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Juan F. De Paz · Vicente Julián
Gabriel Villarrubia · Goreti Marreiros
Paulo Novais *Editors*

Ambient Intelligence—Software and Applications—8th International Symposium on Ambient Intelligence (ISAmI 2017)

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e-mail: kacprzyk@ibspan.waw.pl

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Editors
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Departamento de Informática y Automática, Facultad de Ciencias
Universidad de Salamanca
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Departamento de Sistemas Informáticos y Computación
Universidad Politécnica de Valencia
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Salamanca
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Instituto Superior de Engenharia do Porto
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Preface

This volume contains the proceedings of the 8th International Symposium on Ambient Intelligence (ISAmI 2017). The Symposium was held in Porto, Portugal during June 21–23 at the Polytechnic of Porto.

ISAmI has been running annually and aiming to bring together researchers from various disciplines that constitute the scientific field of ambient intelligence to present and discuss the latest results, new ideas, projects and lessons learned, namely in terms of software and applications, and aims to bring together researchers from various disciplines that are interested in all aspects of this area.

Ambient Intelligence is a recent paradigm emerging from Artificial Intelligence, where computers are used as proactive tools assisting people with their day-to-day activities, making everyone's life more comfortable.

After a careful review, 33 papers from 15 different countries were selected to be presented in ISAmI 2017 at the conference and published in the proceedings. Each paper has been reviewed by, at least, three different reviewers, from an international committee composed of 120 members from 24 countries.

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- Ambient Intelligence for e-Healthcare (AIfeH)
- Future Environments and Solutions for Ambient Intelligence (FESAmI)
- Security in Ambient Intelligent Environments (SAmIE)

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We want to thank all the sponsors of ISAmI'17: IEEE Sección España, CNRS, AFIA, AEPIA, APPIA, AI*IA, and Junta de Castilla y León.

ISAmI would not have been possible without an active Program Committee. We would like to thanks all the members for their time and useful comments and recommendations.

We would like also to thank all the contributing authors and the Local Organizing Committee for their hard and highly valuable work.

Your work was essential to the success of ISAmI 2017.

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Collection of State Information in Live Digital Forensics

Fábio Freitas[1] and António Pinto[2(✉)]

[1] GCC, CIICESI, ESTG, Politécnico do Porto, Porto, Portugal
8080176@estgf.ipp.pt
[2] GCC, CIICESI, ESTG, Politécnico do Porto and CRACS & INESC TEC, Porto, Portugal
apinto@inesctec.pt

Abstract. In a digital forensic investigations, the investigator usually wants to get as much state information as possible. Examples of such scenarios are households with wireless networks connecting multiple devices where a security incident occurs. USB devices present themselves as interesting vehicles for the automated collection of state information, as it can store the applications that collect the information, can store the results and can also facilitate the information collection by enabling its automatic operation. This paper proposes a USB solution to facilitate the collection of state information with integrity guarantees and multi-platform operation. Moreover, the proposed solutions is the only one that performs an extensive and homogeneous artifact collection, independently of the underlying operating system.

Keywords: Digital forensics · Live · State information

1 Introduction

In Incident Response (IR) [1] situations, the investigator tries to collect as much information as possible. The goal of an IR investigation can be to confirm the existence of the incident, to provide rapid detection and containment, to identify facts and collect information, to minimize business interruption or network operation, to recover from the incident, to manage the public perception of the incident, to collect evidence that enables legal or civil action against the perpetrators, to inform the top management, or, finally, to improve the organization's reaction to future security incidents [4].

State information can be included within the collectible information and its analysis emerges as an important aspect of digital forensics, especially when dealing with IR situations that involve multiple networked equipment. This type of procedure is usually named as live forensics. The objective of this type of forensic analysis is to collect volatile data before shutting down the system to be

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analyzed. In live forensics, one collects information such as a copy of Random Access Memory (RAM) memory or the list of running processes. State information is volatile and will be lost once the equipment is turnoff. State information may contain artifacts of interest to the analyst, such as [12]: the list of running processes; the history of commands executed on the console; recently used passwords (some in readable text); instant messages; IP addresses; who is logged on to the system; which network ports and applications are listening for IP connections; system information; list and history of connected devices, among others.

The collection of state information in live forensics should not be seen as a substitute of traditional forensic analysis. Instead, it should be seen as complementary. Live forensics will collect information that is not available otherwise. Traditional forensic analysis involves the bit-by-bit copying of data stored in media and its subsequent analysis. Such bit-by-bit copy and analysis is typically performed on a reduced set of equipment since it is a lengthy process. On the other hand, the collection of state information, which can be automated, becomes a source of complementary information that can be very useful. It enables the identification of the connections established between various devices and, hence, check for viruses, spyware, malware or other malicious programs that use the network to communicate with a control server, for example.

Universal Serial Bus (USB) storage devices are interesting vehicles for building an automated mechanism that collects state information by storing both the applications required for collecting the information and the collection result. These are also easily transportable, can have large storage capabilities and facilitate the automatic collection after insertion into the PC.

Live forensic procedures are not risk-free. On the one hand, in order to collect state information, we are required to use the system under analysis that may be compromised and, possibly, may compromise the collected information. On the other hand, the collection of state information is an intrusive process, in the sense that the collection of state information changes the state of the system being analyzed. Traditional digital forensic analysis focuses on avoiding changes to the analyzed system.

This article is organized in sections. Section 2 describes and compares the existing applications that perform artifact collection in the context of digital forensic investigations or of incident response situations. Section 3 details the proposed solution. Section 4 presents the tests carried out in order to validate de proposed solution and, Sect. 5, concludes this paper.

2 Related Work

Multiple applications that collect artifacts in the context of live digital forensics and incident response are available online and can be obtained freely. Examples being: the ir-triage-toolkit (ITT) [13], the IRKIT [11], the TR3Secure (TR3S) [3], the TR3Secure's fork by Neely (NTR3S) [9], the Live Response Collection (LRC) [5], and the Live Response Scripts (LRS) [6].

The ITT consists of a set of small applications and scripts. The author includes applications of other entities in his set, but states that no license agreements or copyright restrictions are broken. These scripts aim to automate the collection of artifacts to facilitate their subsequent analysis, as well as, the screening of events in incident response scenarios. It can be used in Windows and Linux Operating Systems (OS). It also provides copies of RAM and includes scripts to create tool kits for Linux and Windows.

The IRKIT was created by Bill Dean for his own use. He put together a set of free applications that collect volatile data in a script. All applications should fit on a USB storage medium and be ready for use in IR situations. Can only be used in systems with the Windows OS.

The TR3S is yet another set of scripts for collecting digital artifacts on connected systems. It was developed by Corey Harrell and is made available in his blog *Journey Into Incident Response*. Harrell needed a set of applications to respond to systems during attack simulations and one of the applications had to quickly collect volatile data. The commands required for the proper functioning of TR3S are not made available directly due to copyright limitations. Can only be used in systems with the Windows OS. The NTR3S is a fork of the TR3S project by Neely. The motivation behind this fork was related to the need to adapt TR3S to the way that Neely's response and screening team worked in malware detection situations.

The LRC was developed by Brimor Labs and consists of a collection of commands and scripts for the collection of artifacts in digital forensic investigation scenarios. This has the particularity of being able to be used in multiple OS, such as Windows, Linux and macOS. The application was tested on a wide variety of OS versions.

The LRS takes the form of three scripts for the collection of artifacts in digital forensic investigation scenarios, one script for each reference OS. Scripts for Linux and macOS do not depend on external applications.

Table 1 compares the tools identified. Three main factors were considered in this comparison: the multi-platform support, the amount of information collected, and if the collected information was homogeneous among the various supported OS. The table shows the percentage of artifacts collected by each tool, organized by information groups and by client OS (Windows (W), Linux (L) and macOS (M)). Each percentage was obtained by calculating the number of artifacts each tool collected over the total number of artifacts collected by all tools, per information group.

The network information group considers artifacts such as: the network interfaces configuration, IP and MAC addresses, routing table, ARP table, DNS cache, network connections, and associated processes. The status information group considers artifacts such as: open files, running processes (process identification number, running time), and a complete list of files in the file system. The system information group considers artifacts such as: the system date and time, including the time zone, OS version, list of services and programs configured to automatically run at startup, system configuration, and the list of installed

Table 1. Collected artifacts by information group (in %)

	ITT			IRKIT			TR3S			NTR3S			LRC			LRS		
Information	W	L	M	W	L	M	W	L	M	W	L	M	W	L	M	W	L	M
Network	60	20	–	80	–	–	100	–	–	100	–	–	60	80	100	80	60	60
State	67	67	–	67	–	–	67	–	-	67	–	–	100	67	67	67	67	67
System	–	50	–	75	–	–	50	–	–	50	–	–	100	50	50	75	50	50
User	33	67	–	100	–	–	100	–	–	100	–	–	67	33	33	33	67	67
Devices	100	50	–	100	–	–	50	–	–	50	-	–	100	50	100	–	100	100
Integrity	100	100	–	–	–	–	–	–	–	–	–	–	100	100	100	–	–	–
Logs	–	–	–	-	–	-	100	-	-	100	-	-	50	100	100	–	–	–
Autorun	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
RAM copy	100	100	–	100	–	–	100	–	–	100	–	–	100	–	100	–	–	–

software. The user information group considers artifacts such as: the list of tasks scheduled to run automatically, the list of local user and group accounts, and the history of system accesses. Device information group considers artifacts such as: the loaded drivers and modules, memory capacity, hard disk information, and the list of mounted file systems. Integrity information group considers artifacts such as: result of multiple cryptographic hash functions (MD5 [10], SHA1 [7], SHA512 [8]) over all collected artifacts and the tool itself. Finally, the log information group considers artifacts such as: the Operating System (OS) and application logs [4].

In conclusion, none of the identified tools performs an extensive and homogeneous artifact collection that is independent of the underlying OS.

3 Digital Forensic and Incident Response USB

In a digital forensic investigation, or in a response to a computer security incident, the investigator must comply with standardized procedures that include the use o specific applications and the validation of the integrity of the collected artifacts. The proposed solution, named Digital Forensic and Incident Response USB (DFIRU), aims to provide the investigator with an application that enables him to automatically collect artifacts in a standardized way and with integrity validation. Moreover, the artifact collection must be extensive, homogeneous, independent of the underlying operational system, portable and automatically executed when possible.

The proposed solution, depicted in Fig. 1, consists of a main application, developed in Java, that runs OS specific collection scripts. The scripts are arranged in 7 information groups. In turn, these scripts will execute commands that will perform the artifact collection on the target system. The DFIRU application is stored in a USB drive. The storage device can be formatted in multiple formats, in the prototype the Extended File Allocation Table (exFAT) [2] format was selected due to its native read and write support in the target operating systems (Windows, Linux and macOS). Moreover, the exFAT supports files larger than 4 GB, which are expected if memory dumps are performed. The automatic

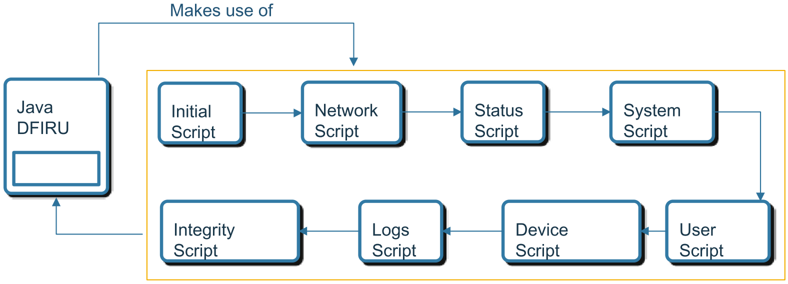

Fig. 1. DFIRU architecture

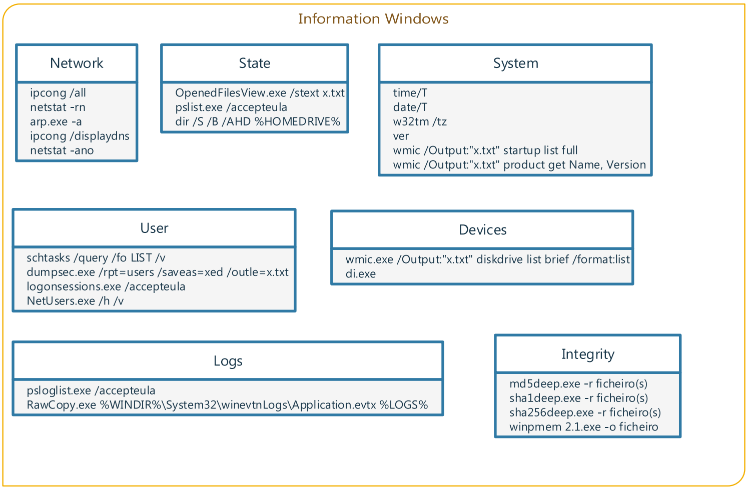

Fig. 2. Sample commands per information group (Windows)

execution of the proposed solution is implemented using the USB *autorun* functionality. This feature has native supported on both Windows and Linux. In macOS, and newer versions of the Windows OS, the user is required to manually launch the proposed solution because the *autorun* functionality is being deprecated due to security considerations.

Figure 2 presents a sample of the commands that are used by the scripts in the multiple information groups for the Windows OS. In order to collect artifacts of all information groups, 21 scripts were created, which were distributed by groups as follows: 2 for network, 2 for state, 2 for system, 2 for user, 2 for devices, 2 for logs, 8 for integrity, and one additional script that is used to prepare the output files and folders needed to save the collected artifacts. The need for 2 scripts per group is related to the level of privileges of the user that initiates the artifact collection (with or without administrator privileges). The integrity group required additional scripts because the application (see Fig. 3) has extra features for this group. These were then duplicated for users with or without administrator privileges.

4 Validation

The proposed solution was installed on a USB storage device using a device setup script that was develop for that purpose. The installation script includes the formatting of the USB storage device, the copying of the java application and associated scripts to the correct folders within the USB storage device, and the copying or downloading of the utilities required by the various scripts. Some utilities, due to distribution restrictions imposed by their developers, are downloaded at this time. The installation script has variants for the various

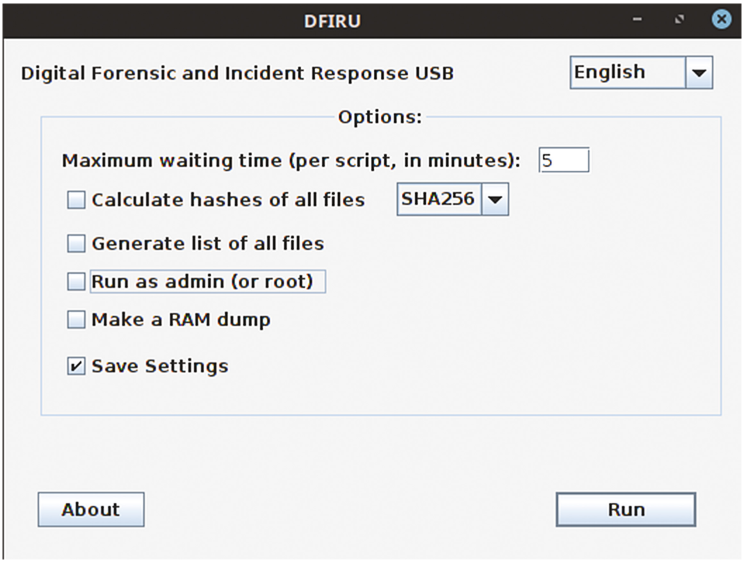

Fig. 3. Main window of the DFIRU java application

supported operating systems (Linux, Windows and macOS). This script also facilitated the process of validating the proposed solution.

In particular, the proposed solution was validated in terms of its overall functionality, portability and self-execution. A USB device was setup successfully with the proposed solution in all the reference operating systems. The USB device, after setup, was then disconnected and reconnected to test the *autorun* functionality. The *autorun* was successful in older versions of Windows and some Linux distributions, such as Fedora, but failed in recent versions of macOS and Windows 10. Moreover, the artifact collection with all available options selected was tested multiple times in all reference operation systems. The artifacts were correctly collected, resulting in a USB device containing the proposed solution and the collected artifacts. The proposed solution successfully registered its own activity and calculated cryptographic hash values of the collected artifacts and generated files.

5 Conclusion

The proposed solution consists of an application developed in Java that collects state information that is both extensive and homogeneous in all supported operating systems. Both the solution and the information collected are stored on a portable storage medium. Whenever allowed by the operating system, the proposed solution makes use of the self-execution mechanisms to automate the process of collecting artifacts. The proposed solution registers its own activity and calculates cryptographic hash values of the collected information and of the generated files. To the best of our knowledge, the proposed solutions is the only one that performs an extensive and homogeneous artifact collection, independently of the underlying operating system.

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Computer Vision Algorithms Fishing Vessel Monitoring—Identification of Vessel Plate Number

Joao C. Ferreira[1,2,3(✉)], Jorge Branquinho[1,2], Paulo Chaves Ferreira[2,4], and Fernando Piedade[2]

[1] Instituto Universitário de Lisboa (ISCTE-IUL), ISTAR, Lisboa, Portugal
{joao.carlos.ferreira,Jorge_Branquinho}@iscte.pt
[2] INOV INESC INOVAÇÃO, Lisboa, Portugal
{paulo.chaves,fernando.piedade}@inov.pt
[3] Centro Algoritmi, University of Minho, 4800-058 Guimarães, Portugal
[4] Escola Superior Náutica Infante Dom Henrique- ENIDH, Paço de Arcos, Portugal

Abstract. In this research work we developed a set of algorithms and approaches for vessel plate number identification, to be integrated in a Vessel Monitoring System (VMS). In addition, it was developed a solution that allows the creation of a history log of port exits/entries to assist the monitoring activities. This system will be based on a database and image processing equipment for use in the port, which will allow the identification of passing vessels (through the capture and processing of profile images of the vessel in order to identify the call sign, IMO or registration).

Keywords: Fish · Vessel · CCTV · Image processing · Plate recognition · VMS

1 Introduction

Illegal, unreported and unregulated fishing (IUU) is one of the greatest threats to the preservation of endangered species, responsible for the destruction of marine habitats, distortion of competitive logic, weakening coastal communities and places licensed fishers at a disadvantage. According to data from the European Commission of fisheries and maritime affairs [1], illegal fishing accounts for about 15% of global catches, amounting around 10 € billion/year [1, 2].

