition rates, the ones that have a noticeable standard deviation (considering only the integers) can be assumed being meaningful.

2.2.3 Textual Analysis

The first step in this analysis is the study of the Concordances in which we can examine the context where every word or segment we choose is [1,10]. Then we calculate the TF-IDF rate which sorts the research's results according to the frequency and distribution of the search keyword in the documents provided. The TF-IDF is equal tf-idf $= tf \cdot \log \frac{N}{n}$ where tf is number of occurrences of an element, and the remaining part is the logarithm of the ratio between the number of documents building the Corpus (N) and the number of documents which present that element (n). Another import part of Textual Analysis is the co-occurrences identification, where with co-occurrences we identify those couple of near elements that repeat in the text. This identification is useful to define the primary concepts contained in the Corpus.

3 Experimental Campaign

Our experimentation aims to analyze online social networks data sets in order to derive as much information as possible. The data set analyzed comes from the social network Yelp, founded in 2004, which publishes crowd-sourced reviews about local businesses [30] and it is made up of 50 tuples structured this way:

- anonymized user name
- anonymized reviewed place
- date of the review
- review

3.1 TaLTac Analysis

Prior starting the analysis we pass through the Text Pretreatment, and so after the parsing of the Corpus we normalizeit and compute the sub-occurrences.

The next phase is the Textual Analysis, here we start with the identification of the segments, these are saved in two file: the former is “Lista dei Segmenti (con indice IS)” which contains the segments with their relative number of occurrences, number of elements forming the segment and the IS index; the latter, named “Lista dei segmenti Significativi” is a list of the significant segments. Then we analyze the specificity of our Corpus together with the computation of the TFIDF index, these data are saved in the same location under the name of: "Vocabolario" and "Lessico". The last operation of our study is the Textual Analysis with the concordances and co-occurrences computation.

The results of these operations show that the system without knowing anything of the data submitted can retrieve meaningful information, such as the TFIDF index that shows how much a word is important in the document, or the co-occurrences which show the main concepts of the text thanks to the couple of words that recur all the time. Unfortunately TaLTac can not perform all the analysis on our data set due to the fact that it is in English and so our work is not totally complete. Even though our results are few, they are very significative.

3.2 GATE Analysis

Our first operation with this software is the initialization of ANNIE with Defaults, once all the Processing Resources are loaded we run ANNIE and start in sequence:

- Document Reset PR The document reset resource enables the document to be reset to its original state, by removing all the annotation sets and their contents;
- ANNIE English Tokeniser The tokeniser splits the text into very simple tokens such as numbers, punctuation and words of different types;
- ANNIE Gazetteer The role of the gazetteer is to identify entity names in the text based on lists;
- ANNIE Sentence Splitter The sentence splitter is a cascade of finite-state transducers which segments the text into sentences;
- ANNIE POS Tagger The tagger produces a part-of-speech tag as an annotation on each word or symbol;
- ANNIE NE Transducer
- ANNIE OrthoMatcher The Orthomatcher module adds identity relations between named entities found by the semantic tagger, in order to perform coreference.

Thanks to these operations we can overcome TaLTac limits and run a Grammatical Tag on our data set. It must be said that our original data have been modified, indeed we are going to analyze only the review section due to the fact that in GATE the other information are meaningless.

4 Experimental Results

From our initial data set, made up of more than 5000 tuples, we extracted, as said, our 50 samples from which we obtained these results:

Thanks to TaLTac functions we can say that our peculiar lexicon, shown in Fig. 1, is composed by words with highest occurrences and TFIDF like: "games", "beer", "good", "great", "food", "place" so it is reasonable to assume that the

Forma grafica	Occorrenze totali	Lunghezza	TFIDF	Forma grafica	Occorrenze totali	Lunghezza	TFIDF
was	83	03	3,37217	they	38	04	1,82534
s	62	01	2,72497	here	21	04	1,82342
for	71	03	2,61815	area	15	04	1,79898
games	34	05	2,46866	bar	24	03	1,79825
is	97	02	2,36757	get	20	03	1,78191
beer	24	04	2,19451	great	20	05	1,77350
are	34	03	2,10028	as	17	02	1,77066
to	132	02	2,07886	with	37	04	1,76399
t	37	01	2,06400	had	27	03	1,75748
good	37	04	2,06279	it	57	02	1,75409
selection	15	09	2,06025	place	44	05	1,75382
you	46	03	2,04468	out	27	03	1,72490
were	32	04	1,98688	I	131	01	1,71641
there	29	05	1,97350	fun	13	03	1,70398
that	57	04	1,95741	4.0	15	03	1,65914
-	25	01	1,93592	It	18	02	1,65544
Great	7	05	1,92191	The	52	03	1,65391
in	56	02	1,91502	from	24	04	1,64308
on	47	02	1,90879	wings	9	05	1,64125
food	39	04	1,87488	be	18	02	1,62180
1	26	01	1,86714	&	20	01	1,59426
of	91	02	1,84201	have	46	04	1,59094
1qCuOcks5HRv67OHovA	26	22	1,58947	but	48	03	1,57259
all	18	03	1,58031	can	12	03	1,55776
and	194	03	1,57490	5.0	10	03	1,55417

Fig. 1. Peculiar lexicon by occurences

ID Fr...	Intorno sinistro	Forma grafica	Intorno destro
fragm...	, and authentic . If you' re looking for good Irish	food	and a cold pint , you can' t go wrong at the Pour House
fragm...	worth seeking out . They have some of the best Irish	food	I' ve had in Pittsburgh- the colcannon is awesome and
fragm...	out of this world . If you' re not looking for Irish	food	, then try the grilled cheese- and make sure you ask
fragm...	there on a Saturday night with a mind to try the Irish	food	. Apparently , we were out of luck . I' ve always thought
fragm...	secrets of restaurant success is to actually stock	food	for people to eat . He told us before we ordered that
fragm...	were out " . At that point , realizing that the only	food	to be had in the place was what was crusted on the
fragm...	heoc96QXrTbecWVw933qhQ | 2011-08-20 Best Irish	food	in the Burgh . Great bar food too . The service is
fragm...	2011-08-20 Best Irish food in the Burgh . Great bar	food	too . The service is maybe a bit surly and it' s not
fragm...	Excellent wings and sandwiches , generally good	food	otherwise , and fair prices-- nice casual place . The
fragm...	1qCuOcks5HRv67OHovAVpg tPUGLIDZLF7HrOC46NqT...	food	here can actually be a little hit and Miss , but I
fragm...	wonderful character and ambiance of this place , but the	food	was average at best . We were there on a Pens play-off
fragm...	2 people working all the tables in both rooms . Our	food	came to us cold and unimpressive at that . Our orders
fragm...	were pretty good , also . If you are looking for good	food	, Homestead better choices at Blue Dust or Tin Front
fragm...	beer selection , but it won' t be for a while . The	food	has always been average at best , and the pizza sub
fragm...	op2Gve4sAMQ4qEzq2Tad0g | 2013-09-15 I' m reading o...	food	is really hit or Miss . I' ve only gone to Duke' s
fragm...	Miss . I' ve only gone to Duke' s one time , but the	food	was good . It wasn' t too busy so our service was very
fragm...	very attentive and it didn' t take long to get our	food	at all . The place is separated between a bar area

Fig. 2. Concordances of the word “food”

reviews analyzed talk about a place to eat food, drink beer or play some games and that the main audience thinks that it is a good place (Fig. 2).

Thanks to the Tokeniser we can distinguish spaces from words, and thanks to the Gazetteer and POS Tagger every word in our data set has a description. At the end of our analysis with this software we can assert the grammatical features of our data and we can give even more meaning to the analysis described in Sect. 3.2.

5 Conclusions

Social networks analysis is an emerging trend among scholars and researchers in the last years. In literature, there are various instruments and project to achieve different kind of analysis, yet in our work, we focused on the analysis of the content of the text obtained from the social media. Through our investigation it was possible extracting the hot topics for the different information sources, as, in our case, the reviews analyzed. This study can be the starting point of further analysis on the domain of cybersecurity, through the detection of text containing dangerous messages, viral market advertising, thanks to an analysis of the feedback from the users or costumers, or information crawling.

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DGP Application for Support Traffic Information Systems in Indoor and Outdoor Environments

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Abstract. V2V and V2I systems are networks in which vehicles and roadside units are nodes able to broadcast environmental conditions over large distances. Each vehicle has an on-board unit (OBU) which may have several kind of sensors (satellite-based positioning systems and positional sensors like digital compass, accelerometers and gyroscopes), may be connected to the car control unit, and has a long-range wireless module (able to transmit up to 1000 m away).

We used DGP for determination of vehicles position in space using a simple algorithm.

The resulting matrix is diagonal symmetric and it's therefore possible to apply a DGP algorithm.

1 Introduction

In this preliminary section we present the concepts of Vehicle-2-Vehicle (V2V), Vehicle-2-Infrastructure (V2I) and Distance Geometry Problem class (DGP) used for wireless positioning of vehicles.

V2V and V2I systems are networks in which vehicles and roadside units are nodes able to broadcast environmental conditions over large distances. Each vehicle has an on-board unit (OBU) which may have several kind of sensors (satellite-based positioning systems and positional sensors like digital compass, accelerometers and gyroscopes), may be connected to the car control unit, and has a long-range wireless module (able to transmit up to 1000 m away). For longer transmissions, it is moreover possible to use road side units (RSU) as relays, in order to reach even higher distances. When a car detects nearby potential dangers (ice, oil, bad road conditions etc.), it is able to alert nearby users in order to reduce risk of accidents.

Distance Geometry Problems is the study of sets of points based only on their relative distance, in order to determine their shape in space, which can then be aligned with known fixed points in order to determine the position of all points [15, 16]. There is a large community working on this class of problem, as it has several applications in nature sciences like biology and chemistry. We used DGP for determination of vehicles position in space using a simple algorithm. First of all we calculate the distance matrix between all the vehicles in an area, using the OBUs. Each node is able to estimate its distance from nearby elements using Received Signal Strength (RSS), and all the

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distance vectors are joined to form the corresponding distance matrix. All the items on the diagonal have value 0 (as it represents the distance between a node and itself). Other elements may not match across the diagonal, i.e. $d_{x,y} \neq d_{y,x}$ and it's therefore important to average values: $d_{x,y} = d_{y,x} = (d_{x,y} + d_{y,x})/2$. The resulting matrix is diagonal symmetric and it's therefore possible to apply a DGP algorithm which transforms the distances in a floating graph, which is then roto-translated using fixed points in space (which may be road side units) with known coordinates.

2 Proposed System

In this paper we present a novel DGP-based technique, able to determine and broadcast traffic information using a smart combination of on-board units, DGP and a fixed transmission infrastructure made of roadside units. It allows OBUs to alert nearby users in order to avoid congested paths and reduce transit times.

3 Related Works

To explain in detail how the study operates, it is necessary to focus on the reliability of the two selected methods that provide the distances among devices. The considered methods are affected both by errors; indeed, in last years, they have become subject of interest. Concerning the INS, since it was developed, errors in localization's prediction were a well-known problem. In [7], Filyashkin and Yatskivsky studied a system to predict the evolution of the errors in INS, to improve its accuracy. Many studies have been done, in recent times, also on the possibility of improving the WFPS [8]. In this work, it is meant to find a way to merge data given by the above-mentioned localization methods, to obtain a more accurate localization than those obtained using only one of them. In similar works, authors show ideas to exploit two localization system: PDR (Pedestrian dead reckoning) and WFPS based on RSS. In [10], the systems have been fused [13] to improve the localization of a device moving through an indoor path [12]. The work in literature [11] exploits the two methods to ensure a better localization of a device in an indoor space. Differently from these papers, this one would show a method to decrease the errors in localization, considering more devices over a space and exploiting their inertial and Wi-Fi distances matrix.

4 Distances Matrix Symmetrization

At this point, as a matter of interest, the observation of distances matrices has revealed a discrepancy, for example, between the distance from the A point to the B point and its reverse: they are not the same. This situation does not allow individuating distances among distinct devices since it is not possible for a device to be at a different distance from another. For this reason, it has been looking for a way trying to solve the problem through the symmetrization of matrices. In literature, there are many studies that use this technique for similar scenarios, in [18] it is shown a sturdy method that finds its application in the matrix symmetrization problem.

$$X[m,i] = \frac{R[m,i] * N[m] + R[i,m] * N[i]}{N[m] + N[i]}. \tag{1}$$

Further analysis led to the *DISY* algorithm that, using the matrix of errors and the array of errors, through a weighted average, retrieves a symmetrical matrix.

Algorithm 1. Distances Symmetrization (DISY)

```
Input:    R / E / N  → Raw Matrix of Distances / Array of Errors /
                        Normalized Array of Errors
Output:   X          → Symmetric Matrix
/* initialize output matrix and other variables */
T ← −1                       // Output matrix initialized to -1
n, z, i ←matrix length
for x ← 1 to n do
   m = pos_min(E)            //position of min in E array
   E[m] = max(E) + 1         //increase min to not select it again
   for i ← 1 to n do
      if i = m then
         X[m, i] = 0         //it is a diagonal point
      elif X[m, i] = −1 then
         X[m, i] = (R[m, i] ∗ N[m] + R[i, m] ∗ N[i])/(N[m] + N[i])
         X[m, i] = CSV(E[m], X[m, i])
return X
```

Procedure 1. Consistency Symmetric Value (CSV)

```
Input:    E / V  →  Error of Value to Check /  Value to Check
Output:   C      →  Checked Result
C = V
if (V > V + E) then
   C = V + E
elif (V < V − E) then
   C = V − E
return C
```

In (1) is indicated the weighted average between the product of a distance with his error and its transposed value with transposed error value. The distance in $R[m, i]$ is multiplied for its normalized error ($N[m]$); at the same time, also the distance in $R[i, m]$ is multiplied for its normalized error ($N[i]$); the two results are summed and then divided for $N[m] + N[i]$. At the end of this calculations *DISY* could build the symmetric matrix, but there are cases where some calculated distance value is greater than the raw distance value added to his error or lower than the raw distance value subtracted to his error. *CSV* checks if this is the case; if it is, it considers as correct the value the raw value added to his error or raw value subtracted to his error according to case.

5 Study Case

In this phase, a study case is proposed to show the effective improvements in a system above specified, starting from two raw distances matrix and then arriving to a result matrix. For a proper representation of the whole work, as sample, the starting matrices chosen are 7 × 7.

Step 1 Raw Matrices and Array of Errors: In this initial step, the system obtains two raw 7 × 7 matrices (The Inertial and Wi-Fi Raw Matrix, Tables 1 and 2) and two arrays that contain the error in distance (Table 3), associated to each cell of both matrices. Both matrices and arrays are affected by inconsistence, except the array of errors average (composed by the average between both arrays), that will help to find a starting point to upcoming phases.

Table 1. Raw Wi-Fi distances matrix. (In meters)

Pts.	A	B	C	D	E	F	G
A	0,00	16,33	15,20	11,90	5,33	12,59	9,57
B	18,21	0,00	7,23	18,95	11,25	25,23	7,80
C	15,50	11,80	0,00	10,10	9,90	17,20	14,90
D	9,50	14,80	14,90	0,00	2,50	7,80	17,50
E	9,80	17,20	9,55	6,99	0,00	11,78	15,24
F	8,55	25,84	19,75	2,50	12,56	0,00	20,50
G	11,80	7,90	18,20	21,04	13,29	21,90	0,00

Step 2 Normalization: The data have to be now standardized. Previously it has been discussed the adopted methodology to normalize the arrays according to the necessity of the problem. In this case, normalization problem is solved implementing (1) in an algorithm developed in *MATLAB*, exploiting the built-in Norm function (Table 4).

Step 3 Distances Matrix Symmetrization: The Array of errors normalized form allows to refine also the raw data associated to the given matrices. The arrays retrieved from Step 2 will be used to symmetrize matrices. To symmetrize matrices, (2) has been exploited to create *DISY* algorithm. For the case needs.

Tables 5 and 6 show the results of the Experiment on matrices. The distances matrix has got consistent values that is utilised to calculate the last matrix.

Step 4 Distances Matrix Merge: The symmetric matrices are now used to obtain the conclusive distances matrix which presents a more accurate representation of values than the one of the two symmetrized matrices.

Table 7 shows data obtained by applying *DIME* algorithm. As it is possible to notice, this last matrix is extremely more reliable even accounting for errors. In example taken the point C of each matrix and array:

It presents 0,90 as Wi-Fi error, 0,50 as Inertial error (Table 4).

Looking at its values in Tables 5 and 6, and then in Table 7, it is trivial to deduce that values referred to C in the final Matrix are mostly similar to that in Table 5

Table 2. Raw inertial distances matrix. (In meters)

Pts.	A	B	C	D	E	F	G
A	0,00	11,22	14,50	10,50	7,90	15,00	13,70
B	17,90	0,00	4,60	6,10	20,30	19,80	4,60
C	22,10	3,50	0,00	15,90	13,84	20,22	18,30
D	15,62	14,66	15,98	0,00	9,26	4,55	23,81
E	7,50	12,25	12,90	8,20	0,00	7,80	11,90
F	4,56	27,16	20,15	2,21	13,29	0,00	15,87
G	13,50	5,98	19,12	20,59	16,54	21,90	0,00

Table 3. Array of errors. (In meters)

	A	B	C	D	E	F	G
WiFi	2	4	2	5	4	6	2
Ins	5	7	10	7	2	9	5
AVG	3,50	5,50	6,00	6,00	3,00	7,50	3,50

Table 4. Normalized array of errors.

Pts.	A	B	C	D	E	F	G
WiFi	0,90	0,81	0,90	0,76	0,81	0,71	0,90
Ins	0,76	0,67	0,52	0,67	0,90	0,57	0,76

Table 5. Symmetric Wi-Fi distances matrix. (In meters)

Pts.	A	B	C	D	E	F	G
A	0,00	17,22	15,35	10,80	7,33	10,81	10,69
B	17,22	0,00	9,80	16,94	14,23	25,52	7,85
C	15,35	9,80	0,00	12,10	9,73	18,32	16,55
D	10,80	16,94	12,10	0,00	4,81	5,24	19,42
E	7,33	14,23	9,73	4,81	0,00	12,15	14,21
F	10,81	25,52	18,32	5,24	12,15	0,00	21,28
G	10,69	7,85	16,55	19,42	14,21	21,28	0,00

(Wi-Fi). This is because the error associated to Wi-Fi detection is lower than the Inertial one.

Step 5 Plotting: Now, all data is obtained: to prove that there is an effective improvement using data calculated in the final matrix, a representation of all this distances matrices is needed. Through the already quoted Neato and GraphWiz is possible to represent distances matrices as Graph.

Figures 1, 2, 3, and 4 contain the graph associated to matrices in Table 5, 6, and 7.

Table 6. Symmetric inertial distances matrix. (In meters)

Pts.	A	B	C	D	E	F	G
A	0,00	14,34	17,59	12,89	7,68	10,53	13,60
B	14,34	0,00	4,12	10,38	14,25	23,20	5,34
C	17,59	4,12	0,00	15,94	13,24	20,18	18,79
D	12,89	10,38	15,94	0,00	8,65	3,47	22,09
E	7,68	14,25	13,24	8,65	0,00	9,80	13,90
F	10,53	23,20	20,18	3,47	9,80	0,00	19,32
G	13,60	5,34	18,79	22,09	13,90	19,32	0,00

Table 7. Symmetrical result matrix. (In meters)

Pts.	A	B	C	D	E	F	G
A	0,00	15,90	16,37	11,76	7,52	10,68	12,02
B	15,90	0,00	7,23	13,98	14,24	24,47	6,70
C	16,37	7,23	0,00	13,51	11,59	19,00	17,57
D	11,76	13,98	13,51	0,00	6,84	4,41	20,64
E	7,52	14,24	11,59	6,84	0,00	10,91	14,05
F	10,68	24,47	19,00	4,41	10,91	0,00	20,38
G	12,02	6,70	17,57	20,64	14,05	20,38	0,00

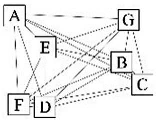

Fig. 1. Inertial distances matrix graph

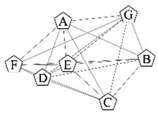

Fig. 2. WiFi distances matrix graph

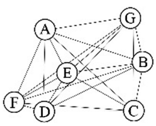

Fig. 3. Merged distances matrix graph

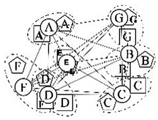

Fig. 4. Distances matrix compared graph

After the single representation, the three resulting graphs have been overlapped in order to provide an all-around view to the effective amendment brought by the graph in Fig. 3. By observing Fig. 4, it is possible to notice that merged matrix nodes are located in positions that keep count of both Wi-Fi and Inertial values and their errors.

6 Conclusions and Future Work

DIME algorithm represents a simple way to obtain, starting from two inaccurate distances matrices and their errors array, a third more accurate matrix. To acquire a visual feedback, the N*eato* program can be used; however, it does not realize a highly accurate graph because of data inconsistency it changes the least possible distances data. Therefore, the algorithm could be improved so that when there is a data inconsistency it modifies the graph adapting the distances calculated with greater error. Recent studies developed car2car systems [17] useful to exchange messages; exploiting this work it would be possible to exchange also positions, building a car network [20], perhaps taking advantage of the cloud [14] to save data [18, 19].

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LoDGP: A Framework for Support Traffic Information Systems Based on Logic Paradigm

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Abstract. Nowadays, many studies demonstrate that one of the main causes of traffic congestion is the search for available parking lots. In this paper, we want to exploit the VANETs potentialities in order to overcome this problem, with the aim of improving the traffic conditions, by helping drivers to easily identify free parking lots in a urban area. The challenge is try to use information exchange between vehicles, in order to communicate parking information. To this goal, we analyze the well known distance geometry problem (DGP), by adapting it to our situation. This problem cares about how, starting from a graph, we can locate its nodes according to the known distances between some pairs of them. In our situation, the idea is to deal with the DGP, by using an inverse procedure: we start from a network where each vehicle is located by a global positioning system (GPS), and then we want to obtain a corresponding graph which contains useful information about parking lots in a certain area. For this purpose, we divide a huge urban area in some smaller clusters, by exploiting road side units (RSUs) and we separate vehicles in three groups corresponding to three possible states they can assume within a cluster, associating a different color to each of them in the corresponding graph. We make clear this model by means of logic programming, which offers compactness and intuitively, allowing us abstracting from concrete structures and variables concerning a procedural language and to explain the features of this framework in an elegant way. To this end, we provide a Prolog algorithm for the graph configuration and evolution.

1 Introduction

VANETs are a very hot issue in scientific researches, since there are several important and useful applications. In our recent works, our challenge was the improving of traffic conditions, with the aim of reduce road accidents, trying to exploit the inter-vehicular communication of the most frequent road exceptional events, in order to let the driver avoid them.

Now our attention is again on the improvement of traffic, but in this work we focus on available parking lots detection.

Typically, searching for a free parking in urban areas involves a huge waste of time and the traffic congestion in general. In order to overcome this problems, in this work we propose a framework where it is possible to detect available parking lots in a specific

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area and communicate it, by exploiting the VANET's potentialities. In order to do this, we preventively divide a very big urban area in smaller ones, so that we can scale down our problem, by using road side units.

Subsequently, we analyze the distance geometry problem, which is source of inspiration to handle the vehicles network in order to transmit useful parking information. We describe a model in which each vehicle can assume three different states in the network and is associated to a corresponding colored node in a graph. These three states and all the possible changes in the network are explained by means of logic programming: we define Prolog facts and rules in order to illustrate the graph creation and its following evolution, and how could be useful to retrieve important parking information.

The entire work is organized as follows: (*i*) in Sect. 2. there are many scientific researches on these topics, with useful proposals and inspirations; (*ii*) in Sect. 3. we propose our framework, starting from the urban area clusterization, until the graph creation, by using an inverse approach to the distance geometry problem; (*iii*) in Sect. 3.5, a logic algorithm for graph creation and evolution is provided and analyzed; (*iv*) in Sect. 4 we finally come to the conclusion of this work, with possible hints for future works.

2 Related Works

Parking lot detection in urban areas is a widespread topic in inter-vehicular communication context, since it involves a big waste of time for drivers, and it is often cause of traffic congestion. The improvement of traffic conditions is one the main goals in our recent works [18, 19, 20], and this is the reason why we focus our attention on parking lot detection in this work. Many authors studied the impact of parking lot searching to the traffic conditions: in particular, in [9] the observe that, because of the expensiveness of private parking, generally people prefer cruising a free parking lot, and this is obviously reason of traffic congestion. The same author, in [10], asserts that searching for an available parking lot generates about the 30% of traffic. This is surprising, since it demonstrate that a significant part of traffic is not caused by people going somewhere, but by people cruising for a parking lot.

In literature, we can find many other works concerning parking detection with the aim of helping drivers in their searching, by using parking reports as object of information exchange between vehicles. In [6], they highlight how VANETs is a suitable context for the challenge of decreasing the time needed in order to find an available parking lot, and they propose a network based on V2I (vehicle to infrastructure) communication, between OBUs (on board side units) placed inside each vehicle and RSUs (road side units) placed along the road. This is source of inspiration for our work, as we will explain in the next section. Moreover, in [7] they see parking detection as an important application of VANETs, and their approach is based on two kinds of information, object of transmission: (*i*) atomic information, concerning the availability of a single parking automat, and (*ii*) aggregated information, concerning a big area that includes more than one parking automat. In [8], instead, a predictive approach is used: they exploit the age of information about parking lot and they take into account the time needed in order to reach it, by trying to predict the situation at the arrival time; they do this by opportunely providing a mathematical model [13, 14].

In [11], they exploit the spatial and temporal heterogeneity in order to design a model for urban parking that allows to analyze a network of curbside parking. Furthermore, in [12], they emphasize how VANETs application to parking problem is essential, and propose a model to understand if, given an available parking lot, it will be again free at the time of arrival of a certain vehicle.

3 Framework Configuration

In this section, we describe our approach in parking lot detection, by analyzing many functional aspects in any of the following subsections. We initially repartition a big urban area in some smaller ones; then we distinguish three groups of vehicles we deal with inside a cluster, whit the respective way to understand when they belong to a group rather than to another one; subsequently, we explain how an inverse approach to the DGP could help us to handle the communication of parking information between vehicles.

3.1 Clusterization

In order to describe our framework for handling and communicating parking information, we start by clustering a huge urban area, by exploiting road side units (RSU). The reason why we do this is that the explanation of our model in a reduced area could result simpler and clearer. In many VANETs applications, road side units are used with the aim of take part to the information exchange between vehicles. Similarly, we want to use RSUs as cluster-head of a certain cluster: each RSU generates a corresponding cluster, including all those vehicle that are on its communication range. In this way, the problem of finding a parking lot in the whole city is reduced to the same problem, but in a smaller urban area.

As we can see from the illustration 1, the clusters can overlap: this means that a vehicle could belong to more than one cluster at the same time. This is something we will deal with, in the next sections (Fig. 1).

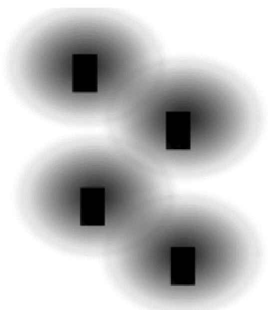

Fig. 1. An example of cluster creation starting from RSUs.

3.2 Vehicles Classification

For the purpose of parking lots detection, we want to distinguish three kinds of vehicles within a cluster, which represent three possible states for them:

- "parked" vehicles;
- "finding" vehicles;
- "leaving" vehicles.

"Parked" vehicles are those that have already found a parking lot and now they are fixed (and turned off) in the cluster; "finding" vehicles are those that drive around the cluster, searching for a parking lot in the corresponding area; eventually, "leaving" vehicles are those that, from the "parked" state, start a movement inside the cluster: a vehicle of this last group is likely moving toward another cluster, in which it could assume any of three states again (Fig. 2).

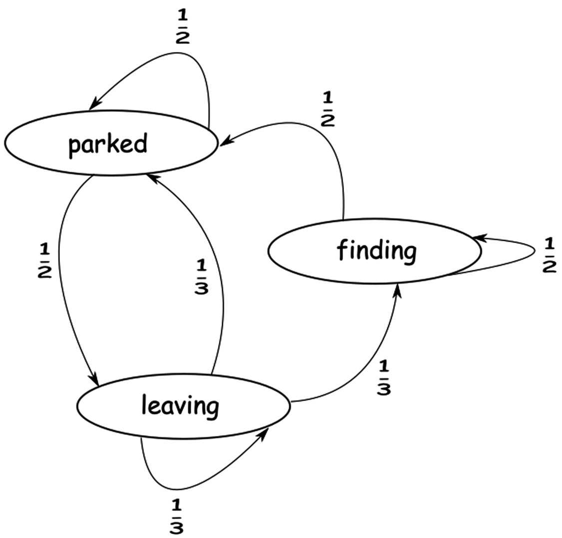

Fig. 2. View of possible states for a vehicle as a DTMC.

In the illustration 2, we show the three possible states for a vehicle within a fixed cluster, using a Discrete Time Markov Chain (DTMC). By definition [17], a DTMC is a stochastic process $\{X_t\}_{t \in \mathbb{N}}$ such that:

$$\begin{gathered} \forall n \in \mathbb{N} \text{ and } \forall\, x, x_0, .., x_n \in \mathbb{R} \\ P(X_{n+1} = x \mid X_n = x_n, .., X_0 = x_0) = P(X_{n+1} = x \mid X_n = x_n) \end{gathered} \tag{1}$$

A discrete time Markov chain can be seen as a probabilistic transition system, where each node represents a possible state of the process and each transition is labeled with the probability to move from a state to another, with the property that the summation of probabilities on the outgoing arcs from a fixed node must be 1 [17].

By analyzing the picture, we observe that a in any moment a "parked" vehicle could stay equal or move to "leaving" vehicle inside a fixed cluster, with equal probability: a "parked" vehicle unlikely moves to "finding" one within the same cluster, but it can look for another parking lot in a new cluster, at most. Since we are considering all the possible states of a vehicle in a given cluster, we assume that it's not possible the movement from "parked" to "finding" vehicle.

Similarly, with equal probability and in any moment, a "finding" vehicle can remain equal or move to "parked" state if a parking lot is found inside the cluster.

A "leaving" vehicle, instead, could stay equal or move to both "parked" and "finding" states, since probably it changes cluster, where it can be identified as any of the three different kinds of vehicles.

3.3 Use of Distance Geometry Problem

The distance geometry problem (DGP) consists in finding the coordinates of a set of points in a 3-dimensional space, according to known distances between some pairs of points [1].

In particular, starting from an indirected weighted graph, where weights represent the distances between vertexes, the DGP can be seen as a constrained optimization problem, which minimizes the norm of the difference between the two vectors corresponding to the two vertexes, according to the weight on the arc between them [1]. In practice, let A and B be two vertexes of the graph and x_A and x_B the corresponding vectors, and let $\mathrm{d}(A,B)$ be the weight on the arc between A and B, we want the distance between these two vectors coincide with the distance between the corresponding vertexes:

$$\|\mathrm{x}_\mathrm{A} - \mathrm{x}_\mathrm{B}\| = \mathrm{d}(A, B). \tag{2}$$

In order to solve this problem, they typically do some assumptions: in particular, in [2] is shown that the feasible region of the optimization problem becomes discrete if an order to the vertexes is applied. Moreover, in [3] the triangular inequality is assumed and this reduces the possible localizations for a node to at most two possibilities.

We can find in literature other approaches to the DGP, for instance in [4] this problem is approximated by using a lower and an upper bound to the distances rather than a fixed value; similarly, in [5] is proposed a quite different release of the well known Branch & Prune algorithm for the solution to the DGP, by considering intervals instead of a precise distance.

3.4 Graph Creation

In this work, with the aim of improving the traffic condition by helping drivers to find available parking lots in urban areas, we want to exploit the approach in solving the DGP in the other way round: we start from a network where each node is opportunely located by means of GPS, that we assume is owned by each vehicle. In order to be able to communicate parking information, we want to obtain a meaningful graph, starting from the actual localization of nodes, that can help the driver to retrieve information about available parking lots in the cluster where the vehicle is. In order to make the graph full of information, we use the clusterization and the vehicle classification of the previous subsections. We assume an indirect graph representing a specific cluster, such that each vehicle in the cluster is a vertex in the graph, the edges are inserted according to the following property: there is an arc between two vertexes if and only if both the nodes belong to the group of "parked" vehicles and at least one of them is the closest vehicle to the other. In this way, the "parked" vehicles are linked between them, while the "leaving" and "finding" ones have no incident edges. The idea is that this graph grows dynamically, by adding (*i*) an isolated node every time a new vehicle is moving within the cluster and (*ii*) a connected node every time a vehicle parks in the cluster, by linking it to the closest parked node. Now the most interesting part comes: when a parked vehicle leaves its parking lot, the corresponding node in the graph will not be deleted, but will be marked as available and the information about the new free parking lot will be sent to all the "finding" vehicles in the cluster taken into account. If within the cluster there are just "leaving" vehicle, it is useless warning about available parking lots, since they are likely changing cluster.

The graph representing the cluster taken in to account have some linked red nodes, i.e. the "parked" vehicles, and some isolated nodes: "finding" vehicles in blue and "leaving" ones in yellow. When a red node leaves its parking lot, it automatically becomes a yellow node, since we assume it won't park in the same cluster again. Now, the corresponding node becomes green (3.b), with the meaning that it is an available parking lot. The blue nodes in the cluster will be noticed about the change, so they can reach the free parking lot. It immediately follows the problem of the concurrency between the two "finding" vehicles.

3.5 Logic Algorithm

In this section, we explain how our model works, by exploiting elegance and clarity of logic programming, and Prolog code in particular, as we did in our previous works [18, 19, 20]. To this aim, we provide a logic algorithm that explains the graph creation starting from the actual network configuration, by distinguish the three groups of vehicles, as explained above: the algorithm associates a different color to each group of vehicles, according to the illustration 3. The graph creation, within a given cluster identified by the variable *cluster*, starts with the *crate_graph* procedure. Supposing that a list *nodes* with all the vehicles detected in the cluster has been already created, each member of this list is analyzed: if a stopped, and thus a "parked" vehicle v_1 is detected, then the closest vehicle v_2,between the "parked" ones, is linked to v_1 by an edge between them. Once all nodes in the list are analyzed, the vehicles classification is realized, by means of *paint_graph* procedure, which distinguishes vehicles through *parked*, *leaving*, and *finding* procedure:

- *parked* procedure iterates on the elements of the list *nodes*, by associating them the red color whenever a node has at least an edge, since it means that it is a "parked" vehicle according to our model [15, 16];

- *leaving* procedure iterates on that red nodes for which a move is detected, since this means that we deal with a vehicle that was previously parked and now is leaving: such nodes are then colored by yellow, and all the incident edges are deleted. Moreover, the *send_message* procedure is invoked, in order to opportunely warn interested vehicle about available parking lot. This last procedure consists in sending the warning if a blue node is detected in the same cluster where sender, i.e. the leaving vehicle is;
- *finding* procedure, finally, associates the blue color to each node that is neither red nor yellow.

Example of graph creation and parking lot detection in Prolog

```
create_graph(nodes,cluster):-

  forall((member(v1,nodes),stopped(v1),
        closest_and_stopped(v2,v1),member(v2,cluster))
        ,  assert(edge(v1,v2))),paint_graph(nodes).

paint_graph(nodes) :-
  parked(nodes),leaving(nodes),finding(nodes).


parked(nodes) :-
  forall((member(v,nodes),edge(v,_)),assert(red(v))).


leaving(nodes):-
  forall((member(v,nodes),red(v),move(v)),
        (assert(yellow(v)),retract(edge(v,_)),
        send_message(v,cluster))).

send_message(v,cluster):-
  blue(v1),member(v1,cluster),
  assert(available_parking_lot(v)).

finding(nodes) :-
   forall((member(v,nodes),not(red(v)),
      not(yellow(v))),assert(blue(v))).
```

4 Conclusions

The challenge faced in this work is try to use information exchange between vehicles, in order to communicate parking information. To this goal, we analyze the well known distance geometry problem (DGP), by adapting it to our situation. This problem cares about how, starting from a graph, we can locate its nodes according to the known distances between some pairs of them. In our situation, the idea is to deal with the DGP, by using an inverse procedure: we start from a network where each vehicle is located by a global positioning system (GPS), and then we want to obtain a corresponding graph which contains useful information about parking lots in a certain area. For this purpose, we divide a huge urban area in some smaller clusters, by exploiting road side units (RSUs) and we separate vehicles in three groups corresponding to three possible states they can assume within a cluster, associating a different color to each of them in the corresponding graph. We make clear this model by means of logic programming, which offers compactness and intuitively, allowing us abstracting from concrete structures and variables concerning a procedural language and to explain the features of this framework in an elegant way. To this end, we provide a Prolog algorithm for the graph configuration and evolution.

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The 4th International Workshop on Distributed Embedded Systems (DEM-2017)

Cost and Energy Efficient Indoor and Outdoor Localization of Rail Cars in a Confined Maintenance Site

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Abstract. The Belgian national railway company (NMBS) is interested in localization of rail cars in their maintenance sites, which consist of both indoor and outdoor environments. Several localization technologies and methods are currently available, each with its benefits and drawbacks regarding accuracy, range, cost, power consumption, and environmental characteristics. After examining several localization systems with regards to application requirements, power and cost constraints, we found passive RFID to be the most suitable and developed a proof of concept for a real workshop environment.

1 Introduction

Every day a billion devices calculate their location or have it processed by another device in a network. Some calculate the route from point A to point B, while others alert the fire brigade when a wildfire occurs. Besides environmental monitoring and traffic control, a wide range of localization devices is used for industrial and medical monitoring [21]. Companies and research organizations try to fulfill these aspirations by improving the range and accuracy of localization technologies. Furthermore, they endeavor to provide these technologies in every aspect of our society.

This research is the result of the aspiration to automatically locate rail cars on a repair site from NMBS Technics. NMBS Technics is the department of the National Railway Company of Belgium (NMBS) responsible for the acquisition and maintenance of rail vehicles. We developed a proof of concept of the location system for the Central Repair Workshop (CRW) situated in Antwerp. The CRW is part of the NMBS Wagon Maintenance Services (WMS) and is specialized in the maintenance of freight rail cars [22]. This CRW site covers 120,000 m^2 including a 7,000 m^2 building in which most repairs are performed. Every morning the site's chief checks the new rail cars that have entered the CRW. He stores their location and other rail cars' characteristics in an excel sheet on his desk. Subsequently, he divides the rail cars over the tracks, so that they are on the correct

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track to enter the CRW building and are in the right order. The actions required for these displacements are communicated with the operators via intercom. During the day, rail cars are moved depending on the progress and adjustments in the operation schedule. Often an operator needs to know the specific rail car's location and again retrieves this information via intercom. Manually collecting and updating a rail car's location is inefficient and can be alleviated by implementing a Wireless Sensor Network (WSN) that keeps track of the rail cars and provides the storage and visualization of this information. By using automatic localization the chief's workload is reduced with one hour a day, resulting in a yearly saving of 0,125 Full-time equivalent per maintenance site.

The CRW requested a system capable of localizing rail cars when they enter a specific zone. A zone has a size between 20 and 200 m. In this paper we present a cost and energy efficient localization method for rail cars in a confined maintenance site, taking into account the specifications imposed by the CRW. In Sect. 2 we discuss the state of the art in localization methods and technologies. In Sect. 3 we present our solution. In Sect. 4 we discuss the results from our field tests, followed by our conclusions and future work in Sect. 5.

2 Localization Methods and Technology

Localization in a wireless local area network (WLAN) can be performed with a wide range of methods. A device with an unknown location is defined as a node, while a device with a preconfigured location is an anchor node or beacon.

- **Proximity detection or Cell of Origin (CoO)** uses symbolic relative location information [8]. The anchor node that receives the strongest signal from the node forwards its position as the node's location. The method is rather used to detect a node's presence in the surroundings instead of its current spatial location.
- **Angle of arrival (AoA)** uses the angle of a node's transmitted signal and an anchor node to determine the node's position. It requires at least two anchors to obtain a position in a 2D plane. Triangulation uses more than two beacons for localization, so that the accuracy is improved. The method's implementation is uneconomical due to the additional antennas for the angle measurements [8].
- **Lateration** refers to the methods which measure the distance between a node and an anchor node with multiple reference points. Trilateration indicates that at least three anchor nodes are used to determine the node's position. Time of Arrival (ToA), Time Difference of Arrival (TDoA), and Round Trip Time (RTT) are types of lateration techniques which differ in the importance of synchronization between the WSN's components [8,19,21].
- The **Received Signal Strength (RSS)** of a node's message can be used to determine its location. This nonlinear relation between signal strength and distance is referred to as received signal strength indicator (RSSI).

- A **fingerprint database** contains features of reference points in an area. During the offline phase, radio maps are created with predefined points that have different radio signal characteristics. During the online phase the system is operational. The RSSI at an unknown position is compared with the database. The closest match is the estimated node's location. The main drawback is the unreliability of the radio maps when environmental changes occur. The time-consuming calibration must be re-executed to update the database [8].

These localization methods can be implemented using various wireless technologies. For outdoor localization the Global Position System (GPS) is most commonly used. This satellite-based localization system has an accuracy less than 10 m. In some cases GPS is unreliable or unavailable, such as indoors, in dense forests and cities with large buildings. Hence, other localization technologies should be used in these environments. We examined a number of these technologies to verify their applicability for locating rail cars.