Fisheries control focus not only on the verification of fishing activities at sea, but also acting on all points of the chain, since the time of leaving the vessel to the placement of fish on the market. The management of the fishing activity is based on obtaining estimates of fish abundance and mortality imposed by fishing.

Most of the existing technologies allow the monitoring of vessels during their activity, tracking the vessel's position over time and determining the fishing activity through logbooks or other reports produced by the vessel's captain. As such, currently, the only reliable means of verifying the fishing activity are the on-site inspection from

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the exit of the port until the return of the vessel. The proposed system aims to provide the surveillance authorities with an automatic solution that responds to the needs identified in the monitoring, control, management and surveillance systems of fishing activities. To meet those needs, it is intended to develop a surveillance system that allows the control of entrances and exits of fishing vessels in the port, in particular by collecting and processing vessel profile images that identify call sign, IMO (International Maritime Organization number) or registration. A database will hold a log of the port's entries and exits by associating the ship's identifications with the detection timestamp. The data captured by the cameras is evaluated through a computer vision approach to identify vessel plate number.

2 Proposed Approach and State of Art in Fishing Monitor System

OCR systems are generally comprised of five basic but integrated elements: (1) Presence detection and triggering; (2) Image capture; (3) OCR software algorithms for pattern recognition; (4) Exception management software applications; and (5) Electronic data integration and communication with other systems. In this work we describe an implementation of this applied to vessel plate number identification, at the harbour entrance. Most of our work was oriented for an operational solution using main computer vision approaches using OpenCV and MATLAB.

Through the development of computer vision algorithms, it is possible the recognize plate numbers of vessels, a complex problem due to missing standards on plate number labels (skewness, different font size and use of non-contrasting colours). Our implemented approach, takes into account a first approach of pixel-based detection, followed by object based detection.

Feature Detection [3] used to identify relevant parts/information in an image and can be used to find differences and similarities between objects. Generally, most image processing algorithms start from the features of the image, focusing essentially on edges, corners and blobs and Hough transformations (lines, circles, ellipses, parabolas). When comparing objects, we are looking for repeatability in features between two or more images. The concept of feature detection refers to methods able of making local decisions at every image point, and evaluate whether a given point contains a distinguishable image feature of a given type or not [4].

Method 1—Pixel-based detection—In this model, the pixels of the image are extracted and compared with a previously developed model, in order to identify each pixel, either as background, or foreground (object). Pixel-based detection parses the detected features and verifies if they match those of the object, while feature detection is the prior step which only focuses on finding features of an image. In Fig. 1, an image is presented as an input (a), in which we want to extract the boat. Assuming we already know which features are contained in the boat (for example, contain circle-like objects like the tires around the boat and one well defined line such as the prow) and which are definitely not present in the boat (for example, no edges detected), we can create a mask-like matrix containing the silhouette of the object (b). This matrix is a binary image containing ones (white) and zeros (black), corresponding to the presence or

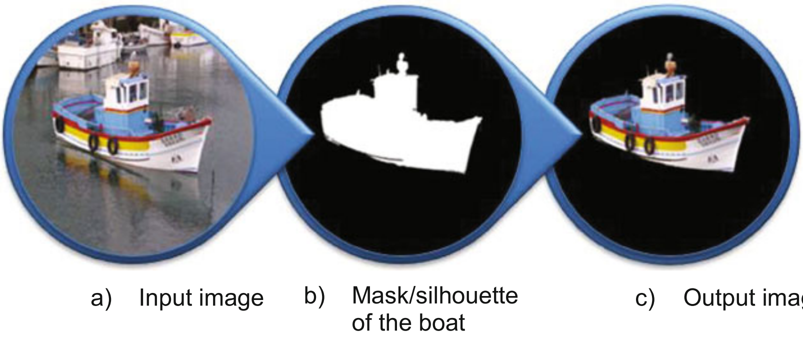

Fig. 1. Theoretical example of a process of pixel-based detection

absence of the object. In theory, it is now possible to distinguish the silhouette of each object in the image. After performing this filtering, we multiply the matrix with the original image. This step is done to subtract the background to the image, given that any value multiplied by zero is zero (black) and any RGB value times 1 is itself (object pixel RGB). Assuming the previous step is done correctly, the output is an image containing the object (c). Note Fig. 2 is a theoretical representation and typically the output isn't as "clean" as shown. The pixel-based detection method typically has better results in indoor environments where there are no significant changes in the background than in outdoor environments where changing brightness, shadows and atmospheric conditions may be some of the sources of noise [5].

Method 2—**Object-based detection**—This second approach requires a previously trained classifier. The training begins with a set of positive examples (images containing the object), an even larger set of negative examples (do not contain the object and can be a typical background) and a file containing the bounding box with the object location for each of the positive images. The training step consists in identifying the features contained in each of the bounding boxes for each of the positive images. To put in perspective, positive images could correspond to images containing fishing vessels (such as shown in Fig. 2a) and negative images with pictures of the sea,

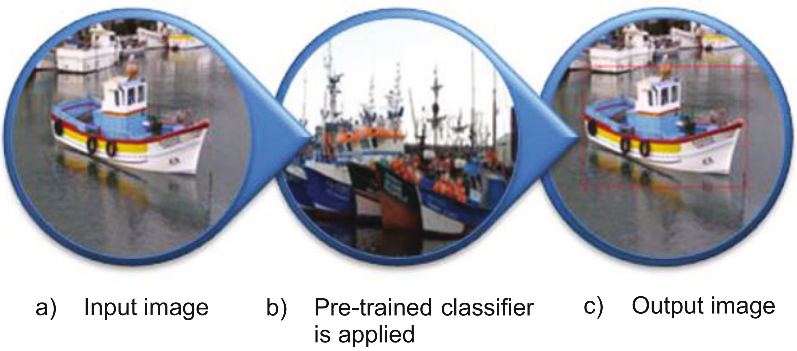

Fig. 2. Theoretical example of an object-based detection algorithm

Fig. 3. Identification of vessel bow through HOG process

harbour or non-related scenarios, such as cities. The training requires a considerable amount of samples that is why the positive images suffer transformation, such as translations, rotations and scaling, and are merged with the negative images, generating many more samples. While training, all the common features of the object are compared and stored. Any image can be used as negative as long as it does not contain the object, but if real-life scenarios are used there is a bigger chance the algorithm can distinguish it in its environment. On the other hand, to ease the training video frames can be used if the video is filmed in a non-static environment.

During the execution of the algorithm (illustrated in Fig. 2b), a floating window navigates through each frame of the image, scaling and undergoing translations in all possible locations of the image. The reason why the window is scaled relates to its ability to detect objects at different distances. A binary classifier evaluates the presence of the object features in each position of the window. Each relevant object (group of features) found is marked with a box/window that surrounds it, so that it is visible to a user (Fig. 3c). Methods such as Support vector machines (SVM), AdaBoost and Random Forest Classifiers have been successfully used in the past to sort the contents of the window [5, 6]. However, to complete only one frame in its entirety, it is necessary to adjust the window 10–100 thousand times, causing severe delays in the execution time. Using simple and sensitive classifiers, such as SVMs, to, in a first step, traverse the entire image and return a list of locations in the image where there is a greater probability of locating the intended object, while in a second step, a more effective classifier is run in the marked places, confirming the objects, is a good way to increase the performance [6, 7]. This method is called cascading.

This approach typically fails when the background is far from static, such as when a mobile camera is used for image capture, or when there is a partial occlusion phenomenon. A common solution is using HOG detectors constructed with the notion of edges produced by the object in certain well-defined and non-random locations. It can also be complemented by using Viola and Jones detectors, which combine simple features with cascade classifiers as well as contrast detection [5, 6]. Precautions should also be taken to avoid overtraining [6]. This approach presents better results, especially in outdoor areas with the possibility of partial occlusion [5].

3 Implement Solution at Harbour

The proposed solution is composed of two parts, one registering the identification of the fishing vessels entering or exiting the harbour (non-boarded system) and other monitoring fishing activities in each ship (boarded system). The methods and algorithms that we will be discussing later on will be implemented under the architecture addressed below and must be operational under particular constraints that may arise by that same architecture. The non-boarded system will be placed in a harbour (Nazaré's harbour), leaving several options regarding the placement of the camera. As different locations may require different algorithms, considering the inputs are disparate as well, the location chosen may be relevant to guarantee correct results. On the one hand, placing the camera closer to the sea allows a wider gap between each side of the canal, with public access and possibility to contemplate undulation. On the other hand, placing it inside the canal has some privileges, such as restricted access, passage width of 80 m and had the additional advantage of boats slowing down when nearing the core of the harbour. The hardware concerning the non-boarded system of two cameras: one low resolution video camera (Bosch's DINION IP starlight 7000 HD) and a photographic high-resolution camera (IDS' UI-5490RE-C-HQ). The filming camera seeks moving vessels nearing the canal, triggering the photographic camera when the ship enters or exits the harbour. One of the solutions developed for the system is composed of three modules: (1) the vessel detection module—responsible for finding a possible vessel in the surrounding area, using the context camera, and triggering the photographic camera. To implement this step, we adapted an already built Kalman filter in MATLAB. (2) the ROI (regions of interest) are extracted using a cascade classifier, where we extract the object and identify regions that may contain elements of interest (namely areas containing characters), then we apply the pre-processing to crop each region, improve its quality and applying rotation or de-skew, if proven necessary; (3) OCR module—tasked with recognising and extracting the text in each area detected by the previous module.

4 Results

Since the authorization process for harbour installation is pending, we created a considerable dataset for our testing environment, based essentially on marine photography blogs [http://jjcm-embarcacoesdepesca.blogspot.pt/] and [http://palangreiro.blogspot.pt/] and [http://barcosdepescaemportugal.blogspot.pt], amateur videos [https://www.youtube.com/watch?v=JQZJuwtSB0s], and more recently, extracted from imageNet and VesselFinder [8]. Later, we would create and add blender animations to this dataset, mainly because some conditions such as fog and waves could be manipulated, as well as camera angles, providing a good and extent test case scenario. Our database at the time of the first tests was composed of 125 pictures (and another 182 background images for the cascade training). Keep in mind some pictures had to be filtered out of the dataset, because they didn't fit for the purpose, e.g. they were not Portuguese professional fishing vessels or the image quality was not sufficient for a clear reading of any of the ship's registrations. Currently 464 new pictures were added, totalling 589 images of vessels. Since the models of the animation can be altered and produce new animations, a vast number of animations can be rendered. Currently only one vessel [8] was modelled, but if proven rewarding, new models can be created. The vessel detection based on Kalman filter was implemented with a success of 100%, for the tests it run. The tests were composed of (1) an animation of a fishing boat navigating past the camera in which the sea was static (no waves) and later for a simulation of normal undulation (2) amateur videos of vessels near ports. The output of the motion detection module is an image that, on a first process, is flipped horizontally if the boat is pointing to the left. This step is done because we are looking for the prow and to do so, it is required two classifiers one for each direction of the prow. This seemed to be unnecessary work, because flipping the image to best fit the classifier is easier and faster. This is done using simple MATLAB functions that converts the image to a matrix of pixels and inverts the order of each row, flipping the image. In addition, the image may be scaled if it is too big, in order to reduce both the processing time and reduce the number of non-relevant features. This process is performed with a success rate of 100%. The second step is the application of a previously trained Histogram of Oriented Gradients (HOG) cascade classifier, used to find the features of the prow of the vessel, see Fig. 3. The most successful classifier was trained with around 200 negative images and 125 positive images of fishing vessels. Its success rate is around 50% (precision) with a recall of 98%. Most failures are due to ships being too close or too far away, not corresponding to the typical images in which the classifier was trained. Also rounded prows were not used in the training and naturally failed. This experiment proves further training is required, as well as a greater variety of positive images. Another experiment consisted in increasing the number of negative images to 1500 by using frames of videos of harbours and sea. This second experiment resulted in an increment of the recall and a decrement of the precision, as it would be expected given we are specializing the classifier to detect those few vessels given in the positive images. In short, some hypothesis arises from these experiments, to increase the recall a greater number of negative images is required and to increase the precision a greater number of positive images is required. After the installation in harbour a greater variety of images can be acquired improving the algorithm performance. The measures of precision are based on correct plate identification based on over all tests performed and recall is based on wrong labels based on the number of cases tested.

Third, the regions detected by the classifier are cropped. Note there are false positives (Fig. 4) meaning multiple regions can be detected. To apply the crop, simple MATLAB functions are used, cutting only the relevant portion of the image. If no regions are detected, the input image is used and if several are detected, the remaining steps are repeat for each of the cropped regions, see Fig. 5. Next step is the OCR process to identify plate labels. This is a very complex process due to the lack of standards. The process on vehicles plates is easier due to the existence of standards—the registrations are printed with a low-reflective foreground and a high-reflective background. Most of our problems came from letters of different size most of them are skewed and/or distorted, the colours used and a curved shape of vessel prow. To overcame this process several approaches were implemented. The main approaches, see results of Fig. 6, were based on a previously trained OCR algorithm to the regions (MATLAB's OCR function is used). Results may vary from almost the complete

Fig. 4. Pre-processing, enlarge prow region

Fig. 5. Example of OCR outputs

registration to none characters detected. First, we look for MSER (Maximally Stable Extremal Region) features to find the registration and try to isolate it. It uses the previous output image as input and returns that same image if it fails. Due to the lack of standards, most of characters were skewed and for a correct OCR process, a rotation is applied (within certain limit values and taking into consideration the direction of the boat). OCR is applied to each rotation and the best-fitted angle is chosen based on: number of desirable characters ([A–Z], [a–z], [0–9], '.', '–', '_') and a higher degree of certainty, example of this is the output of Fig. 5. Sometimes we had problems with background colour, similar to plate numbers. For that we need to convert the previous image to monochrome red (appears to be slightly better at finding darker colours than grayscale), apply a filter to all values over 90 of intensity (in a scale from 0 to 255, it means a light region) and sets of pixels with area less than 30 (very small).

A binary image is produced because of the previous steps. In this set of tests, we were looking only for characters painted in darker colours, because a similar process could be developed for lighter colours. This procedure is repeated for the outputs of the cascade classifier's result (prow of the vessel) to compare if any character was missing. With a bigger region, the thresholding may result in the loss of characters detected in the previous step, resulting in fewer visible characters. In the end, four results are showing for each region detected, corresponding to four OCR results: the cropped image of the region and its thresholded version; a further zoomed image of the vessel's registration and its corresponding thresholded version. Regarding this approach, the

Fig. 6. Example of the words detected after the application of the OCR function before the isolation of the registration

classifier needs further improvement that is more training with more images that are positive and with a greater diversity negative image in order to properly detect the prow of ship. This approach also requires a classifier for the remaining parts of the vessels that may contain text, but will always have a great disadvantage: the text in the vessel is not always positioned in a specific place like the prow, for example, the back of the ship or the cabin, which requires a classifier for each. In addition, the detect object (like a prow, for example) can have the registration in a variety of places, with a variety of colours, shapes and rotations. On the other hand, when trying to isolate the registration, most of the time a few characters were excluded and, because no de-skew methods were applied, the output had some of the text but also a lot of gibberish. Judging from this experiment, the zoom sometimes improved the OCR's results, mainly reducing some of the noise. Another future improvement would be to apply linear regression on all bounding boxes on the zoomed image, in order to identify one or the two lines composing the registration. Next, the bounding box should be expanded and/or moved along the defined lines, in order to detect the remaining characters.

5 Conclusions and Discussion

We developed a prototype to identify vessel movements at harbours in a similar approach of vehicles in Electronic toll collection (ETC) system. This problem has a great complexity due to the lack of standards, shape of the hull (curved), poor colour contrast between vessel background and letters used of vessel identification. We tried several approaches to solve a diversity of these problems. In spite of the system architecture being composed of three modules, a great deal of effort was put into the Region of Interest Module, mainly because the other two modules are not as innovative as this, hence they will be easily addressed. In addition, they tend to be composed of only one well-defined algorithm. On the other hand, despite the existence of multiple algorithms for text detection in natural images, none addressed this specific problem, therefore the interest in developing such a solution. The earliest solution to produce acceptable results is the one described throughout this paper, consisting of a Kalman filter applied to features detected in the image for the vessel detection module, a HOG classifier to detect the prows of the vessels and a simple rule-based mechanism to zoom in near the registration for the ROI module. The OCR module rotates each input image in order to detect the best candidate solution, and extracts its text. This solution is far from ideal but still functional. Its biggest flaw was the scarce and repetitive training set, mainly because most photos of the set consisted in boats sideways and very few photos of up front vessels. Selecting the regions of interest in the dataset can be a very time consuming task, but if provided with a good dataset this approach may become extremely accurate. Other two approaches for the ROI detection module consisted in: (1) calculating intensity histograms and thresholding to its peaks, obtaining only the lighter and darker colours of the image; (2) obtaining the MSER features of all of the image, filter all values by its area, eccentricity, Euler Number, solidity and bounding box aspect ratio. The bounding box of the remaining features would then be expanded and merged with its neighbours. All boxes containing only one feature would be excluded. The boxes would then be thresholded by the rate of Harris and SURF features in each box. This last approach was much faster than the classifier solution, more generalized as it does not stick only to the prows and particularly accurate, except for up close photos of vessels, were the character size suffers a greater variation. This work is part of a monitor system to control vessel fishing activity based on CCTV. A key weakness of CCTV is a design inability to prevent tampering. Unlike VMS, which is an entirely enclosed solid-state monitoring device, CCTV system has exposed cameras, sensors and wires throughout the vessel, and there are too many uncontrollable ways to fault the system.

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Preliminary Development of a Walk-Helper Application Agent with an Assistant Personal Robot

David Martínez, Dani Martínez, Eduard Clotet, Javier Moreno, Marcel Tresanchez, and Jordi Palacín(✉)

Department of Computer Science and Industrial Engineering, University of Lleida, 25001 Lleida, Spain
palacin@diei.udl.cat

Abstract. This paper presents a preliminary implementation of a walk-helper mode embedded in an Assistant Personal Robot as a complementary feature implementation in the mobile robot. This mode enables a bidirectional interaction between the user and the mobile robot in order to perform a short displacement. On the one hand, the user drives the mobile robot by pressing its support arms and, on the other hand, the mobile robot is aware of obstacles and unstructured areas in order to smoothly correct the user path. This new application has been tested with users in controlled environments providing optimistic results from feedbacks.

Keywords: Robot agent · Assistant personal robot · Walk-helper

1 Introduction

The concepts Ambient Intelligence (AmI) and Ambient Assisted Living (AAL) are getting stronger since the last years by means of new technological solutions for our homes and other human-frequented places. This fact involves the development of new systems and devices focused on easing the daily living routines of people, especially those ones who require specific dependence needs. AAL applications are usually designed to provide care and accessibility services for people with everyday difficulties such as the elder and the disabled people. Ethics, dignity, and respect [1] are important guidelines that should be determined when developing such solutions because of the potential fragile emotional sensibility of users. For example, AAL systems must not treat his users as objects; otherwise, they have to give them the chance to be part of the solution enabling reciprocal interaction and subtle encouragements.

Mobile robots are an interesting platform for AAL services offering application versatility and environment adaptability. So, they are becoming popular among researchers and companies that develop advanced AmI and AAL solutions. In this direction, telepresence robots were proposed in order to allow disabled people to assist and participate in social events as if they were in person. For example, [2] proposed a telepresence robot system designed for people with severe disabilities, which was controlled by a brain-computer interface, and it was applied to several experimental

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cases with users under different medical conditions. In a similar line, robotic wheelchairs are also addressed in this field such as the proposal in [3] in which is implemented several command options as well as an autonomous navigation system. As another example of an AAL robotic system, a shopping companion was proposed in [4] capable of following the user while the robot is carrying the purchased products in order to ease the daily life of elder people. Furthermore, automatic fall detection methodologies are popular in this field and its implementation on mobile robots is proposed in [5] for household domains that are the most frequented by the target users. In a similar direction, the work proposed in [6] describes adaptive path planning method for an own-made walk-helper robot. Nevertheless, this paper presents a newer and innovative feature for assistive robotics, a walk-helper mode for polyvalent assistive robots which can be used by persons with cognitive-motor difficulties.

The development of the Assistant Personal Robot (APR) used in this paper was described in [7]. The initial proposal of the APR was developed mainly focused on the telepresence capabilities but the design was open to include additional features. This paper proposes a preliminary implementation of a walk-helper in a second generation APR. The main idea is to include different robust assistive services to the APR in order to develop a complete polyvalent platform. The walker mode is proposed as an assistive service designed for helping people with mobility problems to encourage them to walk with a smart support providing path adaptation and guidance along the displacement. The interaction between the user and the mobile robot is bidirectional giving the main control to the user.

2 Mobile Robot Platform

This section presents the different features of the used mobile robot platform, which are considered relevant for this preliminary implementation: the mechanical design and the control unit.

2.1 Mechanical Design

The original design of the APR was inspired in a semi-humanoid shape. The current APR implementation reduced the generation of vibrations and included an improved suspension system. The motion system is based on three omnidirectional wheels capable of performing any movement in any direction [8]. The mobile robot has a 12” touch screen as a face for human-computer interaction and two arms which are used for walk support in this paper. The arms are hold by two Dynamixel MX-28T servomotors with a stall torque of 2.5 N/m. Figure 1 shows an image of the whole structure of the APR used in this paper.

2.2 Control Unit

The main control unit of the APR is a battery-powered computer with an Intel Core i7-6700 3.40 GHz processor, 16 GB of DDR4 memory, and a solid-state drive hard disc (Fig. 2). This system is directly attached to the robot structure by using 3D-printed

Fig. 1. Second generation APR without protection case

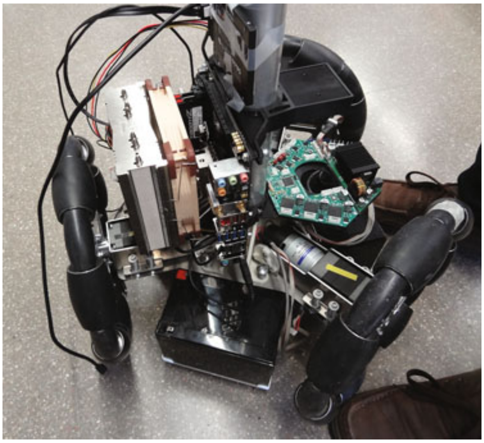

Fig. 2. Detail of the APR control unit system and the embedded motor control system

coupling pieces and is adapted to include a high performance cooling system. This computational configuration allows to execute advanced robot routines that require high computational resources. Furthermore, at the opposite side is placed a custom motor control board with three H-bridges and an ARM-based microcontroller for PWM signal generation. Three 12 V 12Ah DC batteries power the whole robot system.

3 Walk-Helper Application

This paper is focused on the development of a robot-embedded mode and this section describes the details of its implementation. The proposed methodology is an assistive routine that will be available in the APR assistive robots. The methodology conceives a collaborative procedure between the user and the robot in which the user leads the forwarding direction and the robot provides physical support and automatic corrective displacements.

3.1 User Control Parameters

The walker mode of the assistive robot can be activated in any moment the robot is stopped by grabbing both arms from behind and holding them to a comfortable height as shown in Fig. 3. After few seconds, the robot recognizes the walker mode activation order and interrupts all the other assistive tasks labeling them as pending tasks which will be resumed once the user finishes using the walker mode. When the user has reached its destination, he has to release both robot arms and after 20 s being inactive, the robot disables the walker mode and returns to its normal operation mode.

The walker mode provides the user a set of different performable displacements such as forwarding, backwards, arc-rotation, and self-rotation. The forwarding order makes the robot displacing straight and is performed by slightly pushing down both arms simultaneously. Otherwise, if the user pulls up both arms with a similar touch, the robot goes backwards. The mobile robot is also capable of performing an arc rotation having the user as the center of the virtual circle in which the robot follows its edge. To perform this displacement the user has to pull up one arm and push down the other; then, the mobile robot starts moving by the side in which the arm is up. Finally, the user can rotate the mobile robot on itself by only pulling up the arm which corresponds to

Fig. 3. User activating the walker mode of the APR

the desired rotating sense. The reference position of the arms in such displacements is taken and stored when activating the walker mode with the preferred arm height. In addition, as well as the arm position goes farther from the reference position the mobile robot increases its speed.

3.2 Adaptive Path Correction

While the user is commanding the mobile robot under the walker mode, the robot executes an embedded path correction procedure that is continuously aware of the robot environment. This system uses environmental information obtained by the laser range sensor placed at the mobile robot. In a first iteration, the robot checks if there are front obstacles in a short range up to 30 cm that does not allow the robot to pass through. If there is any obstacle, the robot corrects the user order to automatically perform a lateral displacement until the obstacles disappear. If there is no obstacles under 30 cm, the second iteration is executed. In this point, the robot analyses the obstacles within a range of 2 m and localizes the free spaces among them. Those free spaces are depicted as vectors which mid-points are virtually connected to the center of the robot creating other vectors from the robot to the free spaces. These resulting vectors are considered as potential paths for a new corrective displacement. Finally, the vector with the closest angle from the robot current orientation is chosen as the actual corrective direction. Figure 4 shows an example of a situation where the robot detects an obstacle and computes the corrective direction.

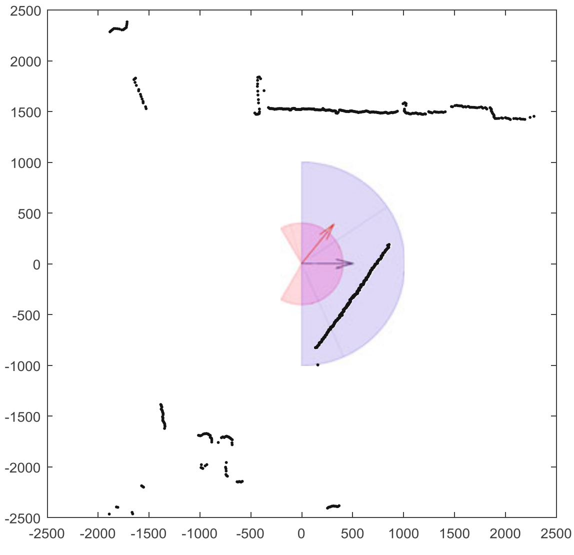

Fig. 4. Laser scan representation with current robot orientation (*blue*) and the computed corrective vector (*red*). Red and blue areas depict the safety areas

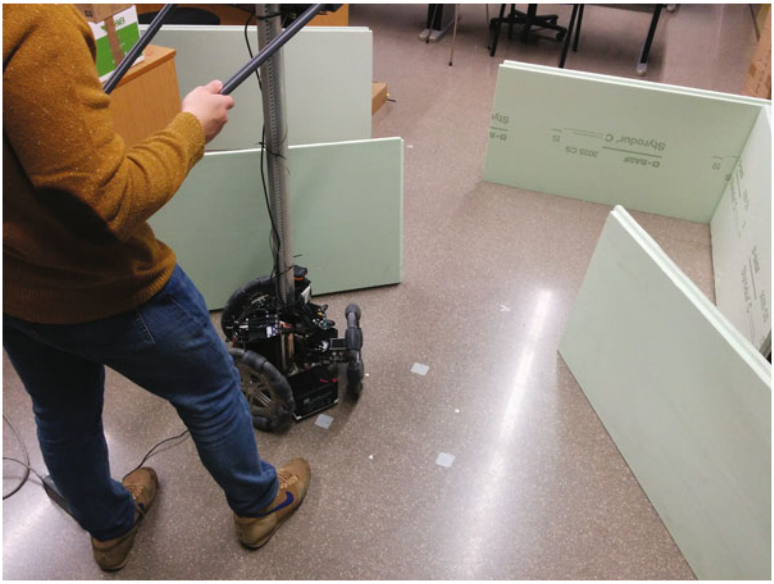

Fig. 5. User controlling the APR in walker-helper mode passing through obstacles

4 Experimentation and Results

This section presents some experimental tests carried out in a controlled indoor environment with volunteers as users of the APR operating in walker-helper mode. For this validation stage, two users were asked to participate in this tests that were carried out in different environments with complex shaping like complicated doorways and obstacles in a laboratory. In this preliminary experiment the users have to travel from an initial position to a predefined destination with the help of the APR. Figure 5 shows a frame progression taken when developing the experiment in which the user is always moving forward and the robot corrects the direction by itself in order to avoid collision with the obstacle. The average of the forwarding speeds during the experiments was approximately 0.24 m/s.

The feedback declared by the uses during these experiments defined the usability and comfortability of the automatic corrective procedure when navigating in complex-shaped areas with the help of the mobile robot.

5 Conclusions

This paper presents a preliminary application service for assistant robots based on emulating a walk-helper with dynamic improvements for people with motor difficulties. The mobile robot used in this paper to implement the walk helper mode has two arms that can be used as a direct physical support. The user can activate the walker mode by simply holding on the robot arms at the back for a while in a desired height. At this point, the user has several basic control actions to guide the mobile robot while the mobile robot automatically corrects his path when detecting obstacles or places requiring complicated maneuvers. Future work will be focused on performing an extensive validation of this methodology in order to obtain reliable and definitive results. Moreover, on providing a robot full-guidance service based on autonomous navigation in which users does not have to previously know the path to their destination.

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Preliminary Application of an Assistant Personal Robot as an Ambient Monitoring Tool

Eduard Clotet, Dani Martínez, Javier Moreno, Marcel Tresanchez, and Jordi Palacín(✉)

Department of Computer Science and Industrial Engineering, University of Lleida, 25001 Lleida, Spain
palacin@diei.vdl.cat

Abstract. Parameters such as illumination, humidity and temperature are directly related to the quality of life and safety of the inhabitants of a house, especially in the case of elders and kids. With this objective, an autonomous mobile robot which operates as a personal assistant has been equipped with a measuring device which monitors such parameters. The mobile robot displays graphically the measures obtained over a map of the explored area. This paper describes the implementation and results obtained when using the mobile robot as an autonomous mobile monitoring device in order to identify and locate areas which temperature, light or humidity are out of a recommended range.

Keywords: Assistant personal robot · Ambient monitoring tool · Home assistant · Autonomous agent

1 Introduction

Temperature, light and humidity are considered three of the most important parameters that will define the comfort level of a house. Although each person has different preferences when defining the configuration at which they feel comfortable, the average home temperature, light and humidity should range between 24 °C (summer) to 22 °C (winter), 300 to 500 lx, and 45% humidity respectively. The importance of maintaining the appropriate values for temperature and humidity was described in [1], where a study is conducted to determine how the ambient conditions affect to different group of students.

These three parameters do not only condition the comfort levels of a home, but also its safeness, as poor illuminated areas can lead to domestic falls and accidents [2], or inappropriate humidity levels can have a negative effect over the inhabitants health [3] and physical structures [4].

Due to the large temperature variations between different seasons of the year, the use of thermostats to measure and adjust the temperature in indoor environments is considered basic in any type of building. However, other important parameters such as light and humidity are not commonly measured and adjusted. For example, light sources are commonly replaced with ones with different characteristics, and humidity

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problems are hard to notice until long-term exposure causes health or structural problems. In this direction, this paper presents the preliminary implementation of an autonomous agent designed to perform periodical explorations in a building and monitor temperature, light and humidity. Therefore, the main idea of this paper is to develop an integrated capability of a polyvalent assistant mobile robot in order to gather such ambient information, which can be used for further robot decision-making routines or for accurate environmental supervision of a human-living area.

2 The Assistant Personal Robot (APR)

The Assistant Personal Robot (APR) model 02 (Fig. 1) is the second evolution of a mobile robot designed as a personal assistant, a human-operated robotic platform created with the objective of improving the life quality of elders and mobility impaired people [5]. This version of the mobile robot is equipped with a high-performance onboard computer, providing the computational power required to performing SLAM (Simultaneous Localization And Mapping) operations, autonomous navigation, and simultaneously processing additional data obtained from different sensors. The use of a computer also allows the possibility of connecting a wide range of onboard measuring devices through multiple USB ports.

Fig. 1. Image of the APR prototype during an exploration

3 Exploration and Data Monitoring

At this moment, the environment exploration task of this approach requires an initial human-guided exploration in order to create the map and deal with the different obstacles and situations present in a real building. During this exploration, the robot uses the onboard LIDAR (Light Detection and Ranging) device to obtain multiple scans that, once merged by combining variation of the ICP algorithm [6] (Iterative Closest Point) with the data returned by the robot encoders [7] conforms a two dimensional representation of the explored area (Fig. 2). This process is an enhancement of the limited area measurements performed in [8].

This map is used to determine the navigable areas by projecting a grid of unoccupied coordinates. In this grid, each existing node is considered a valid reachable position, and it is connected while its immediate neighbors, giving as a result a navigation tree. The resulting navigation tree is stored in a persistent file, and will be automatically loaded every time the robot is working inside that specific area. To find a path between the initial robot position and the target node, the A* algorithm [9] is used; each path is composed of multiple nodes that are used as waypoints that the robot needs to visit in order to reach its destination. To avoid creating paths with an excessive number of waypoints, the list of waypoints is simplified by removing consecutive nodes that are located forming a straight line.

At the scheduled hour, the robot computes the route to the specified destinations (target nodes) and starts its navigation procedure while monitoring the desired parameters and recording the measured data. The ICP algorithm is used again in order to identify the current robot position. This allows the robot to identify its current position in the map along with the displacements required to reach the next waypoint. This information is also used to register the exact location and time at which each sensor measure is obtained. Once the exploration is completed, the robot sends the recorded data to the server and returns to its initial position.

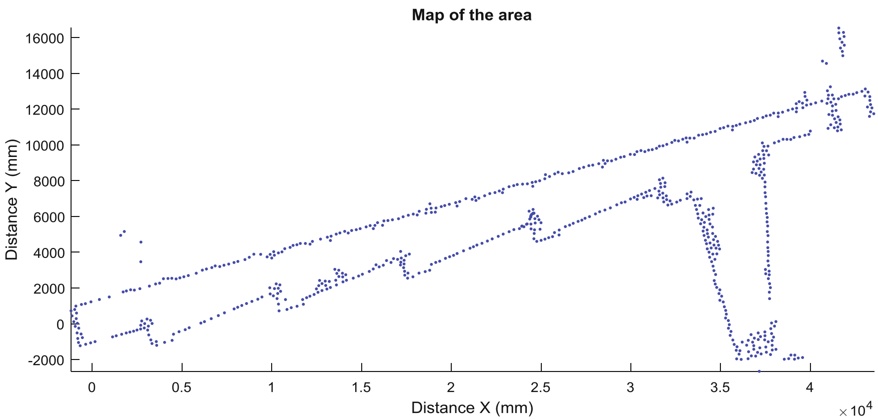

Fig. 2. Map of the main experimentation area used for ambient measurement

Fig. 3. Image of the main experimentation area

4 Results

This section presents the preliminary results obtained during the exploration of a selected experimentation area which, in this case, is the second floor of the Polytechnic School from the University of Lleida (Fig. 3).

Figure 4 displays the route followed by the robot during the development of an exploratory experiment. In this case, the mobile robot spends 4 min and 39 s to reach the target node, traveling a total distance of 41.49 m, and taking 394 temperature, light and humidity lectures.

Figure 5 displays the dynamic evolution of the measured temperature, light and humidity levels during the exploration.