- **WiFi** is scalable and has an accuracy of 1 to 5 m. WiFi devices do not need additional software or hardware adjustments to determine their position in WiFi networks, making it an economical solution. The main disadvantage is its higher power consumption compared to other technologies [8].
- It is possible to obtain an indoor proximity solution with the proprietary standard **Bluetooth**. Bluetooth LE based beacons cannot be used for real-time positioning due to the repetition of the discovery procedure to get a node's location [8].
- **Zigbee** has a lower data throughput than WiFi and Bluetooth. However, it has a longer range of up to 100 m in free space [19,30]. Kuo et al. demonstrated an average positioning error of 3 m using the Linear Intersection Algorithm (LIA) outdoors. Indoor localization resulted in a position error of 5 m [15].
- Henriksson examined the RSS position in **LoRaWAN** networks. He concludes that this approach gives unreliable results for indoor localization. He suggests the usage of ToA or AoA to improve the accuracy [9].
- **Ultra-wideband (UWB)** can provide high-resolution (2.5 cm) indoor and short-range outdoor localization using TDoA mainly due to its short pulse duration and wide frequency spectrum [38].
- **Geomagnetic** localization uses the anomalies in the earth's magnetic field caused by reinforced concrete and metal objects to create a fingerprint. The main disadvantage is the assumption that the environment is static. Any reposition or removal of objects in the area could make the fingerprint inconsistent with the real word. This phenomenon is demonstrated by Vandermeulen [34].
- **LocataNet** is similar to GPS, but it uses ground beacons instead of satellites [12]. The coverage of a Locata's beacon is narrower than GPS whereas Locata can accomplish an accuracy of 2 cm [19].
- A **Radio Frequency Identification (RFID)** network consists of RFID tags and electromagnetic readers. Active RFID tags have an internal power source and thus a longer reading range then passive tags. Passive tags are less expensive due to the absence of a battery. The accuracy of an RFID localization system depends on the tag type and the frequency range [32,37].

Currently, no single technology can provide the location in every environment with high range, high accuracy as well as low cost and low energy consumption. Consequently, a hybrid positioning system is required that combines multiple technologies [8]. Weyn et al. defined the LocON protocol to combines GPS, LPR, WiFi, UWB and RFID localization. A set-up was tested in the Faro Airport. They concluded that accuracy can be greatly increased by filtering contradicting location information retrieved from the different systems [35].

We take a closer look at RFID due to its low-cost and low power properties. RFID tags could be used to mark rail cars that have entered the CRW and are removed from the rail cars when they leave the repair site. It should be taken into account that tags must endure the industrial environment. A passive tag consists of an integrated circuit connected to an antenna. The tag receives energy that is transmitted from an RFID reader. The captured radio waves depend on which frequency the antenna is tuned on. Generally, a larger antenna collects more energy and provides the tag with a further read range. The received energy is used to power the tag's circuit and sends data in a modulated wave back to the reader. This data contains the tag identifier (TID), Electronic Product Code (EPC), user memory, and reserved memory [1,16]. Active tags are not suitable for the WSN because they cost at least ten times more than passive tags [33]. Furthermore, they are more voluminous [31]. Another disadvantage is that the tag's battery only lasts three to five years. A Battery-Assisted Passive (BAP) tag also has an internal power source, but it lacks a transmitter, so the total captured reader's energy is used for backscatter. BAP tags have a price and communication range between the passive and active tags [11].

In addition to active and passive tags, there are also different operating frequencies, namely Low (LF), High (HF) and Ultra High Frequency (UHF). UHF tags have the highest data transfer rate, but their sensitivity to interference is higher. Nevertheless, UHF tags can be used in challenging environments due to developments in the tags' design, antennas, and readers. Additionally, the cost of passive UHF tags is lower than the other two tag types. Finally, since the rail cars width varies and a gap is needed between the rail car and the reader so that operators can always observe the whole vehicle, the distance between reader and tags is at least 1.0 m. The distance of LF and HF is limited to 10 cm and 1.0 m respectively. The UHF antennas, however, operate in the far-field which denote a maximum range of 4.0 m. These antennas use electromagnetic coupling instead of magnetic coupling used by near-field reader antennas [11].

3 Proposed Solution

As discussed in the previous section, a wide range of technologies can be used for the WSN. When the main focus is low cost and low power, RFID is most suitable for implementation. It consumes less power than WiFi, Bluetooth and Zibgee. Additionally, it is better suited for proximity localization in a continuously changing industrial environment with large metal objects. We opted for passive UHF RFID due to its low cost and longer range, especially if the extra cost of lost tags is taken into account. Since the WSN's location technology is proximity, the longer reading ranges of active and BAP tags do not offer a benefit in comparison with passive UHF tags. The lack of internal energy source reduces maintenance and total expenditures. Since only proximity detection is required, it also simplifies the overall implementation. The other discussed methods are neglected for this system, as they imply a too complex elaboration for a challenging industrial environment.

Figure 1 gives a schematic overview of the whole system. The passive RFID setup consists of a reader, an antenna, tags, and a component to transfer tracking data to the backend. The Nordic ID NUR Devkit v1 is used as the reading component. The reader has four Sub-Miniature version A (SMA) antenna connectors [23,24], reducing the reader's cost by a factor of four. The reader has a lower price than other industrial readers, where prices above €1 000 are no exception. An alternative for the Nordi Devkit is the less expensive M6E Nano Simultaneous RFID Reader from SparkFun Electronics. It has only one antenna connector and thus resulting in a higher total cost. For the tags we used Confidex Silverline Slim On-Metal Labels which have a reading range on metal of 4 m in ideal conditions and have an adhesive back optimized for metal surfaces [6]. Since they have no protective case, more expensive tags such as the HID InLine Ultra Mini tags from Rain RFID should be used in the final implementation. To deploy the proposed system in the CRW, 42 antennas are needed to divide the CRW in a same number of zones, along with eleven readers in protected enclosures, each connected to a Raspberry Pi 3 (RPi3). The chief's routine is redefined as follows. Each morning he verifies the new rail cars that entered the CRW. He provides each rail car with a tag and stores this relation in the database. During the day the readers register rail cars when they enter or leave a zone. All the changes are stored in databases and can be consulted with a web application. Therefore, the operators do not need to contact the chief whenever they want to know the location of a specific rail car.

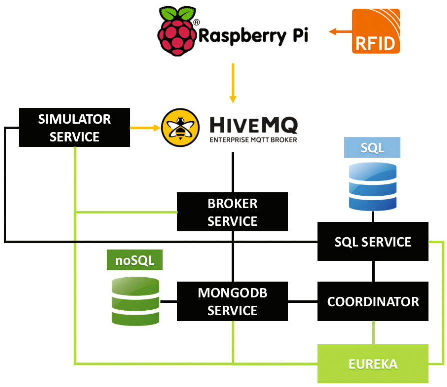

Fig. 1. Overview of the system. The black boxes represent the microservices.

The RFID's messages contain the reader's identifier, the tag's EPC, and the message's flag. The flag indicates if a rail car is standing in front of a reader longer than allowed, which is important for the backend where the rail car's location is calculated. MQTT is used to retrieve information from the readers [20]. Each client sets up a TCP connection with a central server or broker, such as HiveMQ [10,26]. Another widely used machine-to-machine protocol is CoAP. However, since it uses UDP instead of TCP it does not provide message delivery guarantees [3,28]. The broker's information is transferred to the backend with WLAN using an RPi3. Initially, we considered using a low power protocol such as Dash7. However, WiFi is already available on site. Moreover, using the RPi3's built-in WiFi adapter is more cost efficient as no additional hardware is required.

For the backend microservices are used, rather than a monolithic architecture. The services are independently deployed, loosely-coupled, and communicate with each other using lightweight protocols [2,17]. The downside is an increased development effort and additional execution overhead because each instance has its own Java Virtual Machine [29]. The microservices are registered using Netflix's Eureka, which integrates with Spring Cloud and the RestTemplate injection [25]. Other applications can query this central registry to discover where a service is located [36]. Spring Boot provides a framework for web-based applications [27]. Spring Cloud extends it with extra tools to build commonly used distributed patterns. It also supports Eureka, so that service discovery can quickly be enabled and configured [18].

Two types of data need to be stored. The static data consists of the rail car's information, the environmental characteristics, the reader's position and which tag is connected to a rail car. They follow a predefined scheme and thus they are stored in a separate table on a relational database [4]. The database is managed by Microsoft SQL Server, because the CRW already operates with this manager. The dynamic data currently only encompasses the tag ID, the reader that registered the tag, and the time stamp. Nevertheless, it should be possible to store other information from the location network which does not need to have a predefined scheme (i.e. schema-on-read). Therefore, it is stored as JSON-like documents in a noSQL database. MongoDB maintains the noSQL database, as it offers good performance and is easy to manage [13]. Whenever a tag is detected by a reader, its location is stored in the noSQL database. The database pushes the new inserted data to the coordinator which calculates the zone where the registered rail car is located. The coordinator also allows to add a rail car and assign a tag to a rail car. When the coordinator service receives a localization message, it checks the messages flag. If the flag does not give an error, the timestamp and the tag's zone are stored in the relational database. An error flag is given when a rail car occupies a reader for too long. The coordinator will not determine the tag's location with this flag, because it does not know the rail car's direction when it is shunted again. Instead, it warns the user of this error and allows him to manually assign tag to the right zone.

4 Test Results

To test the application a simulator microservice was developed. It contains a representation of the CRW site with the different tracks, tags, and devices. The goal is to simulate the readers' behavior with individual agents and test correct backend operation. Specific Java agent frameworks such as JADE encompass the implementation of multi-agent systems, and graphical tools to debug and manage the agents [14]. However, because these added features are not required for the simulation, a simple thread pool and a Spring TaskExecutor are used instead. The simulated parameters of a device depend on the device's parameter model. The parameters' values are derived from measurements on the CRW. Device simulation is performed on the level of its communication with the MQTT broker. Parameter models, MQTT broker information, and identifiers of the virtual devices are stored as JSON files which makes the data lightweight, human-readable, and allow rapid parsing with a Java API. The rail cars in the simulation can be moved across the virtual world. A virtual device notifies the coordinator whenever a rail car passes it. This notification process is performed in the same manner as that of a physical device.

Two measurement sessions where performed on the CRW site in which the influence of the tag's position on a rail car and the antenna's position on the tag's detection were tested. During each experiment the antenna was moved in a perpendicular line to the tag. When the tag was registered, the distance between the tag and antenna was measured. Multiple samples were taken for each series and were registered with a Nordic RFID tool. The results of these experiments are shown in Table 1. In Table 1a the tag and the antenna's height are at 1.20 m and 1.10 m relative to the ground surface of the platform respectively. The table shows a remarkable difference of 32 cm between a horizontal and a vertical tag. It is an unexpected result because of the antenna's circular polarization which should allow the tag to be read independently from its orientation. The metal frame's shape can be responsible for the difference, but more tests are required to identify the root cause of the variation. The 1.20 m series in Table 1b delivers an acceptable deviation and reading distance. Therefore, it is considered to be the best distance for a static measurement in this environment. In the fifth series

Table 1. Average reading distance and deviation for *(a)* tag orientation with a tag height of 1.20 m and *(b)* for varying antenna height with tag height 1.20 m.

(a)

Orientation	Distance	Deviation
Horizontal	1.26 m	0.01 m
Vertical	0.94 m	0.03 m

(b)

Antenna height	Tag Position	Distance	Deviation
1.10 m	Exterior	1.26 m	0.01 m
1.20 m	Exterior	1.38 m	0.02 m
1.30 m	Exterior	1.42 m	0.08 m
1.40 m	Exterior	1.29 m	0.09 m
1.20 m	15 cm cavity	1.25 m	0.08 m

of this experiment the tag was placed in a cavity 15 cm deeper in the rail car's frame, whereas the tag in the four other series was on the frame's exterior, which resulted in a reduction of the reading range with 13 cm. The possibility to place the antenna between or along the rails was tested during other experiments. The result showed that the tag and the antenna should be aligned on one line to be sure the tag was registered. In one experiment a row of rail cars with tags were shunted where one tag was placed on the exterior of a wide frame, while another was placed on a 15 cm narrower frame. This experiment resulted in no registrations when the distance to the wider frame was 1.12 m and only the registration of the wider rail car when the antenna was placed at 70 cm of this frame.

The experiments indicate that the variance in read distance is caused by the position of the tag and the antenna. For a real implementation it is preferred to place the antenna on the platform along the tracks. For safety reasons it is not possible to place the antenna between the rails. Additionally, placing the antenna on the ground along a rail is not recommended, as the tags are still attached on the bottom of the frame which is not ergonomic for the CRW chief, who has to place the tags on the rail cars. The total width of a rail car's frame varies between the 3.15 m and 2.82 m. This gives a difference of 16.5 cm in width on each side of a track. This should be the variable distance between the tag and the antenna as long as the tags are placed on the exterior of a frame. From the static measurements a distance of 1.20 m is sufficient, while the distance with the dynamic experiment was only at 70 cm with just one registration. We suggest that a distance of 55 cm to widest allowed rail cars or 2.13 m relative to the middle of the track would be ideal to set up the antenna. Nevertheless, more tests are required to determine the ideal position of the antenna in this industrial environment.

5 Conclusions and Future Work

Performing accurate indoor outdoor and localization is challenging. It is even more so in dynamic industrial environments with large metal surfaces, such as rail car maintenance sites. Based on the requirements of the CRW, we have investigated and demonstrated a proof of concept localization setup capable of locating rail cars in zones with sizes between 20 and 200 m. We have shown that passive RFID is well suited for this purpose when only proximity is needed and the required density is low. Moreover, it is low power and the tags are low cost. Our proof-of-concept effectively decreases the chiefs workload and remedies the inefficient intercom communication with the operators, saving the CRW time and money, that can be invested in digitalization projects to build a future-proof NMBS.

A drawback of the current RFID system is the absence of knowledge about the direction of a shunted rail car. There are two ways to obtain this information with the current equipment. A first solution is to declare a zone boundary with two antennas instead of one. A rail car changes from one zone to another when it has passed the two antennas. The sequence in which the antennas register a rail car indicates its direction. The main disadvantage of this method is that it doubles the amount of required readers and antennas. The second option is to provide two tags on each rail car. The rail car's direction is based on the order in which the tags are registered. Indeed, twice the amount of tags are needed, but it is less expensive than the first approach, as the tags needed for the CRW in this project amount to only 10% of the cost of the NFC readers. The disadvantage of this method is that the chief must perform the same operation twice on each rail car. The information of the localization network is processed and stored in a backend. It is built as a collection of independent microservices that can be upgraded or expanded without a shutdown of the whole system. Additionally, it decouples the backend from the used localization technology. A potential improvement is to run each service in an independent container with the open-source framework Docker. Each containers is a self-contained Operating System (OS). Compared to a dedicated virtualized OS, it does not require the same resources. It guaranties that the microservice always runs the same and independently from where it is deployed [5,7]. Finally, the reading range of the WSN can be improved by using readers with a higher radio frequency power. Consequently, these readers have an higher price then the current ones. The reading distance could also be improved by taking additional measures to minimize interference from the metal surface of the rail car by adding an additional spacer between the RFID tag and the rail car. Additional research of RFID under various environmental circumstances (e.g. weather conditions, different rail cars and different speeds) will also further improve the robustness of our proof of concept.

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Wireless Surface Electromyography

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Abstract. Surface Electromyography (sEMG) is used in the evaluation of muscle activation patterns during body movements. Artefacts in sEMG-signals and analysis are caused by the movements of the cables between the sensor and electrode. Hence, there already exist some pre-amplified and wireless sEMG electrodes. These deliver black box devices to end users, for commercial reasons. However, there is a demand for open source devices from a research perspectives. This paper explores the development of an open source wireless sEMG device that distributes the processing of the raw sEMG data between the wireless electrode and the researcher's computing device. In cooperation with CSEM Landquart (CH) the possibility for the use of electrode-printing technology will be evaluated. We show that Bluetooth Low Energy has a high potential as a low power wireless communication protocol in this application, but that further improvement of the signal-to-noise ratio is necessary.

1 Introduction

This paper situates itself within the field of wireless surface electromyography (sEMG). Such sEMG captures the potentials of the electric fields generated by contracting muscles and analyzes the muscle activation patterns, i.e., amplitude, fatigue and coordination. This is an active subject of research. For example, [4] devised a sEMG recording system to detect muscle fatigue. Lee and Lee [9] created an SMS application using an EMG signal of clenching teeth. Since a physical reaction is divided into muscle reaction and a visible reaction, EMG is also a good tool for measuring and subdivision in reaction time measurements.

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The current EMG systems have a common problem: they are wired over the body to a central gateway. Even using pre-amplification and a coating, these wires can cause noise artefacts due to movements of the electrode cables. Wireless sEMG copes with this problem. However, the industry mostly delivers black box devices to end users, without the possibility to validate the system's accuracy and to process the raw data independently, e.g. Noraxon Desktop DTS System [10]. This black box implementation limits its applicability in research.

Researchers tend to begin from raw sEMG-data, to evaluate new data analysis methods, such as different types of wavelets [5]. Therefore, the focus of this research is to develop a distributed, wireless sEMG device that avoids this black box context. Additionally, we want to evaluate the use of skin patch electrode sensors in cooperation with CSEM Landquart (CH). The main goal of this thesis is to develop a Proof of Concept (POC) for wireless sEMG. The POC is developed with a Bluetooth Low Energy (BLE) transceiver module, combining a low energy consumption with a sufficient data throughput. This allows to make a comparison between standard electrodes and printed patch electrodes.

This paper continues as follows. First, Sect. 2 reviews the current state-of-the-art in sEMG and wireless low power communication. Then, Sect. 3 describes the proof of concept architecture of our device. Subsequently, Sect. 4 provides an evaluation of our device by capturing a set of muscle contractions. Finally, in Sect. 5 we draw our conclusions.

2 State of the Art

Reaz et al. [12] provide a good description of the techniques used for EMG signal analysis. They describe the main characteristics of the signal. EMG-signals have an amplitude of 0 mV to 10 mV (−5 mV to 5 mV). Noise adds up to the signal while traveling through different tissues.

Reaz et al. [12] provide two ways to maximize the quality of an sEMG acquisition. Firstly, the Signal to Noise Ratio (SNR) should contain the highest amount of information possible from the EMG signal and a minimum amount of noise contamination. Secondly, the distortion of the signal must be as small as possible. This means that unnecessary filtering, distortion of signal peaks and notch filters are not recommended.

De Luca [6], a pioneer in sEMG, provides the rules of thumb concerning sEMG recordings. An important factor is the design of electrodes and their amplifiers. According to De Luca, the dominant energy of the EMG signal is located in the 50 Hz to 100 Hz range. From the overview of De Luca, it is clear that compromises have to be made in order to devise a general-purpose electrode. These compromises concern the dimensions and configuration of the detection surfaces and the inter-detection surface distances. De Luca [6] made an experience-based statement, claiming that the use of parallel bar electrodes 1 cm long, 1 mm wide and spaced 1 cm apart, prove to be the best overall choice (Fig. 1).

The authors of [4] developed a wireless sEMG recording system and applied this to muscle fatigue detection. Despite the fact that the article has gained

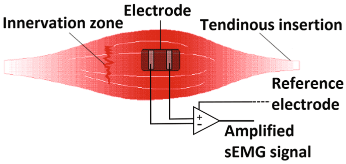


Fig. 1. Schematic of the differential amplifier configuration

some interest, it does not comply with the overall tendency to evaluate the signal between 20 Hz to 500 Hz. Chang et al. have devised it to a sampling rate of 2 kHz, whereas they consider the signal frequency range to be 100 Hz to 1000 Hz.

Supuk et al. [15] designed, developed and tested a low-cost sEMG system and its use in recording muscle activity in human gait. However, the high-pass frequency for the device is designed to be 3 Hz. This contradicts the findings of De Luca [6], being that motor units have a firing of 0 Hz to 20 Hz. In the testing stage, Supuk et al. [15] have compared their results with existing measurements by applying equal filtering and denoising algorithms, such as Daubechies 10 wavelets (db5 in Matlab) and soft thresholding techniques.

Chowdhury et al. [5] describe an in-depth summary of classification techniques for sEMG signals. In addition to the noise sources mentioned by [12], and [5] add ECG artefacts as a noise source. The magnitude of these artefacts are mostly dependent on the placement, however, a decent Common Mode Rejection Ratio (>90 dB) together with a placement along the heart's axis can minimize this contamination. Due to an overlap of frequency spectra of ECG and EMG signals it is very difficult to remove these artefacts, requiring compromises to be made. One possibility is to place a high-pass filter at 100 Hz. This essentially removes the effect of ECG interference, however, this also removes most of the energy content of the EMG signal.

Chowdhury et al. [5] suggested wavelet analysis to process sEMG datasets, claiming that in the pre-processing stage wavelet de-noising algorithms have been successful over the past years. Chowdhury et al. [5] recommended using Daubechies wavelet functions, with a specific recommendation for Daubechies wavelets at decomposition level 4.

A moderately new technique in data analysis is Empirical Mode Decomposition (EMD). EMD is a method to analyze the underlying notion of instantaneous frequency, and provides insight into the time-frequency signal features. Huang et al. was the first to introduce EMD [8].

Andrade et al. [1] made a comparative study between EMD and different wavelet prototypes. They examined the effects on attenuation of EMG background activity (noise). The wavelet prototypes used are Daubechies 4, 6 and 8 (db2, db3 and db4). A downside to the EMD approach is that the computing time required to calculated the Instantaneous Mean Frequency (IMF) is rather high compared to wavelets computing time. Another downside to EMD is its sensitivity to the presence of noise. It also has a mode-mixing problem. To solve the previous issues, a more robust, noise-assisted version of the EMD algorithm, called Ensemble EMD (EEMD) has been developed. A noise-assisted version of the EMD algorithm, called Ensemble EMD (EEMD) is used. Zhang and Zhou [19] have proven that EEMD provided the best surface EMG denoising performance compared to all other methods, especially in cases of power-line noise, white Gaussian noise, baseline wandering and ECG artefacts.

Von Tscharner [17] stated that signals often carry more information than what is displayed by methods such as Root Mean Square analysis. According to him time-frequency analysis of myoelectric signals has not yet led to satisfactory results in order to separate simultaneous events in time and frequency. To solve this problem, he suggested the use of a filter bank of non-linearly scaled wavelets with specified time-resolution in order to extract time-frequency aspects of the signal. His procedure has been developed to calculate the signal intensity in such a manner that the power of the signal in time can be approximated. In order to make a comparison, the sEMG toolbox has been provided with both an orthogonal Morlet Wavelet approach and the non-orthogonal approach of von Tscharner [17]. For that purpose, a pilot study is planned.

From the above, it is clear that it is best to place the transmitter as close as possible to the detection surface. To increase battery life, we want to build a system that has little energy consumption. Thus, this section reviews the choice between low power communication protocols, BLE and DASH7 [18].

Firstly, Gomez et al. [7] summarized an evaluation of BLE, stating that it has a good compromise between throughput rate and low energy consumption. Omre and Keeping [11] further specified the research of Gomez et al. [7] into a medical context. In his research he quotes the U.S. Food And Drug Administration (FDA) and other medical bodies on their concern about the potential EMI generated by wireless connected devices. The FDA states, according to Omre: "Wireless coexistence and data latency remain concerns because the data transfer rate can slow slightly or even dramatically with an increase in the number of similar transmitters in a given location. In many cases it is essential that medical data, including real-time waveforms and critical control signals and alarms, be transmitted and received without error."

Another issue with BLE is that it transmits in the already crowded 2.4 GHz band, whereas DASH7 transmits in the less crowded, long range 433 MHz, 868 MHz (EU), and 915 MHz (US) bands. Operating in the 2.4 GHz band is a major challenge with consequences for product design. BLE operates at 1 mW (0 dBm) output power, which falls well below the FCC guidelines of 125 mW. Additionally, BLE only transmits for 1% or less of the time, since most modern medical electronics have been designed with a high degree of EMI immunity.

The most important factor in the decision for a transmission protocol, however, is the throughput rate. Whereas DASH7 has a maximum data rate of 166.667 kbps, BLE reaches out to a theoretical rate of 1 Mbps. BLE allows a better resolution to be sent to the receiver, and is therefore chosen as the wireless communication protocol in the proof of concept.

3 Proof of Concept

Considering the outcome of the analysis above, BLE is chosen for the development of the prototype. The system requirements are taken as a starting point, from which a system overview is established. The EMG sensing node consists of a transmitter, an MCU, an sEMG-sensor and a battery.

The BGM111a256v2 was chosen as a transmitter and MCU, since it has a small form factor and suits the requirements. The BGM111 was developed by Silicon Labs and allows integration of the BlueGiga Bluetooth Smart software stack. The BGM111 is also fully compatible with BGScript [13].

BGScript promises quick and easy development. Therefore, the first prototype trial was programmed in BGScript. However, the overhead introduced by BGScript is too large in order to achieve the desired data rate. According to Silicon Labs [14] this is caused by BGScript being an interpreted language, of which the limitations are typically reached in applications where fast data processing or data collection from peripherals is needed. If the application needs to read an analog sensor thousands of times per second and process the data, BGScript based applications will not offer enough performance. However, Silicon Labs does provide a good starting point for an alternative way of programming. In the Simplicity Studio IDE they allow the user to select several demo projects for the BGM111. These examples are written in C-code and contain the basics for most common use cases.

For the prototype, an sEMG amplifier board developed by BitAlino was used. The BitAlino board consists of an amplifier circuit meeting the requirements for sEMG measurements. In this prototype, the connector was modified to be able to connect the sensor patch using a flat flexible connector.

In terms of BLE structure, the sensor node will act as a server and a peripheral. Any Bluetooth Smart enabled device can be used to connect with the sensor node. The connecting device will then be the client and central node. A connection setup using the BLE protocol is advertisement based. Thus, by activating the BGM111, advertisements will be sent out stating that the device is available for connection. Once a connection has been established, the client will send read commands for a specified Generic Attribute (GATT) characteristic, to the server. The Automation IO Attribute [2] with the Analog characteristic are chosen for this purpose, since they suit the requirements. This characteristic has to be declared in the server's Generic Attribute Profile (GAP). When this command arrives, the server will reply with the sensor data stored within the GATT characteristic. Note that the attribute has to set to primary in order to be discoverable. Simplicity Studio contains a GATT editor tool, but this contains some minor inconsistencies towards the Bluetooth SIG standard. The Automation IO attribute is defined as a primary attribute in the documentation [2]. However, in the GATT editor the default value is set as secondary attribute preventing it from being discoverable, and therefore making it unreadable.

The next challenge is enabling to read from several sensor nodes. The BLE protocol allows up to seven concurrent connections. In this case, the Central/Client device will schedule the multiple read actions in a consecutive manner such that a 1 kHz sampling rate can be achieved on all sensor nodes.

Another point of consideration is the data throughput. The BLE protocol promises a theoretical data rate of 1 Mbps. However, according to Townsend et al. [16] a more realistic estimation results in about 125 kbps. The Analog-to-digital (ADC) converter on the BGM111 has a 12-bit resolution. Taking this resolution into consideration combined with the sEMG sampling requirement of 1 kHz, results in a data throughput of 12 kbps. Thus, this leads to a maximum of 10 sensor nodes connected to the central device. Therefore, the only remaining restriction is the Android BLE stack restriction of 7 concurrent connections on the central device.

For the first prototype a single connection setup is realized. This connection is made between the BGM111 with the C-code program flashed to it on the server side. On the client side an Android Bluetooth Smart Ready enabled device is used. An Android application is developed for this purpose.

Most difficulties in this part are inconsistencies in the implementation of the BLE stack. The Silicon Labs implementation allows both devices to set the latency and connection intervals. When the Android BLE stack receives a parameter change command, it uses a self proposed 'best-option' for the parameters with few to no insights in to which values are used. Therefore, the connection parameters are best requested and set from the Android device. The Android BLE stack allows to set a priority for the connection, this priority sets the connection parameters to a compliant value.

Another difference in stack implementation is the Maximum Transmission Unit (MTU) per connection interval. The Silicon Labs BLE stack (v.2.3.0) allows a maximum MTU of 255 byte. Therefore, to decrease the amount of connection intervals, leading to a lower power consumption, the link MTU was requested to 255 byte from the BGM111. However, the Android BLE stack only allows a maximum MTU of 123 byte. If the MTU is set higher than the maximum, Android resets the MTU to the default value of 39 byte. In this case it requires 4 times more connection intervals to send a packet of 123 byte.

When using BLE in the sEMG application, an evaluation of packet size versus connection interval time is necessary to optimize the link throughput. Therefore, a thorough knowledge of the stack implementation and its limitations is necessary. In the Android application, the data is visualized to the user. If the user is pleased with the measured data, the data can be saved to the external storage of the device.

The sEMG sensor is based on the voltage potential differential principle. As mentioned above, this signal has an amplitude in the order of a less than 5 mV. Therefore, to be able to measure this signal, it must be amplified to a level suitable for recording. The amplification should be without attenuation and with all desired frequencies present in the signal.

To measure this low potential difference a precision Instrumentation Amplifier (In-Amp) INA333 is included in the design. Offering high common-mode rejection (110 dB at a gain larger than 10). This In-Amp is combined with a

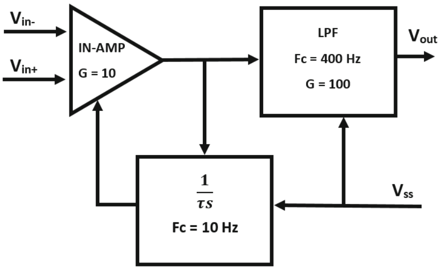


Fig. 2. Block diagram of the sEMG sensor. The gain is 1000, the bandwidth is 10 Hz to 400 Hz. An AC-coupled In-Amp to reject DC input voltages is followed by a 4th-order lowpass Butterworth filter.

low-noise high speed Operational Amplifier AD8694 to perform further amplification and bandpass filtering.

The first stage of the circuit is derived from the classical configuration of the In-Amp with three amplifiers, with an additional stage of AC-coupling. This approach is preferred since it allows precise control of DC levels. Thus, rejecting undesired DC offset voltage introduced by the electrode-skin interface. The DC-component is subtracted by means of a feedback loop to the reference input of the In-Amp, via the integrating network, resulting in a first-order highpass response. The cut-off frequency of the highpass filter depends on the time constant of this integrating network. For this sensor the high pass frequency is designed at 10 Hz. Therefore, the noise impact at low frequencies is minimized as well as the baseline wander introduced by context variables such as user breathing activity and motion artifacts. Furthermore, it is important to implement a lowpass filter to filter out the region of interest concerning the sEMG measurement. For this purpose, a 4th-order Butterworth filter is implemented. This filter consists of a two stage cascade of second order filters using a Sallen-Key architecture.

The circuit is described in Fig. 2 and allows to acquire data with acceptable quality in most use cases. To further improve the quality of the signal, a third common electrode—also called "reference electrode"—is added to the circuit. This reference electrode is connected to the V_{ss}. In addition to the reference electrode, a further improvement to the classical designs is the proximity of the transmitter to the measurement location. This allows the signal loss, due to cable resistance, to be decreased.

4 Data Evaluation

The system is evaluated through a trial measurement. The trial data consists of a series of four isometric maximal contractions measured on the long head of the biceps brachii, see Fig. 3. The placement of the electrodes followed the recommendations of [3]. The reference electrode was placed on the processus styloideus of the radius. The measurements provide a comparison between the

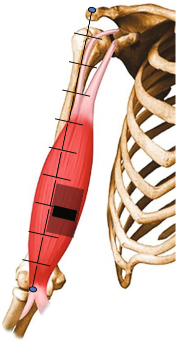
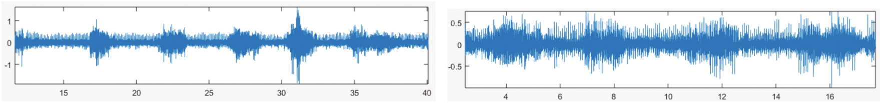


Fig. 3. Recommended electrode placement on the Biceps Brachii. The red zone is to be avoided [3].



(a) (b)

Fig. 4. Raw data of four consecutive contractions of the Biceps Brachii, measured in (a) with a 3-lead circular electrode interface and in (b) with a 2-lead patch electrode interface and a 1-lead circular electrode as a reference electrode.

classic electrodes with the printed electrodes. Furthermore, it allows an overall system evaluation. Comparing the two methods is done by means of accepted EMG analysis tools. The Matlab GUI creates an sEMG envelope by first rectifying, and then smoothing the data. The data is smoothed by means of a Gaussian convolution filter. The GUI also allows a graphical view of the wavelet bands for the weak orthogonal wavelet approach presented by von Tscharner [17].

In the data displayed in Figs. 4a and b, the four contractions measured in both manners are displayed. From these figures it becomes clear that the patch setup introduces a lot of noise. This is partly due to the fact that unshielded electrode cables were used. In the final prototype, there will be no need for cables, since the patch electrode can be inserted on the board itself without cables. Further evaluation hereof is necessary to establish a rigid conclusion concerning the patch electrodes. However, it does become clear that even though some noise is introduced, the contractions are still slightly visible. Certainly after the EMG envelope processing, the contractions become clearly visible, see Figs. 5 and 6.

The data provided by the 3-lead electrode measurement is used in this analysis, in which Von Tscharner's non-orthogonal wavelet approach was implemented. This approach is considered a valid EMG-processing technique. A clear representation of the actual contractions is displayed, see Fig. 7. Compared to the original signal, the Tscharner wavelets display little to no activity in between

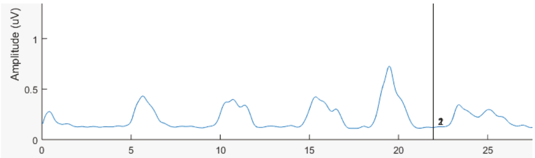


Fig. 5. EMG envelope of four consecutive contractions of the Biceps Brachii, measured with a 3-lead circular electrode interface.

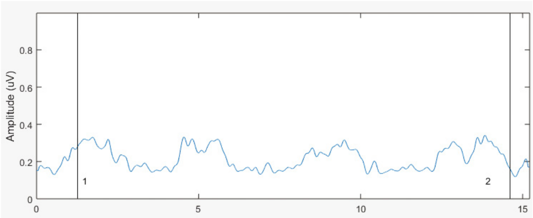


Fig. 6. EMG envelope of four consecutive contractions of the Biceps Brachii, measured with a 2-lead patch electrode interface and a 1-lead circular electrode as a reference electrode.

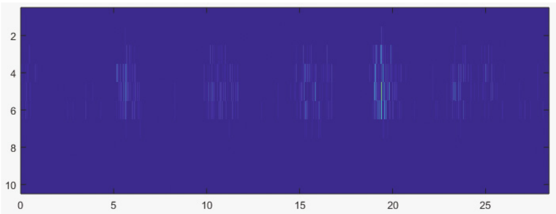


Fig. 7. Von Tscharner non-orthogonal wavelet processing of four consecutive contractions of the Biceps Brachii, measured with a 3-lead circular electrode interface.

contractions. The activity lies mostly within the 4th frequency band, meaning a center frequency of about 92.36 Hz [17].

5 Conclusion

A distributed sEMG capturing device is successfully developed, using both new approaches as well as existing techniques. The capturing of sEMG has been further explored by means of the sensor patch. This has proven to show potential. However, further research is necessary in order to decrease the SNR. In the second prototype, the connection for the sensor patch has been provided on the board, removing the need for wires between the sensor and the board as well as increasing SNR.

Exploring the applicability of low-power transmission techniques, this pilot study has proven BLE to be a versatile technology with a high usability. The implementation of Von Tscharner's non-orthogonal wavelets proves to be a good resource to catalog activity in an EMG signal. A lot of possibilities for future research lie in the development of new processing techniques.

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Context-Aware Optimization of Distributed Resources in Internet of Things Using Key Performance Indicators

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Abstract. The recent advancements in Internet of Things (IoT) show us a glimpse of a future in which all our devices are connected to the internet, providing users with services that make life easier, more comfortable and safer. Although this interconnectivity seems simple, in practice management of the IoT hardware and the enormous amounts of data it generates is challenging. To bring the connected future into reality and build advanced and useful services, better resource usage estimation (memory, bandwidth, storage etc.) and resource management is required. We propose a IoT optimization methodology, where resources are estimated at each level of the IoT architecture (i.e. nodes, edges and cloud). Using these estimates, the executed code is redistributed across the network in order to optimize the cost and efficiency of the IoT environment, while taking into a specific context (e.g. environment). Initially, we aim to apply this methodology for statically defined contexts. In our future research we aim to perform the optimization at runtime, redistributing tasks across the IoT network dynamically as the context of the nodes changes.

1 Introduction

Over the years, our quality of life has been improved with gradual advancements in wireless sensor networks, health care related services, smart phones, and other pervasive means. Cisco Systems calculates that an expected 50 billions of devices will be connected to the Internet by 2020. By 2019, 45 percent of IoT-captured data will be stored, processed, analyzed, and acted upon adjacent to, or at the Edge of, the network [13]. With the recent innovation in Internet of Things (IoT), devices, services, and people are ubiquitously interacting with each other almost all the time. The seamless communication also provides a new dimension to generating huge amount of data. The objective of IoT is to facilitate a network infrastructure through inter-operable communication protocols and software which allows interfacing and integration of physical as well as virtual sensors, computers, smart devices, vehicles, and dumb objects such as household items, food and medicines [17].

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In order to keep up the current growth and ever-increasing interconnectivity, highly efficient management of the IoT network is essential. A few years ago, the approach to enhancing network efficiency and dealing with the increasing amount of connected devices to the Internet shifted towards computation, control, and data storage in the cloud. Although data centers are crucial in fulfilling huge computational requirements, cloud computing is facing challenges in terms of low latency, real time analytics and meeting performance requirements of many application services. Fog Computing is an emerging paradigm that overcomes these challenges and increases infrastructure efficiency by providing low-latency, bandwidth-efficient and resilient end-user services and management. However, because of the limited computational strength of these devices, it is not always possible to deploy processing operations to the edge of the network [6]. Fog computing plays a role as a middleware entity amongst underlying IoT nodes and overlying cloud data center. The fog serves as an initial information interpreter that has ability to estimate resources according to potential context. As fog is localized, it is more aware of how the underlying resources at the IoT node level can be managed [9].

Although fog computing provides a partial answer to the enhancement of network efficiency, resource estimation is still the utmost critical part of overall service provisioning. Accurate resource estimation allows us to perform optimized resource allocation, scheduling, and in the end, efficient service provisioning. Ideally, usage of resources is optimized throughout all levels of the IoT network, taking into account Key Performance Indicators (KPIs) such as memory, processing, security, communication and power consumption in each of the connected devices, while asserting that requirements of the IoT applications (e.g. timing constraints) are respected. However, this is challenging in an IoT environment. First of all, we are dealing with a large degree of heterogeneity in available resources, as there are large differences in hardware architecture between the edges, the cloud and even between individual sensor nodes. Combined with different requirements for the applications running on these devices, the complexity of the optimization process increases significantly. Secondly, in order to optimize towards these KPIs, we need to determine which factors are most important for a given context. We can define contexts for the user (e.g. preferences, location, health conditions), the environment (e.g. location), the application (e.g. health monitoring, proximity detection), the IoT network (e.g. local or global scale, policy requirements) and the device (e.g. battery status, available sensors, connected peripherals and available communication links). When considering a static environment, we can optimize the application for the specific properties of a single context (e.g. optimizing for low power usage in a battery-operated mobile device). However, in a highly dynamic IoT environment, the context changes continuously. In order to optimally exploit the available resources, a more flexible and adaptive approach to resource allocation is needed. Although context awareness is currently being explored in the state of the art, a methodology to address these challenges is yet to be defined [8,16].

In this paper we propose a methodology that employs context-aware multi-objective KPI optimization to efficiently exploit the available resources in an IoT architecture. Initially, we aim to optimize a resources for statically defined contexts. In our future research, we aim to perform this context-aware optimization at runtime, redistributing resource usage across the nodes and edges, and dynamically adapting and re-optimizing when the context changes.

The remainder of this paper is organized as follows. In Sect. 2, we provide an overview of the State of the art technology which also includes benefits and drawbacks in different circumstances. In Sect. 3, we will describe our proposed methodology in static IoT environment which includes context-aware optimization of resources at different levels of a generalized IoT architecture using multiple KPIs. In Sect. 4, a proposed use-case scenario will be elaborated. Finally, in Sect. 5 we discuss the conclusion of our research and future directions.

2 State of the Art

In this section we will discuss the state of the art in resource management, starting from the cloud level down to the node level. Cloud Computing is can be recognized by its on-demands processing and storage resources. These resources can, for example, be consumed to evaluate data generated by IoT objects in batch or stream format. Researchers from both the commercial and academic world have attempted to express precisely what cloud computing is and what its distinctive characteristic are. Buyya et al. have defined it as follows: “Cloud is parallel and distributed computing system consisting of a collection of interconnected and virtualized computer that are dynamically provisioned and presented as one or more unified computing resources based on Service level agreements established through negotiation between the service provider and consumer [7,14].” Vaquero et al. have stated that “clouds are a very large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically configured to adjust to a variable load (scale), allowing also for optimal resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the infrastructure provider by means of customized Service-Level Agreements [12,14].” Abu-Elkheir et al. have characterized the organization of data in IoT. The authors pin-point how different design parameters can work to organize data properly. But how the data and IoT nodes are going to be handled at the cloud layer, as well as how generated data is managed is not a part of their study [5]. Cubo et al. confirm Abu-Elkheir’s findings and elaborate on the integration of this approach for heterogeneous devices in a cloud environment [11]. Bonomi et al. present their architecture for Fog computing. However, they do not address practical implications and resource management for IoT [6].