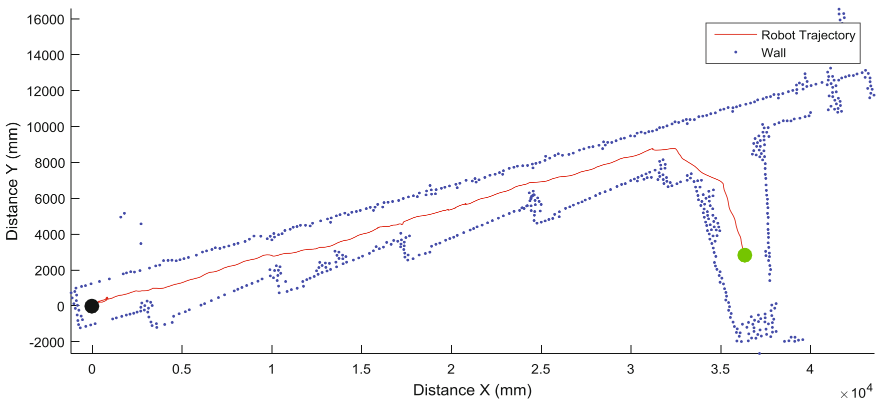

Fig. 4. Visual representation of the trajectory followed by the mobile robot during the exploration. The *green* circle represents the initial node, while the *black* one represents the target node

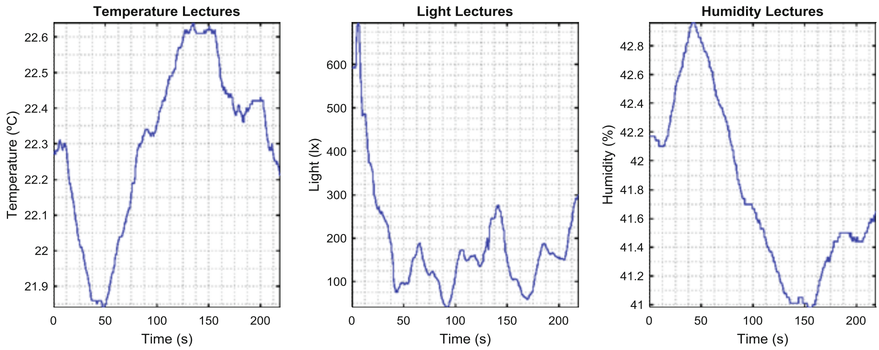

Fig. 5. Dynamic evolution of the parameters measured

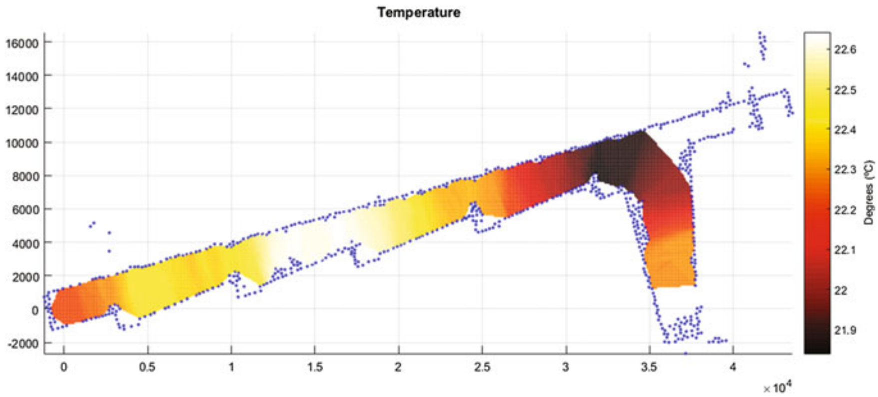

Fig. 6. Graphic representation of the temperatures measured during one exploration

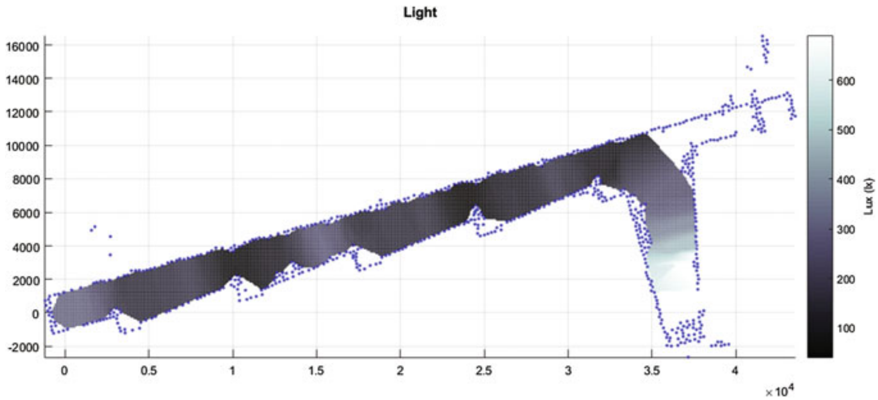

Fig. 7. Graphic representation of the light conditions measured during one exploration

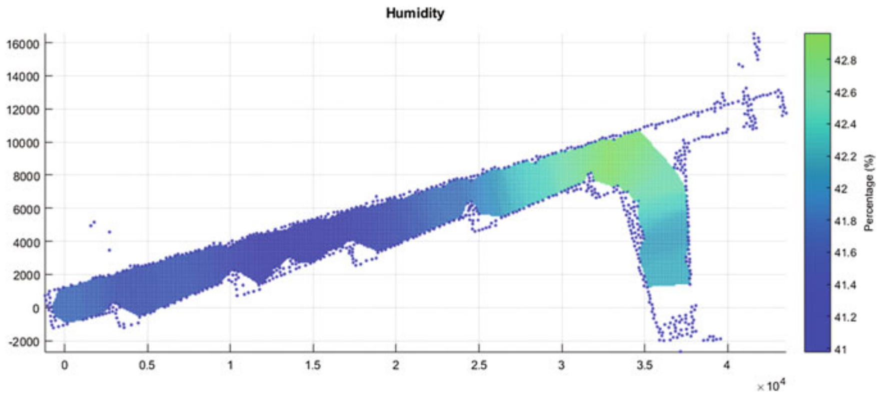

Fig. 8. Graphic representation of the humidity percentage measured during one exploration

Since the robot records the coordinates at which each value is obtained, the representation of the measured data can be displayed by interpolating a three dimensional surface between the points that conform the initial map; then, the measured values are introduced to define the height and color. The values at the edges of the map are stipulated according to the nearest lecture obtained during the exploration. If the nearest lecture is further than a specific distance, it is considered that there is no consistent lecture for that position, and will not be represented in the map. The result of this process is shown at Figs. 6, 7 and 8, which shows the graphic representation of the temperature, light and humidity respectively.

5 Conclusions

This paper presents the preliminary implementation and evaluation of an autonomous mobile agent implemented in a mobile robot. This robot has been designed to perform scheduled monitoring routines in order to identify and locate inadequate ambience conditions that may become potential threats for the inhabitants of a house. To achieve such objective, an APR has been equipped with multiple sensors to measure temperature, light and humidity. The robot has been also modified to support autonomous navigation capabilities based on the use of an onboard LiDAR device and a variation of the ICP algorithm to perform the required SLAM operations. As holonomic robots cannot rely on their kinematics model to plan trajectories, a waypoint-based navigation system has been implemented applying a shortest path algorithm, such as the well-known A* algorithm, in order to compute the path that leads the robot to the target node.

In this proposal, the position of the mobile robot is updated continuously so the gathered ambient data can be combined with its location, giving as a result an enhanced visual representation that simplifies the evaluation process when locating inefficient heat areas, low lighted surfaces, and inappropriate humidity levels.

Finally, the reliability of using an onboard computer ensures its compatibility with almost any device that can be USB connected to a computer, extending its possible uses in research and industrial fields as an autonomous measuring and monitoring device.

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MuSec: Sonification of Alarms Generated by a SIEM

Luís Sousa[1] and António Pinto[1,2(✉)]

[1] GCC, CIICESI, ESTG, Politécnico do Porto, Portugal
{8090228, apinto}@inesctec.pt
[2] CRACS & INESC TEC, Porto, Portugal

Abstract. The information generated by a network monitoring system is overwhelming. Monitoring is imperative but very difficult to accomplish due to several reasons. More so for the case of non tech-savvy home users. Security Information Event Management applications generate alarms that correlate multiple occurrences on the network. These events are classified accordingly to their risk. An application that allows the sonification of events generated by a Security Information Event Management can facilitate the security monitoring of a home network by a less tech-savvy user by allowing him to just listen to the result of the sonification of such events.

Keywords: Network security · SIEM · Sonification

1 Introduction

Monitoring a network to detect intrusions, vulnerabilities, and attacks is usually an arduous task. The manager of a network sometimes encounters a large amount of data which makes it difficult to task. There are several applications or open-source platforms that allow the network manager to have all the information he needs to monitor a network and detect attacks. Open Source Security Information Management (OSSIM) [3] is an example that was identified as the preferable open source solution [5].

OSSIM allows the manager of a network some ease of monitoring because the main information about the state and what is happening on the network is presented in a dashboard. Even so the task of a network manager is not uncomplicated because it depends the size of the network and the utilization of OSSIM requires continuous attention and specific expertise in order to understand whats happening. A less tech-savvy home user is unable to use such a solution.

A possible approach is to convert the information produced by the SIEM into something more intelligible by the home user, such as sound or music. Recently,

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several researchers [16,20], have been looking for alternative representations for network monitoring, like sonification techniques (data transformation into music) with several advantages.

The objective of this work is to create an application that allows sonification of the events that come from OSSIM. It makes it possible to simplify the work of those who are checking the status of the network, as there is no need to be consulting the service and only have to listen to the sonification results of such events.

This article is organized into sections, containing a total of 6 sections. Section 2 evidence in which the sonorization consists and the results of its application in several areas. Section 3 explains what SIEM is, what are its advantages. Section 4 presents the proposed solution to the problem in question. Section 5 speaks about the results of this solution. Section 6 focuses on a small conclusion on the subject and the article, and a future work is presented.

2 Sonification

Sonification is a way of transforming data and relationships into an acoustic signal for interpretation or communication purposes [16]. In [9], the authors state that sonification can only be called sonification if the sound is objective, if the transformation is systematic and if is reproducible, in other words, the sound results must be structurally identical for the same input. The human hearing capabilities differ significantly from their visual capabilities. Humans have a greater temporal resolution of what they hear than of what they see, and in this way, can have better performance with overlapping information in the auditory domain than in the visual [11]. Another advantage is that humans can become accustomed to sound patterns that continue to be susceptible to change even if these are subtle changes [11]. Sonification appears to be an appropriate and criterious solution for monitoring systems, since it performed while the persons go about their daily routine [10,11]. When a high volume of data to be monitored is presented visually we get a lot of data on a single screen. An auditory display provides a useful and sometimes a substitute supplement for a visual display [10].

Audio is excellent in guiding or forwarding the listener to key data [10]. There are some attempts and previous studies on the application of sonorization to data coming from a network of computers. Each one with a different approach with respect to obtaining the data to be processed and to the way the data is sonified. In article [7], a monitoring system has been created that allows operators to identify excessive network traffic and spam, transforming network events into acoustic signals. This allows the system administrator to focus on more important things, while monitoring the network through the acoustic signals that are reproduced. The authors of the article [18], have elaborated a system that sonifies a network in real time. It alerts the administrators on operations that are being carried out in both the abnormal traffic and the normal one. In the Interactive Network Sonification (InteNtion) [8] project, the goal was to create an innovative approach to network traffic monitoring by adding a new dimension, the sound. Traffic was analyzed using the SharpPCap library, collecting traffic, that was then, parsed and transformed in sound to help the administrator efficiently detect intruders on the network.

There are other projects that have similar approaches like: Songs of cyberspace [6], Stetho [14], NeMos [15], NetSon [21], SonNet [20]. In the Songs of cyberspace [6] project, sonification techniques are used to examine the flow of data from the network. The sound system is used to support the entire surrounding environment and the decisions to be made at the moment. The NeMos [15] project is a client-server Java application for monitoring a distributed system with sound. The server captures the data and the client produces the sound that is captured. The authors main objective was to complement a visual system. The project NetSon [21] is a system that allows a large-scale organization to monitor metadata on a network in real time through sound. Due to the volume of data being analyzed every 24 h in a large organization, only relevant aspects are considered and processed.

The SonNet project [20], developed in Java, captures packets on a network and transforms them into sound according to the information of each packet. The captured packets are sent via the Open Sound Control (OSC) protocol to an object written in the Chuck language [12,19]. OSC is a protocol that offers flexibility and enables communications between computers, sound synthesizers and other multimedia devices [22,23]. Communication is done by OSC messages that do not have a predefined number of arguments and its format is independent of the transport layer [24]. A Chuck object receives the OSC messages with information about each captured packet and creates real-time sounds. The Chuck language was used because it is an audio programming language for the creation of sound and music in real time. It is free, open source and is available for Mac OS X, Windows and Linux.

3 Security Information Event Management

An SIEM is an application that monitors a network and generates events based on occurrences in the network. These events are classified according to the danger they present to the network. In 2012 there were about 85 SIEM applications, paid and free [1]. Companies are embracing the use of SIEM solutions to enhance their network security and monitoring capabilities [13]. OSSIM [3] is an example application. It is an unified platform developed by AlienVault that is free, open source and based on the Debian operating system [2]. OSSIM has four main components [2]:

- **Sensor**: Receives the logs from network devices through the *rsyslog* service and stores them locally. After which, the OSSIM parses and normalizes each type of *log* and sends everything to the server.
- **Server**: Performs the risk assessment by aggregating and correlating the received events and by comparing them to a database know behaviors.

- **Web interface**: User for system administration, binds and manages the components and security tools that compose the OSSIM.
- **Database**: Stores the logs, events and the system configuration.

OSSIM includes functionalities [2] such as: the collection and normalization of logs; the prioritization of events and risk assessment; the analysis and correlation of events; the generation of alarms and response actions; vulnerability analysis; intrusion detection and network monitoring. All captured events are saved, analyzed and normalized. In event prioritization and risk assessment, the server assigns priority values to the logged events. This server as a baseline for the establishment of the risk of a particular event, in order to alert the user. The risk of an event is calculated in real time using the following formula [4]:

$$risk = (value * priority * reliability)/25$$

The *value* refers to the importance of the machine that generated the event (values ranging from 0 to 5). This is manually assigned in the OSSIM configuration and has a default value of 2. Priority refers to the importance of the event itself. It is a measure that is used to determine the impact that the event might have on the network (values ranging from 0 to 5). Reliability is a value that indicates if an attack is real or not (values ranging from o to 10). OSSIM uses the value 0 for false positives and the value 10 for a real attack. All events are analyzed and correlated to each other to detect possible attacks and anomalies.

4 Proposed Solution

The proposed solution assume that the home user has an OSSIM set-up in his home network, where all his sensors and other devices are connected. Moreover, the OSSIM is assumed to be set-up to generate events in conformance to the users' expectation. The proposed solution must then satisfy the following requisites:

1. Collect events from an OSSIM server, accessing its database.
2. Sonify all collected events.
3. Operate independently of the underlying operating system (Windows, Linux or macOS).
4. Operate with or without a graphical interface.
5. Work immediately on startup when deployed on an appropriate device (such as a Raspberry PI).

The proposed solution, named Music-enabled Security (MuSec), creates acoustic signals for each network event generated by an OSSIM server. Is a simple and objective application, without additional configurations, that works in parallel with the OSSIM and takes full advantage of the hearing capacities of a human. The architecture of the proposed solution, depicted in Fig. 1, comprises two main components: the Java MuSec, and the Chuck MuSec. The network traffic is captured by OSSIM, which then does the internal processing of each

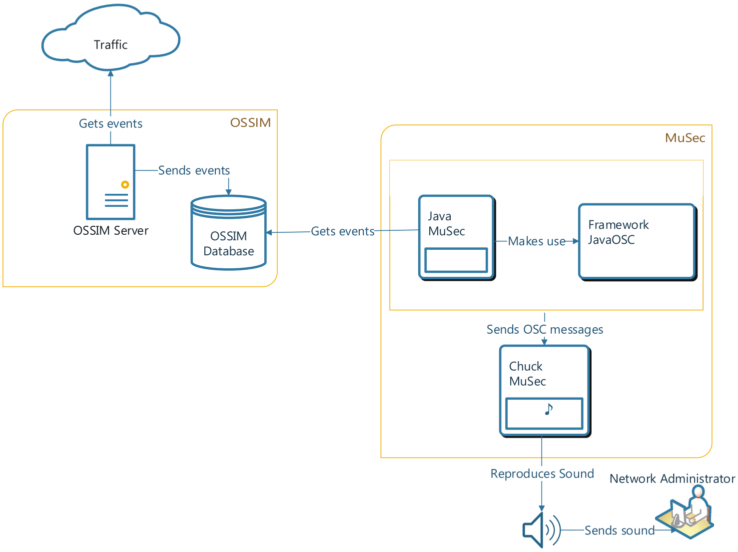

Fig. 1. Application architecture

captured event. It categorizes events by risk level, priority, reliability, and other features, and stores information in a MySQL database, generating logs.

The Java MuSec accesses the OSSIM MySQL database and extracts useful information about each event and, with the help of the framework JavaOSC [17], communicates through the OSC protocol with an object written in Chuck language, the Chuck MuSec. In this communication, OSC messages are sent with information about a particular event, mainly its characteristics such as: risk, value, priority and reliability. After which, the Chuck MuSec, transforms the received events into acoustic signals that will be listened by the user. Each risk level is mapped to a particular sound. The sounds are musical loops stored in wav files that represent relaxed sounds, when in the presence of low risk events, or heavier sounds such as heavy metal loops and hard rock loops, when in presence of high risk events. The discrepancy between these sounds efficiently alert the user when something is affecting the network.

5 Validation

To perform the validation of the proposed solution, functional tests were performed while using multiple operating systems. The goal was to verify if the application was running successfully in all supported operating systems. The application ran successfully in both command line and graphical modes in Linux Mint 17.3 x86 (see Fig. 2), macOS X El Capitan x64, and in Windows 10 x64.

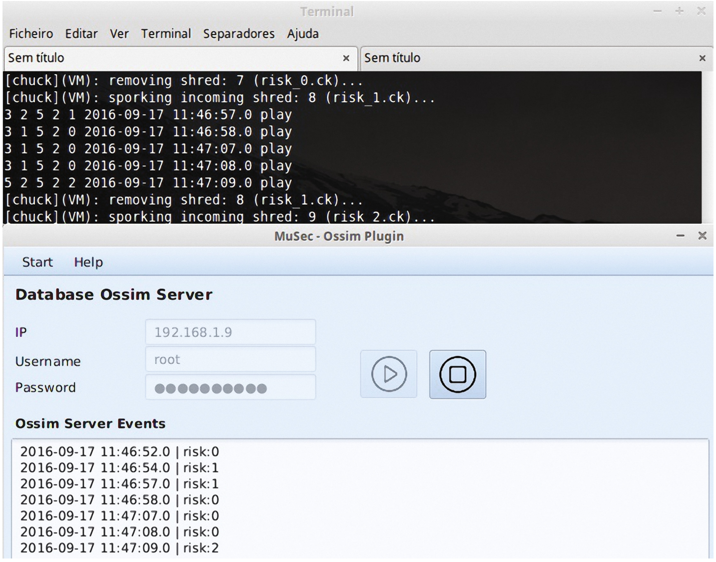

Fig. 2. MuSec running on a Mint 17.3 system with graphical interface

In the pursuit of the validation of the applicability of the proposed solution to a home scenario, the proposed solution was deployed on a Raspberry Pi 2, configured and setup to run in the command line mode at system startup. Afterwards, the (home) user would only need turn the device on listen to the event sonification. A OSSIM server was previously installed and setup to monitoring all network traffic. This setup was allowed to run for a one month period. Several scripts were developed to collect information about the state of the system and of the proposed solution. During this monitoring period, the Raspberry Pi 2 suffered multiple power failures but was able to automatically restart its sonification task.