Aazam et al. have proposed a number of methodologies to manage IoT resources. Firstly, Aazam et al. trim unnecessary information gathered by the end nodes by installing smart gateways. These gateways are used to pre-process and filter-out data near the edges to avoid over-usage of resources during the information transfer towards the cloud [1]. Secondly, Aazam et al. have highlighted how different resources can be estimated efficiently using fluctuating relinquish probability [2]. Thirdly, Aazam et al. have devised a methodology, referred to as MEdia FOg Resource Estimation (MeFoRE), to provide resource estimation on the basis of service give-up ratio, also nominated as a Relinquish Rate (unpredictable service abortion pattern), and further enhance Quality of Service (QoS) based on previous Quality of Experience (QoE) and Net Promoter Score (NPS) records [3,4]. Although their proposed approached addresses a number of optimization issues in IoT, Aazam et al. do not take into account the context of the nodes into their optimization methodology [1–4]. Charith Perera et al. explain how Context Awareness for IoT architectures is valuable to automate tasks according to context [16]. Nevertheless, the main issue here is that the resources are often not used optimally according to context, resulting in issues such as overpowered end nodes, unused resources on the edges, excessive communication with the cloud backbone. In order to perform efficient context-aware resource optimization we have to take into Key Performance Indicators (cost, energy, memory, security, etc.) at each level i.e. nodes, edges etc. of IoT architecture with respect to its context. Furthermore, for efficiency and speed these KPIs should be estimated in a decentralized manner so that the overhead on the network is minimized.

In summary, most of current literature still focuses on management of cloud resources, data flows within an IoT architecture and IoT resources without considering the (potentially dynamic) context of the devices and applications. The optimization methodology proposed in this paper, where tradeoffs between different layers within the IoT architecture are considered based on the context of the IoT devices, has not been expressed in the past works.

3 Proposed Methodology

In the initial research of our methodology we consider three main research areas, namely a generic IoT architecture, cost estimation and dynamic reconfiguration. In this section we will elaborate on each of these topics. In this proposed methodology, we initially assume a static IoT environment with a single application in a static context. This context has an influence on the most optimal IoT resource allocation strategy. Depending on the context different sensors and different algorithms will be required, some more complex and some with more strict timing constraints. When a worker walks through a factory, for example, accurate localization might be important near a crane, whereas energy conservation for the worker's wearable device is a priority when there are no hazardous areas nearby.

3.1 IoT Architecture

For the IoT architecture in our methodology we break down the IoT network in several layer, namely the sensor nodes, the edges, the cloud and the actuator nodes. Figure 1 shows an overview of this generic IoT architecture. On the top we

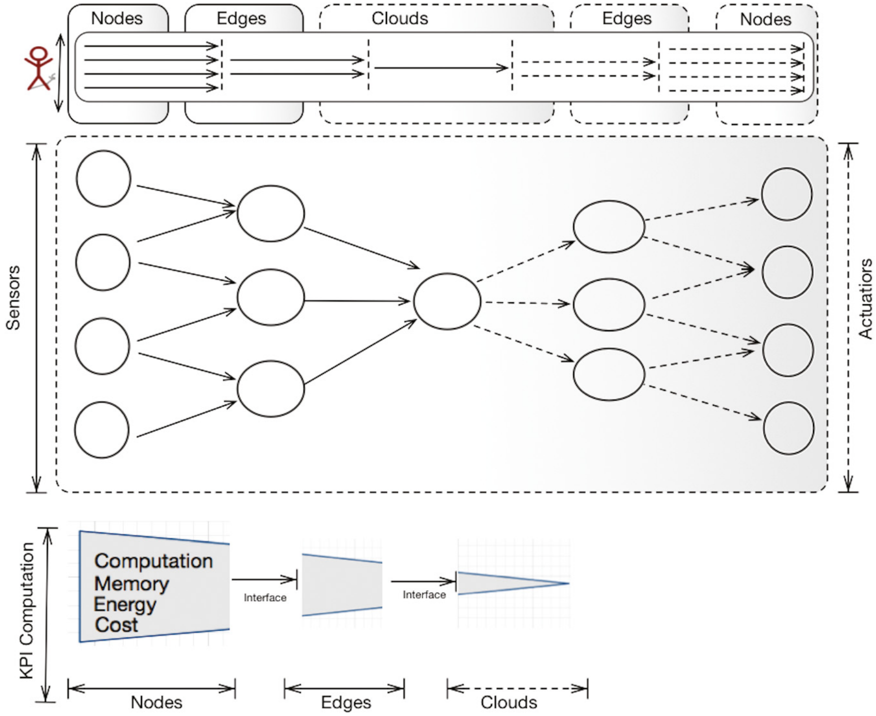

Fig. 1. Context-aware proposed architecture

see the various components of the architecture, namely the sensor nodes, edges and cloud. Nodes can have sensors, actuators or both. Sensors are defined on the left side and actuator are defined on the right side. The purpose of the sensors is to sense and capture information from the environment such as humidity, temperature, activity and smoke, and forward their sensed information towards other nodes in the IoT network (e.g. edges, the cloud or actuators). The purpose of the actuators is to perform an action when triggered by a certain event (e.g. turn on fire-alarm when smoke level is above than specified threshold). Note that the sensors and actuators in this representation could be located on the same device, this split representation is only for understanding of the proposed system. KPI evaluation is performed at each layer of IoT Architecture and available via interfacing with the component if required for further evaluation.

In our approach we assume that by definition a processing, sensing or actuating task is not assigned to a single end-node nor distributed using a static allocation pattern (e.g. cloudlets on the edges). Instead, each node is considered equally responsible for all tasks that need to be performed by the network as a whole. Each IoT node (e.g. device, edge or backbone), contains a number of applications that require certain inputs, outputs and resources. Through multi-objective optimization, these tasks will be distributed across the network

Table 1. Static Environment Example

Context	Components	KPIs			
		Computational cost	Energy cost	Data transfer cost	Memory cost
User	Node	Y	Y	Y	N
	Edge	N	Y	N	Y
	Cloud	Y	N	N	Y
	Front end	Y	Y	Y	Y

based on KPIs context, requirement definitions and available resources in the IoT environment. When the context of a device changes, a new optimal distributed resource allocation strategy is determined. In order to perform such an optimization we need to quantify the cost of executing or tasks on a specific resource, for this purpose we need to define a cost estimation methodology.

3.2 Cost Estimation

As discussed before, we assume a static IoT environment with a single application in a static context. Based on this context we can determine the most suitable task distribution using the KPIs in the IoT network. We assume that the nodes in our network are smart enough to compute resource usage for a number of predefined KPI's (Computational Cost, Energy Cost, Memory Cost and Data Transfer Cost).

In Table 1 we consider a static context (e.g. user) with a single node and a single edge in which we evaluate the overall cost to perform certain task. The table shows a potential context in which some KPIs are relevant for a specific architectural level, and some are not. After identifying the relevant KPI parameters. We assign a weight factor w to each of them, depending on the importance within that specific context. Based on the number of components and the number of KPIs, we can consider the total cost of the application. Assume an application is divided into a number of components, then the cost of a specific allocation strategy can be calculated using Eq. 1, where C is the total cost, w_{ij} and C_{ij} are respectively the assigned weight factor and the calculated resource cost that are assigned to KPI j for application component i. The value of this weight factor can vary depending on the context. For example, a mobile device that is suddenly connected to a power outlet should no longer consider power as an important KPI.

The equation for this initial weighted cost model is shown in Fig. 2, where we explains how the cost calculation is perform for each component.

$$C = \sum_{i=0}^{\#components} \sum_{j=0}^{\#KPIs} w_{ij} C_{ij} \tag{1}$$

The final goal is to distribute the application components i in such a way that the total cost C is minimized. It is clear that this is a very complex optimization

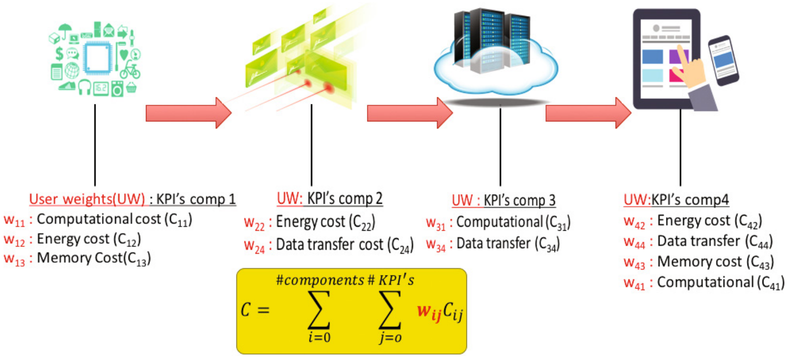

Fig. 2. Static environment over-all cost

problem, hence additional research into optimization strategies will be required. However, by considering the weight factors within a specific context part of this problem can be tackled in a more targeted way.

3.3 Dynamic Reconfiguration

According to our assessment of the state of the art, dynamic reconfiguration and optimization of wireless sensor nodes based on their context, is lacking among most of the current research efforts. In order to provide this flexibility, a modular architecture is needed that allows devices to transfer processing, sensing and even actuation tasks to other nearby nodes. For example, lets consider sensor node S that is capable of sensing light, temperature and humidity. Node S is deployed in area L. Currently, sensor node S measures only temperature as it is the expected requirement of the node level software to make the decisions. Later, the node may require to measure the light level of area L. Now node S needs to be configured to measure not only temperature, but also light level as well. This new configuration setting needs to be pushed to the sensor node from the cloud. Alongside, we propose a component based collaboration in-between levels, where the executed code is redistributed across the network in order to optimize the cost and efficiency of the IoT environment. This will be achieved with a modular, layer-based approach. The application itself is divided into layers, based on the IoT reference architecture by Fremantle [10]. Depending on the requirements of a given task and the context, the node will perform operations up to a certain application layer (e.g. aggregation, event processing,...). The remaining layers are outsourced to other IoT devices (e.g. an edge node, the IoT backbone) based on available resources and constraints. In addition the inputs and outputs are also considered as modular components. This means that the sensors and actuators are not by definition on the device itself. For example, if localization can be performed using nearby fixed edge nodes rather than by the device itself (e.g. to conserve energy), the input to the application can be provided by the external nodes. The output of notifications might also be assigned to another device rather than the internal actuator on the IoT device itself, depending on the context. For example, in a noisy environment a nearby warning light might be more efficient to notify a user than a speaker signal. The advantage of this modular and dynamically optimized approach is that the network is significantly more adaptive to changes. In addition, a demand driven context-centric approach allows for more efficient exploitation of the distributed hardware resources.

4 Use Case Scenario

To clarify our context-aware approach to optimizing resource we will illustrate our proposed methodology with an example use case. A potential scenario where context-aware optimization would be useful is in an industrial environment. Let's consider a factory worker that is equipped with a wearable devices that has a number of sensors to monitor vital signs, location and environmental information such as temperature. Assume this person moves through a production plant passing a variety of potentially hazardous environments. Depending on the local hazard, different types of sensor information are more valuable than others. Near a crane, for example, accurate localization and proximity detection are essential for safety, so that the crane operator knows when someone passes underneath the crane load. Near a in a freezer on the other hand, temperature and vital readings are more relevant. In case of a hazard (e.g. factory fire) the requirements of the application itself might have to be adjusted, regardless of the factory workers position (e.g. provide accurate location and vital signs continuously, even if the wearable normally operates with low refresh rate to conserve energy).

Although an over-dimensioned statically defined IoT infrastructure might be capable of delivering these services, it is clear that a more optimal and cost efficient solution can be defined if the changing context is taken into account. For example, nearby edge nodes might handle part of the processing or provide additional sensor data, disabling certain features of the application or disable unnecessary sensors on the wearables (e.g. to conserve energy). When no other nodes are nearby, or no spare resources are available, more will need to be handled on the device itself. If multiple workers are in the same location, not all data might have to be sent to the cloud for analytics. In case of an emergency more network bandwidth and resources could be allocated to specific tasks, and so on. This use case shows that a context-aware approach to resource optimization can be beneficial in efficient exploitation of the available resource. Similar scenario's can be described for other application domains such as health and elderly care.

5 Conclusions and Future Work

In this paper we have presented a methodology for context-aware optimization in IoT. We have presented an overview of the state of the art where we pointed out that although significant advances are made on the various related domains, a methodology that covers the IoT architecture from node to cloud level, has yet to be defined.

We identified the primary research domains that will be investigated in order to realize an adaptive context-aware IoT platform. We found that resources estimation is one of the key aspects for providing efficient resource allocation. We have presented an initial weight-based approach in this paper. However, in future research this should be expanded towards a multi-objective oriented optimization methodology in which the KPIs are evaluated using more advanced cost models. Accurate estimates are especially important if we want to optimize to changing context at runtime, as not all nodes will be aware of all available resources of all the other nodes in the IoT network.

Resource usage can be optimized by redistributing processing, sensing and actuation tasks over network based on the current context. In addition to a cost model, this requires a flexible architecture that supports task reallocation to other nodes, edges or the cloud. For this purpose, we have proposed a layered architecture in which an application is by definition not assigned to a single end-node. Instead, each node is considered equally responsible for all tasks that need to be performed by the network as a whole. These tasks should be distributed across the network based on context, requirements and available resources. When the context changes, tasks will be redistributed in order to obtain a new optimum. Further research on dynamic task distribution is required, especially if we want to consider constrained applications such as the industrial use case where some information might be time critical. IoT management frameworks such as GITAR might offer a potential solution to implement such type of dynamic reconfiguration scenarios [15].

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Acsim: Towards Hyper-scalable Internet of Things Simulation

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Abstract. With the rise of internet-connected devices a novel approach for application testing and validation is required. This paper explores the possibility to test hyper-scale Internet of Things environments using state-of-the-art simulation techniques. More specifically, a Software In The Loop simulation (SIL) method is introduced which enables the interaction between virtual simulated models and actual real-life Internet of Things devices. Furthermore, we present Acsim, a custom hyper scalable and distributed agent-based simulation framework to test and validate Internet Of Things applications. Finally, a use-case developed in the Acsim framework is presented to demonstrate both the SIL and hyper-scalable capabilities.

1 Introduction

In recent years there has been a significant increase in the number of internet-connected devices, by 2020 it is expected that up to 20 billion devices will be connected to the internet [17]. This internet of things (IoT) will give rise to novel services that will highly influence our way of living with regards to transportation, shopping, health and safety.

An Internet of things implementation implicitly requires a large amount of devices geographically distributed across the environment. All of these devices have very different requirements and constraints, which, when combined at a large scale, make the Internet of things an increasingly complex environment. A significant challenge lies in testing large scale, complex IoT applications. Current testing methodologies do not provide a cost-efficient way to validate IoT applications at such a large scale. The complexity of IoT-applications operating in such a large-scale environment introduces many additional challenges in application development. Developers need to be fully aware of the complexity and scale of the environment. Deploying untested applications on an operational IoT environment without considering these factors comes with a great danger. Operational stability can no longer be guaranteed as the IoT application often won't behave as expected at a larger scale. Therefore, the Acsim simulator is

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presented in this paper. Acsim enables functional validation and testing of IoT applications by means of simulation. The use of simulation based testing is considered a more cost-effective solution. Acsim enables IoT testing by introducing the Software-In-The-Loop (SIL) simulation paradigm. SIL allows the IoT middleware which is under validation to directly interact with virtual, simulated entities. Because IoT systems inherently require a large amount of entities, the goal of Acsim is to simultaneously simulate between tens of thousands to more than hundreds of thousands entities which will lead to more realistic IoT testing scenario's.

2 Related Work

In the current state of practice, many IoT projects are tested in small-scale, lab-based testbeds with a limited number of sensors and people interacting. Examples of these are presented in several initiatives aiming at testing IoT applications such as w-Ilab [3] and Senslab [9]. These testbeds are limited to respectively 200 and 2000 devices and a small team of developers interacting with it. To guarantee successful deployment of a large-scale IoT application, a representative, isolated test environment that approximates the scale and complexity of an actual IoT network is required [4]. An example of such a large-scale testbed is the European-funded Smartsantander project [16] which envisions the deployment of up to 12000 devices in multiple cities. However, the cost to deploy and use such a large-scale testbed is very high and won't be feasible for many starting IoT projects. Instead, leveraging simulation technologies is considered a cost-effective alternative because it allows to quickly prototype very complex and diverse environments. Many simulators already exist to test a variety of IoT related properties. Examples of such simulators can be grouped in two major categories:

1. **Low-level networking simulators:** Various simulators exist to test low-level aspects of specialized IoT systems. These are often linked to IoT operating systems. For example, both the Contiki and TinyOs operating systems have their own dedicated simulator: Cooja and Tossim, respectively. Aside from these system level simulators there are also various generic simulators such as ns-3 and Omnet++. These simulators are focused on simulating low-level aspects of a single node like for example network, communication and power behavior. As stated by Brambilla et al. this precludes the possibility to simulate a high number of IoT nodes [4].
2. **Internet of Things simulators:** There are multiple simulators that can be used to model IoT environments or wireless sensor networks (WSN). For example, the cupcarbon simulator [15] allows to model both moving and static sensors in a city of things context using a GIS-based GUI. The main goal of this simulator is to test and validate distributed algorithms, network topologies and protocols on WSN's. A similar IoT simulator can be found in iFogSim [11] by Gupta et al. which allows to model edge-computing topologies to estimate parameters like power consumption and generated network traffic. But

again the scalability problem remains. Other IoT simulators have been introduced in the last few years to solve this scalability issue. Examples are Deus [1], Mammoth [13] and Gaia/Artis [7]. Most of these simulators are developed in an academic context and active development of the first two seems to be halted. However, the latter, Gaia/Artis introduces a novel multi-level simulation approach to combine both coarse-grained simulation and more low-level simulation techniques using the Omnet++ framework. This approach allows to increase the simulation scale while keeping the appropriate level of detail when needed.

As shown, many simulators can be used to model complex Internet of Things environments, but only a few meet the scalability requirements necessary to model IoT applications in a virtual environment. The Gaia/Artis simulator seems to be a viable solution to cope with this scalability issue. However, Gaia/Artis focuses on simulating technical properties rather than the functional properties of IoT applications. Furthermore, documentation and examples are limited. Therefore it was decided to develop a custom simulator, named Acsim.

3 Acsim - Architecture Decisions

The Acsim architecture is mainly inspired by the scalable IoT simulators mentioned above. It has been built from the ground up to be both elastic and hyper-scalable. Also, Acsim is focused on modeling functional properties of IoT applications to allow for extensive testing. The following sections will motivate the architectural decisions that have been made related to the simulation methodology and the scaling capability in further detail.

Simulation methodology
One of the most popular simulation methodologies used for IoT and Wireless Network Sensor(WSN) simulation is Discrete Event Simulation (DES) [6]. With DES a system is modeled as a discrete sequence of events. A centralized event data structure and global clock is used to control the entire simulation. This allows for very efficient limited scale simulation, approximately 100 to 1000 simulated entities, depending on the available resources and the computational complexity of the entities. However, when the number of entities increases beyond this scale the computational complexity will become too large for regular workstations. As a possible solution, High Performance Computer (HPC) architectures can be used, but the use of HPC will increase the cost beyond acceptable levels for most IoT use cases. With the rise of cloud computing, the distribution of DES simulations over cloud nodes is seen as a cost-effective alternative. Multiple approaches are described in literature to solve DES distribution, more specifically Parallel Discrete Event Simulation (PDES) and Parallel and Distributed Simulation (PADS) are proposed by D'Angelo et al. [8]. However, these approaches pose additional difficulties with regards to maintaining consistency and handling data distribution over the cloud network. Furthermore additional effort is required from modelers to enable efficient distribution and scalability.

A different approach can be found in the Agent Based Simulation methodology [14]. With this approach each simulation entity, which is referred to as an agent, behaves autonomously. Its individual state and behavior can vary and evolve by interacting with other agents and the environment. This inherent modular and bottom-up approach allows for both an easier modeling process and a better fit for simulation distribution compared to PADS and PDES. All of this makes ABS a great fit for modeling and simulating IoT applications on a large-scale. It was therefore decided to leverage the ABS methodology as a basis for the Acsim simulator.

Software in the loop simulation

Software in the loop (SIL) simulation is derived from the hardware in the loop (HIL) simulation method, which allows embedded systems to be tested in a virtual environment that contains emulated sensors and actuators. Compared to real-life testing of an embedded system, HIL is considered a more efficient and cost effective simulation method [5]. Within the context of IoT testing the component under validation is not an embedded hardware device but the IoT application itself. This allows simulated agents, which represent IoT actors or IoT sensors and actuators, to interact directly with the IoT backbone. The backbone won't notice any difference between real-life or simulated virtual IoT entities. This methodology precludes the need for expensive large IoT testbeds. Furthermore, a hybrid simulation approach can be implemented where both real-life and virtual IoT entities interact with the IoT application under validation.

Distributing agents

A technique had to be found to efficiently distribute simulation agents across multiple nodes to improve scaling capabilities of the Acsim simulator. In literature various techniques and frameworks are presented. For example, the Java Agent Development Framework (Jade) [2] is a framework to run, manage and configure agents on a distributed environment. Furthermore, it implements the FIPA Agent Communication language (ACL), which is a standardized language that defines how agents should interact with each other. However, the ACL language is designed to describe multi-agent systems rather than agent based simulation systems. Also, the Jade framework does not seem to be under active development and lacks modern reactive features. Therefore, it has been decided to describe and distribute agents using the actor model instead. The actor model is a conceptual model which enables the development of concurrent computation running on multiple threads and multiple machines. It eases the development of highly scalable applications, while not focusing too much on low-level aspects. It was first described in the 1970's by Hewitt et al. [12]. The primitive unit of computation is referred to as an actor, it can be compared to an object being the primitive unit of computation in the Object Oriented Programming (OOP) paradigm. A main advantage of the actor model is that it doesn't matter whether interacting actors are running on the same machine or if they are distributed across multiple machines. That is because each actor can run independent from one another and is able to communicate with other actors using asynchronous message passing. The core around the actor model is built around this asynchronous message passing capability. Best practices around actors prescribe that actor state should be isolated and immutable, this decreases the risk of generating dead locks and similar low level complexities that come into play with distributed computing. As a result, it allows developers to focus more on modeling business logic. There are multiple software libraries and programming languages build on the basis of the actor model concept. One of which is the Akka toolkit. It is a Java based toolkit that provides the necessary functionality to implement applications using the actor model. Within the context of agent based simulation an agent can be implemented by multiple actors, these actors will represent a dedicated part of agent behavior and interaction.

3.1 Demonstrator

To demonstrate the main capabilities of the Acsim framework a simulation use-case was developed that will be discussed in this section.

SeRGIo - Smart Task Distribution use case
The SeRGIo use case is used as an example to demonstrate both the scalability and SIL simulation capabilities of the Acsim framework. SeRGIo is a smart city pilot project that will be rolled out in Antwerp and possibly other Belgian cities. However, SeRGIo is different compared to other smart city project. Whereas a typical smart city project mainly focuses on gathering quantitative information, the SeRGIo use case will allow for collecting qualitative information as well. This quantitative data will be gathered by actively polling citizens by means of a smartphone application. For example, if the city council is interested in monitoring the cleanliness of a neighborhood it can use the SeRGIo middleware to distribute sensing tasks to citizens that are currently in the neighborhood.

Task distribution
An important aspect of the SeRGIo project is the Task Distribution Service (TDS). This component, which is part of the middleware, is responsible for selecting citizens and distributing a task at the most appropriate time and location. The selected time and location will depend on the following aspects:

- The previous behavior of participants: Using deep learning techniques, the TDS will estimate both the likelihood that a user will be at a certain location at a specific time and the likelihood that a user will respond. The location estimation will be realized using state of the art trajectory analysis techniques.
- Participation rate: The TDS will take previous sensing tasks performed by a specific user into account to prevent the intrusive spamming of single participants, as this will negatively impact their participation rate.
- The data relevance: When the current sensed datapoints are outdated, their relevance will decay. For example, if the last cleanliness estimation is more than two weeks old, it will be preferable to gather additional data points to make sure the relevance is kept up-to-date.
- Data customer deadline: When it is specified that data points need be obtained before a certain deadline, the TDS can dynamically increase its intrusiveness in case that the deadline will not be met.

It is obvious that the complexity of the TDS is very high, as trade-offs need to be made between data customer interests and the participant interests. Intensive validation and testing will be required during the development process to effectively construct this TDS middleware. However testing in a real-life testbed will be difficult since a great number of participants are required to gather a minimum amount of data. Instead, the Acsim simulator was used to simulate participants that interact with the SeRGIo middleware.

SeRGIo Architecture

Figure 1 illustrates the Acsim implementation of SeRGIo Participants. The blue boxes represent an actor within the Acsim framework. The SergioInitiator actor is responsible to launch multiple participant agents, these agents will walk a certain route in the city and broadcast their GPS locations to the SergioMiddleware over an Mqtt message bus. The SeRGIo middleware receives the location updates from the different agents as if they were real-life participants. Thus the middleware won't make any distinction between the virtual participant agents and the actual participants. When a new sensing task is created the SeRGIo middleware will share this task to a participant agent. The participant agent will then be able to perform the task and send back the sensed data. The participant agent itself consists of multiple actors, each actor is immutable. The SergioParticipant actor is responsible for implementing the main behavior of a participant, it is able to accept or reject sensing tasks and share its location with the middleware. The RouteActor is launched by the SergioParticipant actor. It is able to virtually walk a certain route and calculate the current location of a participant. The Messageactor is used to send and receive messages over the MQTT bus to the SeRGIo middleware.

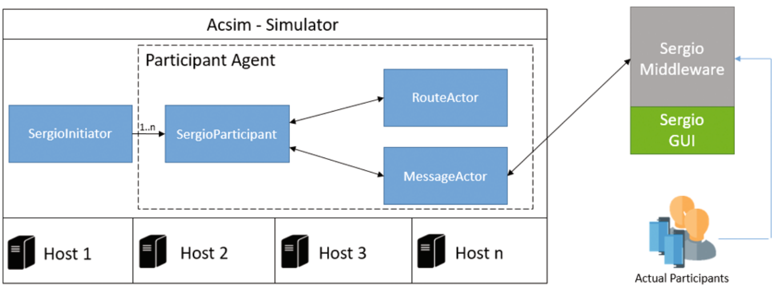

Fig. 1. Acsim - SeRGIo architecture

4 Conclusion and Future Work

In this study, the Acsim Internet of Things simulator was introduced, an agent based simulator which implements the actor model to largely increase scaling capabilities compared to state of the art IoT simulators. Therefore, a first step has been taken in the direction of hyper-scalable simulation. Current simulators focus mainly on testing low level aspects of IoT applications instead of the overall functional behavior of these systems. Acsim tries to fill this gap at a scale which is appropriate for IoT testing. Also, the Software in the loop methodology was presented, a novel approach for testing IoT applications by enabling middleware interaction with both virtual and real-life agents. The SeRGIo use case demonstrates that these principles can be very powerful to validate and test IoT applications at a scale that would otherwise be too expensive and impractical.

This paper mainly focuses on optimizing state-of-the art simulation techniques from an architectural standpoint. However, scalability still depends on the number of hosts the simulation platform can be distributed to. Further research can look into dynamically optimizing simulation models by implementing model abstraction techniques [10]. These techniques could allow highly detailed models to be replaced by more abstract models that have similar, but often less accurate behavior. These abstract models require less computational resources and can therefore positively impact the scalability of the overall simulation. This process can even be made dynamic, meaning that abstraction levels can autonomously increase when less details are required. Also, at this moment in-depth knowledge of the actor model is required to model application behavior in the Acsim simulator. In further releases, modelers shouldn't be aware of these low-level aspects.

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Automatic Reverse Engineering of CAN Bus Data Using Machine Learning Techniques

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Abstract. The CAN (Controller Area Network) bus connects different *Electronic Control Units* (ECU) inside a vehicle. Valuable information about the state of the vehicle is present on this bus and is useful to track driver behaviour, the health of the vehicle, etc. However, the configuration of this bus is not publicly disclosed by the car manufacturers. Therefore, reverse engineering techniques need to be applied. Nevertheless, performing these techniques manually is cumbersome and time consuming. In this paper, we propose an automation of the analysis steps of reverse engineering in order to improve and facilitate the process. Two approaches of automation are discussed, namely an arithmetic approach and machine learning using classification. In conclusion, we show that reverse engineering of CAN bus traffic is at least partially possible by applying machine learning techniques and the performance of the classifiers increases when adding additional features to the analysis.

1 Introduction

Modern cars contain complex electronic and mechatronic systems that monitor and control various aspects of the vehicle. These systems work together to increase the safety and comfort of the driver. The different systems communicate over one or multiple CAN (Controller Area Network) buses. The CAN bus is common in all modern car. Luxury cars have up to 100 *Electronic Control Units* (ECU) and more then 1 Km of cables connecting them all. Figure 1 shows a generic CAN bus configuration. These networks are usually divided in different subnetworks according to their function and specific needs, such as high-speed CAN (CAN-C) for the motor management and low-speed CAN (CAN-B) for climate control. As a result, a major part of information about the inner workings of a vehicle can be learned by examining CAN bus traffic. This information is useful to track driver behaviour, the health of the car, etc.

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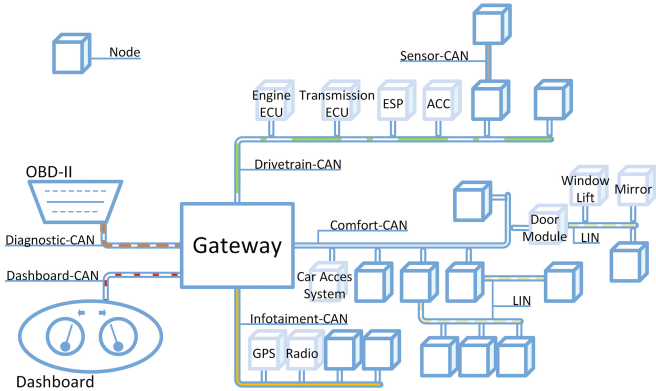

Fig. 1. Generic model of a car CAN bus. Multiple subnetworks with different functionality are interconnected through gateways.

However, the problem is that although the CAN protocol is standardised, the actual implementation differs for every manufacturer and even differs for every model. Automotive manufacturers are free to choose which ID represents which data, how the data is represented, etc. This configuration is not publicly disclosed. This means that CAN bus traffic for every car has to be analysed and reverse engineered in order to obtain useful information. Furthermore, reverse engineering rises legal and ethical questions [1].

Current reverse engineering techniques are relatively straightforward, but time consuming. They rely on trial and error and require knowledge of the inner workings of the vehicle's different subsystems. The time required to reverse engineer a vehicle increases dramatically as the vehicle becomes more complex. Therefore, we applied two different techniques, i.e. arithmetic and machine learning approach, to automate this process, reducing the analysis time and effort while acquiring sound results.

In this paper, we will first discuss state of the art methodologies used to reverse engineer a CAN bus. Second, we present two different approaches to automate the reverse engineering process. Final, we discuss our results and performances of the implemented automation techniques.

2 Controller Area Network

The CAN protocol is a standard developed by Robert Bosch GmbH to create an efficient and reliable communication bus between nodes in real-time applications. Every message transmitted on the CAN bus carries a specific identifier. This identifier does not directly indicate the sending or receiving node, but instead identifies the content of the message.

The CAN standard specifies the general structure of a message, but does not define other aspects, such as byte order, signedness, amount of signals in one message, byte alignment, scale, etc. This approach provides great flexibility, allows manufacturers to efficiently use the CAN bus and basic 'security' through obscurity. However, it also significantly increases the complexity of reverse engineering the network.

3 Reverse Engineering

Reverse engineering the traffic on the CAN bus is a relatively straightforward process, but is fairly time consuming. Current techniques rely on manual analysis of the traffic and require knowledge of the inner workings of the vehicle and its different subsystems.

Hermans et al. [4] extended on a technique outlined by Eisenbarth et al. [2] for locating features in source code and applied it to CAN data frames. The proposed reverse engineering process consists of five steps as shown in Fig. 2. This five step methodology seems to be a good summary of reverse engineering techniques for CAN bus data as others often follow these steps, although not explicitly.

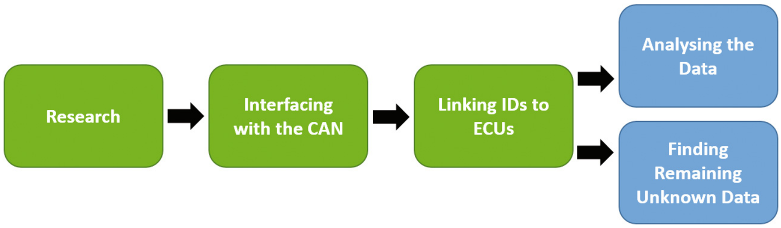

Fig. 2. Flow chart of the five step reverse engineering process.

Research. The first step is investigating the car's construction and which functionality it has, e.g. ABS, airbags, etc. In addition, it is recommended to look up on which network these functions are located and how these networks interconnect in order to know which data to expect, i.e. the wiring on the electrical schemes.

Interfacing with CAN Bus. The second step is interfacing with the CAN bus. This is the stage where one collects as much data as possible. All the messages will be stored for further analysis. Interfacing with the CAN bus is achievable through either the OBD-I, II plug, if the car supports this functionality, or (in)direct physical contact with the network.

Linking Identifiers to ECUs. The third step is linking the found IDs to their corresponding ECUs. Combined with the previous step, a first indication is provided as to which signals are contained in each message.

For this step, two major methods are presented in literature. A first method is to unplug each control unit one by one and to note which IDs disappear from the network, as presented in [4]. However, Rokicki and Szczuwoski [8] noted that identifying a node by disconnecting it may also change the behaviour of other nodes in the network which may result in an incomplete picture of the network. Therefore, they introduced their own solution, which is to insert their own two nodes between the target node and the rest of the networks. These two nodes act as gateways and allow them to observe the direction of the data flow. However, Freiberger et al. [3] concluded that the approach of [8] is less error-prone, but more time consuming compared to [4] because of the rewiring needed when inserting a gateway between a node and the CAN network.

Analysing the Data. The fourth step is finding the *essential* data in the recorded data sets. During this step, associations need to be found between the data points and features, e.g. a correlation can probably be revealed when the speed is monitored in relation to time and so, linking a certain ID to the messages that represent the speed. To find the essential data, the researcher has to complete the tedious task of plotting all data and finding matches in the acquired data sets.

When acquiring CAN data, we need to consider what test cases to perform. Depending on a clever selection of cases, this step becomes easier to accomplish. A simple example would be to turn on the car, but leaving the engine off while moving the throttle pedal in order to determine the throttle position.

Finding Remaining Unknown Data. The final step is analysing the remaining *unknown* data. The possible combinations of IDs with the remainder of data can be reduced even further when more IDs get linked in the process. The fourth and fifth step are performed in parallel, as indicated in Fig. 2.

4 Automating the Process

Performing the reverse engineering process manually as described in Sect. 3 is exceedingly time consuming [3]. The major part of the effort is needed during the last three steps of the process as shown in Fig. 2. The goal is to automate these steps as much as possible so that we are able to reduce the manual labour and cut down the high data analysis time. In this paper, our main focus is on reducing the data analysis part of the process. Therefore, we applied different data analysis methodologies and evaluated the effectiveness of these approaches.

Arithmetic Approach. A first approach that we investigated is to use an arithmetic methodology with the *Root Mean Square* (RMS). This technique allows us to compare two signals and calculates the deviation between them. As a reference signal, the data obtained from the *On-Board Diagnostics* (OBD) connector is used. With OBD, we are able to request standardised real-time data if the car supports the desired *Parameter IDs* (PID), such as engine RPM, vehicle speed, etc. The algorithm will compare the OBD signal with every byte and selected combinations of bytes in the CAN messages. The RMS calculates the deviation of every data point. The results with the lowest average deviation has a higher probability to represent the wanted signal. In case that OBD does not provide the wanted signal, we will use simulation to acquire the necessary signals. For these simulations, we use the AMESim tool to run a simulated car model. This simulation provides us a realistic representation of the system values. It is important to note that the simulated signals do not necessarily have the same formatting as data on the CAN bus, e.g. different offset, scale, etc. By applying a normalisation on the data, better results are obtained.

Machine Learning. In essence, the classification of CAN data is a time series classification problem. Many classification techniques exist, but most of them are designed for situations where there are multiple input features and an associated class. The difference with time series data is that these input features are not independent from each other, i.e. their order matters. However, it is still possible to use regular classification techniques by calculating different features based on the series and using those for classification.

In recent years, neural networks have become popular for machine learning tasks. The development of *Convolutional Neural Networks* (CNN) caused a massive increase in accuracy in tasks, such as image classification [6]. With some modifications, these networks can also be used for time series classification [10].

Neural networks such as CNNs are stateless, they have no memory of previous inputs. This is a disadvantage for time series classification, as the previous states of a signal provide valuable information. Therefore, a so-called *Recurrent Neural Network* (RNN) has an internal loop that serves as an internal memory [7]. This allows the network to take context into account. An example of RNN is the *Long Short-Term Memory* (LSTM) network, these types of neural networks perform particularly well at pattern recognition tasks and have revolutionised speech recognition [5,9].

In order to train a sound and useful neural network, lots of data is needed. In the following sections, a brief discussion is made on how the data sets were acquired and processed as data plays a major role in machine learning.

Data Acquisition. For our research, we performed experiments on two different cars, namely a 2007 Ford Focus and a 2012 Hyundai Veloster 1.6 GDI. In order to acquire the CAN data, we made a connection through the OBD connector with a Kvaser Leaf SemiPro. The CAN traffic is recorded by a self-developed tool which allows us to incorporate global timestamps for synchronisation. Besides recording CAN traffic, we collected GPS data from the Racelogic VBOX 3i Dual Antenna to enrich our data with extra features, such as latitude and longitude, speed, heading, etc.

The data used is collected by simultaneously recording CAN traffic and GPS data while driving. The data is then processed and filtered to build a training dataset for the different classifiers. In addition, each classifier is trained once with and without GPS data in order to compare their performance. The idea behind using positioning and orientation data as extra features is that it might provide extra knowledge of the vehicle state that could be used to more accurately classify each signal.

Data processing. After data acquisition, we extract all signals of interest from the recorded CAN traffic. In this experiment, we selected a couple of signals as features to train the classifiers, i.e. throttle position, brake pressure, engine RPM, vehicle speed and steering angle. Other signals such as counters and intermittent signals are used as well which are classified as '*other*'.

Messages on the CAN bus are transmitted at different rates up to 1 Mbit/s. Additionally, these rates are not constant due to message preemption. The data recorded on the VBOX however is at a constant 100 Hz. It is important to have a constant sampling rate as synchronisation between data points is crucial. Therefore, the CAN and GPS data is resampled and interpolated at a rate of 10 Hz, as it was the lowest among the signals of interest. Resampling the data at the lowest rate is more convenient, since upsampling might introduce extra features. These features could cause false results as the classifiers might learn to use them to classify signals.

Signals on the CAN bus may be represented in different formats, e.g. offset, scale, etc. In order to create generic working classifiers, all data sets have to be normalised. Otherwise, classifiers might learn to classify based on the scale or offset of signals. As a result, a classifier is obtained which will only work on vehicles with the same data formatting. Therefore, we scale each signal in the interval [0, 1].

A similar operation is performed on the speed from the GPS data. Although the scale will be the same for every vehicle, some of the classifiers used are sensitive to scaling. During testing, it became apparent that momentary loss of the GPS signal causes false speed readings that are often much higher than the actual speed. To avoid problems due to these false readings, the speed data is normalised only with readings where the number of satellites is above a certain threshold.

Sliding window. Before feeding the data to the classifiers, a window technique is applied to the CAN data. This allows us to split the input/test sets into multiple subsets of a fixed length. A first advantage of applying a sliding window is that it significantly increases the amount of samples in the dataset. Second, the CNN and LSTM require a fixed data input size which the sliding window provides.

Identifying Signals. Each classifier is trained on signals that are manually extracted from recorded data. However, this is not the actual aim of automation as we want to be able to determine the meaning of unseen CAN data without manual effort. In order to find signals in the CAN traffic, an adjustable window scans across the CAN messages. For example, first classifying on byte level, then every subsequent two bytes, etc. However, CAN messages may contain multiple signals of any length, with any byte order and signedness. Just trying every combination will become computationally expensive very fast. A better approach is to gradually identify signals by first evaluating at byte level and then, when the confidence of the classification is above a threshold, narrowing down the search interval. Therefore, identifying the exact location of the signal. The result with the majority score determines the final class. For our research, we only considered sequences with one or two bytes.

5 Results

All results in this paper were acquired from a Hyundai Veloster (2012) and a Ford Focus (2007). In the following sections, we discuss the results for each methodology described in Sect. 4.

Arithmetic Approach. In a first step, we performed multiple test drives while recording the CAN bus and diagnostic information from the OBD connector. The requested data from the OBD contains the throttle position, vehicle speed and engine RPM. The ten best results from the RMS method are shown in Table 1A. At this point, a visual inspection is required to verify the results. In Fig. 3, we plotted the vehicle speed with the four CAN signals which have the smallest RMS deviation. The first three results, e.g. A0-4, 18F-3 and 316-6, are a close fit compared to the OBD speed with PID 7E8-3 and resemble the vehicle speed. The latter result however, represents the first byte of the RPM. We know this from the data we acquired from manually reverse engineering the car.