6 Conclusion

The proliferation of computers, smartphones and other devices that connect to home networks that, in turn, are connected to the Internet, is a reality in current days. On the one hand, the traditional home user does not understand or use security monitoring systems due to its complexity. On the other, attacks or security incidents that make use of any Internet connected device is recurrent. Most of the times, the home user is unaware of its participation. There are security monitoring solutions, some of which are even free to use and capable of detecting a significant number of attacks, such as the OSSIM, but the home user is unable to used on his daily life.

The proposed solution reduces this gap by allowing non tech-savvy home users to perform security incident monitoring without requiring any technical expertise or background. The proposed solution achieves this by using sound, through the sonification of the events generated by an OSSIM server. The home user has only to listen to the sound and, upon its change, will understand if his home network is being attacked or not.

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Online Conversation Application with Confidentiality, Anonymity, and Identity Requirements

Pedro Fernandes[1] and António Pinto[1,2](✉)

[1] GCC, CIICESI, ESTG, Politécnico do Porto, Porto, Portugal
8080084@estg.ipp.pt
[2] CRACS & INESC TEC, Porto, Portugal
apinto@inesctec.pt

Abstract. The increase in usage of smartphones and the ubiquity of Internet access have made mobile communications services very attractive to users. Messaging services are among the most popular services on the Internet. In recent years, this services started to support confidentiality and anonymity. A recurrent problem with the existing messaging solutions is their lack of resistance to impersonation attacks. The proposed solution addresses the impersonation problem, without neglecting user confidentiality and anonymity, by forcing users to exchange the required cryptographic material among themselves. Moreover, this exchange must use a proximity communication technology, forcing the users to physically meet.

Keywords: Impersonation · Anonymity · Online conversation

1 Introduction

The increase in usage of smartphones and the ubiquity of Internet access have made mobile communications services very attractive to users. Messaging services being among the most popular because these of its availability, functionality and lower costs of communication. In particular, these services make international communications free, if the user already has Internet connectivity, and very attractive due to functionalities as the use of emoji or photo and video sharing.

In recent years, these messaging services started to support end-to-end (E2E) encryption in order to protect the transmitted content from eavesdropping when used over unsafe communication channels. In E2E encryption, the messages are encrypted at the source terminal, sent through the network, and decrypted only at the destination terminal. Servers, if used, are expected to not be able to access the exchanged messages in clear text form [6]. This may not the be case if the server has access to the cryptographic material used to encrypt the messages.

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Whenever the server securely transfers messages from source to destination and is unable to access the messages, or to identify the user who sent the message, we are in presence of a secure messaging platform that enables both confidentiality and anonymity This is sometimes referred to zero-knowledge applications [8].

The interest in secure forms of sending online messages has grown substantially and lead the Electronic Frontier Foundation (EFF) to evaluate [3] the existing ecosystem of smartphone applications that offer secure messaging services. The list of messaging applications is very long and difficult to maintain due to the frequent appearance of new ones. This study is currently identified by EFF as outdated and motivated the authors to extend it.

All modern messaging applications, to the best of our knowledge, enable users to directly communicate without requiring them to confirm their real identify. This opens the possibility of a user assuming the identify of another, i.e. user impersonation. This is a problem that potentiates ill-intentioned users, possibly with criminal intent, to try and deceive more susceptible users such as children or less tech-savvy older people. The proposed solution, while maintaining users' privacy and anonymity, enables secure E2E communications, solves this user impersonation problem by requiring a first, physical interaction between the communicating users. This first interaction is based on a proximity communication technology.

The paper is organized in sections. Section 2 describes the related work, in particular it compares secure messaging applications. Section 3 details the proposed solution, which is then evaluated in Sect. 4. Section 5 concludes this paper.

2 Related Work

A set of secure messaging applications was selected from the ones available in Google Play and App Store. The selection was based on the ones that better performed in the previously mentioned study of the EFF and that had the more installations. In particular, *TextSecure*, *Signal*, *Telegram*, *WhatsApp*, *Threema* and *Wickr* were selected.

TextSecure is a free and open-source mobile application for the Android platform that allows the to send encrypted text messages. It was first released in 2010 by *Open Whisper Systems* [12]. In October 2015, *TextSecure* had been installed over 1 million times through Google Play [9]. The protocol initially used by *TextSecure* was a protocol derived from the Off-the-Record (OTR) protocol [11]. It comprised four stages: (1) registering; (2) sending/receiving a first message; (3) sending of a follow-up message; (4) sending of a response. The application relays its messages to the destination to the server that, in turn, transmits the messages to the destination. The parties communicate with the server via Representational State Transfer (REST)-Application Programming Interface (API) over secure Hypertext Transfer Protocol (HTTPS). The delivery of the actual message is performed via Google Cloud Messaging (GCM) which basically acts as a message delivery intermediary [18]. Currently, *TextSecure* implements the algorithm *Double Ratchet* (also known as *Axolotl ratchet*).

Signal is the successor of both the *RedPhone* (voice calls encryption) and of the *TextSecure*. *Signal* was launched in 2015 and is a secure instant messaging and voice call application that uses E2E encryption. The encryption keys of the users are generated and stored in their smartphones and not on the application servers [3]. *Signal* was built with mechanisms to resist Man-in-The-Middle (MiTM) attacks. For voice calls, the application displays a word on the screen, if the two words match at both ends of the call, then the call is considered secure [13,15]. There is a similar mechanism for messages that consists on the mutual verification of digital signatures. The protocol used by the *Signal* application is open source and is known as the *Axolotl* protocol.

Telegram provides E2E message encryption and self-destructing messages. *Telegram* has more than 100 million monthly active users. The application offers two types of chats: the standard chat that uses an encryption key that is shared with the server and can be accessed from multiple smartphones; and the secret chat (*Telegram* (*Secret Chats*)) that uses E2E encryption and can only be accessed by the devices that are in possession of the required cryptographic material. The adopted protocol, named *MTProto*, uses RSA2048 [1], Advanced Encryption Standard (AES) 256 bits and the Diffie-Hellman key exchange [2]. The *MTProto* protocol comprises three components [14]: the high-level component, the authorization component, and the transport component. The high-level component defines the method by which the API queries and responses are converted into binary messages. The authorization component defines the methods used for user authentication and messages encryption. The transport component defines the method to be used by clients and server for message transmission over a network protocol. The *MTProto* supports multiple transport modes, such as Hypertext Transfer Protocol (HTTP), HTTPS, Transmission Control Protocol (TCP) and User Datagram Protocol (UDP).

WhatsApp is another Internet messaging application. Numbers of September of 2015 put their user base in the 900 million users [10]. *WhatsApp* uses a store and forward approach for message transmission. When a user wants to send a new message, it is first stored on the *WhatsApp* server, and then the server relays the message to the destination user. Once the message is received by the destination, it is removed from the server database [5]. *WhatsApp* uses the same protocol as *TextSecure* (*Axolotl* or *Double Ratchet algorithm*).

Threema is another free and open source Internet messaging application with support for E2E encryption and user anonymity. As of June 2015, *Threema* had 3.5 million users, most of them from German-speaking countries. Each user, at the application start, receives a randomly assigned a *Three-ID* that will be used for user identification. In this process, neither the user mobile phone number or email address is required. Users can verify the identity of their *Threema* contacts by scanning their QR code when they physically meet. Using this feature, users can be sure that they contain the correct public key of their contacts, providing message confidentiality and resistance to MiTM attacks [16]. *Threema* was designed to store as little data on servers as possible. The contact lists are managed only on the users smartphones and messages are deleted immediately after they have been delivered. *Threema* supports E2E encryption [17].

Wickr is another free Internet messaging application that offers confidentiality. It includes the ability to set a time-to-live for each message. The recipient's application erases the encrypted message from their smartphones, trying to ensure that the message can no longer be retrieved. The *Wickr* Secure Messaging protocol is specifically designed to prevent servers from accessing both the keys or detailed information from users. Supports E2E encryption by implementing multiple encryption layers [7]. The data, stored or in transit, is encrypted with AES256. Each message is encrypted with a new encryption key, deleted after its use (Perfect Forward Secrecy). Message encryption keys are then encrypted with the public key (Elliptic Curve Diffie Hellman (ECDH) 521) of the recipient. All user content is deleted after the user logs off. The unique identifier of the smartphone, Unique Device Identifier (UDID), is never sent to the *Wickr* servers in an effort to assure user anonymity. *Wickr*'s Secure Shredder erases all data on the smartphone so it can not be recovered.

These applications were compared in the Secure Messaging Scorecard of EFF [4]. Table 1 extends this comparison for the selected applications. The comparison criteria is fivefold: (1) transport; (2) provider; (3) entities; (4) anonymity; (5) identity. If all communications are encrypted while being transported through the network, then the first criteria is satisfied. The second criteria requires that all communications must be encrypted E2E, which means that the keys needed to encrypt/decrypt messages must be generated and stored on the smartphones and not on the servers. The third criteria requires that there is an internal method for the verification of the identity of the involved entities and of the integrity of the channel, even when the server or third parties are compromised. The forth criteria requires that the identity of the user is not known by the server. The last criteria requires that the users can be sure of the other users identity because that had a physical interaction as proof of their identity.

For instance, the *TextSecure* application despite satisfying the three initial criteria, does not provide user anonymity nor requires any prior physical interaction between users in order to establish a conversation between them. Off the selected applications, only *Threema* permits the use of an interaction between the users as a form identity confirmation, but because it can be made remotely, undermines its fulfilling of the last criteria.

Table 1. Application comparison

	Transport	Provider	Entities	Anonymity	Identity
Text-Secure	Yes	Yes	Yes	No	No
Signal	Yes	Yes	Yes	Yes	No
Telegram	Yes	No	No	No	No
Telegram (*Secret-Chats*)	Yes	Yes	Yes	No	No
WhatsApp	Yes	No	No	No	No
Threema	Yes	Yes	Yes	Yes	No
Wickr	Yes	Yes	Yes	Yes	No

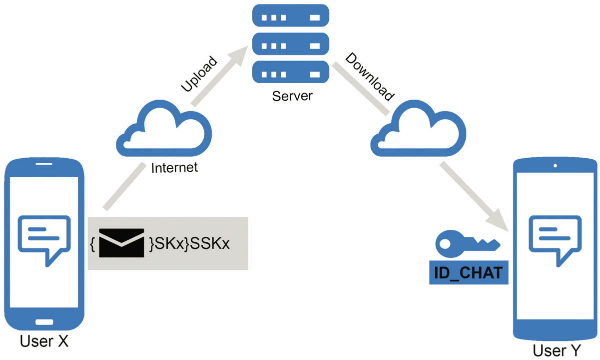

Fig. 1. Application architecture

3 Eko

The architecture of the proposed solution, named Eko, is depicted in Fig. 1. It comprises end user terminals, which are smartphones, and a server. An user X, in order to send a secure message to an user Y, prior to its upload to the server, firstly encrypts the message with the chat symmetric key (SK_x), and then encrypts this result with a second chat symmetric key (SSK_x). The SK_x is only known by the users X and Y, while the SSK_x is known be the users and the server.

All cryptographic material is generated at the smartphones, except for the SSK_x that is generated by the server. The conversation identifier (Id) is also generated by the server to avoid Id collision. Each conversation is represented by a data structure named *ID_CHAT* that is detailed in Table 2. In addition to Id and the cryptographic material, it includes a time stamp and a message validity in number of days.

All data transmitted by the application uses E2E encryption, guaranteeing that all communications with other users is confidential. The server uses the conversation identifiers to select the appropriate decryption key to process each message but is unable to decrypt the message content and to obtain the identification of the users that take part in each conversation, thus providing anonymity.

Table 2. Conversation data structure: *ID_CHAT*

Variable	Description
SK_i	Conversation user key
SSK_i	Conversation key shared between users and server
Id	Conversation identifier
T_s	*Timestamp*
V	Validity (1, 10, 15, 30 days)

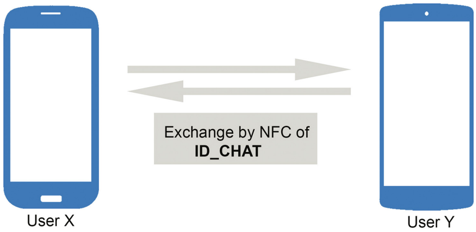

Fig. 2. *ID_CHAT* exchange between users

Users, in order to start exchanging messages with each other, first have to undergo a physical interaction consisting of exchanging an instance of the data structure *ID_CHAT* be means of a proximity communication technology. Example technologies being Near Field Communications (NFC) or Bluetooth Low Energy (BLE). The *ID_CHAT* data structure is generated by one user, and then directly shared with the remaining users, without interaction with the server, as shown in Fig. 2.

4 Validation

Prototype client and server applications were implemented to validate the proposed solution. The server was developed using the Laravel framework and contains the necessary access points for the operation of the clients. The client application was developed using the Ionic framework that allows multi-platform development. The functional assessment was successfully performed and the identified requirements were satisfied.

A security analysis was also performed considering the confidentiality, anonymity and impersonation. The *confidentiality* of the messages exchanged between client and server is obtained by means of E2E encryption. The keys used to encrypt messages in conversations, the SK_x key, is generated in the smartphone of the user that creates the conversation and stored locally. It is never uploaded to the server. The second key, the SSK_x key, is known by the participants of a conversation and by the server. Finally, being a web-based service, the server is deployed only in its secure mode (HTTPS).

The proposed solution guarantees user *anonymity* by the way it creates and uses the *ID_CHAT* data structure. The identity of the user that sends each messages is unknown to the server. Each message assumes the form:$(chatId : Ts : \{\{Username : Msg\}_{SK_X} : chatId : Ts\}_{SSK_X})$, where $\{a\}_b$ means a encrypted with key b, and $a : b$ mean the concatenation of a with b. The identity of the user that sends each message can only be decrypted with the SK_x key that exists only in the *ID_CHAT* data structure on the smartphones.

The proposed solution addresses the *impersonation* problem by imposing a previous interaction between users for the conversation to take place. This interaction comprises the generation of a new *ID_CHAT* data structure and its direct exchange with the other user's smartphone by means of a proximity communication technology. This way, the users must physically meet in order to communicate.

5 Conclusion

Messaging services are among the most popular services on the Internet. In recent years, this services started to support confidentiality and anonymity. A recurrent problem with the existing messaging solutions is their lack of resistance to impersonation attacks. The proposed solution addresses the impersonation problem without neglecting user confidentiality and anonymity. A prototype of the proposed solution was implemented and functionally verified. A analysis of the security of the proposed solution was also performed.

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Motion Detection in an Intelligent Textile Mattress Cover

Nelson Pimenta[1(✉)], Paulo Chaves[1], Luís Fernandes[1], and Diana Freitas[2]

[1] INOV INESC Inovação, Lisboa, Portugal
{nelson.pimenta,paulo.chaves,luis.fernandes}@inov.pt
[2] Flexitex - Fábrica de Tecidos S.A, São João da Madeira, Portugal
dianafreitasflexitex@flexitex.pt

Abstract. In this paper we present a new solution for continuous monitoring of body position and motion over a mattress cover, using intelligent textiles. The main focus of this work is the analysis of the data generated by this intelligent mattress, through the identification of body movements along the bed. The output of this work is to be used as an overall solution in the home and healthcare market, where monitoring activities is an important need.

Keywords: Intelligent textiles · Electronic textiles · Remote healthcare monitoring

1 Introduction

The intelligent textiles have been receiving a lot of interest and research in the last decade [1, 2]. As the industry matures and develops there is an increasing demand to turn research results into commercial opportunities, especially in the market of textiles and clothing. This type of textiles tends to generate increased value products with the common properties of textiles but offering additional functionalities. These functionalities are normally achieved using external sensors which are integrated into textiles, or by combining traditional textiles with conductive fibers and materials, which behaves like sensors [3–6], and some kind of electronic unit, for example a microprocessor. The introduction of smart materials and computing technology in textile structures offers an opportunity to develop textiles with the ability to sense and react to the environment and interact with users. There are currently attractive solutions to a wide range of fields of application, such as wearable sensors for health monitoring, protective clothing and sports [2]. One of the recent trends gaining traction in the market is the increase incorporation of the Bluetooth Low Energy (BLE) technology. This wireless technology allows connectivity with smartphones, low power consumption and multi-vendor interoperability. When it comes to the health sector and the third sector, mostly hospitals and social care assistance units, the need to promote financial efficiency in terms of resource allocation to patient monitoring activities is a requirement, particularly for senior public.

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In this paper a new e-textile (electronic textile) structure is presented, a mattress cover, based on a combination of textile materials, conductors and non-conductors, which can be used for continuous monitoring of body position and motion over a mattress cover. This e-textile is integrated in a remote monitoring system where relevant information is made available for to users and caretakers.