To verify our results, we also applied the method using simulation data instead of OBD data. The results are shown in Table 1B. The three correct IDs we acquired from the OBD tests are also present in the simulation results. Nevertheless, they are less accurate. These deviations in the simulation derived from measurements errors of the external sensors used during the test drives.

By applying this methodology, we already matched 24 of the 208 bytes to the corresponding data on the Hyundai Veloster. However, these results are heavily influenced by the information recorded on the CAN bus and OBD standard.

Table 1. Vehicle speed results for RMS method with OBD and simulation

(A) OBD			(B) Simulation		
ID	Byte	Deviation	ID	Byte	Deviation
A0	**4**	**0.003065**	2A0	2-5	0.0
18F	**3**	**0.004920**	**18F**	**3**	**0.006131**
316	**6**	**0.004920**	**316**	**6**	**0.006134**
80	3	0.052117	1F1	7	0.006272
316	3	0.052117	1F1	4	0.006716
1F1	4	0.066539	**A0**	**4**	**0.011192**
2A0	4	0.077394	80	5	0.021227
329	3	0.080275	316	5	0.021227
329	4	0.080775	545	3	0.022280
164	1	0.080838	4B0	7	0.022388

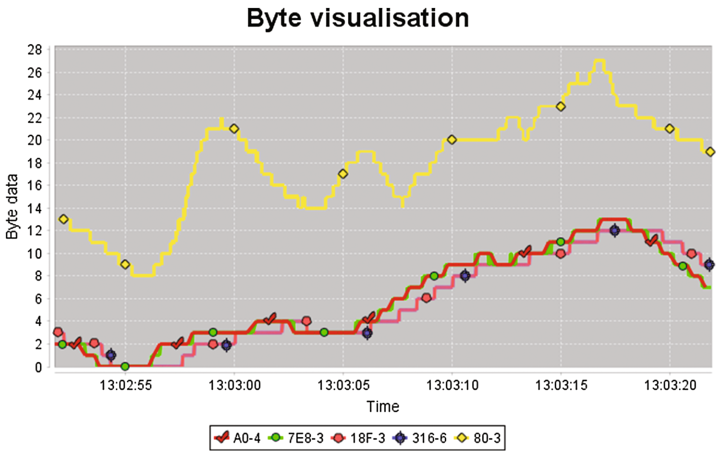

Fig. 3. Signal plot of CAN data with lowest deviations compared to OBD vehicle speed (7E8-3).

In addition, about half of the recorded data contain either counters or constant flags which never changed throughout recording.

Machine Learning. Initially, four versions of every classifier were trained, two pairs with respectively only CAN data and CAN combined with GPS data. Each pair then contains a version where all features are used and one with a greedy algorithm implementation, except for the CNN and LSTM network. The overall performance of the classifiers is shown in Table 2 where the best combination for each classifier are highlighted.

The results indicate that adding GPS data increases the performance of most classifiers. Some classifiers however do not benefit from the extra information. Firstly, the greedy algorithm selects the same features for these classifiers when only CAN data as both CAN and GPS data are provided. Secondly, neural

Table 2. Overall performance of the different classifiers

	CAN	CAN+GPS	CAN greedy	CAN+GPS greedy
Discriminant analysis	64.9	65.6	71.9	**73.0**
K nearest neighbours	63.1	68.6	**76.4**	**76.4**
Logistic regression	68.8	67.3	74.2	**78.1**
Naive bayes	66.5	66.4	**71.9**	**71.9**
Support Vector Machine	64.2	69.8	74.0	**78.2**
CNN	91.0	**93.8**		
LSTM	**90.8**	87.7		

networks perform better than the classic techniques in general when comparing the results. Nevertheless, the benefit of adding GPS data becomes more apparent when we use these neural networks to identify signals in the entire CAN traffic instead of just using test sets as is the case for Table 2.

The results for trained CNNs in Table 3 show the possible matches and confidence scores to discover speed signals in new data. We found that we are able to identify both vehicle speed signals and all four wheel speeds. However, a false positive with a relatively high confidence score was present.

As we use the trained CNN to seek other signals of interest in unseen data, additional observations were made. The position of the *throttle* pedal is represented by both a one and two byte signal which were correctly identified by the CNN. One of the signals was unknown to us before. Additionally, multiple other signals were identified as representing throttle position. However, they seem to symbolise related values, such as throttle body position or other engine parameters. The actual *RPM* signal of the engine was correctly identified. Nevertheless, two other signals were incorrectly identified with similar confidences. The *brake pressure* was identified with a significant confidence. Other '*incorrect*' signals had considerably lower scores. Similar observations were found for the *steering angle* compared to the brake pressure, as the correct signal had a remarkably higher confidence score.

The previous results were obtained from the Ford Focus on which the classifiers were initially trained. To verify the proposed method and its generic properties, we performed the analysis on a '*new*' car, i.e. Hyundai Veloster.

Table 3. Results when looking for speed signals

	Only CAN	CAN + GPS
Possible matches[1]	20	10
Vehicle speed 1[2]	0.65	0.71
Vehicle speed 2[2]	0.60	0.64
Wheel speed FL[2]	0.41	0.48
Wheel speed FR[2]	0.41	0.55
Wheel speed RL[2]	0.16	0.23
Wheel speed RR[2]	0.23	0.42

[1] A possible match means a confidence higher than random chance (1/number of classes).
[2] Confidence score

Two vehicle *speed* signals were identify, however only half of them were discovered. As opposed to the other vehicle, the signals are not byte aligned or include no other signals in the same byte. However, searching for more different signal lengths should solve this problem. The *throttle position* has similar results as the Ford. Yet, two false positives with a high confidence were indicated. This may be due to the resampling operation on these signals which are normally sent at a slower rate of 1 Hz. When attempting to identify the *engine RPM*, the signals with the highest confidence seemed to be related, but did not directly represent it. Although the correct signals were still identified, their confidence score were significant lower than the related signals. The results for the *brake pressure* were poor, as the first signal found was incorrect. The actual signal may represent the vacuum pressure. Even though it is related, it is not at all similar to the training signal. The second signal indicated actually presents steering torque. The false positives may be due to a correlation between the two as a driver normally slows down before turning. For the *steering angle*, there was initially no match. We found that the Hyundai used a signed representation, which is opposed to the offset used on the Ford. When taking this into account, the steering angle was identified correctly without any other matches.

6 Conclusion

The manual process of reverse engineering a CAN network needs immense effort and is time consuming. Interpreting all resulting data requires know-how and time. Automating the analysis offers a considerable overall improvement. In this paper, we suggested two approaches to automate the analysis. The first arithmetic approach is able to match OBD or simulated data to a specific location in the CAN bus traffic. However, this approach still requires visual inspections and its effectiveness greatly depends on the vehicle itself, e.g. data formatting, available data on OBD, etc.

The second approach involves machine learning techniques. The results show the possibilities to, at least partially, identifying signals of interest in the data of CAN bus traffic. Additionally, we have proven to increase the performance of certain classifiers used by including '*other*' data about the state of the vehicle, e.g. GPS speed. However, more experiments on larger datasets and different vehicles need to be performed in order to validate our findings. Furthermore, only signals of one or two bytes were considered in these experiments. In reality, there are many more possibilities. Simply trying ever possible combination will become computationally expensive really quickly. It is therefore useful to look into more efficient techniques to identify the position of signals in CAN data.

Since the promising impact of adding GPS speed as a feature to the classification, future research can be conducted to evaluate the impact of additional data features in the classification process. Therefore, we propose to develop a hardware solution that contains a CAN transceiver with additional sensors, such as GPS and an IMU to collect more synchronised data on different vehicles. Eventually, we want to create a device which will be able to perform the reverse engineering process by itself.

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Estimation Model of Food Texture Considering Sound and Load by Neural Network and Fuzzy Logic

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Abstract. This study aims at constructing a system which infers food textures using neural network and fuzzy logic. The system consists of an equipment which obtains a load change and a sound signal while a sharp probe is stabbing a food, and a hybrid of the neural network and the fuzzy logic model. The neural network estimates a numerical classification degree of the food. The fuzzy logic infers a numerical degree of the food texture considering the estimated classification degrees. In the experiment, the validity of our proposed system is discussed.

1 Introduction

We usually enjoy dining time. Human feels a scent, a taste and a "texture" of foods while eating. The "food texture" generally means a sense of teeth when we masticate the food. If computer can estimate the "food texture", farmers and food manufacturers will utilize such intelligent computer system in order to develop special food products with great texture which every consumer will desire. In addition, the producers could utilize such intelligent system to evaluate own products. For the automatic evaluation system in the human sensibility, the artificial intelligent is applied such as fuzzy logic [1] and neural network [2]. Nowadays the "kansei engineering" is common term in the product design. In this field the fuzzy logic and the neural network are utilized [3]. The term "kansei" is Japanese word expressing the affective sensibility of the human.

Sakurai [4–7] has proposed diagnose method of the "food texture" considering the acoustic vibration sound which occurs while a sharp metal probe is stabbing the food. He suggests that the food texture could be measured by analyzing frequency of the sound. Since considering masticating sound of the food is essential, his work is novel. On the other hand, human judges the food texture considering not only the vibration sound of the teeth but also a load change on the teeth. Therefore Okada and Nakamoto [8] have invented a food texture sensor imitating human tooth which detects the vibration and the load simultaneously. And recurrent neural network is applied to infer the food texture. We also have proposed the equipment to detect the sound, vibration and load. The neural network is applied to infer the degree of two types of food textures [9].

The study [8] emphasizes on application of the artificial tooth, on the other hand the goal of our study is to discover a methodology to measure the "food texture" which

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human feels by considering not only around teeth nerve but also all nerve system sensing the vibration and the sound around the mouth and the ear. Therefor the configuration of the sensor element, the equipment and the inference method are different from [8].

In the present paper we applied fuzzy logic in addition to our former study [9]. Since the neural network could only learn the relationship between the input and the output, the reason is not clear because the neural network is black box. On the other hand the fuzzy logic could explain the relationship to a certain extent as gray box. As the first step to construct the transparent box which could explain inference mechanism of the food texture, we embedded fuzzy logic with neural network system.

2 Overview of the Proposed System

As shown in Fig. 1, the measurement equipment configuration consists of the accelerometer for acquiring the sound signal and the load sensor with strain gage. The system fetches the signals of the sound and the load simultaneously. Then the system extracts data for a certain period and calculates numerical value called "*characteristic value*". The *characteristic value* is given to the neural network model in order to estimate degrees which mean belonging degrees to some classes of a food. The degrees of classes are inputted to the fuzzy inference component. The fuzzy inference part infers the degrees of the food texture such as "munching" and "crunchy". A part surrounded by orange dotted bold line is novelty of the present paper developed from our study [9].

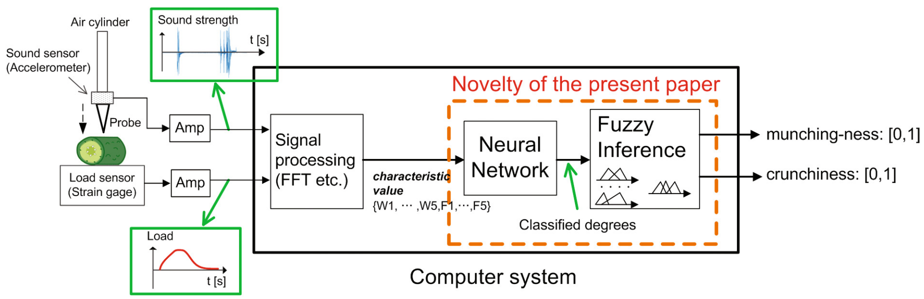

Fig. 1. Overview of the present system.

3 Data Acquisition and Signal Processing

The sound and the load data are given by a signal acquisition device with sampling frequency $f = 25$ [kHz], thus the sampling period $\Delta t = 1/25000 = 0.04$ [ms]. Every measurement period is 10 [s] and 250×10^3 samples are obtained.

3.1 Data Extraction

Signals for 2 [s] time period is extracted. Firstly, maximum load point (1) is found as shown in Fig. 2. Secondly, the point 5% of the maximum load point (2) is searched. Finally, the both of the sound and the load data are extracted from the point (2) by 50000 samples drawn as (3), thus 50001 samples are extracted for analysis.

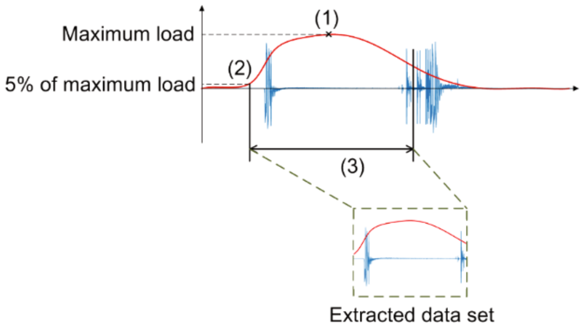

Fig. 2. Signal extraction.

3.2 Load Data Processing

As shown in Fig. 3, the extracted load curb is processed to obtain *characteristic values* W1, W2, W3, W4 and W5 which are explained as follows,

(1) W1 is average value from i = 1 to i = 10000 of the extracted load data.
(2) W2 is average value from i = 10000 to i = 20000.
(3) W3 is average value from i = 20000 to i = 30000.
(4) W4 is average value from i = 30000 to i = 40000.
(5) W5 is average value from i = 40000 to i = 50001.

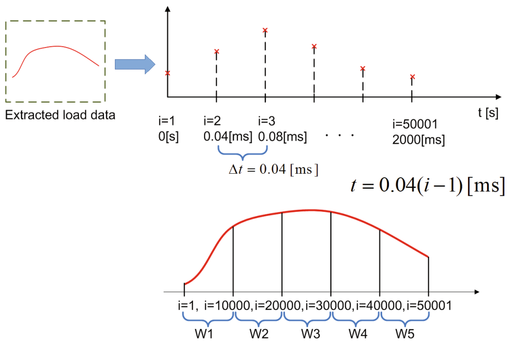

Fig. 3. Calculation of W1 to W5.

3.3 FFT of Sound Data and Conversion to Characteristic Values

As shown in Fig. 4, the extracted sound signal from i = 1 to i = 50000 is converted by FFT. The FFT result is processed to obtain *characteristic values* F1, F2, F3, F4 and F5 which are explained as follows,

(1) F1 is summation from i = 3 to i = 4000 of FFT result.
(2) F2 is summation from i = 4000 to i = 8000.
(3) F3 is summation from i = 8000 to i = 12000.
(4) F4 is summation from i = 12000 to i = 16000.
(5) F5 is summation from i = 16000 to i = 20001.

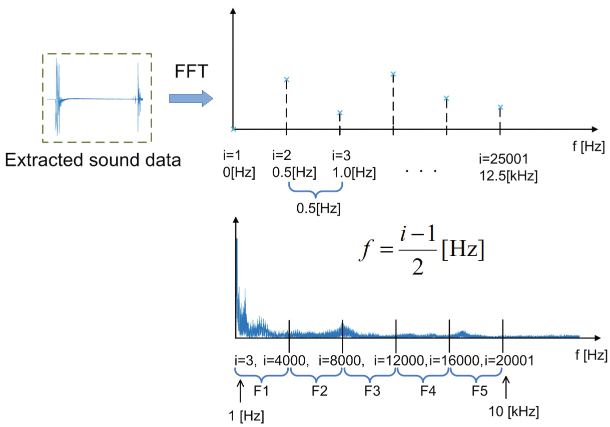

Fig. 4. FFT data and calculation of F1 to F5.

4 Experiment for Data Acquisition

This section describes the food inspect experiment by stabbing the radish and the cucumber. Figure 5 shows the equipment to measure the sound and the load while the sharp metal probe is cutting the food sample when the air cylinder moves down gaining air pressure. The details of food samples are shown in Table 1.

Table 2 also shows the abstract of food samples. No.1 to No.13 are the samples of the radish with peel, on the other hand No.14 to No.26 are the ones peeled with knife.

Table 1. Information of samples.

	The number of samples	Diameter [mm]	Length [mm]
Radish with peel	13	30	30
Radish with no peel (peeled)	13	30	30
Cucumber with peel	13	20 ± 1	30
Cucumber with no peel (peeled)	13	20 ± 1	30

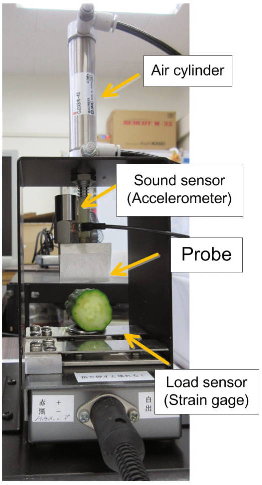

Fig. 5. Food inspection equipment.

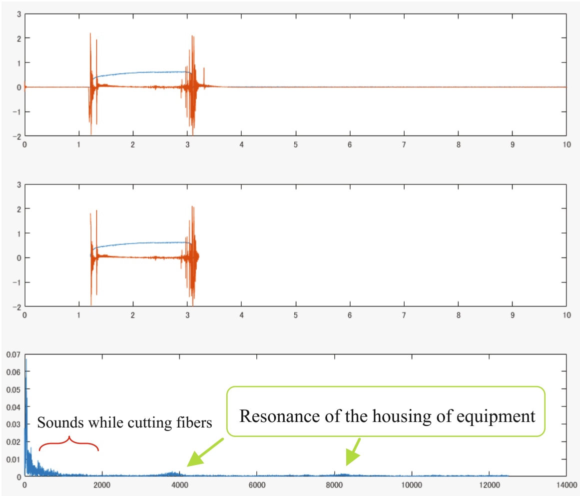

Fig. 6. Sample No. 2 (radish with peel).

Table 2. All sample data.

n (sample number)	1, …, 10	11, 12, 13	14, …, 23	24, 25, 26	27, …, 36	37, 38, 39	40, …, 49	50, 51, 52
Purpose	Training	Test	Training	Test	Training	Test	Training	Test
Kind	Radish	Radish	Radish	Radish	Cucumber	Cucumber	Cucumber	Cucumber
Peel	Having	Having	Peeled	Peeled	Having	Having	Peeled	Peeled

The item of “Purpose” in the table means whether the samples are used for the training of the neural network or for the testing.

4.1 Radish

Figure 6 shows the result of the radish with peel. The top graph illustrates the change of the load with blue line and the sound with red line. The middle graph shows extracted ones. The bottom graph shows the FFT result. It is found that when the prove gets into the sample a loud sound occurs, small sound causes while the prove stay into the sample, and when the sample is cut off, very loud sound occurs. Figure 7 shows the result of the one with no peel. It is found that the radish is cut off rapidly compared with Fig. 6. The small peaks of FFT graph around 4 [kHz] and 8 [kHz] are found in Figs. 6 and 7. These are the frequency of the resonance of the housing of the equipment which are not relate to the kind of samples thus these are noise. The neural network will rule out such noise by learning many samples features.

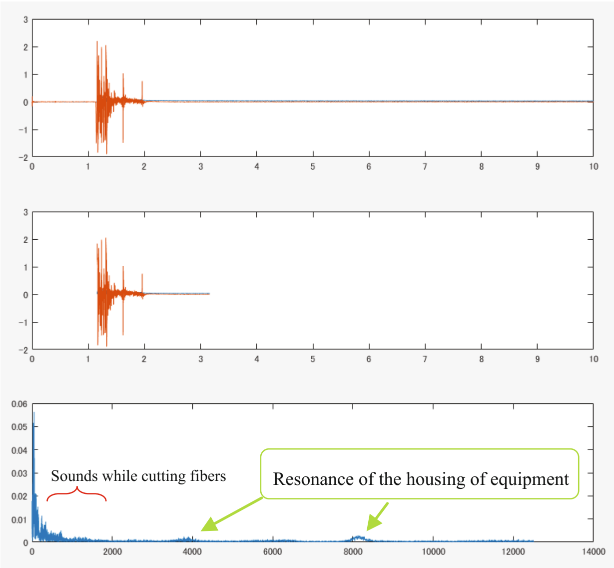

Fig. 7. Sample No. 19 (radish with no peel).

4.2 Cucumber

Figures 8 and 9 show the result of the cucumber with peel and with no peel. It is found that the sound strength and the load of cucumber with peel are stronger than another.

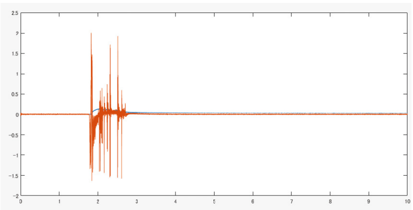

Fig. 8. Sample No. 27 (cucumber with peel).

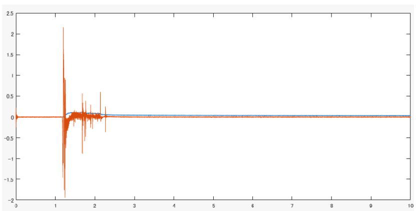

Fig. 9. Sample No. 40 (cucumber with no peel).

4.3 Characteristic Values of Samples

Table 3 shows the average of *characteristic values* of radish. It is found that the W1 to W5 of radish with peel are higher than one with no peel, on the other hand, F1 to F5 of radish with no peel (i.e. peeled) are higher than one with peel. As for the cucumber, the detail is described in the paper [9].

Table 3. Average of characteristic values of radish.

	W1	W2	W3	W4	W5
Radish with peel	0.24	0.32	0.36	0.36	0.31
Radish with no peel (peeled)	0.16	0.11	0.05	0.03	0.02
	F1	F2	F3	F4	F5
Radish with peel	7.81	1.61	1.31	0.97	1.09
Radish with no peel (peeled)	9.74	2.11	1.65	1.39	1.31

5 Neural Network Model

The neural network model for the estimation of the classified degree of food is shown in Fig. 10. The input layer consists of 10 nodes for *characteristic values* W1 to W5 and F1 to F5, and one bias node. The hidden layer 1 and 2 consist of 10 nodes and one bias node, respectively. The output layer consists of four nodes expressing the classified degree in "radish with peel", "radish with no peel", "cucumber with peel" and "cucumber with no peel".

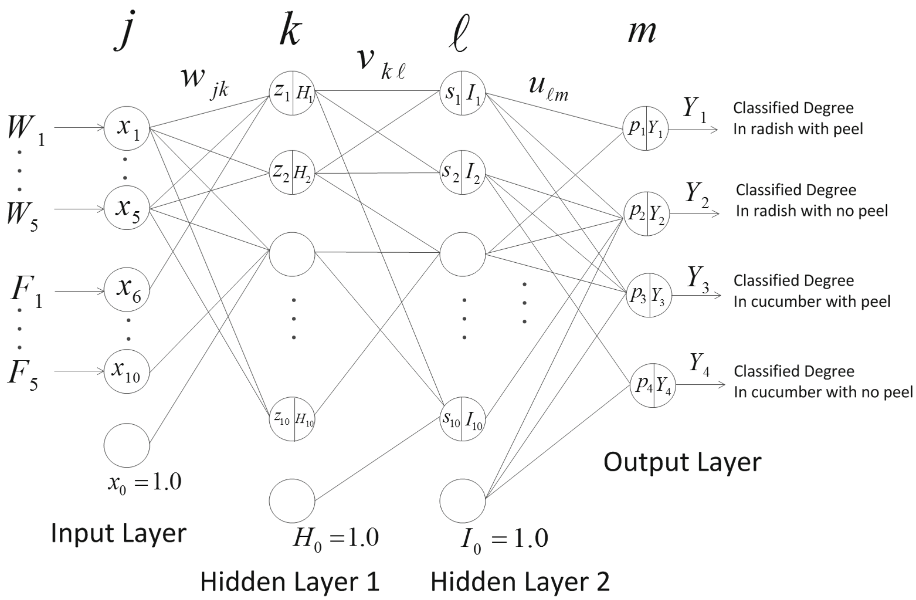

Fig. 10. Neural network model for classifying to 4 classes.

The transfer function of the hidden layer 1, 2 and the output layer are shown in Eqs. (1), (2) and (3), respectively, where x_j is j-th input node value of the input layer,

H_k is output value of k-th node of the hidden layer 1, I_ℓ is output value of ℓ-th node of the hidden layer 2, Y_1 to Y_4 are the outputs of the neural network, thus $m = 1, 2, 3, 4$.

$$H_k = \frac{1}{1 + \exp(-z_k)}, \quad z_k = \sum_{j=0}^{10} x_j w_{jk}, \quad x_0 = 1.0 \; . \tag{1}$$

$$I_\ell = \frac{1}{1 + \exp(-s_\ell)}, \quad s_\ell = \sum_{k=0}^{10} H_k v_{k\ell}, \quad H_0 = 1.0 \; . \tag{2}$$

$$Y_m = \frac{1}{1 + \exp(-p_m)}, \quad p_m = \sum_{\ell=0}^{10} I_\ell u_{\ell m}, \quad I_0 = 1.0 \; . \tag{3}$$

Where w, v and u are the connection weights between the input layer and the hidden layer 1, between the hidden layer 1 and 2, between the hidden layer 2 and the output layer, respectively.

The connection weights are adjusted in order to minimize the difference between the expected value and the output Y_m obtained when particular input values are given to the neural network model. The back-propagation algorithm [2] is employed. The training process of the model is as follows:

Step 1: Prepare data sets.

$D^{(n)} = \{W_1^{(n)}, \cdots, W_5^{(n)}, F_1^{(n)}, \cdots, F_5^{(n)}\}$ for $n = 1, 2, \cdots, N$.

Step 2: Prepare the training input and desired output of the neural network model using the data sets as follows:

$$X_{train} = \begin{bmatrix} W_1^{(1)} & \cdots & W_1^{(N)} \\ \vdots & \cdots & \vdots \\ W_5^{(1)} & \cdots & W_5^{(N)} \\ F_1^{(1)} & \cdots & F_1^{(N)} \\ \vdots & \cdots & \vdots \\ F_5^{(1)} & \cdots & F_5^{(N)} \end{bmatrix}, \; Y_{train} = \begin{bmatrix} Y_1^{(1)} & \cdots & Y_1^{(N)} \\ Y_2^{(1)} & \cdots & Y_2^{(N)} \\ Y_3^{(1)} & \cdots & Y_3^{(N)} \\ Y_4^{(1)} & \cdots & Y_4^{(N)} \end{bmatrix}$$

where X_{train} is the input and Y_{train} is the expected output.

Step 3: Train the neural network model.

5.1 Training of Neural Network

This section describes training of the neural network model. The training data are the samples with No. 1–10, No. 14–23, No. 27–36 and No. 40–49 as shown in Table 2. Table 4 shows desired output for every training and test sample data.

The training process is carried out to adjust the connection weights so that the inputs of 40 data sets correspond to the desired output vector. The iteration to train the network is set to 50 epochs. Figure 11 shows the changing of the error at each epoch, and we can confirm the error declines.

Table 4. Desired output of all samples.

n (sample No)	1, …,10	11, 12, 13	14, …, 23	24, 25, 26	27, …, 36	37, 38, 39	40, …, 49	50, 51, 52
Y_1	1.0	1.0	0.5	0.5	0.0	0.0	0.0	0.0
Y_2	0.5	0.5	1.0	1.0	0.0	0.0	0.0	0.0
Y_3	0.0	0.0	0.0	0.0	1.0	1.0	0.5	0.5
Y_4	0.0	0.0	0.0	0.0	0.5	0.5	1.0	1.0

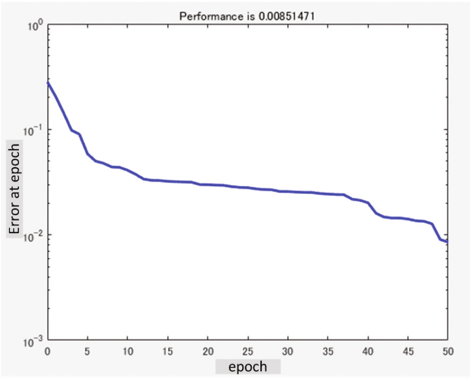

Fig. 11. Error at each epoch.

Tables 5 and 6 show the output result when the data of samples not used for the training are inputted to the neural network model. It is found that classified values are generally moderate for every test sample.

Table 5. The output of neural network for test samples (radish).

Sample number	11	12	13	24	25	26
Y_1	0.896	0.987	0.980	0.438	0.329	0.408
Y_2	0.173	0.300	0.088	0.982	0.874	0.973
Y_3	0.239	0.049	0.251	0.018	0.191	0.017
Y_4	0.007	0.017	0.025	0.023	0.095	0.032

Table 6. The output of neural network for test samples (cucumber).

Sample number	37	38	39	50	51	52
Y_1	0.082	0.163	0.099	0.036	0.016	0.048
Y_2	0.104	0.187	0.142	0.013	0.010	0.015
Y_3	0.927	0.739	0.826	0.276	0.472	0.488
Y_4	0.305	0.277	0.345	0.955	0.931	0.910

6 Fuzzy Inference

This system infers the food texture degree of the munching-ness and the crunchiness using fuzzy inference considering classified degrees obtained from the neural network output. In our former paper [9] the output of the neural network is the food texture degree, however in the present paper in order to make inference reason more apparently, the fuzzy logic theory proposed by Zadeh [1] is adopted. The degrees of the munching-ness and the crunchiness are inferred from the classified degree of one (i.e. radish or cucumber) with peel and one with no peel as shown in Fig. 12. The fuzzy rule Tables 7 and 8 would explain the reasoning mechanism of the food textures to a certain extent. Input (antecedent) and output (consequent) membership functions are defined as shown in Fig. 13. The Mamdani-type fuzzy inference method [10] is applied.

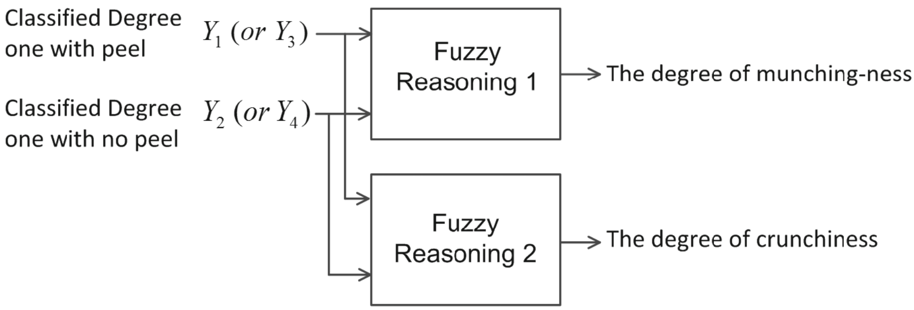

Fig. 12. Fuzzy inference system.

Table 7. Fuzzy rule table for munching-ness.

Munching-ness		Classified degree of one with no peel		
		S	M	L
Classified degree of one with peel	S	S	S	S
	M	M	M	M
	L	L	L	

Table 8. Fuzzy rule table for crunchiness.

Crunchiness		Classified degree of one with no peel		
		S	M	L
Classified degree of one with peel	S	S	M	L
	M	M	M	L
	L	M	M	

Table 9 and 10 show the result of the fuzzy inference for given samples not used for training of neural network. It is found that all values are generally reasonable.

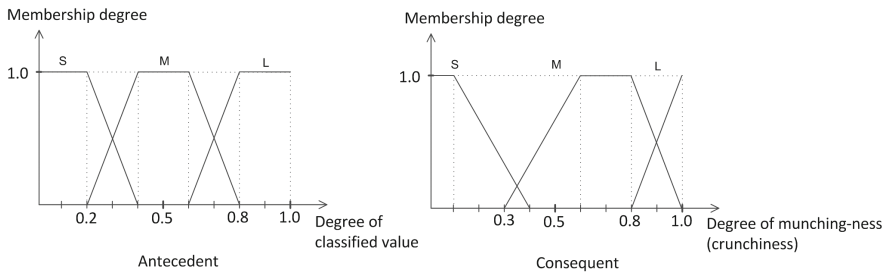

Fig. 13. Fuzzy set of antecedent and consequent.

As shown in Table 9, since the samples No. 11–13 are the radish with peel, the degree of munching-ness is high. On the other hand, since the No. 24–26 are the one with no peel, the crunchiness is high. The result of cucumber in Table 10 is the same tendency as one of Table 9.

Figure 14 shows input-output surface of munching-ness and crunchiness. As left side graph in Fig. 14 shows, it is found that the higher classified degree of "one with peel", the higher degree of munching-ness. On the other hand, the higher value of "with

Table 9. The result of the fuzzy inference for the test samples (radish).

Sample number	11	12	13	24	25	26
Munching-ness	0.937	0.925	0.937	0.670	0.537	0.670
Crunchiness	0.670	0.662	0.670	0.937	0.930	0.937

Table 10. The result of the fuzzy inference for the test samples (cucumber).

Sample number	37	38	39	50	51	52
Munching-ness	0.926	0.715	0.932	0.431	0.670	0.670
Crunchiness	0.662	0.664	0.666	0.929	0.937	0.937

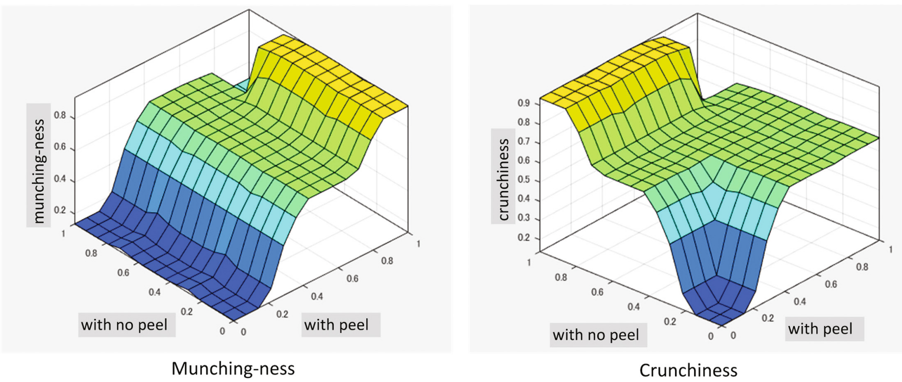

Fig. 14. Fuzzy set of antecedent and consequent.

no peel", the higher value of "crunchiness" (Fig. 14 right side). The inference mechanism of the food textures could be interpretable by the fuzzy logic rule base.

7 Conclusion

We propose a new method to infer the food texture. It's a first challenge to assume the food texture using combination of neural network and fuzzy logic. In a future, we will investigate reasoning method using only the fuzzy logic theory proposed by Zadeh [1]. The goal of this study is to investigate the complex relationships between the sound and the load information, and food texture, and to realize intelligent food texture inference system with comprehensible fuzzy linguistic rule base.

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Adaptive Threshold, Wavelet and Hilbert Transform for QRS Detection in Electrocardiogram Signals

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Abstract. This paper combines Hilbert and Wavelet transforms and an adaptive threshold technique to detect the QRS complex of electrocardiogram signals. The method is performed in a window framework. First, the Wavelet transform is applied to the ECG signal to remove noise. Next, the Hilbert transform is applied to detect dominant peak points in the signal. Finally, the adaptive threshold technique is applied to detect R-peaks, Q, and S points. The performance of the algorithm is evaluated against the MIT-BIH arrhythmia database, and the numerical results indicated significant detection accuracy.

1 Introduction

Cardiovascular diseases are the number one cause of death worldwide according to the World Health Organization [1], and they are projected to remain the main cause of death for several decades [2]. Therefore, cardiac health research has become of significant importance to medical researchers to prevent sudden death from heart diseases using medical treatment, early diagnoses, and computer-aided diagnosis methods (CAD) [3].

Electrocardiogram (ECG) analysis is the most common clinical cardiac test. An ECG is a screening tool for several cardiac abnormalities, since it is inexpensive, simple and risk-free [4]. A single, normal cycle of an ECG is composed of the following six waves: P, Q, R, S, T and U waves [5]. The QRS complex wave is the most noticeable waveform, and it reflects the electrical activity of the heart for total ventricular muscle depolarization [5]. Many published studies have attempted to identify universal solutions to detect QRS complex. The accurate detection of the R-wave peak and the accurate determination of the QRS complex are very important tasks in computer-based ECG analysis. Difficulties may arise primarily due to a low signal-to-noise ratio (SNR), abnormalities that accompany the ECG signals, and the diversity of QRS wave forms.

A typical QRS detection algorithm consists primarily of pre-processing and detection stages. The pre-processing stage focuses on signal filtering to attenuate other

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signal components and artifacts, such as noise, baseline drift, P-wave, and T-wave. The QRS detection stage is used to demarcate the prominent QRS wave by a specific detection technique. Usually, a threshold method is required for the detection of the R wave in ECG signals, and the detection of the Q and S waves are delineated, as well.

In the literature, several investigations dealt with the QRS complex detection for ECG signals. As described in [6], the methods are commonly based on, for instance, geometric matching [7], digital filters [8, 9], empirical mode decomposition (EMD) [10], Hilbert transform [11], derivatives [12], mathematical morphology [13], linear prediction and Wavelet transform [14], length/energy transforms [15], and neural networks [16].

This paper presents the combination of Wavelet transform, Hilbert transform, and adaptive threshold techniques for QRS complex detection. The main motivation is to increase the accuracy of QRS complex detection in ECG signals that presents low-amplitude QRS, negative QRS, non-stationary random effects, and low signal-to-noise ratio.

The remainder of the paper is organized as follows. Section 2 presents the methodology for QRS complex detection. Section 3 presents a discussion of the obtained results. Finally, Sect. 4 presents the paper's conclusions and identifies further research directions.

2 Materials and Methods

The proposed methodology for automatic QRS complex detection consists of five stages. The first stage implies the preprocessing of the ECG signal to distinguish QRS complex. The second stage performs the discrete Wavelet transform for multi-resolution analysis. The third stage consists of obtaining the Hilbert transform to calculate the envelope signal. The fourth stage consists of an adaptive threshold technique to obtain the preliminary QRS complex positions. Finally, the fifth stage consists of a true QRS locator to discriminate the precise position of the QRS complex.

2.1 Pre-processing

A differentiation technique is applied as pre-processing of the ECG signal. This method is performed to distinguish the QRS complex and simplify the QRS detection. The first derivative is performed as follows:

$$\mathbf{y}_0(k) = (\mathbf{y}(k) - \mathbf{y}(k-2)), \quad k = 0, 1, \ldots, N-2\ . \tag{1}$$

Next, the second derivative is obtained as

$$\mathbf{y}_1(k) = (\mathbf{y}(k) - 2 \times \mathbf{y}(k-2) + \mathbf{y}(k-4))\ . \tag{2}$$

The results of Eqs. (1) and (2) are weighted and combined as seen in Eq. (3).

$$\mathbf{y}_2(k) = 1.3 \times \mathbf{y}_0(k) + 1.1 \times \mathbf{y}_1(k)\ . \tag{3}$$

Subsequently, passing the result $\mathbf{y}_2(k)$ through an 8-point moving average filter, $\mathbf{y}_3(k)$ is obtained as shown in Eq. (4).

$$\mathbf{y}_3(k) = \frac{1}{h}\sum_{k=0}^{h-1} y_2(k-h)\ . \tag{4}$$

where h stands for the 8-point samples of the moving average.

2.2 Wavelet Transform

The Wavelet transform is applied to decompose the signal into a set of coefficients that describe the signal frequency content at a given time. The Wavelet transform is performed to analyze the ECG time series. Broadly speaking, there are two types of Wavelets, continuous and discrete. The discrete Wavelet transform (DWT) can be applied for multi-resolution variance analysis. DWT achieves a multi-resolution decomposition of an observed time series $\mathbf{y}(k)$ on J octaves labeled by $j = 1, \ldots, J$. DWT considers the following two filter input responses: $\mathbf{h}(k)$, which represents the low pass filter (the scaling function) and $\mathbf{g}(k)$, which represents the high pass filter (the Wavelet function).

The low pass output is obtained by Eq. (5).

$$w_{j+1}(k) = \sum_{m=1}^{N} w_j(m) \cdot h(2k-m). \tag{5}$$

where k is the shift, the starting point for the Wavelet calculation, and $2k-m$ is the index that incorporates the scaling; $w_{j+1}(k)$ is the discrete scaling function of the discrete time series $\mathbf{y}(k)$, and $w_j(m)$ is the decomposition of the scaling function from the previous level of resolution, with m as an index.

The high pass output is obtained by Eq. (6).

$$wh_{j+1}(k) = \sum_{m=1}^{N} w_j(m) \cdot g(2k-m)\ . \tag{6}$$

where $wh_{j+1}(k)$ is the discrete Wavelet function.

Then, for each level of signal decomposition, a different threshold is selected. The threshold is used to shrink the resulting Wavelet detail coefficients of the noisy signal. A fixed-form threshold is given as

$$T = \sigma\sqrt{2\ln(N)}\ . \tag{7}$$

where N is the length of the Wavelet coefficient, ln stands for the natural logarithm, and σ is given as

$$\sigma = \frac{1}{N}\sum_{k=1}^{N}\left|wh_j(k)\right| . \tag{8}$$

For threshold T, the soft threshold technique is given as follows

$$wh_j(k) = \begin{cases} sign(wh_j(k))(\left|wh_j(k)\right| - T) & \text{if} \left|wh_j(k)\right| > T \\ 0 & \text{otherwise} \end{cases} . \tag{9}$$

where $wh_j(k)$ is the Wavelet coefficient, $sign(wh_j(k))$ is $+1$ if $wh_j(k)$ is positive, and -1 if $wh_j(k)$ is negative.

The hard threshold is given as

$$wh_j(k) = \begin{cases} wh_j(k) & \text{if} \left|wh_j(k)\right| > T \\ 0 & \text{otherwise} \end{cases} . \tag{10}$$

The inverse discrete Wavelet transform is defined by Eq. (11).

$$w_j(k) = \sum_{m=1}^{N} w_{j+1}(m) \cdot h(2k-m) + \sum_{m=1}^{N} wh_{j+1}(m) \cdot g(2k-m) . \tag{11}$$

Figure 1 presents the Wavelet transform reconstruction using the soft threshold alongside the preprocessed signal. In addition, Fig. 2 presents the Wavelet transform reconstruction using the hard threshold alongside the original electrocardiogram signal.

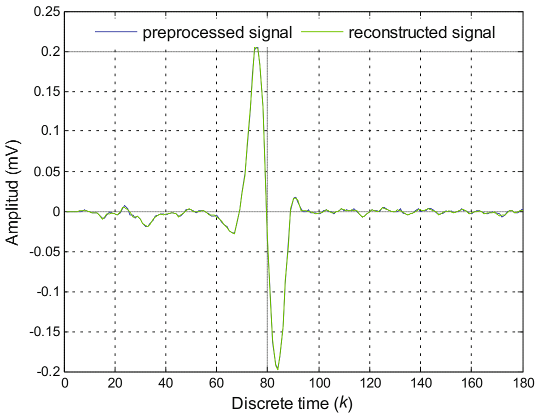

Fig. 1. Wavelet transform reconstruction. Preprocessed (blue) signal and reconstructed (green) signal. Using soft threshold.

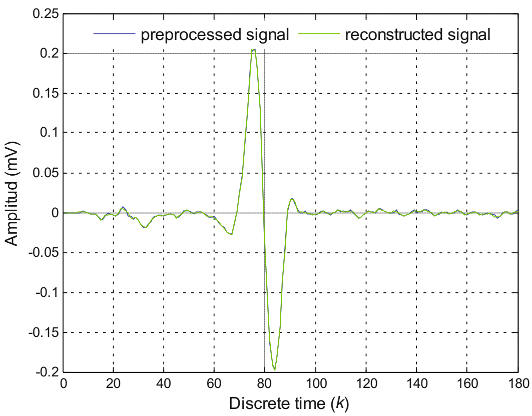

Fig. 2. Wavelet transform reconstruction. Preprocessed (blue) signal and reconstructed (green) signal. Using hard threshold.

2.3 Hilbert Transform

For a discrete time series $\mathbf{y}(k)$, the Hilbert transform is defined as shown in Eq. (12) [17].

$$H(k) = \mathbf{y}_H(k) = FFT^{-1}(\mathbf{f}(k) * \mathbf{h}(i)) \ . \tag{12}$$

where $FFT^{-1}(\cdot)$ is the Inverse Fast Fourier Transform, vector $\mathbf{f}$ stores the Fast Fourier Transform (FFT) of the $\mathbf{y}(k)$ signal, and $\mathbf{h}$ is created as shown in Eq. (13).

$$\begin{array}{lll} 0 & \text{for} & i = (N/2) + 2, \ldots, N \\ 2 & \text{for} & i = 2, 3, \ldots, (N/2) \\ 1 & \text{for} & i = 1, (N/2) + 1 \end{array} \ . \tag{13}$$

Hence, the analytic signal of the discrete time signal $\mathbf{y}(k)$, is given in Eq. (14).

$$\mathbf{z}(k) = \mathbf{y}(k) + j\mathbf{y}_H(k) \ . \tag{14}$$

The envelope $\mathbf{a}(k)$ of $\mathbf{z}(k)$ is described in Eq. (15).

$$\mathbf{a}(k) = \sqrt{\mathbf{y}^2(k) + \mathbf{y}_H^2(k)} \tag{15}$$

and the instantaneous phase angle in the complex plane is defined in Eq. (16).

$$\theta(k) = \arctan\left(\frac{\mathbf{y}_H(k)}{\mathbf{y}(k)}\right) \ . \tag{16}$$

The envelope of the Hilbert transform ($\mathbf{a}(k)$) superimposed alongside the differentiation output $\mathbf{y}(k)$ is shown in Fig. 3.

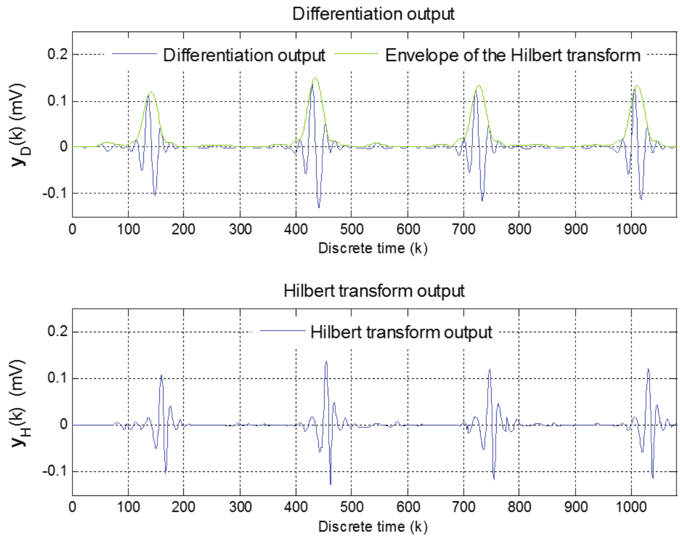

Fig. 3. Hilbert transform of the ECG signal dynamics for one instance of a window of 1080 samples (3 s). (a) Envelope of the Hilbert transform is superimposed on the differentiation output of the ECG signal. (b) Hilbert transform of (a) differentiation output.

2.4 Adaptive Threshold

The adaptive threshold technique is one of the more significant part of the QRS detection method. The adaptive threshold is performed by using a pair of threshold limits called the upper limited threshold (u_{th}) and the lower limited threshold (l_{th}). The upper limited threshold is defined by Eq. (17).

$$u_{th} = 0.5 \times \alpha \; . \tag{17}$$

where α is the maximum value attained $\mathbf{y}(k)$ on the point $k = 1, \ldots, N$. The lower limited threshold is defined by Eq. (18).

$$l_{th} = 0.10 \times \alpha \; . \tag{18}$$

In each stage of the threshold, the number of detected peaks above the upper and lower thresholds and the number of detected peaks is calculated. Therefore, Nu_{th} is the number of QRS complexes detected by u_{th}, and Nl_{th} is the number of QRS complexes detected by l_{th}. The threshold values are updated in iteration time; meanwhile, the number of detected peaks by the up and down limits is different. The value of u_{th} is updated using

$$u_{th}(k+1) = u_{th}(k) - w\Delta \tag{19}$$

where the error weight $w = 0.125$, and $\Delta = u_{th} - l_{th}$ is the difference between the defined two limits. The value of l_{th} is updated using Eq. (20). The error weight w, and Δ are assumed as the same as defined in Eq. (19).

$$l_{th}(k+1) = l_{th}(k) + w\Delta \tag{20}$$

Next, the lower threshold limit is increased by $w\Delta$, and the upper threshold limit is decreased by $w\Delta$, as well. This process continues until the same QRS number (*i.e.*, $Nu_{th} = Nl_{th}$) is obtained.

The QRS complex detection in a window of 1080 samples (*i.e.*, 3 s) of the ECG segment is shown in Fig. 4. In the right, the thresholds are updated to 50% and 10% of the maxima, and 4 QRS complexes were detected by the adaptive threshold technique. In the left of Fig. 4, 200 samples of the first R-peak detected by the adaptive threshold technique are highlighted; the red line stands for the *uth* threshold, and the green line stands for the *lth* threshold.

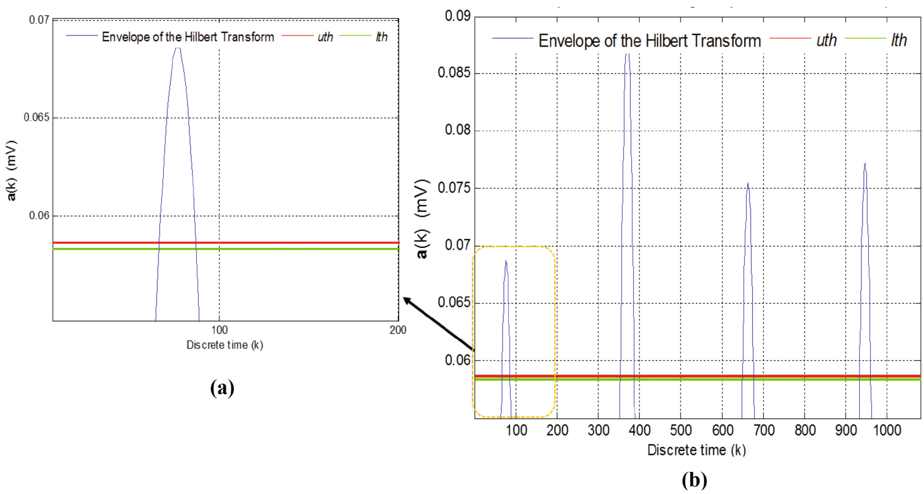

Fig. 4. QRS complexes detected in ECG segment. (a) 200 ECG signal samples, *uth* threshold is illustrated by the red line, and *lth* is illustrated by the green line, $uth = 0.0587$ and $lth = 0.0583$. (b) a frame of 1080 samples of the envelope signal of the Hilbert transform. In this segment, the number of peaks detected by *uth* is $Nuth = 4$, and the number of peaks detected by *lth* is $Nlth = 4$.

2.5 True QRS Locator

The true QRS locator is a simple post-processing stage that detects the accurate locations of R-peaks in the current frame (*i.e.*, 1080 sample points) of the original signal based on the previous results of the adaptive threshold technique. The previous results of the adaptive threshold not only detect the number of R-peaks present in the current frame but also the true temporal R-peak location. This information enables searching for the maximum peak in the original ECG signal into a fixed window (*i.e.*, 36 samples from each temporal R-peak position to detect the true R-peak position).

3 Results and Discussion

The QRS detection method has been validated using the MIT-BIH arrhythmia database [18, 19]. The MIT-BIH arrhythmia database contains records sampled at 360 Hz, with 11-bit resolution over 5 mV range. Each record contains a duration of 30 min and 5.556 s. The QRS detection algorithm was evaluated using the following statistical measures: sensitivity (Se), and positive predictivity ($+P$). The sensitivity Se describes the percentage of true beats that were correctly detected by the algorithm, given by Eq. (21).

$$Se(\%) = \frac{TP}{TP + FN} \times 100 . \tag{21}$$

where FN is the number of false negatives (*i.e.*, QRS complexes have not been detected as QRS complexes), TP is the number of true positives (*i.e.*, QRS complexes detected as QRS complexes). Accordingly, the positive predictivity $+P$ describes the percentage of beat detections, which were in reality true beats, given by Eq. (22).

$$+P(\%) = \frac{TP}{TP + FP} \times 100 . \tag{22}$$

where FP is the number of false positives (*i.e.*, non-QRS complexes detected as QRS complexes).

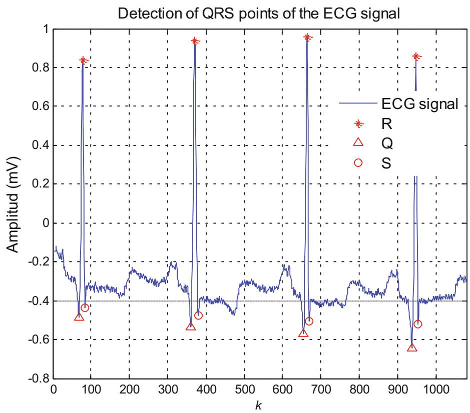

Fig. 5. Detection of the QRS points of normal heartbeats from the MIT-BIH arrhythmia database.

For the QRS complex detection, only the first channel of each record has been processed to enable comparing the results with those of other published works. Figure 5 presents the detection of the QRS points of normal heartbeats from the ECG signal.

To evaluate the actual performance of the proposed algorithm. According to the ECG signal analysis and the literature review, record 203 is one of the most difficult to analyze, since it presents multiform ventricular arrhythmia, sudden changes in QRS morphology, various irregular rhythms, and negative QRS polarity.

Frequency band choice. The frequency band has been applied in the literature without identifying optimal QRS complex range for more accurate detection. Usually, authors determine their frequency band choice experimentally. In this work, the frequency band was selected for designing a band pass filter with the frequency within 5–15 Hz.

Window size. The window size is a parameter to be considered in detection, and related work typically uses a fixed window size for the moving average to demarcate the QRS complex.

Threshold choices. The adaptive threshold is generally determined based on an amount of most recent beats. This work uses a pair of thresholds (upper and lower thresholds), which are initialized in regard to the maximum value attained by the current frame.

4 Conclusions

A method for QRS complex detection in ECG signals is presented. The proposed method has a significant effect in the detection of R-peak and outperforms others. Using Wavelet transform before the Hilbert transform results in removing noise and highlights the R-peaks. The adaptive threshold technique leads to decreased errors in dominant R-peak determination. In this work, the methodology improves the accuracy of detection QRS complexes in records with ventricular ectopics, low signal-to-noise ratio, low-amplitude R-peaks, and negative QRS polarities.

The proposed method was tested against 34 records of the MIT-BIH arrhythmia database. The obtained results show that the proposed algorithm achieves significant detection rates.

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Prediction of Highly Non-stationary Time Series Using Higher-Order Neural Units

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Abstract. Adaptive predictive models can use conventional and nonconventional neural networks for highly non-stationary time series prediction. However, conventional neural networks present a series of known drawbacks. This paper presents a brief discussion about this concern as well as how the basis of higher-order neural units can overcome some of them; it also describes a sliding window technique alongside the batch optimization technique for capturing the dynamics of non-stationary time series over a Quadratic Neural Unit, a special case of higher-order neural units. Finally, an experimental analysis is presented to demonstrate the effectiveness of the proposed approach.

1 Introduction

Measurements of real-world systems are usually influenced by several external processes, which can generate non-stationarity and long-term correlations. A non-stationary time series is usually characterized by time-varying mean, variance, or even both. Hence, the learning process of the adaptive predictive model should then capture the current data behavior (dynamics) for improved prediction accuracy. This can be performed by a retraining (sliding window) technique. This technique can be seen as an offline learning method applied on continuously changing training data. In real-time prediction, the training process needs to use the delayed signal history, and the current prediction process uses the actual signal history to predict an unknown signal. Hence, the weights updated by training on the past delayed signal history are applied to the signal history at time k to obtain a predicted signal at time $k + n_s$. When the real signal arrives at time $k + n_s$, it is then compared to the one predicted at time $k + n_s$ to obtain an error signal and evaluate its accuracy [1].

The prediction capability of a neural network (NN) is based on several elements that influence the accuracy of the network. Such elements include the number of hidden neurons, the number of inputs to be fed into the network, the number of hidden layers, and the learning rate. In order to obtain good predictability (by measuring the prediction error), the optimum parameters must be identified [2].

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The main objective of this paper is to discuss conventional and nonconventional neural networks and to present their potentialities for non-stationary time series prediction. In addition, a sliding window technique alongside the Levenberg-Marquardt optimization technique for prediction is also described to capture the dynamics of non-stationary time series over the predictive model. Experimental analysis is also presented for long-term prediction of non-stationary time series [1–3].

This paper is organized as follows: Sect. 2 describes conventional and nonconventional neural architectures for prediction, including a discussion about the drawbacks of conventional NNs. In addition, it describes a sliding window technique used to capture the dynamics of non-stationary time series to improve the prediction accuracy of neural network architectures. Also, the section presents the batch optimization technique (Levenberg-Marquardt algorithm) applied during the sliding window approach. In Sect. 3, the effectiveness of the sliding window approach presented in this paper (for the Quadratic Neural Unit predictive model) is illustrated and applied on MacKey-Glass time series, which is a highly non-stationary time series. Finally, Sect. 4 describes the conclusions for the prediction techniques presented in the paper for highly non-stationary time series prediction.

2 Materials and Methods

The proposed system for the automatic prediction of highly non-stationary time series is illustrated in the following subsections.

2.1 Neural Network Predictive Model

Nowadays, neural networks are widely used for signal-behavior prediction and information processing. Online training and offline training have been used to train NNs for predicting highly non-stationary time series [1].

The use of NNs for the prediction of highly non-stationary time series is not surprising due to the use of past data. Furthermore, NNs are capable of describing the dynamics of non-stationary time series due to their adaptive, nonparametric, and noise-tolerant properties [1–4].

Some of the properties of the NNs that make them attractive for highly non-stationary time series prediction are as follows: (a) They can generalize; in other words, after the training phase, NNs can often generate good results for a prediction, even if the training data uses unseen input patterns; (b) NNs have been demonstrated as universal approximators, meaning that they can approximate any continuous function to a desired accuracy (but only during the training stage); (c) NNs are data driven, and there is no need to make a prior assumption about the model, which means that NNs are suitable to problems where their solutions need some knowledge that is difficult to specify, but there are sufficient observations or data; (d) NNs are nonlinear, meaning that they are capable of performing nonlinear modeling without any prior knowledge about some relationship between the outputs and the inputs of the problem in question [5–8].

On the other hand, even with the inspiring results of Neural Networks applications for time series prediction, especially in comparison with linear statistical models, the robustness of these results has been in discussion because of some well-known problems related to neural networks such as:

- The intrinsic nonlinearity of the time series data (highly non-stationary) can affect the accuracy of the prediction on a conventional neural network, even if the NN can predict changes in the testing data.
- The existing neuron model in the conventional NNs performs only the summation operation of its weighted inputs; conventional NNs do not perform the operation of product on its weighted inputs.
- Training time on the conventional NN is rather long, and it results in slower performance by the system.
- The prediction results depend on the threshold function (the activation function); the training time is also affected by the activation function.
- Distinct NNs algorithms can produce dissimilar results even if trained and tested over the same data set. This occurs because there are diverse decision classes and limits used in NNs.
- Backpropagation learning has some weaknesses, such as

  (a) Problems of local minima may occur during training.
  (b) The learning rate can be slow.

- The number of hidden layers and hidden neurons to be used in a neural network cannot be predicted accurately. In addition, for complex function approximation, they are large in number.
- Neural Networks are susceptible to the size of the data set and to the size of the network. NNs suffer from overfitting, resulting in the necessity of carefully selecting the learning parameters and training data to achieve good generalization. This becomes critical when the network is applied for highly non-stationary time series prediction [7–9].

In order to overcome the previously mentioned problems of the NNs, several variations of NNs for prediction have been developed in the last decades. Some of these improvements are focused on increasing the computational training time and/or varying the learning algorithms [8, 9].

Hence, to overcome such limitations of the conventional neural networks, higher-order neural units (HONU) have emerged in the literature. The higher-order neural units contain all the nonlinear and linear correlation terms of an input signal [8–10].

A higher-order neural unit incorporates the following characteristics:

- The complexity of the model is reduced because there is no need to select the number of neurons and the number of hidden layers.
- The higher-order neural unit includes the characteristics of both a simple neuron and a higher-order neuron.
- The response of the network should not be affected by the input-output mapping [9, 10].

Higher-order neural units are nonconventional neural units that use polynomial aggregation of neural inputs (the polynomial is of order r). The higher-order combination of inputs and the weights yield to a higher performance since they require a smaller training set and fewer training steps to achieve the desired generalization over the domain that is being worked. Nevertheless, a disadvantage of the HONU is the combinational increase in the number of weights (*i.e.*, the weight number in the HONU increases significantly as the input size increases). Then, the higher-order neural unit models can overcome the drawbacks of the conventional neural networks for prediction tasks. This improvement is performed by several variations in the generalized neuron model and by finding the effect of the activation function for a higher-order neural unit for short and long prediction time [9–11].

2.2 Quadratic Neural Unit

Quadratic Neural Unit (QNU) may be considered as a case of polynomial neural network architecture or as a special case of higher order neural unit. The aim of polynomial curve fitting is to fit a polynomial to a set of data points by minimizing an error function [8, 10]. The static QNU is sketched in Fig. 1.

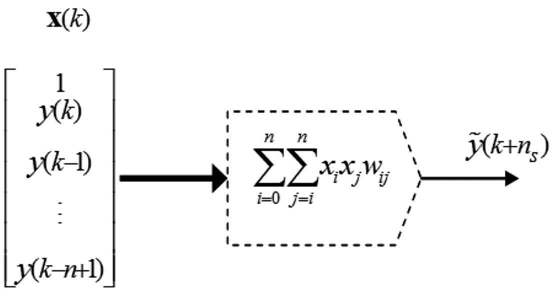

Fig. 1. Static QNU architecture with external inputs (real measured values), without an activation function, for time series (direct) prediction.

The elements of the static quadratic neural unit are given in Eq. 1. Where $\tilde{y}$ is the neural output, $x_1, x_2, \ldots, x_n$ are external neural inputs, and $\mathbf{W}$ stands for an upper triangular weight matrix [10, 11].

$$\tilde{y} = \sum_{i=0}^{n} \sum_{j=i}^{n} x_i x_j w_{ij} = \mathbf{x}^{\mathbf{T}} \mathbf{W}\, \mathbf{x}. \tag{1}$$

The learning and adaptation algorithm for the QNU is presented in discrete time k. The goal of this model is to find the neural output $\tilde{y}$, which should be similar or almost equivalent to the real desired value y. The error $e(k)$ can be defined as the difference between the real value $y(k)$ and the neural output $\tilde{y}(k)$ [9, 10]. Accordingly, the error in discrete time is defined in Eq. 2 as:

$$e(k) = y(k) - \tilde{y}(k). \tag{2}$$

The error should become closer to zero as the learning iteration increases. To achieve this, a performance index or cost function is defined in Eq. 3 as:

$$J(e(k)) = \frac{1}{2}e(k)^2. \tag{3}$$

The adaptation of the static QNU can be written for each single neural weight and for each sample number by means of sample-by-sample adaptation, as in Eq. 4. Thus, the cost function can be minimized [9, 11, 12].

$$w_{ij}(k+1) = w_{ij}(k) + \Delta w_{ij}(k). \tag{4}$$

2.3 Sliding Window Technique

This method can be seen as an offline learning method applied over continuously changing training data. The data organized in the window will be used on a training algorithm in batch learning with a proper iteration number [9, 13].

This technique will ensure the prediction to adapt to the real highly non-stationary time series and changes that appear on it. It is expected to learn from time to time and make better predictions from the past usage data in the current window.

Sliding window learning uses stored data from previous points, making it possible to use advanced second-order algorithms (*i.e.*, such as the Levenberg-Marquardt algorithm in a batch way and batch conjugate gradient algorithms) [4, 9, 13]. A general scheme of the sliding window technique can be seen in Fig. 2.

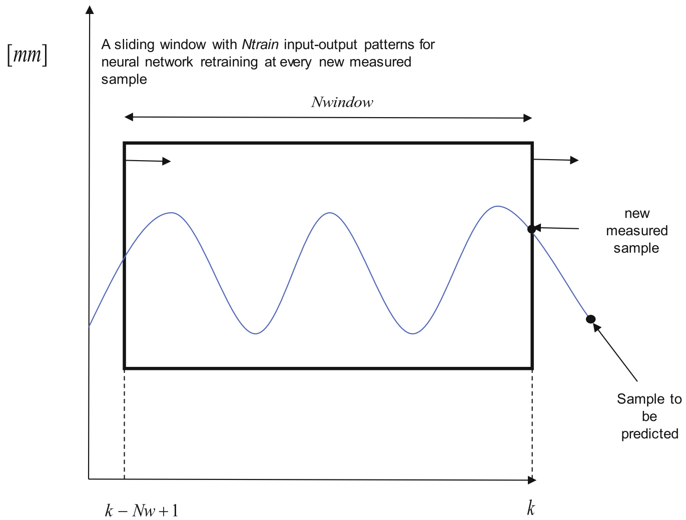

Fig. 2. General scheme of the Sliding (retraining) window for model retraining at every new measured sample [14].

2.3.1 Batch Optimization

Batch optimization is a common strategy for offline learning of adaptive methods. Batch learning is also known as offline learning, or epoch wise. In this approach, the data are taken as a whole batch, and the network is updated only after the whole batch of data has been processed. The Levenberg-Marquardt (L-M) algorithm can be considered as a second-order method for training neural networks. Training with the L-M algorithm provides faster and improved convergence compared to first-order methods such as gradient-descent methods [3, 4, 9, 14, 15]. The common formula for calculating a single-weight increment is presented in Eq. 5.

$$\Delta w_{i,j} = \left[\mathbf{j}_{i,j}^T \times \mathbf{j}_{i,j} + \mu \times \mathbf{I}\right]^{-1} \times \mathbf{j}_{i,j}^T \times \mathbf{e} \tag{5}$$

where Δw_{ij} stands for the incremental change for the weight updating, $\mathbf{e}$ is the vector of errors (see Eq. 6), ^{T} stands for transposition, $\mathbf{I}$ is the identity matrix and μ is the learning rate, which is increased or decreased according to the performance.

$$\mathbf{e} = [e(1)\ e(2)\ \cdots\ e(N)]^T. \tag{6}$$

In Eq. 6, N denotes the number of samples (data length). The Jacobian matrix $\mathbf{j_{ij}}$ contains the first derivatives of the network errors with respect to weights and biases in all patterns (see Eq. 7) [3, 4, 15].

$$\mathbf{j_{ij}} = \frac{\partial \mathbf{e}}{\partial w_{ij}}. \tag{7}$$

The algorithm is said to have been converged when the sum of the square error has been reduced to some previously decided error goal [9, 15, 16].

3 Results and Discussion

In Fig. 3 the approximation capability of QNU retrained has been demonstrated by using the sliding window technique on the prediction of time series generated by the MacKey-Glass equation, which has been obtained with a sampling interval of 1 s. In this figure, the green color shows the prediction of 15 samples ahead (*i.e.*, 15 s). The error between the predicted and the original value is shown by the middle red curve. The QNU was adapted by using the Levenberg-Marquardt algorithm. The prediction has been carried out for $k = 1000$ to $k = 2000$ samples (*i.e.*, 1000 s). In the results, the prediction for $t_{pred} = 15$ s (*i.e.*, $n_s = 15$) prediction horizon is highlighted. The model is configured with $N_{train} = 180$ (*i.e.*, 180 input-output patterns) for the sliding window, $n = 15$ samples back used as inputs to the network. A duration of 14.6918 s of computing time for 1000 s of Mackey-Glass time series can be seen.

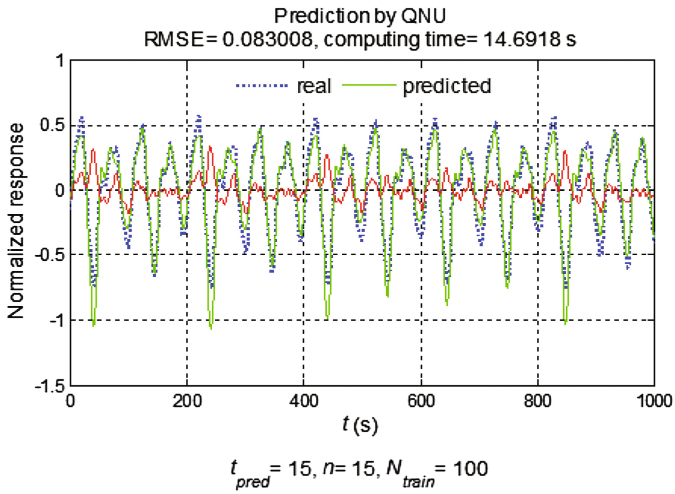

Fig. 3. Prediction of non-stationary Mackey-Glass equation (normalized data) by the QNU predictive model with the sliding window approach. The prediction ahead is of 15 s, which is superimposed on the original data, and the red middle line is the error between original and predicted values.

In the next section, we present the relevant aspects of the above reviewed predictive models and the results that highlight the attractive properties of sliding window retraining for applications.

4 Conclusions

In this work, an outline of the new trends of neural networks applied in time series prediction has been presented. A comparison study of current NN literature has been conducted and presented as well. Accordingly, a study of the nature of the data, for determining the best window size in the retraining approach (*i.e.*, analysis of possible trends in the cyclic pattern changes) and also the proper number of delays fed into the predictive model can help short-term and long-term prediction performance. For this approach, an analysis of the proper parameters to be fed into the predictive model and the determination of window size to capture trends and dynamics in the data are needed. This approach to analysis makes it possible to reduce prediction error.

Finally, we highlight the interesting characteristics of a sliding window approach for technical applications where the data appear highly non-stationary, and we conclude that it is not necessary to use complicated models to achieve superior results.

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Predicting the Short-Term Exchange Rate Between United State Dollar and Czech Koruna Using Hilbert-Huang Transform and Fuzzy Logic

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Abstract. In this paper, the combination of the Hilbert-Huang Transform, fuzzy logic and an embedding theorem is described to predict the short-term exchange rate from United States dollar to Czech Koruna. By Using the Hilbert-Huang Transform as an adaptive filter, the proposed method decreases the embedding dimension space from five (original samples) to four (de-noising samples). This dimension space provides the number of inputs to the fuzzy rule base system, which causes the number of rules, the time for training and the inference process to decrease. Experimental results indicated that this method achieves higher accuracy prediction than the direct use of original data.

1 Introduction

Forecasting financial time series serves an important role in daily life, especially a forecast exchange rate that helps an importer and exporter to choose the best time to import or export products to obtain the highest profit. Researchers have successfully employed approaches for predicting exchange rates. In [1], authors combined kernel regression (KR) and the Function Link Artificial Neural Network (FLANN) to predict the exchange rate from United States dollar (USD) to British Pound (GBP), Indian Rupee (INR) and Japanese Yen (JPY). KR served a role in filtering, and FLANN was a model for prediction. The authors in [2] use chaos theory and reconstructed state space for predicting the exchange rate between USD and EURO (EUR). Fan-Yong Liu [3] uses a hybrid discrete wavelet transform (DWT) and support vector regression (SVR) to predict the exchange rate between Chinese Yuan (CNY) and USD. First, this researcher uses DWT to decompose time series data to different time scales and later appropriately chooses a kernel function for SVR and a prediction that corresponds with each time scale. Her synthesis prediction is obtained from different predicted time scale

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results. The authors in [4] use a local fuzzy reconstruction method to predict the exchange rate between JPY, USD and Canadian dollar (CAD). The authors in [5] use a successful wavelet transform to filter noise in the exchange rate time series before using it to train and predict the base on the Multi-Layer Feed Forward Neural Network. Weiping Liu [6] uses a hybrid neuron and fuzzy logic to predict the exchange rate between JPY and USA. In 1998, Dr. Huang proposed a novel method for decomposition nonlinear and nonstationary time series into a set of multi-time scale signals, which are referred to as intrinsic mode function (IMF). This method successfully applies in many fields, such as an adaptive filter for nonstationary and nonlinear data [7, 8]. In this paper, the combination of HHT, fuzzy logic and an embedding theorem to predict the exchange rate from USD to CZK is presented. This method is simple, adaptive and high-accuracy prediction.

This paper is organized as follows: In the next section, related studies are presented. Section 3 discusses the principle of the proposal method. Section 4 demonstrates the accuracy prediction of the method by experiment. Section 5 presents the conclusion and future studies.

2 Materials and Methods

2.1 Hilbert-Huang Transform

The Hilbert-Huang Transform is proposed by Dr. Huang in 1998 [9] and consists of two parts. The key part is empirical mode decomposition (EMD). In this part, each signal is decomposed into a finite set number of IMFs, which satisfies two criteria [9]:

- The number of extremes and zero crossings must be equal or differ at most by one in the whole data set.
- This number is symmetrical, which indicates that the mean of the upper envelope at any point connects all local maxima and the lower envelope that connects all local minima is zero.

The flowchart of the EMD algorithm to decompose any signal $\mathbf{x}_1(k)$ to IMFs is illustrated in Fig. 1. Three stopping criteria exist. The first criterion was employed by Dr. Huang in 1998 [9]. This stopping criterion is determined using a Cauchy type of convergence test. The test requires the normalized squared difference between two successive sifting operations, which are defined as follows:

$$SD_i = \frac{\sum_{k=0}^{N} \left|\mathbf{x}_{1_{i-1}}(k) - \mathbf{x}_{1_i}(k)\right|^2}{\sum_{k=0}^{N} \mathbf{x}_{1_{i-1}}^2(k)}. \tag{1}$$

For the given small threshold (th) value, the sifting process will stop when SD_i is less than th. For the second criterion, the sifting process will only stop after S consecutive times when the numbers of zero-crossings and extremes remain the same and are equal or differ at most by one. S is the predefining value; its optimal value ranges from four to

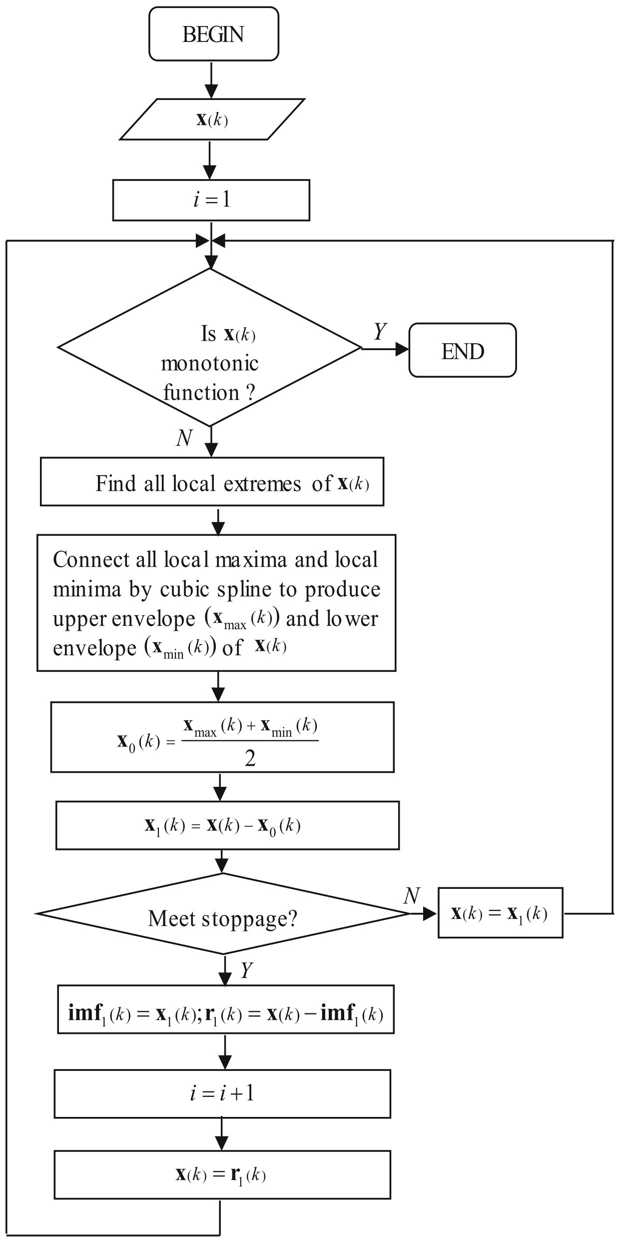

Fig. 1. Flowchart of EMD algorithm.

eight as suggested by Dr. Huang [8, 9]. The criterion has also been suggested by Dr. Huang: the number of shifts should be fixed at ten. In our case, the first criterion is applied.

After the EMD process, a set of IMFs is obtained from high frequency to low frequency oscillation and residue (trend). Summing all IFMs and residue, the original signal is obtained.

2.2 Fuzzy Logic System Uses a Table Lookup Scheme for Time Series Prediction

Assume a data time series $\mathbf{y}(k)$ that has been collected from a system at equal time intervals denoted by $y(1), y(2), y(3), \ldots, y(N)$. The task of the prediction time series is to obtain finding a mapping from $[y(k-n+1), y(k-n+2), \ldots, y(k)]$ to $y(k+1)$, where n and l are constant positive integer numbers, and n is the number of inputs to the predictor. For a simple case, we assume $n = 2$ and $l = 1$. Figure 2 shows the block diagram of the system for prediction. According to the algorithm presented by L. Wang [10], we form $n-2$ input–output pairs $(y(1), y(2) \rightarrow y(3))$, $(y(2), y(3) \rightarrow y(4))$, …, $(y(N-2), y(N-1) \rightarrow y(N))$.

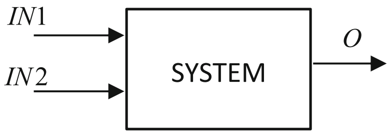

Fig. 2. Block diagram of the system.

Next, we obtain the maximum and minimum of the time series and divide this domain interval into $2 \times R + 1$ regions (R is a positive integer number) denoted by $T1, T2, \ldots, T2R, T2R+1$ and assign each region with a fuzzy membership function. In our case, we choose the shape of the membership function a triangle. Figure 3 illustrates the membership function of input and output with $R = 3$.

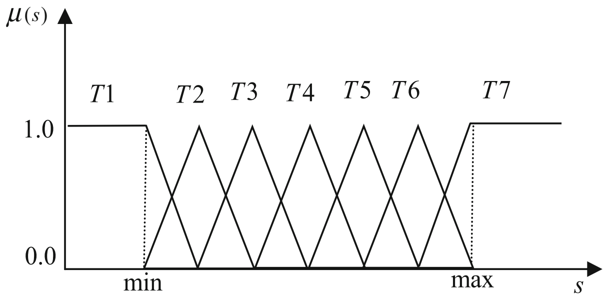

Fig. 3. Membership functions of input and output.

In the next step, we calculate the degree of a given input-output pair in different regions and assign it to a region with a maximum degree and form **IF – THEN** rules. For example, $IN1$ has a maximum degree of 0.8 in region $T2$, $IN2$ has a maximum degree of 0.5 in region $T5$ and O has a maximum degree of 0.9 in region $T6$. Therefore, we form the following rule: **IF** $IN1$ is $T2$ **AND** $IN2$ is $T5$ **THEN** O is $T6$. To repeat this procedure for each input – output pair, we obtain a set of rules. To avoid the conflict rule (two rules have the same IF part but different THEN parts), we only accept the rule from the conflict group that has the maximum degree. We use table – lookup to present a fuzzy rule base. The cells of the rule base are filled by the rules; if more than one rule exists on one cell of the fuzzy rule base, the rule with the maximum degree is applied. The degree of the rule is calculated by Eq. (2).

$$D(rule) = \mu_A(IN1) \times \mu_B(IN2) \times \mu_C(O). \tag{2}$$

We obtain the fuzzy rule base that corresponds to all input-output pairs. The next task is to calculate the output O when we have new input samples $IN1$ and $IN2$. We first calculate the degree of output control of rule k-th in the combined fuzzy rule base that corresponds to the new inputs $IN1$ and $IN2$ according to Eq. (3).

$$\mu^k_{O^k} = \mu_{I^k_1}(IN1) \times \mu_{I^k_2}(IN2). \tag{3}$$

where O^k denotes the output region of rule k, and I^k_j denotes the input region of rule k for the j-th component. We use the center average defuzzification equation to determine the output, given by Eq. (4).

$$o = \frac{\sum_{k=1}^{N} \mu^k_{O^k} \times O^{-k}}{\sum_{k=1}^{N} \mu^k_{O^k}}. \tag{4}$$

where O^{-k} denotes the center value of region O^k, and N is the number of the rule in the combined fuzzy rule base.

2.3 Finding the Embedding Dimension of the Time Series

The method of false nearest neighbors (FNNs) has been proposed in [11] to obtain the minimum embedding dimension. The principle of the method is based on the idea that points that are close to each other may not be neighbors even if the embedding dimension is increased. The FNNs method is used to calculate the adequate number of dimensions for embedding a time series. For a given time series, the data comprises $\mathbf{y}(k)$, where $k = 1, 2, \ldots, N$. The idea of the method is to combine sequence values into vectors and construct d-dimensional vectors from the observed data using a delay embedding as shown in Eq. (5) [11, 12].

$$\begin{array}{c}\mathbf{Y}(k) = [\mathbf{y}(k), \mathbf{y}(k+\tau), \cdots, \mathbf{y}(k+(d-1)\tau)] \\ k: 1, 2, 3, \ldots, N-(d-1)\end{array}. \tag{5}$$

Each vector $\mathbf{y}(k)$ has a nearest neighbor $\mathbf{y}^{NN}(k)$ with nearness in the sense of some distance function, in dimension d. For each vector, its nearest neighbor is obtained in d-dimensional space using the Euclidean distance in Eq. (6).

$$D_d(k) = \sqrt{\sum_{i=0}^{d-1} [\mathbf{y}(k+i\cdot\tau) - \mathbf{y}^{NN}(k+i\cdot\tau)]^2}. \tag{6}$$

Next, the distance between the vectors in d-dimensional space is compared with the distance between the vectors when embedded in dimension $d+1$, as shown in Eq. (7).

$$\frac{|\mathbf{y}(k+i\cdot\tau) - \mathbf{y}^{NN}(k+i\cdot\tau)|}{D_d(k)} > R_t. \tag{7}$$

where R_t represents the threshold. In [11], the authors recommend the range $10 \leq R_t \leq 50$. In our case, $R_t = 10$ and a second criterion of falseness of nearest neighbors has been considered as suggested in [11] (refer to Eq. (8)).

$$\frac{D_{d+1}(k)}{R_a} \geq A_t. \tag{8}$$

where R_a is the standard deviation of the given time series data, and $A_t = 2$. For instance, $\mathbf{y}(k)$ and its nearest neighbors are false nearest neighbors if either Eq. (7) or Eq. (8) fails.

3 Principles of Our Proposal

The principal of our proposal method is illustrated by Fig. 4. First, we decompose a signal into IMFs. Second, we reconstruct the signal without IMF1 (highest frequency oscillation) to reduce noise.