2 System Architecture

The main focus of this work is the analysis of the data generated by this intelligent mattress, nevertheless it is essential to describe the overall remote monitoring system associated. Several architectures and communications technologies, specially dedicated to the area of wearable sensors for smart healthcare systems based on WBAN (Wireless Body Area Network), have been recently proposed [7]. The adopted solution, as shown in Fig. 1, comprehends three major elements: mattress cover, sensor gateway and system manager. The mattress cover has the intelligence to read and process the

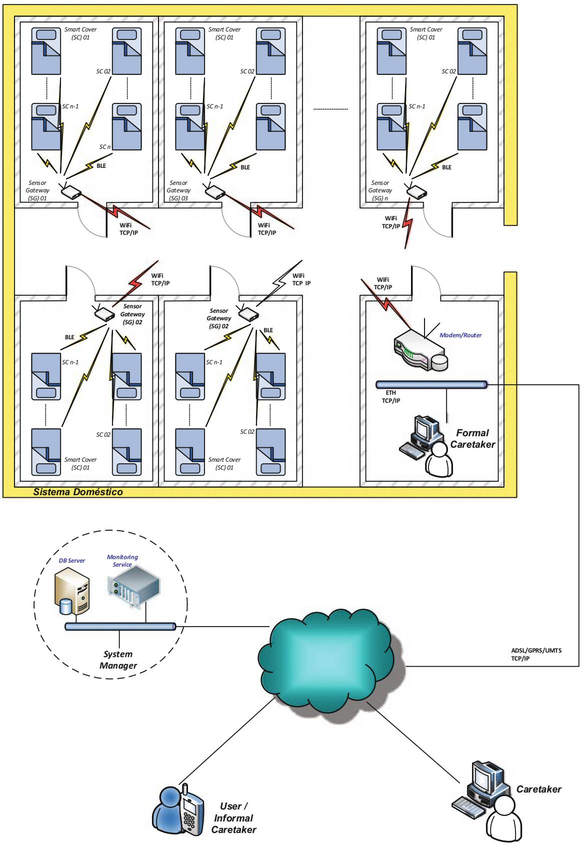

Fig. 1. Architecture of the proposed remote monitoring system

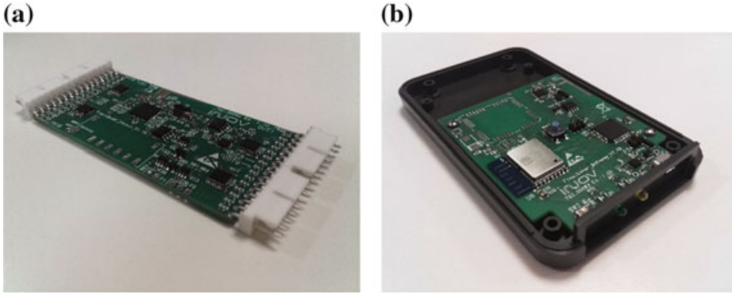

Fig. 2. System components: **a** e-textile sensor module; **b** sensor gateway

electrical signals generated by the e-textile sensor but also to transmit the relevant data, through BLE wireless communication. Figure 2a shows the electronic sensor module PCB, which is embedded in the mattress cover. The BLE technology allows an easy connection to a smartphone or other mobile device, when intended to use in a home user application. For a context of a hospital or social care assistance, a sensor gateway (concentrator) was developed (Fig. 2b), which ensures the desired scalability of the system, mandatory for the healthcare market. The sensor gateway is the element responsible for forwarding the information received by the local wireless sensor network to the remote server, through a local WiFi network or alternatively by GSM. This remote server application is the brain of the system and implements all the tools necessary for the caretaker to manage the resources allocated to patient monitoring activities. The system monitors the movement of persons in bed and issues alerts that signal their continued immobility to their caregivers (or user, if that is the case).

3 E-Textile Structure and Materials

The e-textile structure, the bed mattress, is based on a combination of conductive and non-conductive textile materials and changes its conductivity (resistance) due body movements and pressure over the bed. The adopted solution uses the conductive yarns itself as a sensor, allowing an easy integration of the conductive yarns into textiles by conventional textile production processes. This process allows the development of an intelligent mattress cover, with the same size and shape of a normal mattress cover, becoming an easily scalable product with controlled costs.

The e-textile structure is designed in order to incorporate 8 bands of conductive yarn enabling the detection of movements along the bed. These conductive bands are connected to the e-textile sensor module (such as shown in Fig. 3) responsible for measuring, processing and filtering the collected information and transmitting the relevant data to the remote server application (through the local sensor gateway). The e-textile sensor module has the following features: capacity to read up to 16 conductive bands; powered by internal batteries or by an external power supply; internal battery charger; BLE connectivity; very low power consumption, allowing the operation during several months.

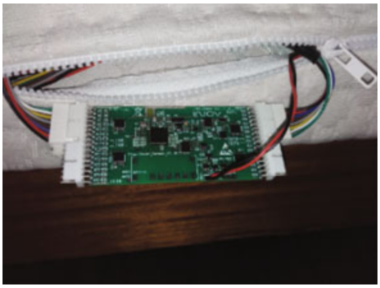

Fig. 3. Connection of the e-textile sensor module unit in the mattress cover

4 Results

In order to evaluate the performance and sensitivity of the e-textile a mattress cover prototype was produced. The prototype was dimensioned to fit a bed used during the period of tests and validations as seen in Fig. 4.

After the production of the prototype and the installation of the mattress cover on a bed, the first tests were intended to measure the electrical characteristics (resistance) of the e-textile in a stable condition, with no weight or pressure on it. This tests were also intended to allow final adjustments in electronics and firmware before connecting it to the remote server and start acquiring data. The Table 1 shows the resistance measured for each of the 8 conductive bands. Some potential problems were identified at this initial stage, since considerable differences were found in the resistance of each conductive band. The mattress cover uses conductive bands and the process of integration

Fig. 4. Installation of the intelligent mattress cover in the bed

Table 1 Initial resistance of the 8 conductive bands

	Band1	Band2	Band3	Band4	Band5	Band6	Band7	Band8
Resistance (kΩ)	160.3	138.1	102.2	207.4	87.2	52.5	62.7	88.7

of the conductive yarns into the textile is the same used in conventional textile production processes, which allows the production of an intelligent mattress with the same size, look and dimensions as a normal mattress. The main issue is that it is very difficult to guarantee the same mechanical proprieties along the textile.

After analysing the preliminary results, the sensors were installed and data was collected with a sampling period of 5 s during a period of 6 months (from July to December 2016).

4.1 Sensor Data Analysis

As a first approach, it is clear that the sensor reacts to movements along the mattress cover, showing significant changes in the resistance, as shown in Figs. 5 and 6 with data measured during the day of 25/08/2016.

The system has a rapid response to variations in pressure/weight, which can allow the detection of movements. However, it has a very slow dynamic response and when the weight/pressure is removed the resistance seems to change immediately (high peak) to values higher than the resting value (with no pressure) and it takes a long time to return to a stable point. This happens because, after weight removal the tissue contracts, the conductive wires that were very tight release and then take some time to return to the natural position. Another observation is the significant changes on the base line resistance for all the conductive bands. This behaviour implies that this sensor applied to this specific application, integrated in a bed mattress, is unreliable if we consider only the absolute value of the resistance at a particular time. Nevertheless, the objective and purpose of the overall system is to monitor the movement of people in bed, detecting movements and issuing alerts to caregivers.

Several methods and algorisms have been recently studied to analyse data generated by wearable sensors used for physiological monitoring of vital signs in healthcare services [8, 9], some of this methods were tested, including Neural Networks. A method for real-time detection and counting of movements was developed, which

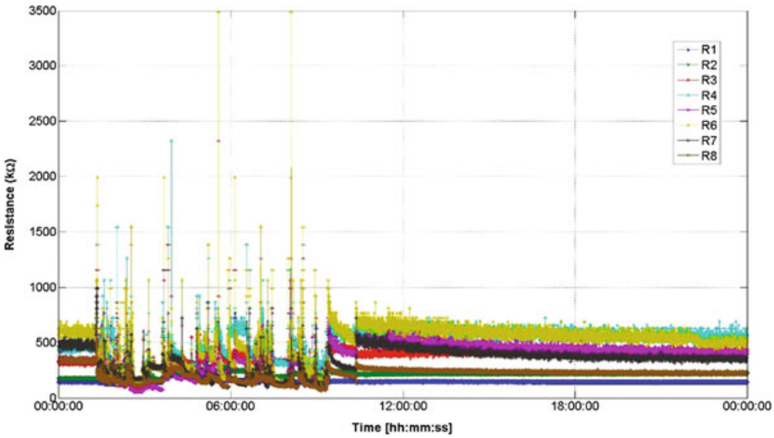

Fig. 5. Resistance measured during the day of 25/08/2016

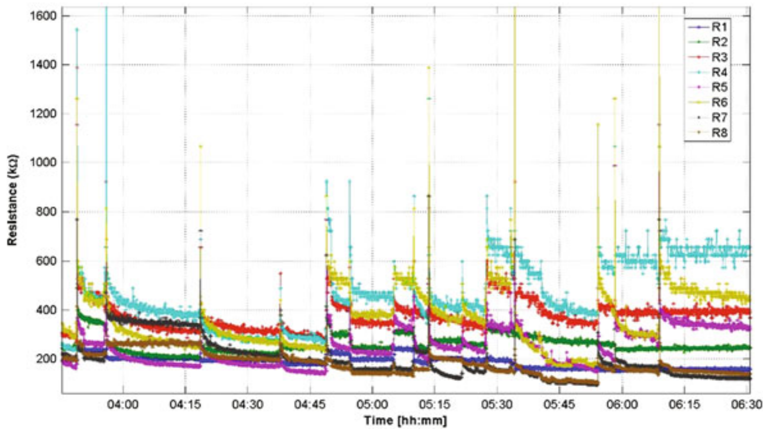

Fig. 6. Resistance measured during the day of 25/08/2016, detail, from 03:45 am to 06:30 am

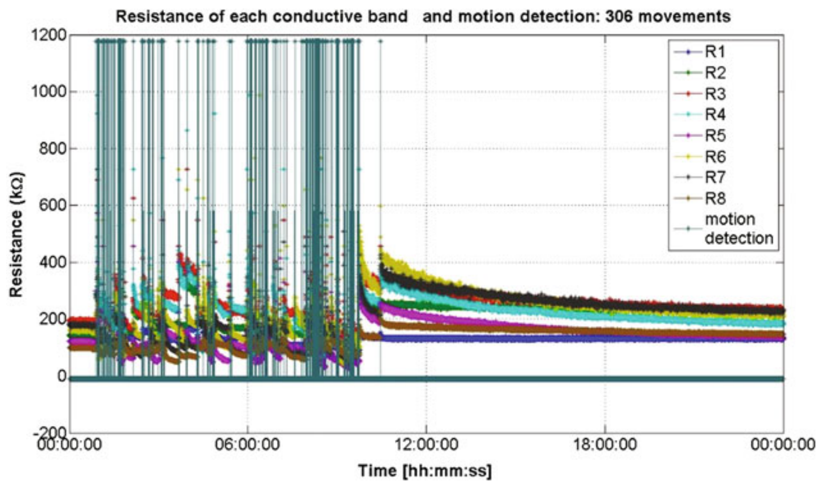

Fig. 7. Sensor resistance measured in 19-11-2016, with motion detection and movements counting (*vertical lines*)

takes in consideration the fast response of the system to changes in the pressure at the mattress cover, and the slow settling time. In Figs. 7 and 8 with a better detail we can see the detecting points (vertical lines), moment where the movements were detected.

The information and results collected during the period of tests was then transferred to the remote system manager. Figure 9 shows a detail on one of the views of the user interface, where the detail on the movements during the last day and last hour is shown to the user or caretaker.

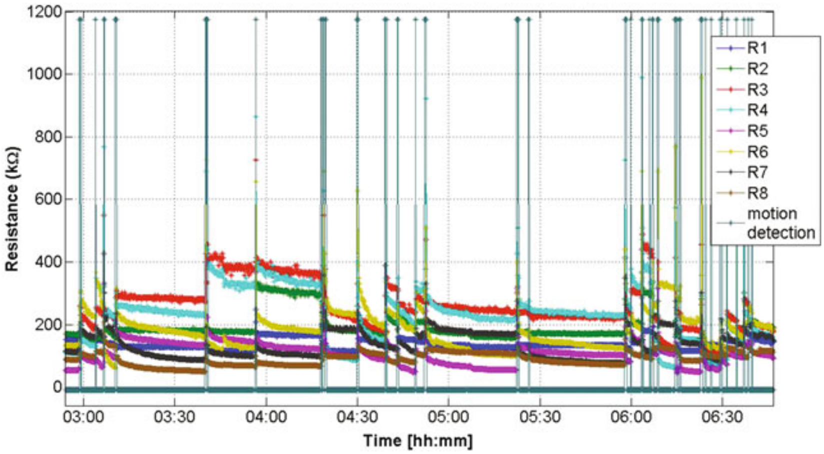

Fig. 8. Sensor resistance measured in 19-11-2016, with motion detection (*vertical lines*), detail from 03:00 am to 06:00 am

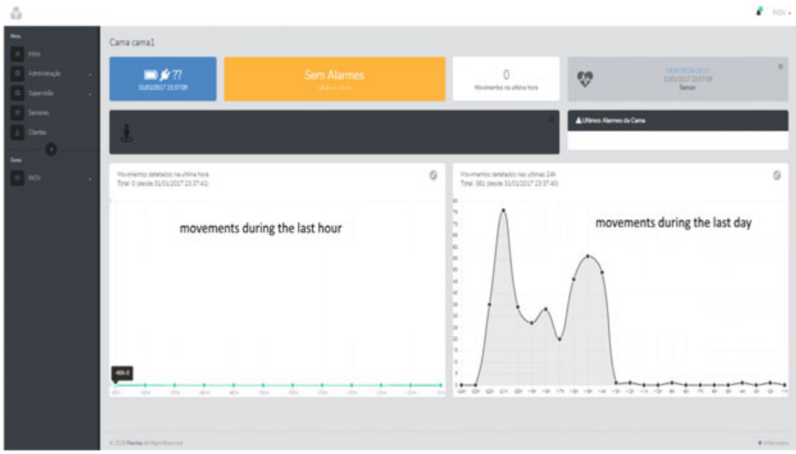

Fig. 9. User interface for the remote application

5 Conclusions

In this paper we have presented a new intelligent textile mattress cover, integrated in an overall solution for remote monitoring of the body positioning and movements in a bed. This textile solution allows production with conventional textile production processes, with reduced costs, allowing an easy installation and expansion of the system, making this solution very appealing for the healthcare industry. An approach method for detection and counting of human movements has been developed. This information allows to generate real-time alarms to the caregivers, when continued immobility of the patients is observed. The overall solution and the information generated can be used to complement, in an efficient way, the resources and materials spent in monitoring and medical assistance activities. In a wider scope the information generated by this application can be used for future investigation of sleep disorders or sleep patterns in general, acting as a preventive measure for monitoring people's health status and to strengthen.

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GoodsPooling: An Intelligent Approach for Urban Logistics

Joao C. Ferreira[1,3(✉)], Ana Lúcia Martins[2], and Rubén Pereira[1]

[1] Information Sciences, Technologies and Architecture Research Center (ISTAR-IUL), Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal
{joao.carlos.ferreira,Ruben.Filipe.Pereira}@iscte.pt
[2] Business Research Unit (BRU-IUL), Instituto Universitário de Lisboa (ISCTE-IUL), Lisbon, Portugal
almartins@iscte.pt
[3] Centro ALGORITMI, University of Minho, 4800-058 Guimarães, Portugal

Abstract. Models supported by ICT tools are developed to raise collaboration and share of resources in urban logistics process, in a kind of "Logistics-as-uber" concept, which allows implementing operations such as "GoodsPooling" concept, equivalent to carpooling concept: daily use of home/work trips to pick and deliver goods on the way. This solution can also be integrated with the use of Taxis or even persons in a public transportation in a sharing solution of persons and goods transportation. This project aims to develop a conceptual model based on already existing city mobility alternatives to reduce dedicated transportation of goods.

Keywords: Collaboration · Logistics · Pooling · Sharing · Freight

1 Introduction

The number of persons living outside large cities (outskirts areas) is increasing due to low household costs and more space [1]. Public transportation offer outside large cities is usually limited and with inefficiencies [1, 2]. It is not unusual that persons who live far from where they work try to share trips to reduce expenses. This process of sharing a personal vehicle with one or several passengers is identified as carpooling [3]. The goal of this paper is to propose a conceptual model that uses the sharing concept for the transportation of Goods taking into account individual daily trips and the needs of goods transportation in the city. With this approach, drivers can increase their income using their regular mobility process. Simultaneously, this is an opportunity for faster and more efficient city logistics at reduced prices for senders and receivers of goods. This new class of logistics does not require specialized facilities or fleets of trucks and can be scaled quickly and cheaply, because it is based on sharing.

Cargo transportation causes a major impact [1] in large cities nowadays (traffic and road occupation during the load and unload of goods). Air pollution is also an immediate consequence, and so is the increase in the consumption of fossil fuels. In fact, according to the European Commission [4], 8–15% of the traffic flow in urban areas derives from logistical operations involving the movement of goods. This

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Fig. 1. Concept overview of proposed system for Goodspooling

highlights the possibility to reduce CO_2 emissions and urban traffic if management is improved in at least part of the volume of goods needing to be moved.

A Goodspooling platform guidelines and principles are illustrated in Fig. 1 overview. This platform registers drivers' routes and times through GPS sensor available in the majority of mobile devices and when there is a need for moving goods identifies potential drivers passing nearby in their daily mobility process. Based on distance the platform defines prices and manages the meeting process for pickup and delivery. All these processes allow real time information integration on mobile device application and mobile device sensors, like accelerometers and GPS. In addition, mobile communication allows users' connectivity on a permanent basis at lower prices. This conjugation of opportunities allows the possibility of dynamic Goodspooling with complementary real time information from traffic.

2 Sharing Approach

The sharing economy is an upcoming reality, linked to several meanings to describe economic and social activity involving online transactions or collaboration activity towards a common goal. These processes are supported by community-based online services and are an upcoming reality, with several success examples, as Uber. These processes were expanded to a diversity of activities, like Airbnb among others. Sharing resources in city logistics is related to three main issues: vehicle sharing, infrastructure sharing and route sharing (Goodspooling concept) [3]. Concerning vehicle sharing, the logistics organisation is similar to that of car or bike sharing or bike sharing systems for people transportation [5]. In this approach, there is no collaboration process during transportation, only a sharing of resources. In the second issue (infrastructure sharing) collaboration between users is not mandatory. The third, less studied, is logistics pooling.

Logistics pooling can be defined by analogy to carpooling [3]. In those transport and logistics schemes, the sender (or the receiver) contracts a company that organises all the transport and distribution related operations, involving other actors like transport operators and logistics providers. This company makes decisions and organises all the distribution processes. The sender (or the receiver) are customers paying for a standard or personalised service. In logistics pooling approaches, the decisions are not made by a single stakeholder but by the group participating on the pooling operations.