Third, we find the embedding dimension of the de-noised signal. Fourth, we use the de-noise time series and obtain the embedding dimension to create a combined rule base system.

Last, we use fuzzy inference and defuzzification to predict the future value of the time series.

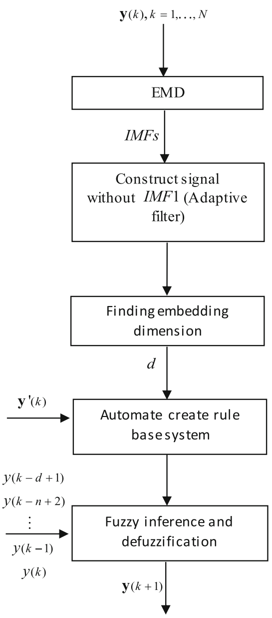

Fig. 4. Prediction time series data based on HHT and fuzzy logic.

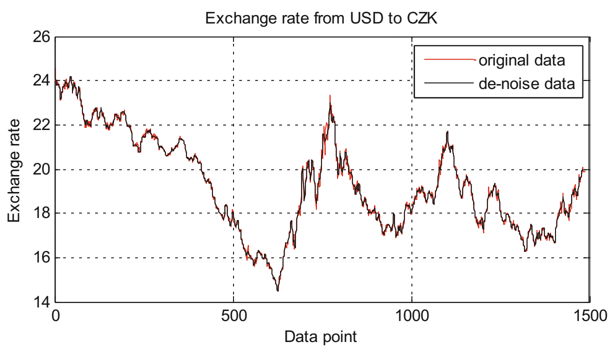

Fig. 5. Original vs denoised data.

4 Experiments

To assess the performance of our proposal, we use the daily exchange rate between USD and CZK from January 2, 2006 to December 31, 2011 (http://www.imf.org/external/data.htm). The total data length of the training set is 1481 samples. We use the exchange rate from January 2, 2012 to January 31, 2012 as test set. Figure 5 shows the original data vs de-noises data using HHT.

Figures 6 and 7 are illustrated number of false nearest neighbor of original time series and de-noise time series.

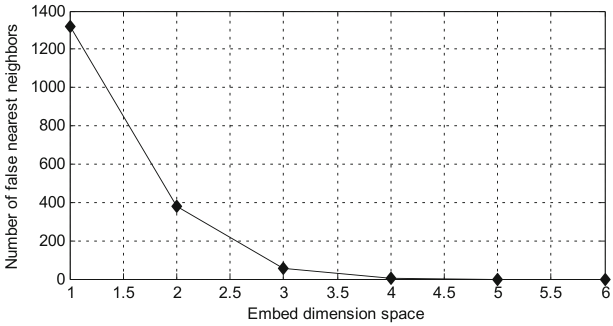

Fig. 6. Embedding dimension of original data series.

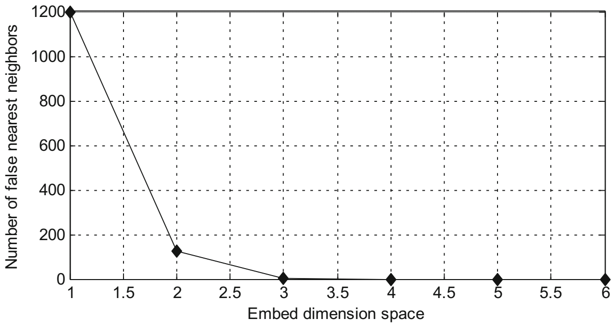

Fig. 7. Embedding dimension of de-noised data series.

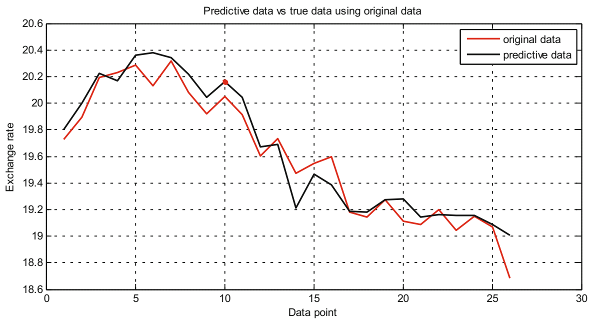

Fig. 8. Prediction data vs true data using original data.

The embedding dimension of the original time series is five, whereas the embedding dimension of the de-noised time series is four. Decreasing the embedding dimension causes a decreasing in the complexity of the dynamic system.

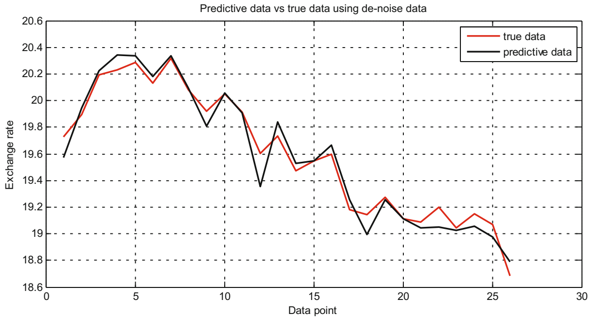

Fig. 9. Prediction data vs true data using de-noise data.

Table 1. Prediction results using original time series and de-noise time series

Data point	True data	Prediction result using original data	Prediction result using de-noise data	Square error using original data	Square error using de-noise data
1482	19.728	19.80154	19.56996	0.00541	0.02498
1483	19.893	20.00358	19.94233	0.01223	0.00243
1484	20.191	20.22731	20.22588	0.00132	0.00122
1485	20.232	20.16680	20.34387	0.00425	0.01252
1486	20.284	20.35865	20.33730	0.00557	0.00284
1487	20.131	20.38123	20.18017	0.06261	0.00242
1488	20.315	20.34327	20.33694	0.00080	0.00048
1489	20.084	20.21717	20.09638	0.01773	0.00015
1490	19.919	20.04309	19.80578	0.01540	0.01282
1491	20.053	20.16510	20.05450	0.01257	0.00000
1492	19.916	20.04421	19.90931	0.01644	0.00004
1493	19.603	19.67438	19.35378	0.00509	0.06211
1494	19.736	19.68936	19.84055	0.00218	0.01093
1495	19.474	19.21435	19.53125	0.06742	0.00328
1496	19.546	19.46789	19.54425	0.00610	0.00000
1497	19.597	19.38827	19.66438	0.04357	0.00454
1498	19.178	19.18892	19.25704	0.00012	0.00625
1499	19.142	19.18345	18.99715	0.00172	0.02098
1500	19.271	19.27229	19.25704	0.00000	0.00019
1501	19.111	19.27770	19.11268	0.02779	0.00000
1502	19.09	19.14382	19.04178	0.00290	0.00233
1503	19.202	19.16210	19.04985	0.00159	0.02315
1504	19.045	19.15661	19.02624	0.01246	0.00035
1505	19.152	19.15409	19.05783	0.00000	0.00887
1506	19.07	19.08777	18.97828	0.00032	0.00841
1507	18.683	19.00777	18.78923	0.10547	0.01124
Mean square error				**0.01658**	**0.00856**

In our case, we decrease the number of inputs to the fuzzy predictor and decrease number of rules in the combined fuzzy rule base, which decreases the time for the training and prediction process.

Figures 8 and 9, shows the prediction results vs true data using original data and de-noise data.

Table 1 lists the prediction results of the two methods. The results in these figures and table indicate that our proposal method achieves higher accuracy than direct use of the original time series.

5 Conclusions

We presented the combination of HHT, and the algorithm of false nearest neighbor to obtain a minimum embedding dimension space and fuzzy logic to predict the exchange rate between USD and CZK. The HHT serves a role in adaptive filters and reconstructed signals without high-frequency oscillation, and the IMF can reduce noise. We use a de-noised signal to obtain the embedding dimension space and training fuzzy logic system. The experiment revealed de-noised signal can decrease the embedding dimension space, decrease the complexity of the system and achieve higher accuracy prediction than direct use of the original signal.

In the future, we apply a genetic algorithm (GA) to obtain the optimal value for number of input and output regions. First, we encode the number of input and output regions as a binary chromosome. Second, we initialize the population with random bit 0 and 1 for each chromosome in the population. We use the mean square error as a cost function to evaluate the chromosomes. We use three common operators of the binary GA: selection, crossover and mutation for each evolution. After some evolution, when the stopping criterion is satisfied, we choose the best chromosome in the last population as the solution, which is the optimal value for the input and output regions.

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Non Linear Fitting Methods for Machine Learning

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Abstract. This manuscript presents an analysis of numerical fitting methods used for solving classification problems as discriminant functions in machine learning. Non linear polynomial, exponential, and trigonometric models are mathematically deduced and discussed. Analysis about their pros and cons, and their mathematical modelling are made on what method to chose for what type of highly non linear multidimension problems are more suitable to be solved. In this study only deterministic models with analytic solutions are involved, or parameters calculation by numeric methods, which the complete model can subsequently be treated as a theoretical model. Models deduction are summarised and presented as a survey.

1 Introduction

So far today, modern intelligent machines are becoming part of numberless fields of application. Learning must be an implicit function inherent in intelligent control systems to enhance industrial robots, face and voice recognition systems, self-driving vehicles, artificial vision, domotics, air crafts control, mechatronic systems and so forth. Intelligent machines relay on their capabilities of perception and sensing, planning, acting, and gradually increasing the capability for learning. Machine learning inherently develops critical functions which may be

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summarised as patterns extraction, classification and recognition [3]. Recognition issues are also referred to as discrimination functions. Regardless a classification and training process is supervised or automatic, it needs to minimise the learning errors and enable itself to recover from faults. A classifier's purpose is to enhance multiple class separability, and reduce data sparseness in an information hyperspace. Discriminant functions with enough degree of dimension must warranty non linearity to recognise any data class [7]. Since a major common tasks is fitting a model for data class discrimination, the concepts of over-fitting and under-fitting are relevant [1,8,9]. A too complex model that has been over-fitted (usually non bijective mapping) has too many parameters w.r.t. the number of observations. It produces poor performance overreacting to minor fluctuations in the training data. Under-fitting occurs when a machine learning algorithm cannot track the underlying trend of the data, such as when fitting a linear model to non-linear data, having poor performance. This work concerns the mathematical analysis of non linear fitting functions $f(\mathbf{x}_i)$ that are used for class discrimination $\mathbf{d}_i$ during a machine learning process [2]. In this study only deterministic models with analytic solutions are involved, or parameters calculation by numeric methods, where the complete model can subsequently be treated as a theoretical model. Let $g(\mathbf{d}_i)$ be an arbitrary data model that is fitted by the model $f(\mathbf{x}_i)$ such that $f(\mathbf{x}_i) \approx g(\mathbf{d}_i)$. For empirical data $\mathbf{d} \in \mathbb{R}^d$ such that $\mathbf{d}_i = (x_1, x_2, \ldots, x_d)^\top$. To treat the data as a bijective function such that $\mathbf{f} : \mathbf{x}_i \to \mathbf{d}_i = f(\mathbf{x}_i)$, then the Cartesian origin of the function $f(\mathbf{x})$ is transformed with angles $\boldsymbol{\lambda}$ for any fitting convenience through

$$\mathbf{d}'_i = \mathbf{R}_d(\boldsymbol{\lambda}) \cdot \mathbf{d} \tag{1}$$

and Cartesian translation in a multidimensional space, by using the translation vector $\boldsymbol{\tau} = (\Delta x_1, \Delta x_2, \cdots \Delta x_d)^\top$

$$\mathbf{d}'_i = \mathbf{R}_d(\boldsymbol{\lambda}) \cdot \mathbf{d}_i + \boldsymbol{\tau} \tag{2}$$

For instance, for a 3D case, let us assume that $\mathbf{R}_3 = \mathbf{R}_1\mathbf{R}_2\mathbf{R}_3$, and $\boldsymbol{\lambda} = (\lambda_1, \lambda_2, \lambda_3)^\top$

$$\mathbf{d}' = \mathbf{R}_1(\lambda_1) \cdot \mathbf{R}_2(\lambda_2) \cdot \mathbf{R}_3(\lambda_3) \cdot \mathbf{d} + \boldsymbol{\tau}_d \tag{3}$$

For any transformed data into a bijective system, the discrimination function is obtained $f(\mathbf{x}) = g(\mathbf{d})$, where now the new theoretical function is re-fitted in the discrimination space

$$f(\mathbf{x}) = \mathbf{R}_3^{-1}(\lambda_3) \cdot \mathbf{R}_2^{-1}(\lambda_2) \cdot \mathbf{R}_1^{-1}(\lambda_1) \cdot (f'(\mathbf{x}) - \boldsymbol{\tau}_d) \tag{4}$$

In Sects. 2, and 3 the exponential and polynomial methods to fit high order continuous non linear data are described. In Sect. 4 an interpolation method for high non linear order with discontinuities is described. In Sect. 5 a non polynomial fitting method for non linear functions is analysed. Subsequently, Sect. 6 treats the topic of transformation of trigonometric functions into purely polynomial functions. Section 7 discusses the topic of multivariate polynomials. Section 8 describes the multi-layer perceptron training method, which is naturally fitting model non linear highly multi-dimension data. Finally in Sect. 9 conclusion is summarised.

2 Exponential and Polynomial Regression

When data $(x_i, f(x_i))$ model an exponential discrimination function with amplitude a, and shape form b, such that

$$f(x) = ae^{bx} \tag{5}$$

We firstly may algebraically manipulate such a general model, by applying the Napierian logarithm in both sides of the equation,

$$\ln f(x) = \ln \left(\mathrm{e}^{bx}\right) \tag{6}$$

thus, developing the logarithm laws, we find that

$$\ln(f(x)) = \ln(a) + bx \tag{7}$$

We linearise the equation by redefining and substituting $\ln(f(x)) \doteq y$, as well as $\ln(a) \doteq c$, in such a way that,

$$y = c + bx \tag{8}$$

now substituting into the previous linear function to solve parameters b, and c by linear regression based on the mean square method,

$$b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2}; \qquad c = \frac{\sum y}{n} - b\frac{\sum x}{n} \tag{9}$$

substituting logarithm-based parameters and solving its algebraic inverse

$$\mathrm{e}\left(\ln(f(x)) = c + bx\right) \tag{10}$$

since $c \doteq \ln(a)$,

$$f(x) = \mathrm{e}^c \mathrm{e}^{bx} = \exp\left(\frac{\sum \ln(f(x))}{n} - b\frac{\sum x}{n}\right)\mathrm{e}^{bx} \tag{11}$$

Now for a logarithmic function, a linear regression is developed

$$f(x) = a + b\ln(x) \tag{12}$$

and

$$z \doteq \ln(x) \tag{13}$$

hence, we temporally substitute z,

$$f(z) = a + bz \tag{14}$$

the parameters are obtained through the mean squared linear regression,

$$b = \frac{n(\sum zf(z)) - (\sum z)(\sum f(z))}{n(\sum z^2) - (\sum z)^2} = \frac{n(\sum \ln(x)f(x)) - (\sum \ln(x))(\sum f(x))}{n(\sum \ln^2(x)) - (\sum \ln(x))^2} \tag{15}$$

and

$$a = \frac{\sum f(z)}{n} - b\frac{\sum z}{n} \tag{16}$$

Substituting in z, and dropping off x from Eq. (12)

$$f(x) = \left(\frac{\sum f(x)}{n} - b\frac{\sum \ln(x)}{n}\right) + b\ln(x) \tag{17}$$

When data exhibit a significant degree of error, unlike intersecting all points, but a single curve that represent the data trend as a group, is known as Regression. Reducing such trend error by the square least allows to adjust data fitting non linear functions [12]. The empirical model $y = y_m + \epsilon$ approximates a suitable theoretical model y_m. For instance, fitting the data assuming a 2^{nd} degree polynomial by the form,

$$y_m = a_0 + a_1 x + a_2 x^2 \tag{18}$$

Thus, the sum of the squared differences yields the residual formula s_r. The residual of the squared sum of the empirical and theoretical fitting model is $s_r = (y - y_m)^2$,

$$s_r = \sum_{i=1}^{n} \left(y_i - (a_0 + a_1 x_i + a_2 x_i^2 + \cdots + a_k x_i^k)\right)^2 \tag{19}$$

By partial derivatives the rate of change of the function w.r.t. each coefficient is determined by the next three equations.

$$\frac{\partial s_r}{\partial a_0} = -2\sum_{i=1}^{n}(y_i - a_0 - a_1 x_i - a_2 x^2) \tag{20a}$$

$$\frac{\partial s_r}{\partial a_0} = -2\sum_{i=1}^{n} x_i(y_i - a_0 - a_1 x_i - a_2 x^2) \tag{20b}$$

$$\frac{\partial s_r}{\partial a_0} = -2\sum_{i=1}^{n} x_i^2(y_i - a_0 - a_1 x_i - a_2 x^2) \tag{20c}$$

Equating to zero each function and algebraically factorising them, a set of linear equations in terms of their coefficients a_i are stated for subsequent solution,

$$(n)a_0 + \left(\sum_i x_i\right) a_1 + \left(\sum_i x_i^2\right) a_2 = \sum_i y_i \tag{21a}$$

$$\left(\sum_i x_i\right) a_0 + \left(\sum_i x_i^2\right) a_1 + \left(\sum_i x_i^3\right) a_2 = \sum_i x_i y_i \tag{21b}$$

$$\left(\sum_i x_i^2\right) a_0 + \left(\sum_i x_i^3\right) a_1 + \left(\sum_i x_i^4\right) a_2 = \sum_i x_i^2 y_i \tag{21c}$$

Algebraically ordering in the matrix form as a linear system $\mathbf{v} = \mathbf{A} \cdot \mathbf{a}$,

$$\begin{pmatrix} \sum_i y_i \\ \sum_i x_i y_i \\ \sum_i x_i^2 y_i \end{pmatrix} = \begin{pmatrix} n & \sum_i x_i & \sum_i x_i^2 \\ \sum_i x_i & \sum_i x_i^2 & \sum_i x_i^3 \\ \sum_i x_i^2 & \sum_i x_i^3 & \sum_i x_i^4 \end{pmatrix} \cdot \begin{pmatrix} a_0 \\ a_1 \\ a_2 \end{pmatrix} \tag{22}$$

solving the system of equations by an algebraic inverse matrix method,

$$\mathbf{a} = \mathbf{A}^{-1} \cdot \mathbf{v} \tag{23}$$

for the actual quadratic problem, the coefficients are a_0, a_1, and a_2. In addition, with standardised error $s_{y/x}$, and coefficient of determination $r^2 = (s_t - s_r)/s_t$.

3 Nonlinear Interpolation

For known precise data set points, a basic procedure is to fit a series of curves crossing through each point directly. This inter-point values estimation is known as interpolation. Let us state the general form polynomial

$$f_n(x) = b_0 + b_1(x - x_0) + b_2(x - x_0)(x - x_1) + \cdots + b_n(x - x_0)\ldots(x - x_{n-1}) \tag{24}$$

where the coefficients are obtained from the next expression,

$$b_0 = f(x_0); \quad b_1 = f(x_1, x_0); \quad b_2 = f(x_2, x_1, x_0); \quad b_n = f(x_n, x_{n-1}, \ldots, x_0) \tag{25}$$

The divided differences are described by,

$$f(x_i, x_j) = \frac{f(x_i) - f(x_j)}{x_i - x_j} \tag{26}$$

likewise, the second divided difference is deduced in the next expression,

$$f(x_i, x_j, x_k) = \frac{f(x_i, x_j) - f(x_j - x_k)}{x_i - x_k} \tag{27}$$

In such a way, the n^{th} finite divided difference is

$$f(x_n, x_{n-1}, \ldots, x_1, x_0) = \frac{f(x_n, x_{n-1}, \ldots x_1) - f(x_{n-1, x_{n-2}, \ldots x_0})}{x_n - x_0} \tag{28}$$

Such differences are useful to evaluate the coefficients of Eq. (25) substituted in Eq. (24) to obtain the interpolating polynomial, as defined next:

$$\begin{aligned} f_n(x) = f(x_0) + (x - x_0)f(x_1, x_0) + &(x - x_0)(x - x_1)f(x_2, x_1, x_0) + \cdots + \\ &(x - x_0)\cdots(x - x_{n-1})f(x_n, \ldots, x_0) \end{aligned} \tag{29}$$

which is known as the Newton's interpolation polynomial of divided differences. To avoid the divided differences calculus, the Newton interpolation is algebraically reformulated to state the Lagrange interpolation, which is concisely represented by

$$f(x) = \sum_{i=0}^{n} [L_i(x) y_i]; \qquad \forall \qquad L_i(x) = \prod_{\substack{j=0 \\ i \neq j}}^{n} \frac{x - x_i}{x_j - x_i} \tag{30}$$

or directly written as

$$f(x) = \sum_{i=0}^{n} \left[\left(\prod_{j=0}^{n} \frac{x - x_i}{x_j - x_i} \right) y_i \right] \tag{31}$$

The general model produces a polynomial equation that fits data of degree $n-1$.

$$y_i(x_i) = a_o + a_1 x_i + a_2 x_i^2 + \cdots + a_n x_i^n \tag{32}$$

4 Splines Fitting

Spline functions are concatenation of different same degree polynomials allowing to fit data segments properly [10]. Yielding better error minimisation that traditional polynomial interpolations [5]. Given a function $f(x)$ that is continuously derivable and divided in n segments along the interval $[t_0, t_n]$ and interpolates data set. Thus, $f(t_i) = y_i, \ \forall \ 0 \leq i \leq n$.

$$f(x) = \begin{cases} f_1(x), & x \in [t_0, t_1] \\ f_2(x), & x \in [t_1, t_2] \\ \vdots & \\ f_{n-1}(x), & x \in [t_{n-1}, t_n] \end{cases} \tag{33}$$

where the k^{th} degree polynomial $f_i(x) = a_0 + a_1 x + a_2 x^2 + \cdots + a_k x^k$ is a part of the whole function $f(x)$. The function f(x) continuity at an arbitrary point s may be defined by the next limits condition,

$$\lim_{x \to s^+} f(x) = \lim_{x \to s^-} f(x) = f(s) \tag{34}$$

For a quadratic function that is continuously derivable for the interval $[t_0, t_a]$, and interpolate the data. Thus if $f'(x)$ is continuous $z_i \equiv f'(t_i)$, and

$$f_i(x) = \frac{z_{i+1} - z_i}{2(t_{i+1} - t_i)}(x - t_i)^2 + z_i(x - t_i) + y_i \tag{35}$$

If so, we must prove the next three conditions $f_i(t_i)$, $f_i'(t_i) = z_i$, and $f'(t_{i+1}) = z_{i+1}$. These define the function f_i only for the interval $[t_i, t_{i+1}]$ as in Eq. (35).

$$z_{i+1} = -z_i + 2\left(\frac{y_{i+1} - y_i}{t_{i+1} - t_i}\right); \qquad (0 \leq i \leq n). \tag{36}$$

And, following the Subbotin condition for interpolating beyond the interval extremes $[a, b]$, and the inner points in the sub-intervals, $f(\tau_i) = y_i \ \forall \ 0 \leq i \leq n+1$, where $\tau_0 = t_0$, $\tau_i = 0.5(t_i + t_{i+1})$, $(1 \leq i \leq n)$, $\tau_{n+1} = t_n$ with the form,

$$f_i(x) = y_{i+1} + \frac{1}{2}(z_{i+1} - z_i)(x - \tau_{i+1}) + \frac{1}{2h_i}(z_{i+1} - z_i)(x - \tau_{i+1})^2 \tag{37}$$

where $h_i = t_{i+1} - t_i$, the coefficients z_i are found by solving the next tri-diagonal system,

$$\begin{cases} 3h_0 z_0 + h_0 z_1 = 8(y_1 - y_0) \\ h_{i+1} z_{i-1} + 3(h_{i-1} + h_i) z + h_i z_{i+1} = 8(y_{i+1} - y_i) \quad (1 \leq i \leq n-1) \\ h_{n-1} z_{n-1} + 3h_{n-1} z_n = 8(y_{n+1} - y_n) \end{cases} \tag{38}$$

5 Trigonometric Functions

Non linear periodical functions are fitting methods through calculation of trigonometric function models [6], and are capable to basically approximate any function. The general Fourier model is provided next (39),

$$f(x) = \alpha_0 + \alpha_m \cos(m\omega x) + \beta_m \sin(m\omega x) \tag{39}$$

Through expressions (40) the Fourier series independent coefficient is calculated.

$$\alpha_0 = \frac{1}{T} \int_0^T f(x) dx \tag{40}$$

and the subsequent Fourier coefficients are calculated by

$$\alpha_m = \frac{2}{T} \int_0^T f(x) \cos(m\omega_0 x) \mathrm{d}x; \qquad \beta_m = \frac{2}{T} \int_0^T f(x) \sin(m\omega_0 x) \mathrm{d}x \tag{41}$$

The function is expressed with the numerical coefficients of the Fourier series.

$$\begin{aligned} f(x) = \frac{1}{T} \int_{x=0}^T f(x) dx + \left(\frac{2}{T} \int_{x=0}^T f(x) \cos(m\omega_0 x) \mathrm{d}x \right) \cos(m\omega_0 x) \\ + \left(\frac{2}{T} \int_{x=0}^T f(x) \sin(m\omega_0 x) \mathrm{d}x \right) \sin(m\omega_0 x) \end{aligned} \tag{42}$$

6 Taylor Series

Taylor's theorem provides a way of expressing a function as a power series w.r.t. the independent variable **x**, but only applied to those functions that are continuous and differentiated within the **x**-range of interest [6]. The theorem establishes that any smooth function is approximated by a multivariate polynomial of the series,

$$f(x_0, x_1, \ldots, x_n) \sim \sum_{k=0}^{\infty} \frac{1}{k!} \left(\sum_{i=1}^{n} (x_i - h_i) \frac{\partial}{\partial x_i} \right)^k f(x_0, x_1, \ldots, x_n) \tag{43}$$

for n variables given in a vector $\mathbf{x} \in \mathbb{R}^n$, such that $\mathbf{x} = \{x_1, x_2, \ldots, x_n\}$. And the k degree Taylor expansion is developed,

$$f(\mathbf{x}) \approx f(\mathbf{x}) + \left((x_1 - h_1)\frac{\partial}{\partial x_1} + (x_2 - h_2)\frac{\partial}{\partial x_2} + \cdots + (x_n - h_n)\frac{\partial}{\partial x_n}\right)^k f(\mathbf{x}) \tag{44}$$

For instance, the expansion of Taylor series for two variables x_1 and x_2, and for $h_{1,2} = 0$, with $k = 2$ degrees (second order derivative) is developed next.

$$f(x_1, x_2) \approx f(x_1, x_2) + \left(x_1\frac{\partial}{\partial x_1} + x_2\frac{\partial}{\partial x_2}\right)^2 f(x_1, x_2) \tag{45}$$

by algebraically expanding the two degree binomial,

$$f(x_1, x_2) \approx f(x_1, x_2) + \left(x_1^2\frac{\partial^2}{\partial x_1^2} + 2x_1x_2\frac{\partial}{\partial x_1 \partial x_2} + x_2^2\frac{\partial^2}{\partial x_2^2}\right) f(x_1, x_2) \tag{46}$$

thus, the second order derivative approximation is

$$f(x_1, x_2) \approx f(x_1, x_2) + x_1^2\frac{\partial^2 f(x_1, x_2)}{\partial x_1^2} + 2x_1x_2\frac{\partial f(x_1, x_2)}{\partial x_1 \partial x_2} + x_2^2\frac{\partial^2 f(x_1, x_2)}{\partial x_2^2} \tag{47}$$

7 Multivariate Non-linear Functions

A multivariate series develops polynomials that may be used to discriminate nonlinear separable multi-class in hyper-dimension spaces [4,13] by the next general expression

$$f(x) = a_0 + \sum_{i_1}^{n} w_{i_1}x_{i_1} + \sum_{i_1}^{n}\sum_{i_2}^{n} w_{i_1 i_2}x_{i1}x_{i2} + \sum_{i_1}^{n}\sum_{i_2}^{n}\sum_{i_3}^{n} w_{i_1 i_2 i_3}x_{i_1}x_{i_2}x_{i_3} + \ldots \tag{48}$$

where a_0 is the independent coefficient; n determines the space dimension. The polynomial degree is established by the number of summed terms. $\sum_i w_i$ determines the coefficients, and $\sum_i x_i$ are the independent variables at i^{th} dimension. This approach makes particularly complex to determine all coefficients value, because multi-dimension numerical recursive methods have to be used, assuming that the independent variables are initially known values.

For instance, a linear polynomial in three dimension

$$f(x) = w_0 + \sum_{i=1}^{3} w_{i1}x_{i1} = w_0 + w_1x_1 + w_2x_2 \tag{49}$$

Another example, for a quadratic polynomial in 2D,

$$f(x) = w_0 + \sum_{i=1}^{2} w_{i1}x_{i1} + \sum_{i_1=1}^{2}\sum_{i_2=1}^{2} w_{i_1 i_2}x_{i_1}x_{i_2} \tag{50}$$

hence by developing the series and algebraically arranging,

$$f(x) = w_0 + w_1x_1 + w_2x_2 + w_{11}x_1^2 + w_2x_2^2 + x_1x_2(w_{12} + w_{21}) \tag{51}$$

8 Multi-layer Artificial Neural Networks

The ANN are discriminant functions native multidimensional and non linear that are trained by linear models [15–18]. Once the synapses parameter converged during training, the feed forward model to be used is particularly a fast and simple expression [11]. Thus, let us define the weighting sum of inputs and weights in the first layer as $net_j = \mathbf{w}^\top \cdot \mathbf{f}_j$. Where the first neurons layer outputs toward the hidden layer is $y_j = g(net_j)$. For the hidden layer $net_k = \mathbf{w}_k^\top \cdot \mathbf{y}$, and the hidden layer outputs [13,14],

$$\mathbf{z} = \mathbf{f}(\mathbf{w}_k^\top \cdot \mathbf{f}(\mathbf{w}_j^\top \cdot \mathbf{x})) \tag{52}$$

The general squared absolute differences error ε of the output neurons layer vector $\mathbf{z}_t$ and their output model vector $\mathbf{z}^o$ is stated by

$$\varepsilon(\mathbf{w}) = \frac{1}{2}\|\mathbf{z}^o - \mathbf{z}_t\| \tag{53}$$

The general back-propagation (BP) learning rule has fundamentals on the gradient descendent. The weights vector $\mathbf{w}$ recursively changes its direction until minimise the error. Thus,

$$\varDelta\mathbf{w} = -\eta\frac{\partial\varepsilon}{\partial\mathbf{w}} \tag{54}$$

where η is the learning factor that by numerical approximations represents the magnitude of the change of direction of $\mathbf{w}$. Such that $\mathbf{w}_{t+1} = \mathbf{w}_t + \varDelta\mathbf{w}_k$. Thus, by using the chain rule for the hidden neurons layer,

$$\frac{\partial\varepsilon}{\partial w_{kj}} = \frac{\partial\varepsilon}{\partial net_k} \cdot \frac{\partial net_k}{\partial w_{kj}} = -D_k\frac{\partial net_k}{\partial w_{kj}} \tag{55}$$

where the sensitivity of the hidden neurons k is $D_k = -\frac{\partial\varepsilon}{\partial net_k}$ and, the output of a single neuron, D_k is

$$D_k = -\frac{\partial\varepsilon}{\partial net_k} = -\frac{\partial J}{\partial z_k} \cdot \frac{\partial z_k}{\partial net_k} = (z_k^o - z_k)f'(net_k) \tag{56}$$

and given the activation function $f(\cdot)$, and its derivative $f'(\cdot)$ as a sigmoid for the hidden layer,

$$f(\mathbf{w}\cdot\mathbf{x}) = \frac{1}{1+\mathrm{e}^{-\mathbf{wx}}}; \quad \text{and} \quad f'(\mathbf{w}\cdot\mathbf{x}) = \frac{\mathrm{e}^{\mathbf{w}\cdot\mathbf{x}}}{(1+\mathrm{e}^{-\mathbf{w}\cdot\mathbf{x}})^2} \tag{57}$$

defining $net_k = \mathbf{w}^\top \cdot \mathbf{y}$, thus $\frac{\partial net_k}{\partial w_{kj}} = y_j$. Therefore, the learning rule for the hidden layer to the outputs is $\varDelta w_{kj} = \eta D_k y_i = \eta(z_k^o - z_k)f'(net_k)y_j$, and

$$\frac{\partial\varepsilon}{\partial w_{ji}} = \frac{\partial\varepsilon}{\partial y_j} \cdot \frac{\partial y_j}{\partial net_j} \cdot \frac{\partial net_j}{\partial w_{ji}} \tag{58}$$

the error rate of change

$$\frac{\partial \varepsilon}{\partial y_j} = \frac{\partial}{\partial y_j}\left(\frac{1}{2}\sum_{k=1^c}(z_k^o - z_k)^2\right) \tag{59}$$

thus, algebraically arranging previous expression,

$$\frac{\partial \varepsilon}{\partial y_j} = -\sum_{k=1}^{c}(z_k^o - z_k)f'(net_k)w_{ij} \tag{60}$$

the hidden layer sensitivity is defined as

$$D_j = f(net_j)\sum_{k=1}^{c} w_{ij} D_k \tag{61}$$

Hence, the learning rule for the weights $\mathbf{w}$ of the input layer toward the hidden layer,

$$\Delta w_{ji} = \eta \mathbf{w}^\top \cdot \mathbf{x} f'(net_j)\mathbf{x} \tag{62}$$

9 Conclusion and Results

This manuscript presented an analysis of numerical fitting methods purposed to be used for solving highly non linear discriminant functions in classification problems of machine learning. We found that numerous problems present non bijective discriminant paths. A partial solution that alleviates the problem is to firstly transform the path of discriminant points by geometric rotations for subsequent model fitting. Some fitting models are depicted in Fig. 1 applied to

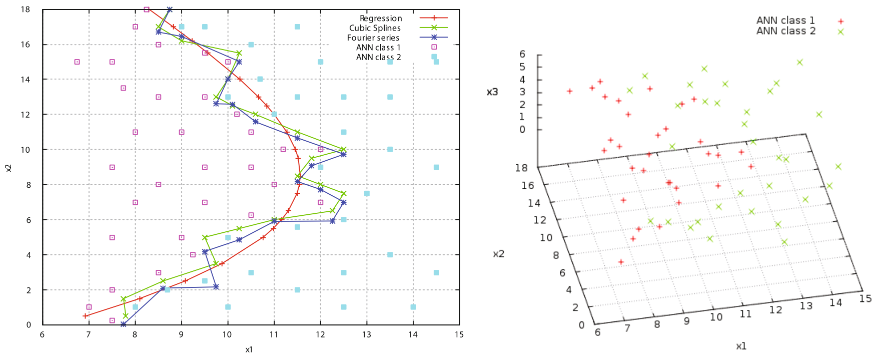

Fig. 1. Left: Different nonlinear fitting methods. Right: Same data set in 3-dimension labelled by a multi-layer Perceptron ANN. Classification performance: regression 99.8%, interpolation 99.82%, cubic splines 100%, Fourier series 99.95%, and multi-layer ANN 100%.

the same data set. Where only interpolation Splines, Fourier series, and multidimensional ANNs are methods capable to over-fit a set of discriminant threshold points that are sequentially nonlinear discontinuous. The rest of the methods yielded small degrees of classification errors.

Regressions and interpolations are numeric fitting methods that are more suitable for off-line systems with prior data. The former performs numerical computation for matrix inversion particularly for massive data. The latter, requires reduced numbers of data representing their trend, requiring symbolic calculation, hence computation becomes more complex than polynomial regressions. Although, regressions and interpolations fit to non linearity, they may fail tracking discontinuities. Thus, a more sophisticated and accurate fitting approach is by using splines. Fitting curves using the Fourier series may work better than polynomials, and even could fit major non linear discontinuities. But yielding complex and long trigonometric functions, limiting mathematical solutions. To diminish this problem, trigonometric/exponential models may further be transformed and approximated to polynomials by the Taylor series. Solving exact parameters for highly multivariate functions becomes too complex. An alternative solution is the multi-layer ANN, where highly dimensional spaces do not represent any problem. ANN overcome numerous discontinuities by increasing the number of hidden layers. Nevertheless, ANN are tided to off-line training for deep learning.

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Stability Analysis of Routing Strategies for the Maximum Lifetime Problem in One-Dimensional Ad-Hoc Wireless Networks

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Abstract. In the paper we discuss solutions of the maximum network lifetime problem in one-dimensional, regular ad-hoc wireless networks. For the problem, nodes of the network generate given amount of data and send it possibly via other nodes to the data collector. To extend the network lifetime the data should be transmitted in such a way, that the energy utilized by the most overloaded node is minimized. We assume, that the nodes use the point-to-point data transmission scheme and the cost of transmission of one unit of data is arbitrary superadditive function of a distance between transmitter and receiver. We show that for the one-dimensional network in which the nodes are evenly distributed on the line and each node generates the same amount of data there exists an equal energy solution of the problem. We treat the amount of data generated by each node and the location of the nodes on the line as the initial parameters of the problem. It is known, that solutions of the problem are very sensitive under change of these parameters. It means, that small change in the value of these parameters can change the optimal transmission graph and the solution. In the paper we analyze stability of obtained equal energy solution under modification of these two sets of parameters.

1 Introduction

Ad-hoc wireless networks are build of wireless nodes which activities are related not only to prescribed functionality but also to the routing processes and retransmission of data received from other nodes. These activities are energy consuming and for networks which nodes characterize limited energy resources it is important to optimize their consumption. This problem is especially important for networks which nodes cooperate to perform some computational tasks and their activities should be designed in a way that the amount of energy consumed by each node enables to perform these tasks for a long time. There are several definitions of ad-hoc wireless network lifetime. In [1], it was discussed the 'functional lifetime' of a sensor network, defined as a number of cycles the network can perform its functions before the first node runs out of energy. In [2] the network lifetime T_{Net} was defined in a similar way as in [1]. It was given by the

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formula $T_{\rm Net}(q) = \min_{i\in L_N}\{\frac{E_i^{(0)}}{E_i^s(q)}\}$, where $E_i^{(0)}$ is the initial energy of the i-th node and $E_i^s(q) = \sum_{j=0,j\neq i}^N q_{i,j}E_{i,j}$ is the energy necessary to send the amount $\sum_{j=1,j\neq i}^N q_{i,j}$ of data by the node to other nodes of the network. The data flow matrix $q_{i,j}$ determines the amount of data which is sent from the i-th to the j-th node. The matrix $E_{i,j}$ defines the cost of transmission of a one unit of data between these nodes. To maximize the network lifetime it means to find such data flow matrix $q_{i,j}$, that the objective function $T_{\rm Net}(q)$ of the problem reaches its maximum, i.e., $\max_q T_{\rm Net}(q)$. In [3] it was identified five power-aware metrics for data transmission in ad-hoc networks which can be used for definitions of the network lifetime. The above two definitions are equivalent to the 'time to network partition', the second metric discussed in [3]. In this paper we utilize the fifth metric defined in [3], and we will minimize the maximum node cost

$$\min_q \max_i \{E_i^s(q)\}.$$

In general formulation, the maximum network lifetime problem depends on a set of parameters which characterize activity of the nodes, available resources, the network environment and topology (understood as a spatial relation between nodes of the network). It is known, that solutions of the problem are very sensitive under change of these parameters, [2,4]. Even, if we know the exact solution of a given optimization problem there is a need to investigate its stability under change of the initial parameters to understand the structure of the solution and limitations of its applications, [5,6]. In wireless ad-hoc networks which nodes characterize limited resources of energy, for example in sensor networks, the most of their energy is utilize in the process of data transmission. For such networks extension of their lifetime can be achieved by designing energy efficient transmission protocols. Knowledge about stability of the exact solution of the maximum network lifetime problem allows to understand limitations of implemented transmission protocols in such networks.