As in carpooling [3], a goods transport pooling involves deliveries having a common trip chain in their overall path, and follows the same principles of multi-echelon transport with cross-docking [6]. As logistics pooling follows similar schemes as integrated supply chains, it is possible to envisage adapting methods from supply chain assessment to estimate the effects of this form of collaboration in a sustainable development viewpoint.

Related Approaches: There are already conceptual models for the development of collaborative platforms that allow the integration of parcels in urban spaces [7], however there are no systems implemented due to the tendency of the market to function individually [7]. There is also the Uber approach Uber Rush (rush.uber.com). This Uber approach lacks flexibility from the sender side to allow parcels joining already existing routes.

Information systems and communication networks are important factors for the development of collaborative relationships [8]. The degree of collaboration between partners can range from a simple exchange of information to the development of strategic alliances [9, 10]. The exchange of information online allows for faster coordination between partners or between autonomous players, enabling collaboration and mutual gains even in situations of previous commercial ignorance between the parties. This informational meeting point does not currently exist for goods, however its absence in the market causes that today parcels inside the cities end up being moved using inefficient solutions. Urban goods transport has specific characteristics concerning urban logistics: large number of operators, some of them very small, a large part of subcontracting. From an environmental point of view, there are several stakeholders and challenges about urban goods movement for public authorities as well as for private stakeholders [11]. The authors observed several projects dealing with urban logistics resource sharing in the last years, most of them being still at a development phase [11]. Most of these projects aim to make in small scale demonstrators a shared approach for vehicles and platforms to reduce their logistics costs and the environmental troubles related to last mile distribution in urban dense zones. Although several urban logistics pooling projects have been started in Europe, they remain at the conceptual level, and no experimentation or evaluation has already been made.

Attempting to fill the gaps left by the current models, the authors propose a new concept similar to carpooling, innovating by fostering the sharing between entities that require resources and entities that are in the market and offer these same resources, for the shipment of goods in a city but trying to match both sides of the relation: transportation, in this case vehicle owner, which is the seller, and receiver. This proposal can be defined analogously to carpooling as the shared usage of logistics resources: material (vehicles, platforms), human (drivers, land operators) and immaterial (software tools, information).

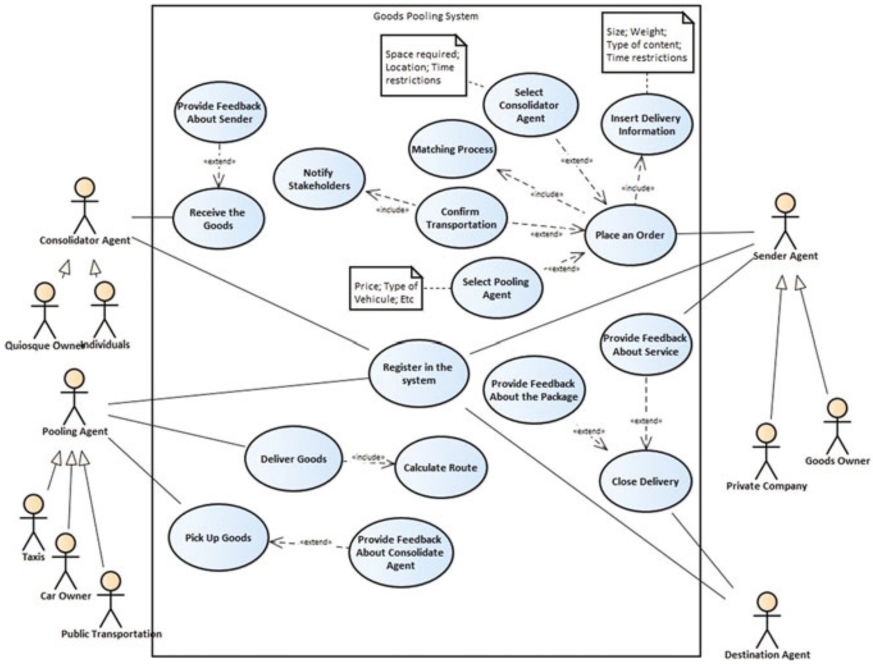

Fig. 2. New transportation paradigm, use case diagram for Goodspooling system

3 Goods Pooling System

As previously stated, the authors developed a platform to materialize the GoodsPooling concept. This platform is the information system that contains and processes all the information needed to operationalize the GoodsPooling concept. The authors went through an exhaustive analysis phase in order to elicit the process(es), actor(s), and role (s) needed to build the platform. Figure 2 shows an UML use case diagram with the most important interactions the actors may have among them and with the platform The transportation company is now represented by the pooling agent that allows the participation of different actors: (1) traditional transportation company; (2) taxis drivers; (3) persons who use public transportation in their mobility process; and (4) car drivers. However, this new concept can occasionally require a consolidation center, represented by the consolidation agent. Street shops identified as Kiosk or individuals can fill this role and receive money for their participation in this process. This consolidation agent is important to fit temporal and geographic matching between sender and receiver. Actors define their restriction and participation rules based on their interests. For example, I as a driver reject picking up goods more than x km away from my usual route, or that take more than x hours, or that include a pick/deliver in a certain region, etc. I, as a Sender, do not want to pay more than X€ or to wait more than Y hours or have a delivery time window more than Z hours/day. Due to the diversity of options and the problem of matching them a consolidation agent is introduced (Fig. 3).

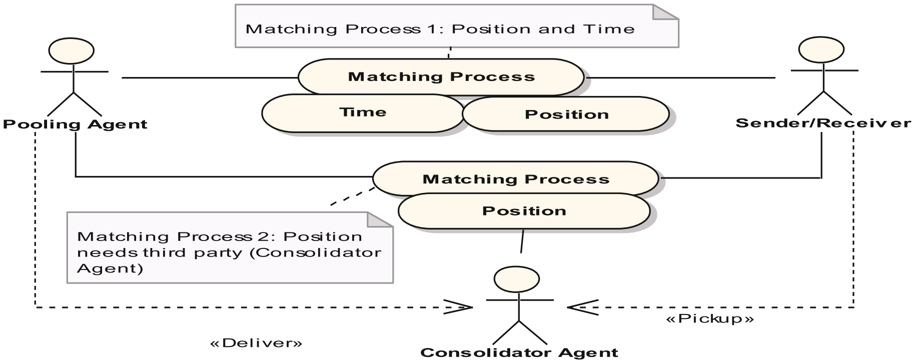

Fig. 3. Matching process complexity based on position and time. Consolidator agent increases matching probability by removing time complexity and helps also on position matching

Based on these new concepts a new platform was developed. This platform uses real time information integration, mobile device sensor manipulation and actions performed on mobile device towards the implementation of sharing daily trips to transport goods with two main applications associated: (1) Web Application; (2) Mobile application. In this case the authors developed an App for Android (Goods Pooling) in a similar approach of dynamic carpooling problem. The main modules of this application are: (1) user interface for Goods transportation request, for drivers to advertise their availability, to perform a secure login and to receive traffic alerts based on GPS data manipulation from others users; (2) sensor data acquisition for mobility purposes; (3) real time matching process in the mobile application with low processing and storage capacity; and (4) tracing location, to help the meeting process of driver and sender; (5) Central Server or Cloud application is responsible to store the sensor data in Driver's and Sender's profile. When a user appears for the first time a registration process is performed. In this process the user defines login, email, password, cellular phone number, and role in the system (driver in the role of carrier or sender). The driver defines the driving distance to the picking point, travel time window to perform the transportation, space and weight available. He can also define the route starting and end point, with a time window or ask the system to fill this information automatically from the data collected by the sensor. The Matching Process is illustrated in Fig. 4 and is based on position and time. If both match the driver can pick goods at the sender and deliver to the receiver. If time windows do not match the system uses a consolidator agent. This process uses actors' locations from GPS information available on mobile devices.

3.1 Matching Process

This is a light process performed at a mobile device application. Figure 5 shows the main steps:

Fig. 4. Flexible process to match drivers' route to sending and receiving locations

1. **Pickup Location Matching**. When the driver starts the trip there is a continuous lookup of goods transportation (Sender and Consolidator positions) in a pre-defined radius from the current driving route. This distance is a parameter configured by the driver and based on Google maps API is possible to define a circular radius with driver current position in the center of the circle. If there is not a match between position and time a consolidation center is suggested. The nearest position is chosen and information exchange to reach picking point starts (see point 3);
2. **Drop Place Matching**. After the sender is identified in step 1 the application based on the drop off preference tries to match it with driver's destination place or route. The authors used previous defined algorithms from their work [12];
3. **Information Exchange About Selected Goods and Driver**. The system selects the sender and informs the driver of the nature of the selected good, with location, dimensions, weight and a photo (if available). As there is the possibility to use a consolidation center (CS), the Sender location is replaced by the CS in these cases. If the driver agrees to perform the request, the sender is informed and the Goods pickup or delivery process starts;
4. **Goods Pickup or Deliver Process**. The driver receives the sender photo and place to pick up with a route suggestion; the sender receives the car plate number, brand, color and indication towards pickup point.

3.2 Location Tracking and Statistics

After the goods selection process the system sends the GPS coordinates, photo of the sender (if they agree to use a photo) and the pickup place to the driver application, with the possibility to use kiosks as consolidation centers (the system handles this process based on alerts). This is an exchange of GPS coordinates between the driver and sender

Fig. 5. Example of a matching process result based on previous driver route and sender position

APP through the server. Taking into account the current location the route advice process the system creates a route proposal between the driver current position and the pickup location and sends it to driver App, where it is represented through Google Maps API interaction. The Sender receives vehicle plate, model and color and the pickup place, as indicated in Fig. 5. During this pick up process the application looks for other goods using the matching process and the sender receives the driver's current position updates.

Based on sensor data, number of goods, it is possible to calculated the distance travelled with sharing goods transportation (km), amount of fuel saved (from shared transportation) and CO_2 gas emission saved based standards patterns configurable (e.g. average consumption of deliver van is considered as 8 L per 100 km and 200 g/km of CO_2). It is possible to account the number of requests, number of offers, and the number of matches that have been done as well as other statistics in line with the ones presented for passengers/drivers. This process allows getting an overall monthly picture of how the system is being used and could be used as decision support.

4 Conclusions

The authors define new goods transportation paradigms taking into account the power of ICT platforms (with good communication, mobile devices and cloud environments) to raise collaboration towards the sharing of transportation resources. This is only a prototype that the authors intend to transform in a commercial solution. There is a progressive market penetration by these approaches and authors intend to create in 2017 a full-scale demonstration of this system in the city of Lisbon from their mobility 2020 project, a Portuguese research project performed in collaboration between ISCTE, TECMIC Company, EMEL with their connection to Lisbon Municipality and INOV, a research institute. In spite of this ICT approach, this type of collaboration system works well with a considerable numbers of users to increase matching possibilities. It is our intention to add an interface to include commercial delivery companies, to be used in the case of having a limited number of users present and no matching is possible. In addition, this approach can be used to fulfil this dedicated transportation.

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Collision Detection System Using Mobile Devices and PANGEA

Alberto Moro(✉), Fabio Andrés, Gabriel Villarrubia, Daniel Hernández, and Juan F. De Paz

Department of Computer Science and Automation, University of Salamanca, Plaza de La Merced, s/n, 37008 Salamanca, Spain
{alberto_moro,andresyv,gvg,danihiglesias,fcofds}@usal.es

Abstract. In the last decades the cost of manufacturing sensors has decreased greatly, making it possible to apply many different artificial intelligence techniques to improve the quality of our lives, one of them being the reduction of deaths in traffic accidents. Such misfortunes are usually caused by the long waiting period between the occurrence of the accident, the calling of the emergency service and their arrival. The goal of this work is to design an intelligent platform that detects a traffic accident automatically and which requires no interaction on the part of the people involved. We will design a low-cost hardware that will be suited to all types of vehicles. The sensors and medical services will be interconnected by a multi-agent system of virtual organizations (PANGEA).

Keywords: Wi-Fi · Smartphone · Emergency service · Embedded sensors · PANGEA

1 Introduction

Several scientific studies [1, 2], have proved that most deaths in traffic accidents,70%, occur between 20–30 min following the accident. It often happens that when an accident occurs the time taken to notify emergency services is too long [3]. For this reason, in many cases, nothing can be done to save the life of the injured. The main objective of this work is to reduce the response time of emergency services through the use of a low cost hardware. The architecture designed will increase the victim's chances of survival by providing medical help as early as possible. This could significantly reduce the percentage of deaths in the coming years. The latest statistics [4] on the use of new technologies indicate that in Europe, 96% of the adult population has some type of mobile phone.

In addition, the figures in [5] reflect that 80% of users who have a mobile device also have a data connection plan, this explains why we have chosen Smartphone as the central element of connection between the damaged vehicle and the medical services. The use of the driver's Smartphone in our system means that it is not necessary to buy additional data services, reducing costs. The Smartphone will not only send emergency alerts, but will also be able to detect the strength of the collision with its own sensors,

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without the necessity of incorporating additional hardware in the vehicle. To evaluate the case study, a mobile application will also be designed for the emergency services, in this way the ambulance drivers will be able to receive emergency calls. This application will show the most optimal route to the place of the accident, depending on the state of the roads and traffic at that time. The connection between the hardware sensors located in the vehicle and the driver's Smartphone will be made via Wi-Fi. All information relevant to the accident such as the geographic location and the outside temperature of the vehicle, is sent remotely to a central server. This information is stored in a database so that it can later be used for data analysis. For example, it is possible to check the geographical areas where most accidents occur or on what type of roads do accidents occur; whether they are primary roads, secondary roads etc.

The rest of this article is organized as follows: the background section provides an overview of similar works on the subject, Sect. 3 includes a case study and the proposal, finally Sect. 4 presents the results and conclusions.

2 Background

After an in-depth review of the state of the art and due to a European regulation that will be in force by 2020, automobile companies are currently developing a system called eCall [6]. By installing sensors in the vehicle, this system has the ability to determine the severity of an accident [7]. At the time of the accident, the system records a voice message from the injured, which is directly heard in the alarm center [8, 9]. The request for help can also be activated manually in cases of slight gravity, by pressing a button that is inside the vehicle. In case the system detects that the vehicle has collided, this procedure is performed automatically.

The eCall system is aimed at being the solution adopted by most companies and government agencies involved in the automotive sector [9, 10]. However, many end-users reject the service as it implies additional costs for a data service from the automobile companies.

This solution is not universal because not all drivers will be able to pay monthly sums for the service. Creating a universal system is the incentive of this work. Another disadvantage that has been found in this system is that eCall will only be available for new vehicles from 2020.

It is still being discussed whether the person who must assume the cost of the system is the final driver of the vehicle or are the concessionaires that sell the cars. This system requires a complex installation during the manufacture of the vehicle, because of this, manufacturers have to modify and reconfigure their production robots which implies high adaptation costs in the manufacturing processes.

The system presented in this work aims to make the solution independent of the vehicle manufacturer, this solution can be deployed in both four-wheel and two-wheel vehicles, and is suitable for both new vehicles as well as the current ones, regardless of the year of manufacturing.

The eCall system is not fully automatic, as it will require human supervision; an operator who will be in charge of notifying medical services manually. These procedures can easily be improved with technology. The following will explain how we obtained a solution that significantly improves upon the performance of eCall and one which can be used by the majority of people involved in the automotive sector.

3 Case of Study

The architecture proposed in this work detects a traffic accident and alerts the emergency service as fast as possible. The most important components of the hardware designed are based on the use of an Arduino microcontroller with wireless technology and an accelerometer. The reduced size of the device and its wireless capability allow for its attachment to any dashboard or motorcycle in a simple way. This device is wirelessly connected to the user's Smartphone, taking advantage of the passenger's data connection so that no additional phone services have to be paid. For the system to be distributed and transmitting data efficiently, a multi-agent architecture called PANGEA [11–15] has been used. The main characteristic of PANGEA is that it allows to develop applications embedded in computationally limited devices in a simple way, through the use of IRC protocol, which is based on the exchange of simple frames based on plain text.

This multi-agent architecture, which has been developed by BISITE, is based on the use of virtual organizations that facilitate the distribution of tasks among the different elements that make up the system.

Figure 1 shows the different agents and the different virtual organizations that make up this case study. First is the virtual sub-organization called User's Car, it is in charge of managing the information coming from the interior of the user's vehicle. Coordinated by the agent with the coordinator role, it will collect the data coming from the hardware devices deployed in the system. The virtual sub-organization Remote Server will receive all the data registered by the sub-organization User's Car in real time and will analyze them, if it detects any type of problem, it will issue an alert through the agent with Alert role. Likewise, this sub-organization will store all data for study and analysis as well as for subsequent historical data reports. Finally, the sub-organization Emergency Unit, composed of the roles: Alerts, Location and Information, is the organization responsible for giving a quick response to an accident alert. This sub-organization is deployed in the intervention unit of the emergency service and will quickly handle the requests for help launched from the sub-organization Remote Server.

3.1 Sensor System

The systems for the detection of accidents operates in two parts, the first one is the sensor installed in the vehicle and the second is the acceleration sensor found in current mobile devices. Increased accuracy is the main advantage of sensors installed in the car because using just the mobile device can lead to false positives. Each of the two systems is detailed below:

The integrated hardware in the vehicle is based on the use of an ESP8266 microcontroller in combination with an inertial measurement unit, an 802.11n Wi-Fi

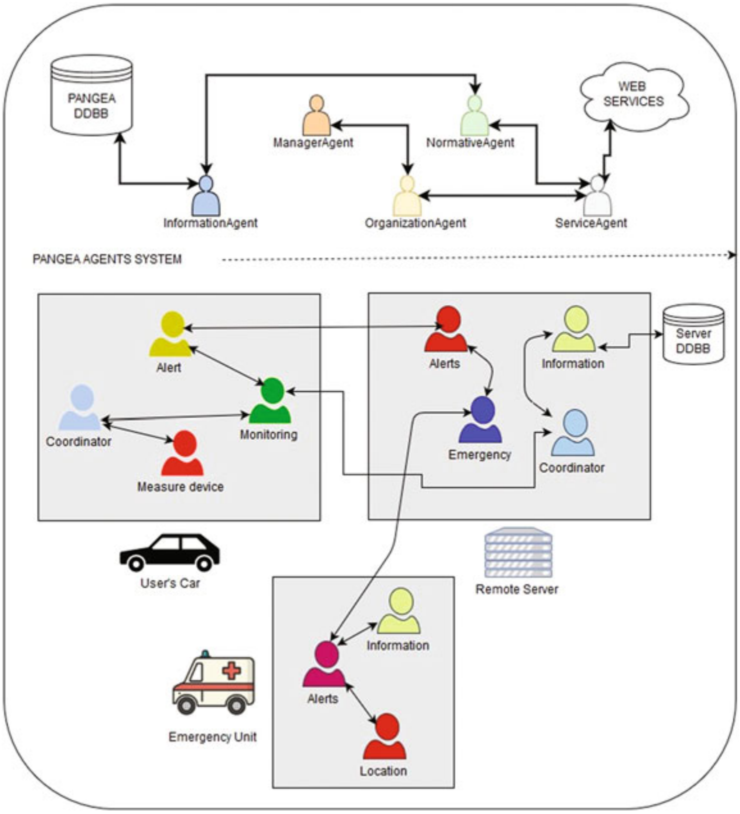

Fig. 1. Virtual organization of the system

wireless communication module, and a LIPO battery that makes the device autonomous. The cost of the prototype is remarkably low, less than 40 €.