In the paper we are considering stability of a solution of the maximum network lifetime problem for a one-dimensional, regular ad-hoc wireless network with one data collector L_N. We assume, that nodes of the network L_N are located at the points $x_i = i$, $i \in [1, N]$ of the half-line and at $x_0 = 0$ there is located the data collector. We investigate stability of the solution under changes of two sets of parameters, the amount of data Q_i, $i \in [1, N]$ generated by each node and location of the nodes x_i in the network. We assume, that the data transmission cost energy matrix $E_{i,j}$ is a function of the distance between nodes of the network, i.e., $d_{i,j} = |x_i - x_j|$. Thus change of the node location causes the change of $E_{i,j}$. The change of node location is described by the $d_i \in (-1, 1)$ parameter which measures the shift of the node from its initial location $x_i = i$. In the paper we solve the maximum network lifetime problem for L_N network for the data transmission cost energy matrix having the property

$$\forall_{x_i<x_j<x_k} \;\; E(x_i, x_j) + E(x_j, x_k) \leq E(x_i, x_k). \tag{1}$$

When the matrix $E(x_i, x_j)$ is a function of the distance between network nodes, the requirement (1) can be written in the form $E(x)+E(y) \leq E(x+y)$, $x, y \geq 0$, which is the superadditive property of a cost function, [7]. Because any function $E_{i,j} = |x_i - x_j|^a$, where $a \geq 1$ satisfies (1), then the most general form of $E_{i,j} \equiv E(x_i, x_j)$ which is an analytical function of a distance between nodes of the network and has the property (1) can be given by the power series

$$E_{i,j}(\bar{a}, \bar{\lambda}) = \sum_{n=0}^{\infty} \lambda_n |x_i - x_j|^{a_n}, \tag{2}$$

where $\lambda_n \geq 0$, $a_n \geq 1$ and $\forall_{i,j}\ 0 \leq E_{i,j}(\bar{a}, \bar{\lambda}) < \infty$. For a regular ad-hoc network L_N the distance between neighboring nodes is equal to one, $d_{i,i\pm1} = 1$ and we can assume, without loosing the generality of the problem that $E_{i,i\pm1}(\bar{a}, \bar{\lambda}) = 1$, which is equivalent to the requirement $\sum_{n=0}^{\infty} \lambda_n = 1$. From the property (1) it follows, that the lowest costs of delivery Q_i of data from the i-th node located at x_i to the j-th node located at x_j is the transmission along the shortest path with the 'next hop' transmission strategy. By the transmission along shortest path between two nodes x_i and x_j we mean the transmission along the distance $d(x_i, x_j)$. We denote by S_N the one-dimensional ad-hoc wireless network which nodes are located at arbitrary points x_i of a half-line. The network S_N can be obtained from the regular one by shifting the location of the L_N network nodes to the points $x_i = i - d_i$, where $d_i \in (-1, 1)$. For a given solution $q(x^0)$ of the maximum lifetime problem for the L_N network, where $x_i^0 = i$, we will search for a non-regular network S_N, with nodes located at the points $x_i = i - d_i$, for which the solution $q(x^0)$ can be extended. In other words, we will search for a region such that $\forall x \in U(x^0)$ the function $q(x)$ is a solution of the problem. Generally, we say that a solution $q(x^0)$ of the maximum network lifetime problem is stable under modification of the parameter x in the region $U(x^0) \subset R^N$, if for any $x \in U(x^0)$ the data flow matrix $q(x)$ is the solution of the problem. The region $U(x^0)$ we call the stability region of the solution $q(x)$ with respect to the parameter $x \in R^N$. We can define stability of a solution in terms of graphs. For a given initial parameters x^0, Q^0 of the maximum lifetime problem the solution can be represented by the transmission graph t weighted by elements of the data flow matrix $q_{i,j}(x^0, Q^0)$. This solution is stable under modification of the initial parameters in the stability region $U(x^0, Q^0)$ if for all $x, Q \in U(x^0, Q^0)$ solutions of the problem have the same transmission graph t.

In [4] it was analyzed the maximum lifetime problem in wireless sensor networks with radio transmission model in which the sensors use the omnidirectional antennas and the maximum achievable transmission rate between the transmitter and receiver is given by the Shannon-Hartley channel capacity formula, [8]. In [4] it was proven that when the transmitter adjust the power of its radio signal to the distance to the receiver and there is no interference of signals the solution of the maximum lifetime problem is equivalent to the solution of the problem written in terms of data flow and data transmission cost energy matrices $q_{i,j}$, $E_{i,j}$.

In the next section, a sufficient condition for existence of an equal energy solution in the L_N network is derived and an analytical solution for the inputs which meet that condition is given. Also, the stability of this analytical solution is examined. We analyze in detail the scope of the parameters Q_i and the location of the nodes x_i, $i \in [1, N]$ for which the solution $q(Q^0, x^0)$ of the maximum network lifetime problem in the L_N network can be continuously extended.

2 Formulation of the Problem

We define the maximum network lifetime problem for a one-dimensional, ad-hoc wireless network S_N build of N nodes and one data collector by the set of following relations

$$\begin{cases} \min_q \max_{i \in S_N} \{E_i^s(q)\}, \\ E_i^s(q) = \sum_{j \in V_i^{(out)}} q_{i,j} E_{i,j} \leq E_i^{(0)}, \\ \sum_{j \in V_i^{(out)}} q_{i,j} = Q_i + \sum_{j \in V_i^{(in)}} q_{j,i}, \\ q_{i,j} \geq 0, E_{i,j} \geq 0, Q_i \geq 0, E_i^{(0)} \geq 0, \end{cases} \tag{3}$$

where $E_i^{(0)}$ is the initial energy of the i-th node, Q_i is the amount of data generated by the node, $E_{i,j}$ is the energy necessary to send one unit of data between i-th and j-th nodes. The data flow matrix $q_{i,j}$ defines the amount of data which is sent between i-th and j-th nodes. By $V_i^{(out)}$ and $V_i^{(in)}$, $i \in [1, N]$ we denote neighborhoods of each node. $V_i^{(out)}$ is a set of network nodes to which the i-th node can send any data, and $V_i^{(in)}$ is a set of nodes from which it can receive any data. The third equation in (3) is data flow conservation constraint, which states that the amount of data generated by each node and the amount of data received from other nodes must be equal to the amount of data which the node can send. All the matrices q, which satisfy the third equation in (3) form a domain of the objective function of the problem

$$E_*(q) = \max_i \{E_i^s(q)\}_{i=1}^N. \tag{4}$$

To solve the problem (3) it means to find a global minimum of (4). The following simple lemma shows that, any local minimum of the objective function (4) is a solution of the problem (3).

Lemma 1. *Any minimum of the objective function (4) is a solution of (3).*

Proof. The feasible set

$$U_F(q) = \{q \in R_+^{(N+1)^2} | \sum_{j \in V_i^{(out)}} q_{i,j} - \sum_{j \in V_i^{(in)}} q_{j,i} - Q_i = 0,\ i \in [1, N]\},$$

where R_+ is a set of non-negative real numbers, is a domain of the objective function $E_*(q)$ and it is a linear in $R_+^{(N+1)^2}$. From the linearity of $U_F(q)$ it follows, that any two points $q_0, q_1 \in U_F(q)$ can be connected by a line segment and $\forall_{t \in [0,1]}\ tq_0 + (1-t)q_1 \in U_F(q)$. The objective function (4) of the maximum lifetime problem (3) is a piecewise linear in the q variable, which means that

$E_*(tq_0+(1-t)q_1) = tE_*(q_0)+(1-t)E_*(q_1)$. Let us assume, that q_0 is a minimum of $E_*(q)$ and there exists another local minimum q_1 such that $E_*(q_0) < E_*(q_1)$, then from the linearity of $E_*(q)$ it follows that $\forall_{t\in[0,1]}$ $E_*(tq_0 + (1-t)q_1) = tE_*(q_0) + (1-t)E_*(q_1) < tE_*(q_1) + (1-t)E_*(q_1)$ and $\forall_{t\in[0,1]}$ $q(t)$ the inequality $E_*(q(t)) < E_*(q_1)$ holds, which means that q_1 cannot be a minimum of $E_*(q)$ in $U_F(q)$ and q_0 is a global minimum. □

Generally, we are looking for solution of the problem (3) in non-negative real numbers $q_{i,j} \in R_+^0$. But, if we assume that

$$Q_i \in Z_+, \quad q_{i,j} \in Z_+^0, \tag{5}$$

then we get the mixed integer linear programming problem for the network lifetime.

Proposition 1. *The mixed integer linear programming problem for the maximum network lifetime is NP-hard.*

Proof. We reduce the partition problem, [9], to the maximum network lifetime problem given by the set of relations (3) and requirement (5). Let us write the definition of the feasible set, given by the third relation in (3), in the form

$$\forall_{i\in[1,N]} \quad \sum_{q_{i,j}\in A_i'} q_{i,j} = Q_i + \sum_{q_{j,i}\in A_i\setminus A_i'} q_{j,i}, \tag{6}$$

where $A_i = \{q_{i,j}, j \in V_i^{(out)}, q_{j,i}, j \in V_i^{(in)}\}$ and $A_i' = \{q_{i,j}, j \in V_i^{(out)}\}$. Because the solution $q_{i,j}$ of (3) must lie on the hyperplane (6), then solving this problem requires to solve the partition problem. □

As can be seen from (3), the problem depends on the topology of the network $\{V_i^{(out)}\}_{i\in[1,N]}$ and the set of the following parameters $\{Q_i, E_{i,j}, E_i^{(0)}\}$. We slightly simplify the problem (3) and assume, that the set $\forall_{i\in[1,N]} V_i^{(out)} = S_N$ which means that any node of S_N can send its data to any other node of the network or to the data collector. We also assume, that the initial energy of the nodes $E_i^{(0)}$ is sufficiently large that allow them to deliver the generated data to the data collector.

In the next sections we investigate the criteria for which an equal energy solution of the problem (3) exists and give the analytical solution of the problem.

3 Solution of the Maximum Network Lifetime Problem for L_N

For the data transmission cost energy matrix of the form (2) and wide range of values of the Q_i parameters, $i \in [1, N]$ there exists an equal energy solution q of the problem (3), i.e., a solution for which the energies of each node are equal $\forall_{i\in[1,N-1]}$ $E_i^s = E_{i+1}^s$. The following lemma estimates the scope of E_i^s for such solutions.

Lemma 2. *For the maximum network lifetime problem (3) with $E_{i,j}$ of the form (2), for which there exists an equal energy solution $q(Q)$, the energy of each node $E_i^s(q)$ is in the interval*

$$E_i^s(q) \in [\frac{1}{N}\sum_{j=1}^{N} jQ_j,\ \sum_{j=1}^{N} Q_j). \tag{7}$$

Proof. The upper bound of the node energy $E_i^s(q)$ we estimate for $E_{i,j} = |i-j|^a$, $a \geq 1$. From the linearity of the problem (3) it follows that this estimation is valid for any $E_{i,j}$ of the form (2). Because for any $a \geq 1$ the energies of the nodes must be finite $E_i^s(q,a) < \infty$, then we have

$$\forall_{i\in[1,N]}\ \lim_{a\to\infty} E_i^s(q,a) = \lim_{a\to\infty}\sum_{j=0}^{N} q_{i,j}|i-j|^a = q_{i,i-1} + q_{i,i+1}.$$

We show that, for $a \gg 1$ and any $Q_i \geq 0$, $q_{i,i+1} \to 0$. Let us assume that $q_{i,i+1} \neq 0$, because of the 'no loop' requirement

$$q_{i,j} \neq 0 \Rightarrow q_{j,i} = 0,$$

the minimum energy of the $(i+1)$-th node necessary to send the amount $(Q_{i+1} + q_{i,i+1})$ of data in the data collector direction is achieved when the data is transmitted to the $(i-1)$-th node, omitting the i-th node. It means that for $a \gg 1$ this energy tends to infinity

$$\lim_{a\to\infty}(Q_{i+1} + q_{i,i+1} + \cdots)E_{i+1,i-1} = (Q_{i+1} + q_{i,i+1} + \cdots)2^a = \infty.$$

Because, in the limit $a \to \infty$, for any $Q_i \geq 0$, the solution of (3) tends to the 'next hop' data transmission strategy, then $\max E_i^s < \sum_{j=1}^{N} Q_j$, which is the upper bound from (7). To estimate the lower bound of E_i^s we remark, that the minimum energy $E_p^{\min}(Q_i)$ necessary to deliver the amount Q_i of data to the data collector, for $E_{i,j}$ of the form (2), is achieved for the 'next hop' data transmission strategy q^{nh} along the shortest path between the i-th node and the data collector, i.e.,

$$E_p^{\min}(Q_i, q^{\mathrm{nh}}) = Q_i \sum_{j=1}^{i} E_{j,j-1} = iQ_i. \tag{8}$$

The total energy $\sum_{i=1}^{N} E_i^s(q)$ consumed by all nodes of the L_N network, for any data transmission flow matrix q is equal to the cost of delivery of all Q_i to the data collector

$$\sum_{i=1}^{N} E_i^s(q) = \sum_{i=1}^{N} E_p(Q_i, q).$$

For an equal energy solutions q, $\forall_{i\in[1,N]}\ E_i^s(q) = E_0^s$, we have $E_0^s = \frac{1}{N}\sum_{i=1}^{N} E_p(Q_i, q)$, and from (8) it follows that the lower bound of E_i^s is $\frac{1}{N}\sum_{j=1}^{i} jQ_j$. □

The following proposition estimates values of the parameters Q_i for which there exists an equal energy solution of (3) for the regular ad-hoc wireless network L_N.

Proposition 2. *For the maximum network lifetime problem (3) with $E_{i,j}$ satisfying (1) and Q_i such that*

$$\forall_{i\in[1,N-1]} \quad Q_{i+1} > \frac{1}{E_{i+1,0}} E_i^s(Q, q, L_i), \tag{9}$$

$Q_1 \geq 1$, there exists an equal energy solution q, and the only non-zero elements of the data flow matrix q are $q_{i,0}$ and $q_{i,i-1}$, $i \in [1, N]$.

Proof. Let us assume that for L_N network and given set of parameters $Q = (Q_1, \cdots, Q_N)$ there exists an equal energy solution q of (3), i.e., a solution for which $\forall_{i\in[1,N-1]}\ E_i^s(q) = E_{i+1}^s(q)$. We denote the equal energy spend by each node by $E_0^s(Q, L_N)$. We add at the end of the L_N network the $(N+1)$-th node and assume that it generates the amount $Q_{N+1} > \frac{1}{E_0^s(Q,L_N)}$ of data. If the $(N+1)$-th node sends the amount $q_{N+1,0} = \frac{1}{E_{N+1,0}} E_0^s(Q, L_N)$ of data directly to the data collector, and the rest of the data $q_{N+1,N} = Q_{N+1} - \frac{1}{E_{N+1,0}} E_0^s(Q, L_N)$ to the nearest neighbor, then it spends the amount

$$E_{N+1}^s(Q) = Q_{N+1} + (1 - \frac{1}{E_{N+1,0}}) E_0^s(Q, L_N) \tag{10}$$

of energy. Because of the requirement (9), the inequality $q_{N+1,N} > 0$ is satisfied and it blocks the data transmission from the nodes of the L_N network to the $(N+1)$-th node. This means that the energy spend by $(N+1)$-th node $E_{N+1}^s(Q, L_{N+1}) \geq E_0^s(Q, L_N)$. The energy $E_{N+1}^s(Q, L_{N+1})$ given by the formula (10) is optimal because it is a sum of the minimal energy $E_0^s(Q, L_N)$ which must spend the $(N+1)$-th node and the energy of the most efficient data transmission in L_{N+1} network - the 'next hop' data transmission strategy. □

From the Proposition 2 it follows that for an equal energy solution of (3) in the L_N network, the energy spend by each node $E_0^s(Q, L_N)$ satisfies the recurrence equation

$$E_0^s(Q, L_N) = Q_N + (1 - \frac{1}{E_{N,0}}) E_0^s(Q, L_{N-1}), \quad N \geq 2, \tag{11}$$

where $E_0^s(Q, L_1) = Q_1$. The Eq. (11) can be easily solved.

Lemma 3. *Solution of the recurrence Eq. (11) for the energy of a node $E_0^s(L_N)$ is given by the following polynomial*

$$E_0^s(Q, L_N) = Q_N + \sum_{j=2}^{N} Q_{j-1} \prod_{r=j}^{N} (1 - \frac{1}{E_r}), \quad N \geq 2, \tag{12}$$

where E_r, $r \in [2, N]$ is the data transmission cost energy matrix $E_{i,j}(\bar{a}, \bar{\lambda})$ from (2) for $x_i = i$ and $r = i - j$.

Proof. By inserting the formula (12) into (11) we get the thesis of the lemma. □

From the Proposition 2 it also follows that for the amount of data Q_i generated by each node in L_N network satisfying (9), the only non-zero elements of the optimal data transmission flow matrix q are $q_{i,0}$ and $q_{i,i-1}$. Putting this requirements into (3) we get the following set of linear, recurrence equations

$$\begin{cases} q_{1,0} = q_{2,0}E_2 + q_{2,1}, \\ q_{i,0}E_i + q_{i,i-1} = q_{i+1,0}E_{i+1} + q_{i+1,i} \quad i \in [2, N], \\ q_{1,0} = Q_1 + q_{2,1}, \\ q_{i,0} + q_{i,i-1} = Q_i + q_{i+1,i}, \quad i \in [2, N], \end{cases} \tag{13}$$

where E_r is the data transmission cost energy matrix from the Lemma 3. The first two equations are the equal energy solution requirements and the next two define the feasible set of the problem (3). In the next lemma we give the solution of (13).

Lemma 4. *Solution of the set of recurrence Eq. (13), for a constant Q_i, is given by the following polynomials*

$$\begin{cases} q_{1,0} = Q_N + \sum_{j=2}^{N} Q_{j-1} \prod_{r=j}^{N} (1 - \frac{E_1}{E_r}), \\ q_{2,0} = \frac{E_1}{E_2} Q_1, \\ q_{i,0} = \frac{E_1}{E_i} (Q_{i-1} + \sum_{j=1}^{i-2} Q_{i-j-1} \prod_{r=1}^{j} (1 - \frac{E_1}{E_{i-r}})), \quad i \in [3, N], \\ q_{2,1} = Q_2 - \frac{E_1}{E_2} Q_1, \quad N = 2, \\ q_{2,1} = \sum_{k=2}^{N} Q_k - \sum_{k=2}^{N} \frac{E_1}{E_k} Q_{k-1} - \sum_{k=3}^{N} \frac{E_1}{E_k} \sum_{j=1}^{k-2} Q_{k-j-1} \prod_{r=1}^{j} (1 - \frac{E_1}{E_{k-r}}), \quad N \geq 3, \\ q_{i,i-1} = \sum_{k=i}^{N} Q_k - \sum_{k=i}^{N} \frac{E_1}{E_k} (Q_{k-1} + \sum_{j=1}^{k-2} Q_{k-j-1} \prod_{r=1}^{j} (1 - \frac{E_1}{E_{k-r}})), \quad i \in [3, N], \end{cases} \tag{14}$$

where E_r is given by (2) for $x_i = i$, and $i - j = r$.

Proof. By inserting the formulas (14) into (13) we get the thesis of the lemma. □

A special case of (14) is a solution the maximum network lifetime problem discussed in [1]. For $E_{i,j} = \sum_{s=0}^{\infty} \lambda_s |i-j|^{a_s}$ and $\lambda_s = E_t \gamma^s \frac{1}{s!}$, $a_s = \alpha + s$, $a \geq 2$, $\gamma \geq 0$, we obtain the cost energy matrix $E_{i,j} = E_t |i-j|^{\alpha} e^{\gamma|i-j|}$ from [1]. For $E_{i,j} = |i-j|^a$ and $a = 2$ the formula for $q_{i,0}$ in (14) can be reduced to the following simple form $q_{i,0} = \frac{i - H_i}{i(i-1)}$, where $H_i = \sum_{k=1}^{i} \frac{1}{k}$ is the i-th harmonic number, [10].

The next two lemmas describe the size of the stability region $U(Q)$, for Q satisfying (9), in which the functions (14) are solution of (3). From the Lemmas 3 and 4 it follows.

Lemma 5. *The formulas (14) give the solution to the maximum network lifetime problem (3) for any Q_N in the interval*

$$Q_N \in (Q_N^{\min}, \infty), \tag{15}$$

where

$$Q_N^{\min} = \frac{1}{E_N}(Q_{N-1} + \sum_{j=2}^{N-1} Q_{j-1} \prod_{r=j}^{N-1}(1 - \frac{1}{E_r})) \tag{16}$$

is a solution of the equation $q_{N,N-1}(Q_N^{\min}, L_N) = 0$.

Proof. The upper bound for Q_N in (15) follows from the Lemma 3 and (9). The lower bound of Q_N is determined by the energy $E_i^s(L_{N-1})$ consumed by each node in the L_{N-1} network. If the Q_N value is such that $Q_N^{\min} E_{N,0} = E_i^s(L_{N-1})$ then the N-th node can send all of its data directly to the data collector. This means that for $Q_N > Q_N^{\min}$, $q_{N,N-1}(Q_N, L_N) > 0$. This inequality is equivalent to (9) for $i = N-1$. The solution of the equation $q_{N,N-1}(Q_N^{\min}, L_N) = 0$, for fixed values of Q_i, $i \in [1, N-1]$ is given by (16). □

The next lemma describes the scope of the parameters Q_i, $i \in [1, N-1]$ for which the functions (14) are solution of the maximum network lifetime problem (3).

Lemma 6. *The formulas (14) give the solution to the maximum network lifetime problem (3) for any Q_i in the interval*

$$Q_i \in (0, Q_i^{\max}), \;\; i \in [1, N-1], \tag{17}$$

where $Q_i^{\max}$ is a solution of the equation

$$q_{i+1,i}(Q_i^{\max}, L_N) = 0, \;\; i \in [1, N-1]. \tag{18}$$

Proof. The constrains (9) give the lower bound of Q_i for which a solution of (3) is given by (14). The constrains were obtained by calculating recursively the minimum value of Q_i for the L_i network, for which the i-th node is the last one and does not receive any data from other nodes. We can improve the estimation of the lower bound for Q_i by taking into account the data received by the i-th node from the nodes $j \in [i+1, N]$ of the L_N network. The improved estimation for Q_i, $i \in [1, N-1]$ is given by the following set of inequalities

$$\begin{cases} Q_1 + q_{2,1}(Q_1, L_N) > 0, \\ Q_i + q_{i+1,i}(Q_i, L_N) > \frac{1}{E_i} E_0^s(Q, q, L_{i-1}), \;\; i \in [2, N-1], \end{cases} \tag{19}$$

where $q_{i+1,i}(Q, L_N)$ is given in (14). The above inequalities allow us to determine the maximum value of Q_i for which the functions (14) are solution of (3). Instead of minimizing the Q_{i+1} value in (19) we can maximize Q_i, and by this the energy $E_0^s(L_i)$, such that $q_{i+1,i} = 0$. The requirement for the maximum value of Q_i, $i \in [1, N-1]$ is given by the set of equations

$$\begin{cases} (Q_2 + q_{3,2}(L_N))\; E_2 = Q_1^{\max}, \\ (Q_{i+1} + q_{i+2,i+1}(Q_i^{\max}, L_N))\; E_{i+1} = E_0^s(Q_i^{\max}, L_i), \;\; i \in [2, N-2], \\ Q_N \; E_N = E_0^s(Q_{N-1}^{\max}, L_{N-1}), \end{cases} \tag{20}$$

where $E_0^s(Q_i^{\max}, L_i) = q_{1,0}(Q_i^{\max}, L_i)$. With the help of (14) one can easily check that the formulas (20) and (18) are equivalent. To estimate the lower bound of Q_i, $i \in [2, N-1]$ we use the inequalities (19). The inequalities (19) are equivalent to set of the equations for $Q_i^{\min}$

$$q_{i,i-1}(Q_i^{\min}, L_N) = 0, \quad i \in [2, N-1],$$

which means that all of data of the i-th node is sent directly to the data collector. From the first inequality in (20) it follows that $\forall_{Q_1}\ q_{2,1}(Q) > 0$ and Q_1 can be arbitrary small, which means that $Q_1^{\min} = 0$. From (14) it follows that the inequality $q_{i,i-1}(Q_i, L_N) > 0$ is satisfied for arbitrary small Q_i, and thus $Q_i^{\min} = 0$. □

4 Solution Stability Under Modification of Node Location

Let us denote by S_N a one-dimensional, ad-hoc wireless network which nodes are located at the points $x_i = i - d_i$ of the half-line, where $d_i \in (-1, 1)$, $i \in [1, N]$. We know, that the equal energy solution of (3) with the data transmission cost energy matrix (2) for $d_i = 0$ is given by (14). We expect, that for small d_i the solution of (3) will be also of the form (14). The solution (14) has been obtained under assumption that $\forall_{i\in[1,N]} E_{i,i-1} = 1$. Change of the node location causes change of the data transmission cost energy matrix elements and the set of functions (14) must be modified to get proper solution of (13) with $E_{i,i-1} \neq 1$. The set of linear recurrence Eq. (13) for an equal energy solution of (3) in the S_N network we write in the matrix form. The data conservation flow constraints, the third equation in (3) and the equal energy solution requirements $\forall_{i\in[1,N-1]}\ E_i^s = E_{i+1}^s$ we write in the form

$$M\boldsymbol{q} = \boldsymbol{Q}_0, \tag{21}$$

where $\boldsymbol{q} = (q_{N,0}, \cdots, q_{1,0}, q_{2,1}, \cdots, q_{N,N-1})$, $\boldsymbol{Q}_0 = (1, \cdots, 1, 0, \cdots, 0)$, and

$$M = \begin{pmatrix} I_{N,N} & A_{N,N-1} \\ B_{N-1,N} & C_{N-1,N-1} \end{pmatrix}$$

is an invertible matrix $(2N-1) \times (2N-1)$. The elements of the matrix M have the form

$$\begin{cases} I_{i,j} = \delta_{i,j}, & i, j \in [1, N], \\ A_{i,j} = \delta_{i,N-j} - \delta_{i,N-j+1}, & i \in [1, N], j \in [1, N-1], \\ B_{i,j} = -E_{i+1,0}\ \delta_{i,N-j} + E_{i,0}\ \delta_{i,N-j+1}, & i \in [1, N-1], j \in [1, N], \\ C_{i,j} = -E_{i+1,i}\ \delta_{i,j} + E_{i,i-1}\ \delta_{i,j+1}, & i, j \in [1, N-1]. \end{cases} \tag{22}$$

In (22) the data transmission cost energy matrix $E_{i,j}$ is given by (2). The form of the matrix M is chosen in such way that allows in an easy way to extend it for an arbitrary number of nodes added to the S_N network. Namely, after adding a new node to S_N network we must resize the matrix M by adding two rows, one on the top and one on the bottom of M, and two columns, one on the left hand side, and one on the right hand side of M. In this section we would like to investigate the stability of the problem (3) under modification of node location by change of the parameters $d = (d_1, \cdots, d_N)$. We estimate the size of the intervals $d_i \in (d_i^L, d_i^R)$ for which solution of the set of linear recurrence Eq. (21) for an equal energy solution of (3) can be extended, where $d_i^L \in (-1, 0)$ and $d_i^R \in (0, 1)$ are maximum shifts from the initial location $x_i = i$ of the node to the left and to the right of x_i respectively. In other words, we will search for a set of networks S_N with the data transmission cost energy matrix (2) for which the solution of the problem (3) satisfies (21). To estimate the asymptotic properties of the optimal energy consumed by each node of the S_N network we must fix the size of the network, i.e., we assume that $D(S_N) = |x_N - x_0| = \text{const}$. The following lemma generalizes the Lemma 2 and estimates the scope of the energy spend by each node of the S_N network, when $E_{i,j}$ is of the form (2).

Lemma 7. *For the maximum network lifetime problem (3), and $E_{i,j}$ of the form (2), for which there exists an equal energy solution $q(Q)$, the energy of each node $E_i^s(q)$ is in the interval*

$$E_i^s(q) \in [\frac{1}{N} \sum_{i=1}^{N} Q_i \sum_{j=1}^{i} E_{j,j-1}, \max_{i \in [1,N]} \{E_{i,i-1} \sum_{j=i}^{N} Q_j\}). \tag{23}$$

Proof. The lower bound for $E_i^s(q, Q)$ follows from the property (1) of the data transmission cost energy matrix (2) and the Lemma 2. The upper bound we determine for $E_{i,j} = |x_i - x_j|^a$ where $a \geq 1$. From linearity of the problem it follows that it is valid for any data transmission cost energy matrix of the form (2). We can use the result of the Lemma 2, which states that for $a \to \infty$ the optimal transmission tends the 'next hop' data transmission strategy. For a fixed size of the network $D(S_N) = |x_N - x_0| = N$ and nodes location at points $x_i = i - d_i$, $d_i \in (-1, 1)$, there is at least one distance $d_{i,j} = |x_i - x_j| > 1$. For the i-th node which distance to the neighboring node is greater than 1, the cost of data transmission does not exceed $E_{i,i-1} \sum_{j=i}^{N} Q_j$ and for $a \to \infty$ grows to infinity. The maximum node cost E_i^s must be selected among all values $E_{i,i-1} \sum_{j=i}^{N} Q_j$ for $i \in [1, N]$, what is stated in the formula (23). □

The next lemma gives the exact form of the energy of each node $E_i^s(q, S_N)$, $i \in [1, N]$ for an equal energy solution of (3) for the S_N network and it is generalization of the formula (12).

Lemma 8. *The energy $E_0^s(S_N)$ of each node of the S_N for an equal energy solutions of (21) is given by*

$$E_0^s(S_N) = \frac{1}{\det M_N} \sum_{k=1}^{N-1} Q_k \prod_{i=1}^{k} E_{i,0} \prod_{i=k+1}^{N} (E_{i,0} - E_{i,i-1}) + Q_N \prod_{i=1}^{N} E_{i,0}, \quad N \geq 2, \tag{24}$$

where $E_0^s(L_1) = E_{1,0}$.

Proof. For an equal energy solution the Eq. (21) for $q_{1,0}$ has the form

$$E_0^s(S_N) = Q_N \frac{\prod_{i=1}^{N} E_{i,0}}{\det M_N} + (E_{N,0} - E_{N,N-1}) \frac{\det M_{N-1}}{\det M_N} E_1^s(L_{N-1}), \tag{25}$$

where $E_0^s(S_N) = E_i^s(S_N)$, $i \in [1, N]$. It is easy to check that $E_0^s(S_N)$ given by (24) is a solution of (25) with the initial condition $E_0^s(L_1) = E_{1,0}$. □

The general solution of the Eq. (21) has very complicated form. In this paper, we investigate the stability of the solution of the Eq. (21) under modification of each parameter $d_i \in (-1, 1)$ separately and for $Q_i = 1$, $i \in [1, N]$. It means that, we will change the i-th node location, keeping all other nodes of S_N in the points $\forall_{j \neq i}\; x_j = j$. The necessary requirement for the stability of a solution (21) with respect to the parameter d_i is given by the set of inequalities $q_{i,0}(d, S_N) > 0, i \in [1, N]$, where $(d_1, \cdots, d_N) \in (-1, 1)^N$. The maximal possible shift of the i-th node to the left d_i^L and to the right d_i^L from the initial location $x_i = i$ satisfies the following equations

$$\begin{cases} q_{i,0}(d_i^L, S_N) = 0, \\ q_{i+1,0}(d_i^R, S_N) = 0. \end{cases}$$

The next lemma estimates the scope of d_i for any $E_{i,j}$ of the form (2), for which the node can be moved without changing the optimal transmission strategy. We have the following

Lemma 9. *For the parameter d_i, $i \in [1, N]$, $N > 3$, $Q_j = 1$, $j \in [1, N]$, the stability region of $U(d_i, E)$, for any $E_{i,j}$ of the form (2), is inside the interval*

$$U(d_i, E) \subseteq (d_i^L, d_i^R),$$

where

$$\begin{cases} d_1^L = -1, \\ d_i^L = -\frac{1}{4}\left(\sqrt{N(8i + N(N+1-i)^2)} - N(N+1-i)\right), \\ i < \frac{N^2+N+2}{2N}, i \in [2, N-1], \\ d_i^L = -1, \text{otherwise}, \\ d_N^L = -1, \end{cases} \tag{26}$$

it the shift to the left and

$$\begin{cases} d_1^R = \frac{\sqrt{N(N^3+2N^2+5N-8)}-N-N^2}{2N-4}, \quad N > 2, \quad d_1^R(L_2) = \frac{1}{3}, \\ d_i^R = \frac{\sqrt{N(8i(1+i)(N-1-i)+N(3-i^2+N+iN)^2)}-N^2(1+i)+N(i^2-3)}{4(N-1-i)}, i \in [2, N-2] \\ i < \frac{1}{4N}(N^2 - N - 2 + \sqrt{4 - 12N + 37N^2 + 6N^3 + N^4}), \; N > 3, \\ d_i^R = 1, \text{otherwise}, \\ d_{N-1}^R = 1, d_N^R = 1. \end{cases} \tag{27}$$

the shift to the right of the senors.

Proof. Because the stability region $U(d_i, E)$ for any E of the form (2) is smaller than the stability region $U_0(d_i)$ for $E_{i,j} = |x_i - x_j|$, then it is enough to show that $U_0(d_i)$ is given by (26), (27). The solution of the Eq. (21) for $E_{i,j} = |x_i - x_j|$, where $x_i = i - d_i$ has the form

$$\begin{cases} q_{i,0}(d_i, S_N) = \frac{iN+(N+1-i)Nd_i-2d_i^2}{2N(i-d_i)}, \\ q_{i+1,0}(d_i, S_N) = \frac{i(i+1)N-(N(i+1)-i^2+3)Nd_i-2(N-1-i)d_i^2}{2(i+1)N(i-d_i)}. \end{cases} \quad (28)$$

The roots of (28) with respect to d_i variable are given by (26) and (27). □

The Fig. 1 shows the allowed moves of the i-th sensor for which the data flow matrix $q(d_i)$ is a solution of the maximum lifetime problem given by (21).

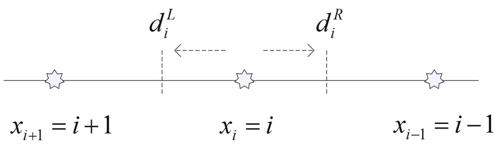

Fig. 1. Moves of the i-th node in the stability region.

From the Lemma 9 it follows that when the number of nodes grows, then the stability regions $U(d_i, E)$ shrinks. The exact size of the stability regions $U(d_i, E)$ can be calculated by solving the Eq. (21) for particular form of (2) and finding the interval in which inequalities $q_{i,0}(d_i, S_N) > 0$, and $q_{i+1,0}(d_i, S_N) > 0$ are satisfied. For example, for $a = 1$, we have $-1 < d_1(S_3) < 0.245$, but for $a = 1.1$, $-1 < d_1(S_3) < 0.21$ or for $a = 2$, $-1 < d_1(S_3) < 0.1$.

In Lemma 9 to estimate the size of the stability region $U(d_i, E)$ we used the particular solution of (3) with the data transmission cost matrix $E_{i,j} = |x_i - x_j|$, i.e., with the exponent $a = 1$, $x_i = i - d_i$ and $Q_i = 1$. Because for $E_{i,j} = |x_i - x_j|$ the costs of delivery of any data to the data collector in S_N do not depend on the number of hops along the shortest path, then there exists an infinite number of solutions of (3). In the next lemma, which we give without the proof, we generalize the solution (28) of (3) to arbitrary Q_i.

Lemma 10. *For the data transmission cost energy matrix $E_{i,j} = |x_i - x_j|$, where $x_i = i - d_i$ and Q_i satisfies (9) an equal energy solution of the maximum lifetime problem (3) is given by the data flow matrix*

$$\begin{cases} q_{1,0} = \frac{1}{N}\frac{1}{x_1}\sum_{j=1}^{N} x_j Q_j, \\ q_{i,0} = \frac{1}{N x_i x_{i-1}}(N(x_i - x_{i-1})\sum_{j=1}^{i-1} x_j Q_j + (i x_{i-1} - (i-1)x_i)\sum_{j=1}^{N} x_j Q_j), \quad i \in [2, N], \\ q_{N,0} = (1 - \frac{N-1}{N}\frac{x_N}{x_{N-1}})Q_N + \frac{1}{N}\frac{1}{x_{N-1}}\sum_{j=1}^{N-1} x_j Q_j, \\ q_{i,i-1} = \frac{1}{N}\frac{1}{x_{i-1}}((i-1)\sum_{j=i}^{N} x_j Q_j - (N-i+1)\sum_{j=1}^{i-1} x_j Q_j), \quad i \in [2, N], \end{cases} \quad (29)$$

if d_i parameters are in the scope (26), (27).

5 Conclusions

In the paper we solved the maximum lifetime problem for the one-dimensional, regular ad-hoc wireless network with one data collector L_N. We assumed, that the nodes utilized the point-to-point data transmission scheme and the cost of transmission of one unit of data was arbitrary superadditive function of a distance between transmitter and receiver. We analyzed stability of the solution under modification of two sets of parameters, the amount of data Q_i, $i \in [1, N]$ generated by each node and location of the nodes x_i in the network. In the paper we estimated the size of the stability region $U(Q^0, x^0)$ for the equal energy solution of the maximum lifetime problem in L_N network, where $Q_i^0 = 1$, $x_i^0 = i$ and allowed change of the nodes location is given by the shift $x_i = i - d_i$, $d_i \in (-1, 1)$. Obtained results indicate, that the discussed problem is very sensitive under change of its initial parameters. Knowledge of the size of stability region for the problem allows efficiently manage the networks. For example, we can control the optimal behavior of the nodes and initiate the routing processes whenever the nodes change the amount of generated data or their location beyond the scope of the stability region.

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Analysis of Mastication Sound for Development of Food Texture Inference System

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Abstract. In this paper, a comparison between a bone and an air conduction sounds is described. The sounds when a human masticates cucumbers and cabbages are observed and analyzed, in order to identify essential sound for estimating a food texture. The sound detected by our food texture estimation equipment in the latest study contains a noise caused by resonance of the housing of the equipment. However such noise is not observed in a human. It is important to grasp actual bone and air conduction sounds by a human. In an experiment of the present paper, it is found that features of the bone and the air conduction sounds are different, and both of these sounds are necessary to assume the food texture. A neural network model is constructed which classifies the cucumber and the cabbage considering the bone and the air conduction sounds. The experimental result and future works are discussed.

1 Introduction

A proper nutritional intake in a daily life is indispensable for maintaining our health. We enjoy a meal which is not only for taking nutrition. Factors in enjoyment of eating relate to taste, scent and "texture". The important studies on the measurement of the "food texture" in the engineering science are papers [1–4] by Sakurai's team. Sakurai has proposed diagnose method of the food texture considering the acoustic vibration sound which occurs while a sharp metal probe is stabbing the food. He suggests that food texture could be measured by analyzing frequency of the sound. Since considering masticated sound of the food is essential, his work is novel. On the other hand, a human judges the food texture considering not only the vibration sound of the teeth but also a load change on the teeth. Therefore Okada and Nakamoto [5] have invented a food texture sensor imitating human tooth which detects the vibration and the load simultaneously. And a recurrent neural network is applied to infer the food texture. We also have proposed an equipment to detect the sound and the load. The neural network is applied to infer the degree of two types of food textures such as "munching-ness" and "crunchiness" [6]. The study [5] focuses on artificial tooth sensor application, on the other hand our study emphasizes to discover a methodology for measuring the food

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texture which a human feels by considering not only around teeth nerves but also all nerve system around a mouth and an ear which sense the miscellaneous vibration and the sound.

In the present paper we have two goals. The first goal is to grasp a sound when a human masticates a food actually. Therefore an experiment is carried out. In our proposed paper [6], the resonance of the housing of the equipment is mixed with the sound caused by cutting a food. Therefore we should observe pure sound when a human masticates the food.

The second goal is to make sure if a neural network model could classify the food kinds based on the signal information obtained from the experiment described above. The bone conduction sound sensor utilized in the experiment of the present paper is piezoelectric element (FUJI CERAMICS CORPORATION, S3SC) shown in Fig. 1. A sound sensor attached on the probe of our equipment [6] shown in Fig. 2 is also piezoelectric element (FUJI CERAMICS CORPORATION, P51C). The equipment [6] can measure the sound and the load change while the sharp metal probe is stabbing the food when the air cylinder moves down gaining air pressure.

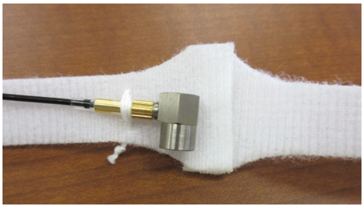

Fig. 1. Bone conduction sound sensor fixed on the band.

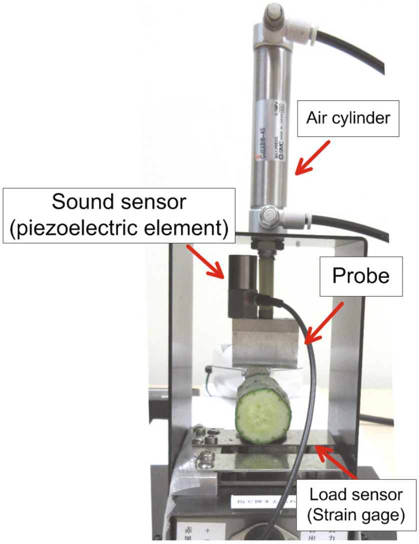

Fig. 2. Food inspection equipment.

The bone conduction sound would consist of low frequency level sound which is related to the food texture such as "munching-ness" and "crunchiness". On the other hand, the air conduction sound would include the strong high frequency level sound which is related to the food texture such as "crunchiness" and "crispness". The air conduction sound is observed using high sensibility microphone (ACO CO., LTD, TYPE 6236) in the following experiment.

2 Experiment of Mastication by Human

We carried out the experiment to detect the bone and the air conduction sounds occurred when a human masticates the food. Figure 1 shows the bone conduction sound sensor fixed on the band with threads. As shown in Fig. 3, the band is winded round the subject's head tightly to touch the sensor on the bone behind an ear in order to sense the bone conduction sound propagated from the teeth. In Fig. 3 on the left side, the high sensibility microphone (air conduction sound sensing device: ACO CO., LTD, TYPE 6236) is shown, which is fixed to the tripod. The signal of the bone conduction sound sensor (FUJI CERAMICS CORPORATION, S3SC) is amplified by the charge and the voltage amplifiers.

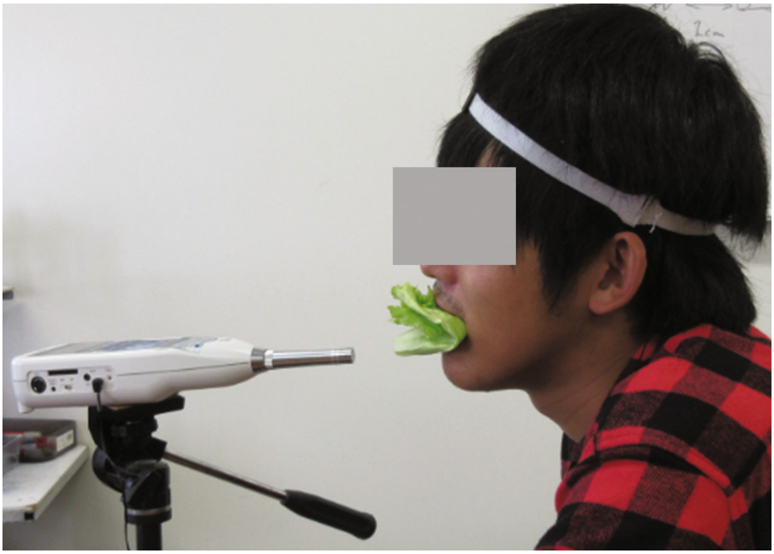

Fig. 3. Experimental situation with winded band and microphone.

The signal of the amplified bone conduction sound sensor and output of the high sensibility microphone are inputted to PC via NI-6002 (National Instruments) and the data is stored. The sampling frequency is set to 25 [kHz], and the measurement time period is set to 5 [s]. We extracted signals for $0.8 - \Delta T$ [s] manually from 5 [s] signals for all samples, where ΔT is sampling period. Since the sampling frequency is 25 [kHz], ΔT is 0.04 [ms]. The extracted signals are seemed to be a masticated moment and which are converted by FFT.

Figure 4 shows the signal at the moment while masticating a cucumber. The top graph is bone conduction sound and the bottom is air conduction one. While the bone conduction sound is a gradual change, the air conduction sound is detected without attenuation of high level frequency.

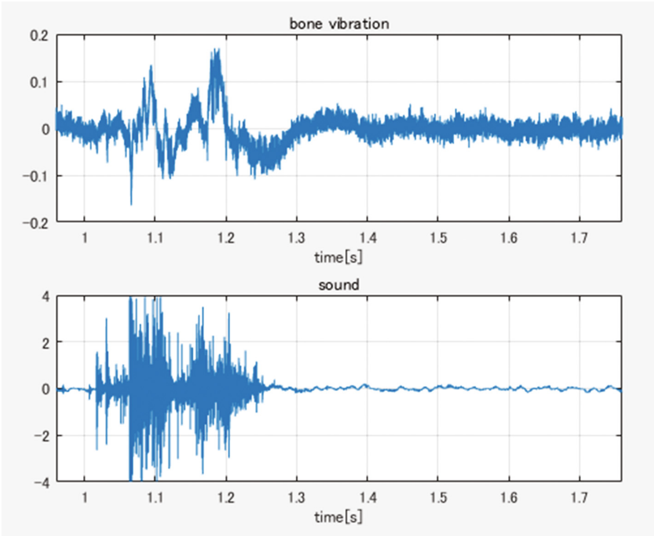

Fig. 4. Bone conduction (top) and air conduction (bottom) sounds by cucumber (Sample No. 3).

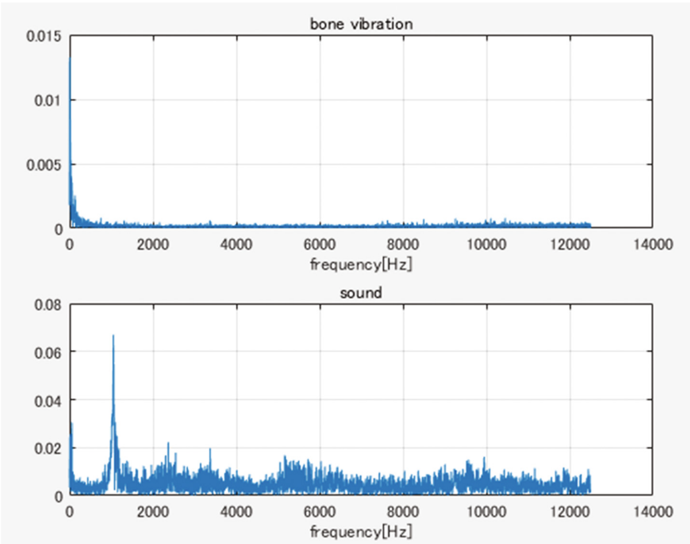

Fig. 5. FFT result by cucumber (Sample No. 3).

Figure 5 shows the result by FFT. There is no peak in the high frequency region on the top graph which illustrates FFT result of the bone conduction sound. On the other hand a conspicuous peak around 1000 [Hz] is found on the bottom graph which shows FFT result of the air conduction sound. The features of the peak of two FFT results are different.

Figure 6 shows the graph at the moment when the cabbage is masticated. As same as the case of the cucumber, the bone conduction sound is attenuated by conducting the bone and the skin.

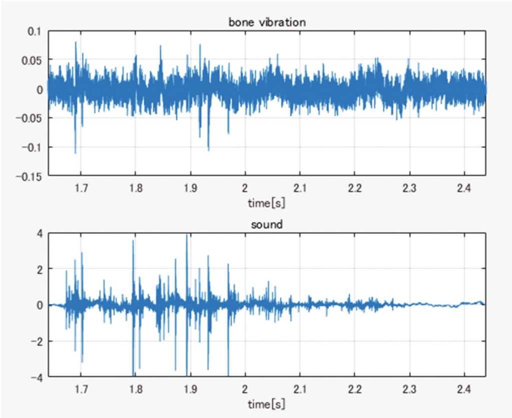

Fig. 6. Waves of cabbage (Sample No. 23).

Figure 7 shows the results by FFT. Bone conduction sound peak appears around 400 [Hz], which is a feature not found in the air conduction sound. In order to identify the mastication sound of the cucumber and the cabbage, it is necessary to consider both of the bone and the air conduction sounds simultaneously.

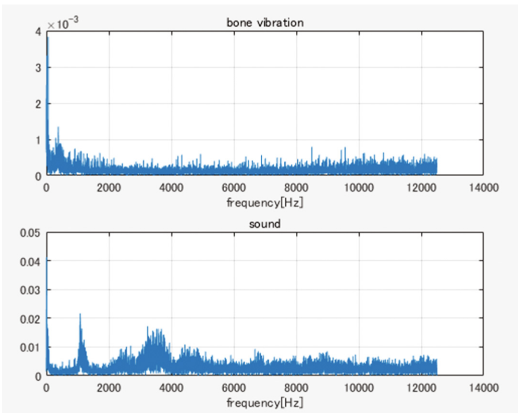

Fig. 7. FFT result by cabbage (Sample No. 23).

3 FFT Result and Characteristic Value

The bone conduction sound and the air conduction sound are converted by FFT. An important information called "characteristic value" is calculated from FFT result. The characteristic value is used to distinguish food kinds by the neural network.

3.1 Bone Conduction Sound

As shown in Fig. 8, the extracted bone conduction sound signal for $0.8 - \Delta T$ [s] is converted by FFT. The FFT result is processed to obtain characteristic values B1, B2, B3, B4 and B5 which are explained as follows,

(1) B1 is summation from i = 3 to i = 401 of FFT result. (2.5 [Hz] to 500 [Hz])
(2) B2 is summation from i = 401 to i = 801. (500 [Hz] to 1000 [Hz])
(3) B3 is summation from i = 801 to i = 1201. (1000 [Hz] to 1500 [Hz])
(4) B4 is summation from i = 1201 to i = 1601. (1500 [Hz] to 2000 [Hz])
(5) B5 is summation from i = 1601 to i = 2001. (2000 [Hz] to 2500 [Hz])

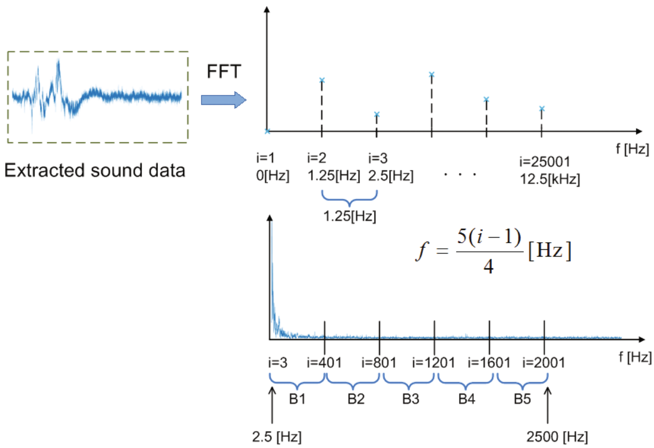

Fig. 8. FFT data and calculation of B1 to B5.

3.2 Air Conduction Sound

As shown in Fig. 9, the extracted air conduction sound signal for $0.8 - \Delta T$ [s] is converted by FFT. The FFT result is processed to obtain characteristic values S1, S2, S3, S4 and S5 which are explained as follows,

(1) S1 is summation from i = 3 to i = 961 of FFT result. (2.5 [Hz] to 1200 [Hz])
(2) S2 is summation from i = 961 to i = 1921. (1200 [Hz] to 2400 [Hz])
(3) S3 is summation from i = 1921 to i = 2881. (2400 [Hz] to 3600 [Hz])
(4) S4 is summation from i = 2881 to i = 3841. (3600 [Hz] to 4800 [Hz])
(5) S5 is summation from i = 3841 to i = 4801. (4800 [Hz] to 6000 [Hz])

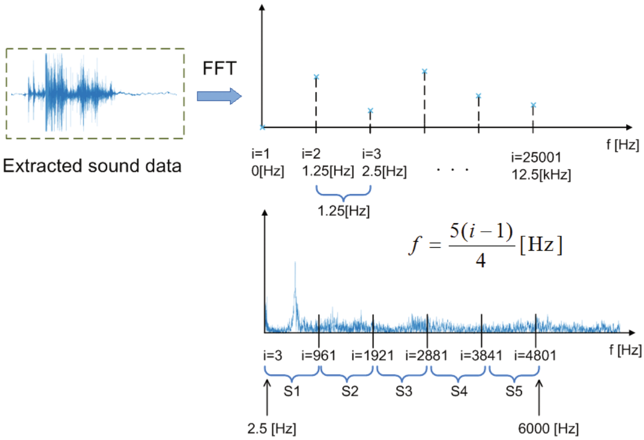

Fig. 9. FFT data and calculation of S1 to S5.

3.3 Summary and Discussion

Table 1 shows all samples used for a construction and an evaluation of the neural network model.

Table 1. All sample data.

n (sample number)	1,…,15	16,17,18,19,20	21,…,35	36,37,38,39,40
Purpose	Training	Test	Training	Test
Kind	Cucumber	Cucumber	Cabbage	Cabbage

Table 2 shows the average of characteristic values of the cucumbers and the cabbages.

Table 2. Average of characteristic values of samples.

	B1	B2	B3	B4	B5
Cucumber	0.47	0.09	0.07	0.06	0.05
Cabbage	0.26	0.08	0.06	0.06	0.05
	S1	S2	S3	S4	S5
Cucumber	4.25	7.24	6.24	4.48	3.91
Cabbage	2.83	2.67	4.53	4.16	3.80

The averages of all characteristic values of the cucumbers are same as or higher than ones of the cabbages, because the sound strength when masticating the cucumbers is bigger than one of the cabbages.

The B1 expresses the sound strength of the bone conduction sound which ranges 2.5 [Hz] to 500 [Hz]. The B1 is biggest among B1 to B5 for both of the cucumber and the cabbage. It is found that the high frequency level is attenuated in the bone conduction sound.

The S2 expresses the sound strength of the air conduction sound which ranges 1200 [Hz] to 2400 [Hz]. The S2 of the cucumber is biggest among S1 to S5. On the other hand, such tendency is not found in the cabbage. The S3 to S5 expressing high frequency level are higher than S1 and S2 in the cabbage. Therefore, the air conduction sound is very useful to distinguish the cucumber and the cabbage. And the food texture “crispness” and “crunchiness” would be related to the air conduction sound.

4 Neural Network Model

The neural network model for assuming the classified degree of the cucumber and the cabbage is shown in Fig. 10. The input layer consists of 10 nodes for characteristic values B1 to B5 and S1 to S5, and one bias node. The hidden layer 1 and 2 consist of 10 nodes and one bias node, respectively. The output layer consists of two nodes expressing the classified degree in the cucumber and the cabbage.

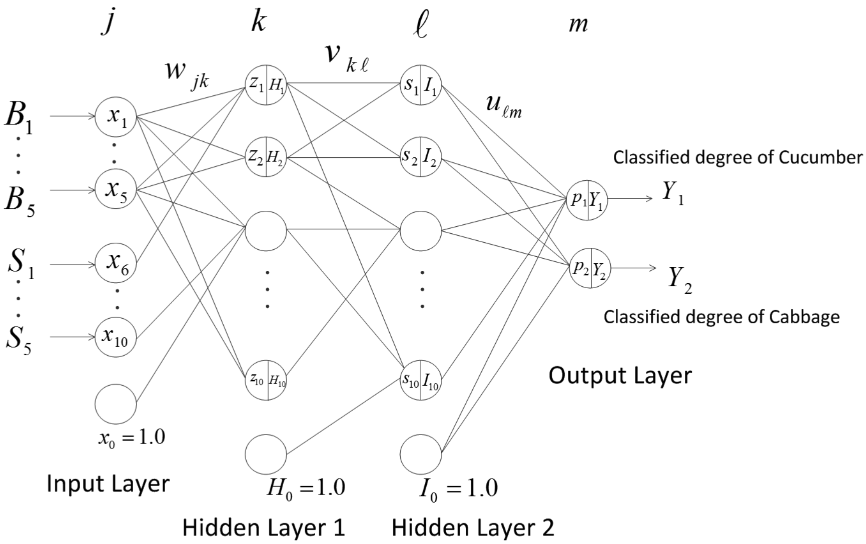

Fig. 10. Neural network model for classification.

The transfer function of the hidden layer 1, 2 and the output layer are shown in Eqs. (1), (2) and (3), respectively, where x_j is j-th input node value of the input layer,

H_k is output value of k-th node of the hidden layer 1, I_ℓ is output value of ℓ-th node of the hidden layer 2, Y_1 and Y_2 are the outputs of the neural network, thus $m = 1, 2$.

$$H_k = \frac{1}{1 + \exp(-z_k)}, \quad z_k = \sum_{j=0}^{10} x_j w_{jk}, \quad x_0 = 1.0 \ . \tag{1}$$

$$I_\ell = \frac{1}{1 + \exp(-s_\ell)}, \quad s_\ell = \sum_{k=0}^{10} H_k v_{k\ell}, \quad H_0 = 1.0 \ . \tag{2}$$

$$Y_m = \frac{1}{1 + \exp(-p_m)}, \quad p_m = \sum_{\ell=0}^{10} I_\ell u_{\ell m}, \quad I_0 = 1.0 \ . \tag{3}$$

Where w, v and u are the connection weights between the input layer and the hidden layer 1, between the hidden layer 1 and 2, between the hidden layer 2 and the output layer, respectively.

The connection weights are adjusted in order to minimize the difference between expected value and output Y_m obtained when particular input values are given to the neural network model. The back-propagation algorithm [7] is employed. The training process of the model is as follows:

Step 1: Prepare data sets $D^{(n)} = \{B_1^{(n)}, \cdots, B_5^{(n)}, S_1^{(n)}, \cdots, S_5^{(n)}\}$ for $n = 1,\ 2, \cdots,\ N$.

Step 2: Prepare the training input and desired output of the neural network model using the data sets as follows:

$$X_{train} = \begin{bmatrix} B_1^{(1)} & \cdots & B_1^{(N)} \\ \vdots & \cdots & \vdots \\ B_5^{(1)} & \cdots & B_5^{(N)} \\ S_1^{(1)} & \cdots & S_1^{(N)} \\ \vdots & \cdots & \vdots \\ S_5^{(1)} & \cdots & S_5^{(N)} \end{bmatrix}, \ Y_{train} = \begin{bmatrix} Y_1^{(1)} & \cdots & Y_1^{(N)} \\ Y_2^{(1)} & \cdots & Y_2^{(N)} \end{bmatrix}$$

where X_{train} is the input and Y_{train} is the expected output.

Step 3: Train the neural network model by the back-propagation algorithm. Table 1 shows the attributes of all sample data.

4.1 Training and Evaluating Neural Network

This section describes training of the neural network model. The training data are the samples with No. 1–15 and No. 21–35 as shown in Table 1. Table 3 shows desired output for every sample data.

The training process is carried out to adjust the connection weights so that the inputs of 30 data sets correspond to the desired output vector. The iteration to train the

Table 3. Desired output of all samples.

n (sample No)	1,…,15	16,…,20	21,…,35	36,…,40
Y_1	1.0	1.0	0.0	0.0
Y_2	0.0	0.0	1.0	1.0

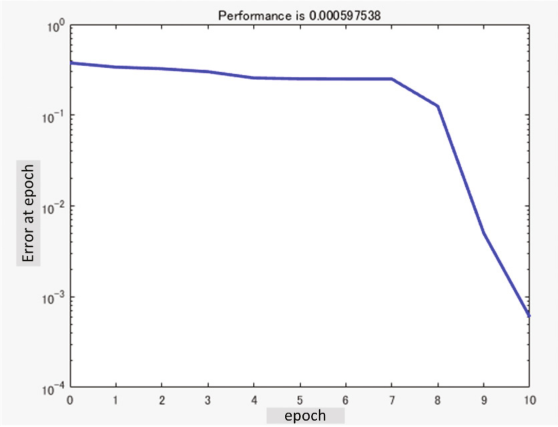

Fig. 11. Error at each epoch.

network is set to 10 epochs. Figure 11 shows the changing of the error at each epoch, and we can confirm the error declines.

Table 4 and 5 show the output result when the data of samples not used for training are inputted to the neural network model.

Table 4. The output of neural network for test samples (cucumber).

Sample number	16	17	18	19	20
Y_1	1.00	1.00	1.00	1.00	1.00
Y_2	0.04	0.04	0.06	0.04	0.06

Table 5. The output of neural network for test samples (cabbage).

Sample number	36	37	38	39	40
Y_1	0.00	0.06	0.12	0.95	0.98
Y_2	1.00	1.00	0.98	0.63	0.23

As shown in Table 4, the neural network distinguishes the cucumber samples correctly. However, as for the cabbage samples, No. 39 and 40 are confused as illustrated in Table 5. It is guessed that the samples 39 and 40 are similar in the sound of the cucumbers. Therefore it would be necessary to also consider the load change using the load sensor as proposed in the paper [6].

5 Conclusion

In this paper, the bone and the air conduction sounds are measured when a human masticates the cucumber and the cabbage. Although the sound obtained by the equipment [6] contains the resonance of the housing of the equipment, such noise is not observed in the mastication sound by the human subject.

The high sensibility microphone detects the air conduction sound which is different from the bone conduction sound. Therefore, it is confirmed that the air conduction sound is important factor to infer the food texture more accurately. The air conduction sound could not be observed with the piezoelectric element sensor attached on the probe of our equipment [6].

In a future, we will attach the high sensibility microphone (ACO CO., LTD, TYPE 6236) with our equipment [6] in addition to the piezoelectric element sound sensor and the load sensor, in order to develop high quality food texture estimation system. For example, distinguishing between a cabbage and a lettuce would be possible in a future.

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Physical-Parameter Identification of Structures From Seismic Responses via Maximum Likelihood Estimation

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Abstract. The physical-parameter that was identified from the measured responses of dynamical system can be used to detect and control the variation of this system. This study presents the use of a maximum likelihood estimation to identify the physical parameters of dynamical system. The measured responses of a dynamical system was used to reconstruct the time series model. The coefficients matrix of time series model can be determined by maximum likelihood estimation. In here, the estimation error was be considered as the normal distribution, then the Gaussian probability density function was be used. Finally, the physical parameters can be calculated from these coefficients matrix. The accuracy of this procedure is numerical confirmed.

1 Introduction

The mathematical model of dynamical system was built by statistical method from the measured responses is well-known system identification. The coefficients matrix of mathematical model can be considered as constant, function of time or function of states, these are corresponds to linear system, time varying system and nonlinear system. There are many kinds of estimation for determining the coefficient matrix, including least square approach [1, 2], maximum likelihood estimation [3], artificial neural network [4, 5] etc. Compared with another parameters estimation approach, the likelihood function of maximum likelihood estimation can be choose via the given properties of the observed data and constructed by the unknown parameters. Next, these unknown parameters can be determined by maximizing the likelihood function [6]. There are many optimal properties such as sufficiency, consistency and efficiency can be found in the maximum likelihood estimation [3].

The applicability and effectively of maximum likelihood estimation for identifying the modal parameters from the output-only collected data in frequency domain has been investigated [7]. The frequency-domain maximum likelihood estimation also has been extended to identify the modal parameters of bridge from the measured nonstationary data [8]. The Bayesian statistical framework was used to defined the objective function, then, the negative log-likelihood function which is mathematically equal to the posterior uncertainty of the modal parameters in terms of their inverse covariance

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matrix would be used to evaluate the most probable value [9]. Zhang et al [10, 11] were extended the Bayesian identification approach for monitoring the health of tower structure and identifying the modal parameters of cable-stayed bridge. However, the resolution of the identified modal parameters obtained from the merging modal identification approaches in frequency domain compared poorly with those were identified in time or time-frequency domain [12]. Some researchers were identified physical-parameters of the Hammerstein finite impulse response moving average (FIR-MA) system by maximum likelihood estimation in time domain and the identified parameters with small estimation errors [13, 14].

The main purpose of this study is to apply an estimation to identify the physical-parameter of dynamical system in time domain. This physical-parameter identification procedure consist by the time series model and maximum likelihood estimation. The time series model can be built by the measured responses of dynamical system. Next, the coefficient matrixes in the time series model are directly estimated through maximum likelihood estimation. The validity of the approach is verified by processing numerically simulated responses of a finite element model of a 5-storey frame.

2 Methodology

A mass-spring-damping system is a typical dynamical system, and its responses can be described by the equation of motion

$$\mathbf{M}\ddot{\mathbf{x}} + \mathbf{C}\underline{\mathbf{x}} + \mathbf{K}\mathbf{x} = \mathbf{f} \tag{1}$$

where $\mathbf{M}$, $\mathbf{C}$ and $\mathbf{K}$ are mass, damping and stiffness matrices, respectively. The vibration responses of the dynamical system including acceleration, velocity and displacement that were noticed by $\ddot{\mathbf{x}}$, $\dot{\mathbf{x}}$ and $\mathbf{x}$. Besides, this system was subjected input force vectors $\mathbf{f}$. According to the central difference approach, the equation of motion of mass-spring-damping system can be rewrote by time series model

$$\mathbf{y}_t = \sum\nolimits_{i=1}^{I} \mathbf{\Phi}_i \mathbf{y}_{t-i\Delta t} + \sum\nolimits_{j=0}^{J} \mathbf{\Theta}_j \mathbf{f}_{t-j\Delta t} \tag{2}$$

where, $\mathbf{y}_{t\text{-}i\Delta t}$ and $\mathbf{f}_{t\text{-}i\Delta t}$ are the vectors of measured responses and input forces at time t-$i\ \Delta t$, respectively; $1/\Delta t$ is the sampling rate of the measurement, $\mathbf{\Phi}_i$ and $\mathbf{\Theta}_j$ are matrices of coefficient functions to be determined in the model. Rearranging Eq. (2) yields

$$\mathbf{y}_t = \bar{\boldsymbol{\varphi}}_t^T \boldsymbol{\theta}, \tag{3}$$

where

$$\begin{cases} \bar{\varphi}_t = \begin{bmatrix} \mathbf{y}_{t-\Delta t} & \cdots & \mathbf{y}_{t-I\Delta t} & \mathbf{f}_t & \cdots & \mathbf{f}_{t-J\Delta t} \end{bmatrix}^{\mathbf{T}} \\ \boldsymbol{\theta} = \begin{bmatrix} \mathbf{\Phi}_1 & \cdots & \mathbf{\Phi}_I & \mathbf{\Theta}_0 & \cdots & \mathbf{\Theta}_J \end{bmatrix} \end{cases} \tag{4}$$

According to the Eq. (3), the observed parameters were noticed as $\bar{\varphi}_t$, and the likelihood function of $\boldsymbol{\theta}$ was formulated by probability density function

$$L(\mathbf{y}_t|\bar{\varphi}_t, \boldsymbol{\theta}) = \prod\nolimits_{t=1}^{N\Delta t} p(\mathbf{y}_t|\bar{\varphi}_t, \boldsymbol{\theta}) \tag{5}$$

In here, the Gaussian probability density function would be considered, based on the follows assumption: the estimated error of the time series is normal distribution. Equation (5) can be rewritten as

$$\begin{aligned} L(\mathbf{y}_t|\bar{\varphi}_t, \boldsymbol{\theta}) &= \prod\nolimits_{i=0}^{N-1} p\left(\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right) + k \\ &= \frac{e^{\left(-\frac{1}{2\sigma^2}\sum_{i=1}^{N-1}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right]^{\mathbf{T}}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right]\right)}}{\left(\sqrt{2\pi\sigma^2}\right)^N} + k \end{aligned} \tag{6}$$

where k is a constant. From Eq. (6), one can take logarithm operation on $L(\mathbf{y}_t|\bar{\varphi}_t, \boldsymbol{\theta})$, then, the log-likelihood function can be obtained

$$\begin{aligned} &\ln \prod\nolimits_{i=0}^{N-1} p\left(\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right) + k \\ &= \ln k - \frac{L}{2}\left(\ln 2\pi + \ln \sigma^2\right) - \frac{1}{2\sigma^2}\sum\nolimits_{i=1}^{N-1}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right]^{\mathbf{T}}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right] \end{aligned} \tag{7}$$

Taking the derivatives with respect to σ^2 and let it equal to zero, one yielded

$$\sigma^2 = \sum\nolimits_{i=1}^{N-1}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right]^{\mathbf{T}}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right]\Big/N \tag{8}$$

Substituting Eq. (8) into Eq. (7), one obtained

$$\begin{aligned} &\ln \prod\nolimits_{i=0}^{N-1} p\left(\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right) + k \\ &= \bar{k} - \frac{N}{2}\ln\frac{1}{N}\sum\nolimits_{i=1}^{N-1}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right]^{\mathbf{T}}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right] \end{aligned} \tag{9}$$

where $\bar{k} = \ln k - L(1 + \ln 2\pi)/2$.

It is obvious that the maximum value of $L(\mathbf{y}_t|\bar{\varphi}_t, \boldsymbol{\theta})$ can be achieved by minimizing the follows objection function

$$J(\boldsymbol{\theta}) = \sum\nolimits_{i=1}^{N-1}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right]^{\mathbf{T}}\left[\mathbf{y}_{t+i\Delta t} - \bar{\varphi}^{\mathbf{T}}_{t+i\Delta t}\boldsymbol{\theta}\right]|_{\bar{\theta}} \tag{10}$$

Typically, Eq. (10) can be simplified and represented by a set overdetermined linear algebraic equation. The solution for the matrix of parameters is determined by a traditional Gaussian elimination method.

By adopting the concept behind the Ibrahim time domain system identification technique, Yang *et al*. [15] and Huang [16] proved that if one constructs a matrix from the coefficient matrices of the time series models as

$$\mathbf{G} = \begin{bmatrix} \mathbf{0} & \mathbf{I} & \mathbf{0} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \mathbf{I} & \mathbf{0} & \cdots & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ \mathbf{\Phi}_I & \mathbf{\Phi}_{I-1} & \mathbf{\Phi}_{I-2} & \mathbf{\Phi}_{I-3} & \cdots & \mathbf{\Phi}_1 \end{bmatrix}_{\bar{N}\times\bar{N}} \tag{11}$$

where $\boldsymbol{I}$ is an $l*l$ unit matrix, l is the dimension of $\mathbf{y}(t)$, and $\bar{N} = I \times l$; then the physical parameters of the dynamical system under consideration can be directly determined from the eigenvalues and eigenvectors of $\mathbf{G}$.

Let λ_k and $\boldsymbol{\varphi}_k$ denote the k^{th} eigenvalue and eigenvector of $\mathbf{G}$, respectively. The eigenvalue λ_k is normally a complex number, and is set to $a_k + ib_k$. The frequency and damping ratio of the dynamical system are computed by

$$\omega_k = \sqrt{\alpha_k^2 + \beta_k^2}; \quad \xi_k = -\alpha_k/\omega_k \tag{12}$$

where

$$\beta_k = \frac{1}{\Delta t}\tan^{-1}\left(\frac{b_k}{a_k}\right); \quad \alpha_k = \frac{1}{2\Delta t}\ln\left(a_k^2 + b_k^2\right) \tag{13}$$

In these equation, ω_k is the pseudo-undamped circular natural frequency, and ξ_k is the modal damping ratio. The eigenvector $\boldsymbol{\varphi}_k$ can be expressed as

$$\varphi_k = \begin{bmatrix} \varphi_{k,1}^{\mathrm{T}} & \varphi_{k,2}^{\mathrm{T}} & \cdots & \varphi_{k,I}^{\mathrm{T}} \end{bmatrix}^{\mathrm{T}} \tag{14}$$

where $\boldsymbol{\varphi}_{k,\ i}$ has l components and satisfies $\boldsymbol{\varphi}_{k,i} = \lambda_k\ \boldsymbol{\varphi}_{k,i\text{-}1}$, and $\boldsymbol{\varphi}_{k,1}$ corresponds to a mode shape of the measured degrees of freedom of the dynamical system.

It is worthwhile to mention that spurious modals other than real system modals occur when $\bar{N} > 2n$ where n is the total number of degrees of freedom of the dynamical system under consideration and is usually unknown. The time series model of dynamical system should consistently arise as (I, J), the time lag parameter of the time series model, increases. Hence, the modal parameters of a dynamical system can be determined from the stabilization diagrams, which display the variations of the identified modal parameters with (I, J). Good science or engineering judgment based on the knowledge on the dynamical system can be very helpful on confirming the dynamical system modals.

3 Numerical Verification

The finite element model of 5-storey frame was built to demonstrate the feasibility of the proposed procedure, and this frame was subjected to a simulated 1999 Chi-chi earthquake at its base in X direction (see Fig. 1). The geometric parameter of this 5-storey frame were 30 cm long, 30 cmwide and 250 cm high. The 5% of the modal damping ratio would be assumed during the simulation process. Plates were fixed on each floor, such that the total mass of frame ate each floor were approximately 65 kg.

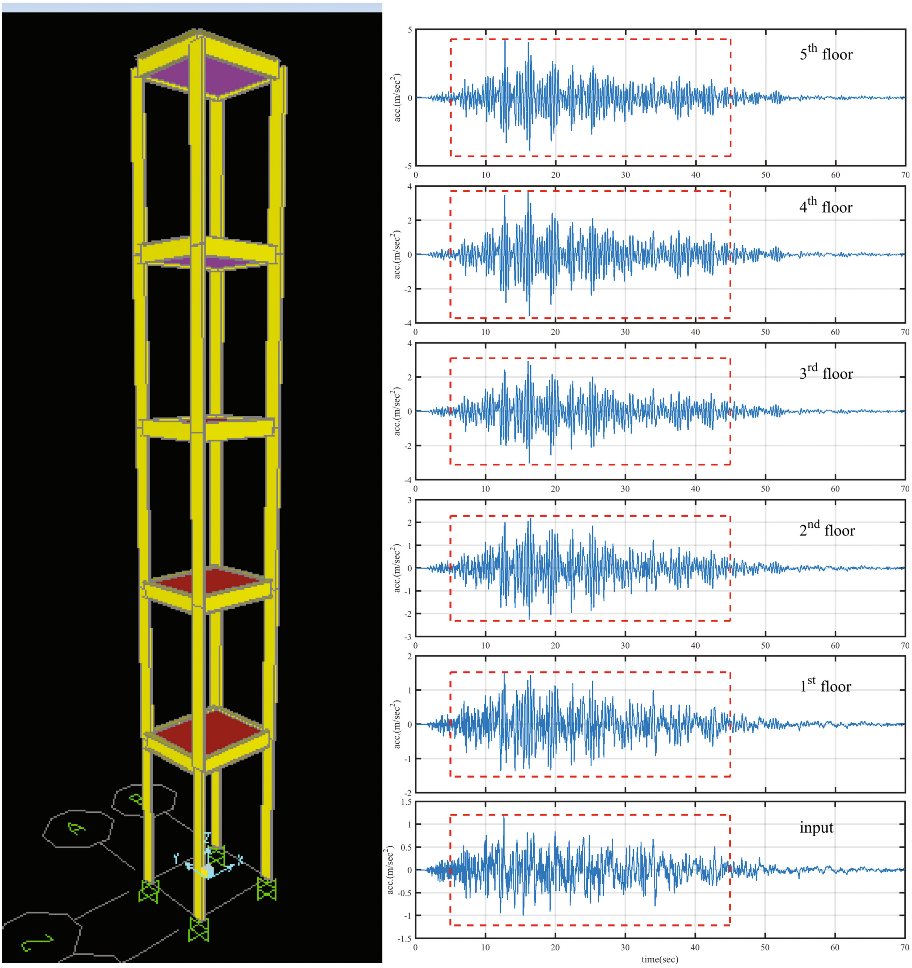

Fig. 1. Schematic diagram of a 5-storey finite element model and its simulation responses.

Table 1. Theoretical modal parameters of numerical models.

	Modal	1st	2nd	3rd	4th	5th
Intrinsic	f_n(Hz)	2.782	8.141	13.003	16.711	19.062
	ξ(%)	5.00	5.00	5.00	5.00	5.00
	φ	1.000	−0.924	0.768	−0.557	0.293
		0.909	−0.275	−0.538	1.000	−0.766
		0.747	0.553	−0.914	−0.281	1.000
		0.529	1.000	0.287	−0.770	−0.916
		0.272	0.761	1.000	0.919	0.544
With weak element	f_n(Hz)	2.667	7.864	12.743	16.556	19.018
	ξ(%)	5.00	5.00	5.00	5.00	5.00
	φ	1.000	−0.948	0.771	−0.572	0.299
		0.915	−0.322	−0.489	1.000	−0.778
		0.765	0.501	−0.935	−0.214	1.000
		0.561	1.000	0.169	−0.837	−0.887
		0.320	0.858	1.000	0.864	0.482

The column is box section with outside depth 1 cm, outside wide 5 cm and flange and web thickness 2 mm. Besides, another frame with weak elements on the first storey. The weak column is box section with outside depth 1 cm, outside wide 4 cm and flange and web thickness 2 mm. Table 1 shows the theoretical physical parameters of these frames. These frame were subjected to base excitation of the 1999 Chi-chi earthquake. The acceleration responses of the base and all floors at t = 5–45 s were used in evaluating physical parameters for these frame. Figure 1 displays the time history of base excitation and acceleration responses in X direction of the intrinsic numerical model subject the Chi-chi earthquake.

The frequency responses function of the dynamical responses are usually used to distinguish the modes of dynamical system. However, in the Fig. 2, the 5th modal is difficult to find out. Besides, the 4th modal is also not obvious, but in the frequency responses function of the 1st floor. Even so, based on the first three modal, the intrinsic frame have a higher nature frequency in each modal than the frame with weak elements in first storey. The acceleration responses of the base and all degree of freedom at t = 5–45 s would be used to identify modal parameters. Table 2 shows the identified physical parameters. The 1st modal is approximately 2.78 Hz, and the higher modal is approximately 19.06 Hz. For the frame with weak element in first storey, the 1st modal was reduced to 2.667 Hz, and the higher modal was reduced to 19.018 Hz. Besides, the natural frequency of each modal between the intrinsic frame and the frame with weak elements in the first storey have obviously decreasing trend. Figure 3 plots the identified mode shapes obtained from processing the simulated input and acceleration responses of all stories by using maximum likelihood estimation. In the physical-parameter identification process, the accurately and stable modal parameters were obtained.

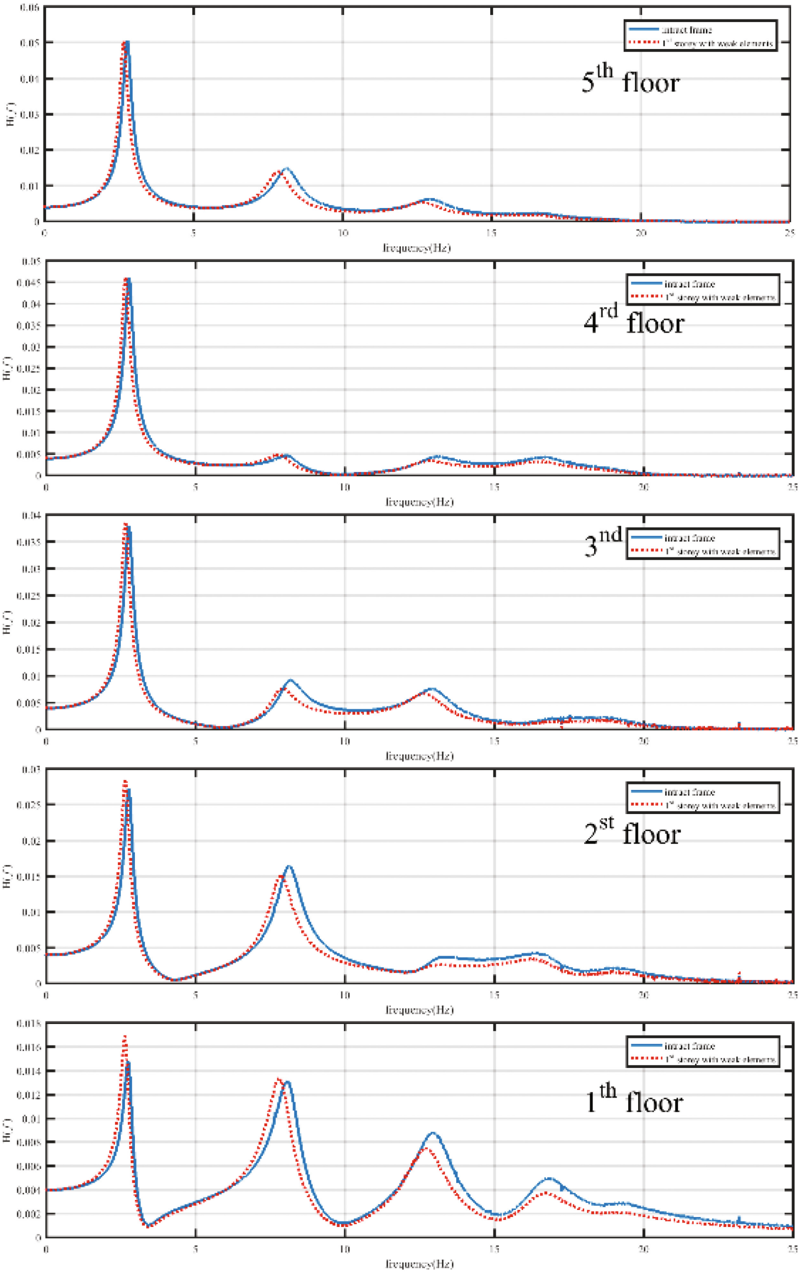

Fig. 2. Frequency responses function of the simulation responses of 5-storey finite element model.

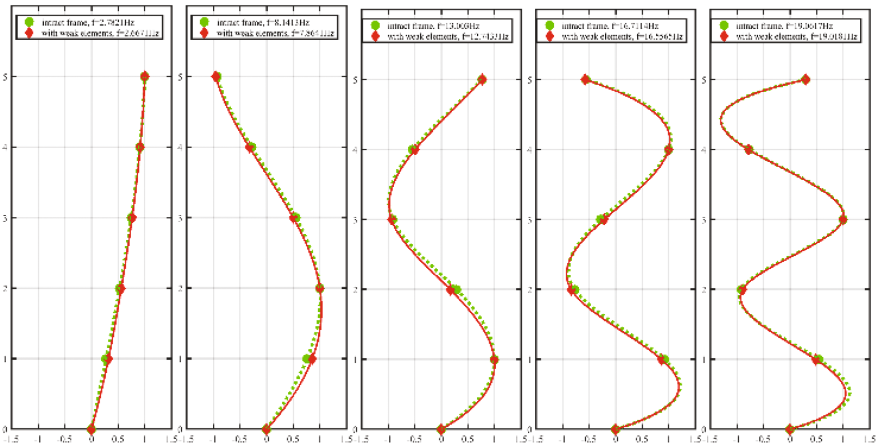

Fig. 3. The identified mode shapes.

Table 2. The identified modal parameters of numerical models.

	Modal	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}
Intrinsic	f_n(Hz)	2.782	8.141	13.003	16.711	19.062
	$\xi(\%)$	5.00	5.00	5.00	5.00	5.00
With weak element	f_n(Hz)	2.667	7.864	12.743	16.556	19.018
	$\xi(\%)$	5.00	5.00	5.00	5.00	5.00

4 Conclusions

A unified procedure to identify the physical parameters of the dynamical system from the measured responses data has been presented herein. This procedure was established through a time series model to describe the responses of the dynamical system. The coefficient matrices of time series model that also related to the physical parameters were evaluated by a maximum likelihood estimation. Then, the physical parameters were evaluated from the eigenvalues and eigenvectors of a coefficient matrix.

To demonstrate its feasibility for application on vibration system, the proposed procedure has been applied to process the simulation vibration of a five-storey finite element model. The identified physical parameters in first three modal from the simulation vibration data closely corresponded to those obtained from the frequency responses function. Besides, the identified results of the higher modal also display an excellent agreement with those identified from the frequency responses function, thus validating the applicability of the proposed approach.

Finally, it is believed that the proposed procedure can be successfully applied to process vibration data of dynamical system despite the variation of physical parameters that was caused by the local damage can be found out.

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