The main element of the hardware designed is the inertial unit of measurement, which allows to control its tilting axes and the speed at which it moves.

Thanks to these parameters it will be possible to calculate when an accident occurred, this is because the sensor will be located in a compact place in which a change in the axes of inclination X and Y (Fig. 2) will indicate a collision, calculating the change in speed at its beginning and at its end. To detect an accident and make sure that it was a serious collision, it is necessary to observe a sudden change in the inclination of the axes as well as the speed of the vehicle 10 s after the collision is zero.

As mentioned before, there is an alternative for users who choose not to install any type of hardware in their car, since an accident can be detected using solely the sensors that are embedded in their Smartphone, however, with lesser precision. Both systems can easily be installed in any type of vehicle once manufactured, regardless of the brand or the year of manufacture, having a great advantage over the eCall system which needs to be installed during the manufacture of the vehicle.

Fig. 2. Example of sensor output values during an accident

3.2 Monitoring and Alert System

Once an accident has been detected by the hardware attached to the vehicle or the sensors embedded in the mobile device an automatic response is generated. The application installed in the user's mobile sends an alert to the central server of the emergency service with data about the accident such as the exact time or geolocation of the vehicle involved in the collision. Once the request arrives, it is determined which ambulance is the closest to the place of the incident, and a notification is sent to the driver's application. The information collected from each accident is stored in a central database, and information on whether the health authorities have attended the place of the accident are added on as well as the time taken to go to the place, the severity… etc. The central emergency server is in charge of evaluating the alerts that have been sent from the different Smartphones of users after a traffic accident has occurred.

Ambulance drivers using this system must install the application that allows them to receive notifications as well as the mapping of the most optimal route, depending on the condition of the roads. This application receives data about the geolocation of the accident and automatically calculates the fastest route to reach it. From the central panel that is managed by the alarm center, it is possible to view the accidents that have already been taken care of by other ambulances or the accidents that need a higher attendance priority, this helps obtain a greater efficiency. Figure 3, is a general diagram of the different actors involved in the process.

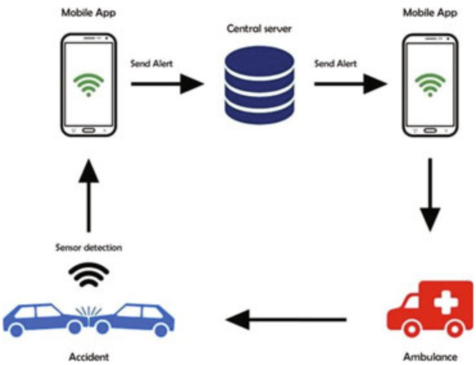

Fig. 3. Alert system diagram

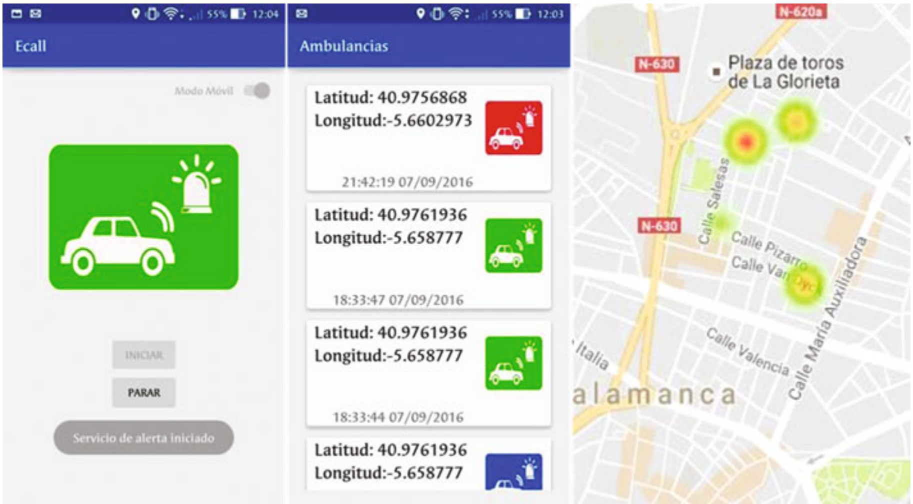

Fig. 4. **a** Sensor application, **b** Ambulance application, **c** Heatmap

4 Results and Conclusions

The use of the multi-agent architecture PANGEA, has allowed for the deployment of algorithms embedded in computationally limited devices. In order to validate the functioning of the system, we carried out simulations of accidents on some highways in the city of Salamanca, Spain. The simulations have been carried out in different parts of the city in order to check efficiency and correctness of the application that automatically establishes a route for the ambulance from its current location to the place of the accident. A central alarm management panel has been designed, it monitors in real-time the accidents occurring and also keeps note of those that have already been attended (Fig. 4). The application has been evaluated by people specializing in car security systems, and they claim that it is a more advantageous system than eCall. In driver's opinion this system is cheaper because it doesn't require buying any more phone services and it can be installed easily by the user and therefore no money is spent on its installation. The developed prototype also allows us to make statistics of the accidents, through a heat map we can view the zones where most accidents have occurred.

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Non-intrusive System for Monitoring the Risks of Sudden Infant Death Syndorme

Daniel Hernández(✉), Gabriel Villarrubia, Alejandro M. Hernández, and Juan F. de Paz

Department of Computer Science and Automation, University of Salamanca
Plaza de la Merced, s/n, 37008 Salamanca, Spain
{danihiglesias,gvg,alexhiglesias,fcofds}@usal.es

Abstract. Sudden Infant Death Syndrome (SIDS) is associated with the sudden and unexpected death of a child under the age of one who is apparently healthy. This unforeseen death, in most cases has no explanation. Although its causes are not known with certainty, we do know of the risks that can trigger them. This work presents a network of sensors to monitor the main risk factors in this pathology, such as: temperature, humidity or the level of gases in the environment. A non-invasive system is proposed since the sensors are not in direct contact with the infant, unlike most monitoring systems available today. In particular, a virtual organization of agents has been developed, it is capable of integrating different sensors on an open and low cost hardware platform.

Keywords: Sudden Infant Dead Syndrome · SIDS · WSN · e-health · Pediatrics · Multi-agent system · PANGEA

1 Introduction

Sudden Infant Death Syndrome (SIDS) [1], also known as "crib death" or "white death", is defined as the death of a child who has not completed their first year of life. The death of the infant occurs abruptly, is unexpected by history and remains unexplained even after a postmortem study. This death usually occurs during sleep [2]. Apparently, a lethal episode is experienced; the infant suffers prolonged sleep apnea, with altered muscle tone and change in skin color, there is no response to small stimuli (only in the case of resuscitation maneuvers [3]).

SIDS is one of the most frequent causes of mortality in developed countries, being the third most frequent cause of death in infants in the USA (8%) and the most frequent in the post-neonatal period (40–50%), especially between the first month and the first year of life. In 90% of the cases it occurs during the first 6 months of life. Maximum incidence of SIDS occurs between the 2nd and 4th month, it is infrequent during the first month of life, sporadic after 6 months and exceptional in children above the age of one. The incidence of SIDS has been decreasing thanks to preventive measures in most European countries, and is now between 1.5 and 2 deaths per 1000 newborns. In Spain, for example, mortality rates are 0.34 per 1000 newborns [2]. Incidence is higher in males than females and in the cold and humid months. This is due to an excess of bedding along with excessive temperature and humidity in the room. Rates increase

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when it comes to siblings, especially if they are twins or triplets and when the birth weight of the baby ranges between 1500 and 2500 g. There is even greater risk if the weight is less than 1500 g [3].

Occurrence rates of lethal episodes in the US are estimated at around 0.5–6% of newborns. Some studies suggest that 5–10% of SIDS victims had previously experienced an episode [4]. At the moment, there are no pathognomonic findings in SIDS (symptoms that would characterize or indicate this disease). It is a multifactorial process that does not follow a specific and unique cause [2]. However, the most widely accepted hypothesis is the one that relates this syndrome to a disorder in cardiorespiratory control by the brainstem, with altered arousal, blood pressure and sleep-wake cycle.

Alteration of respiratory regulation during sleep leads to a ventilation deficit. Babies at increased risk of SIDS would have a lower ventilatory response to hypercapnia or hypoxia, which would trigger progressive respiratory depression. All this, together with external factors (e.g. viral infections, exposure to tobacco smoke) can lead to death [3].

It has been shown that there is a genetic susceptibility in some infants, that, when combined with other risk factors (such as infection, anemia, cardiac abnormalities) could trigger this syndrome. In recent years, other epidemiological risk factors, related to the environment in which the child lives and the care provided, have been given increasing importance; these factors can have a positive influence on the infant and therefore decrease the frequency of SIDS, as shown in [5]. The monitoring of these factors is fundamental to try to avoid that this pathogen generates the death of the baby while it is sleeping.

This work proposes an architecture based on virtual organizations of agents that integrate different environmental sensors together with image processing techniques to monitor the main factors that can trigger SIDS. These agents will be deployed on an open and inexpensive hardware system. The PANGEA [6, 7] platform has been chosen [1] for the design of the architecture, this is because it facilitates the creation of virtual organizations of agents and their integration in different light hardware devices. It integrates different virtual organizations in charge of performing tasks such as the collection of data by different sensors, real-time monitoring of collected data, management of alerts or sending information to a remote server.

The aim of this work is to obtain safer environments that reduce the risk factors involved in SIDS. This system is completely non-intrusive, since no sensor is in direct contact with the body of the baby.

This article is organized as follows: the background section contains a study of the state of the art, the Proposed System section presents the architecture developed in the course of this work. Finally, the results and conclusions obtained are found in Sect. 4.

2 Background

In the current literature it is possible to find some examples of MAS systems [8–10] focused on the remote monitoring of sensors for medical purposes [11]. Work [12], presents an architecture focused on a medical sensor system, used for monitoring the patient's main vital signs from their own home. The proposed architecture in [4] has been taken as the starting point of the MAS architecture design described in the present work. There are also numerous examples of work that focus on monitoring systems for indoor air quality, [13–16]. In these papers the authors propose different strategies for deploying general-purpose sensors, capable of measuring air quality levels in indoor spaces.

It is less common to find works in the literature that focus on systems specifically designed for the monitoring of the newborn's environment, with the end of preventing the risks of SIDS, one of these works is [17]. In this paper, the authors present the NanoPulse Baby SleepGuard system, a device that allows contactless monitoring of newborns, controlling their breathing and heart rate while they are asleep. The baby's breathing is controlled using UWB radar technology that records body movements, controlling the baby's breathing.

Another important work is [18], in this work, the authors make use of a CO_2 sensor to check the concentration levels of carbon dioxide that accumulates around the baby's crib. The authors define a threshold value, if this value is exceeded, CO_2 levels are considered too dangerous and an alert is triggered.

It has been verified that more studies are required on the topic of environmental sensors and their application in the analysis of SIDS risks. The number of works that combine monitoring using environmental sensors and other non-intrusive monitoring methods, ones that measure the pulse for example, is very low. The present work is novel in that it intends to solve current issues with respect to monitoring SIDS by combining methods and addressing more risk factors.

3 Proposed System

To have a better understanding of the proposed architecture, each of the elements that constitute the system will be explained in detail below. The diagram in Fig. 1 shows the main modules that make up the proposed system, based on the PANGEA platform.

The first relevant element in this architecture is the organization Measuring Device. It is in charge of collecting the data from the different environmental monitoring sensors. It is also responsible for the collection and analysis of the images of the camera that will allow obtaining the heart rhythm. The roles involved in this sub-organization are as follows: Alert, monitoring, visualization, sub-organization sensors and sub-organization camera.

The agent with role monitoring will be in charge of analyzing the data obtained by the set of sensors. If values outside the normal range are detected, it interacts with the agent who is responsible for managing alerts. This agent will also provide the data to the display agent. The alert agent will be responsible for sending alerts to the server. The agent with the display role will be responsible for showing the user the data obtained in real time. The sensor sub-organization includes the coordinating agent that is responsible for collecting the data sent by each sensor and four agents (DHT11, MG811, MQ-2, MQ-7) one for each of the sensors connected to the system. The camera sub-organization will manage the collection and analysis of images captured through an IP camera. These are delicate images because they are a minor in their

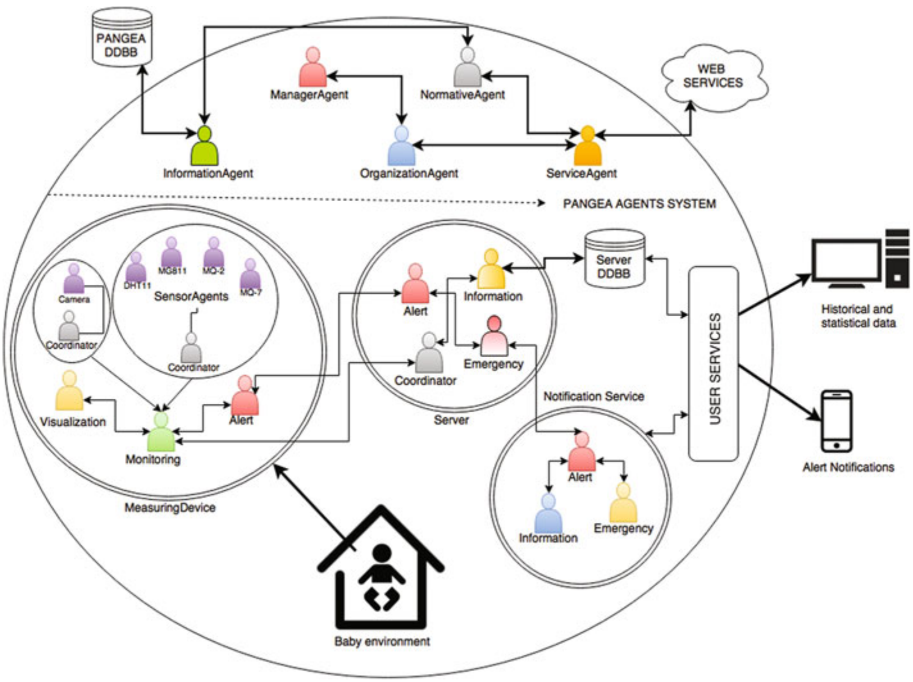

Fig. 1. Proposed MAS architecture

home, this images are analyzed locally and exclusively are sent heart rate data calculated outside the domestic network. These images after being processed are automatically deleted from the system.

The server organization has four roles: Coordinator, alert, information and emergency. The coordinating agent is in charge of managing the information coming from the sensor device. The agent whose role is information is in charge of storing all the data, while the alert agent analyzes the different alerts that arrive from the measuring device. If these alerts require a quick intervention, the emergency agent uses a Notification Service to contact the medical center configured in the system. In this way a quick intervention is performed when the measured values indicate an emergency. For the rest of the cases in which a value is out of the range or an anomaly has been detected, the alert agent sends a notification to the mobile device of the progenitor parents.

3.1 Environmental Sensing System

For the monitoring of the described factors, we will use specialized hardware that has the ability to connect different sensors. This device will act as a central monitoring node in the proposed sensor network. Currently, on the market we can find many types of devices that have this capability. Out of all of them, the Arduino platform is the most widespread, free code and at reduced cost. Therefore, it will be the device used in this work.

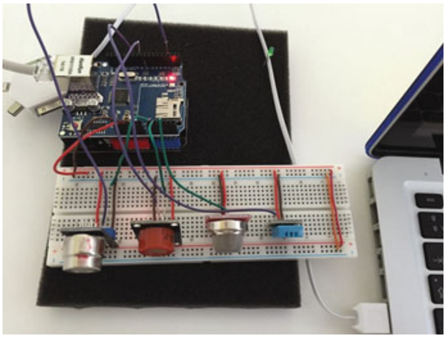

Fig. 2. Prototype based on Arduino board

The description of the environmental sensors that will be part of the architecture are shown below. These sensors are compatible with the Arduino microcontroller and like this one, they have a low economic cost. The sensors included in the project are: DHT11, MG-811, MQ-2, MQ-7. The sensor network connected to the Arduino microcontroller is shown in Fig. 2. This device will be responsible for collecting all environmental data in the infant's room.

In addition, the system will have WiFi wireless connectivity, which will enable the sending of data to the remote server. This is possible thanks to the connection of an ESP8266 module that allows to connect the Arduino microcontroller to the wireless network at home.

3.2 Calculating Heart Rate Through OpenCV

Once the environmental factors in the infant's bedroom are monitored, the task of obtaining the baby's pulse through a non-invasive system is addressed. For this, photoplethysmography (Photoplethysmogram) is used. Photoplethysmography or PPG is a non-invasive means of detecting cardiovascular pulse wave (also called, blood volume pulse) through reflected light variations. This technique provides valuable information that permits to calculate the heart rate. A small, wireless webcam is placed on the frame of the baby's crib, it will capture images needed for the treatment of data.

Firstly, a tracking and face detection system has been developed within the frames of the video in order to locate the region of interest. For this, OpenCV (Open Computer Vision) is used. The face detection algorithm is based on the work of [19] by means of a pre-trained Haar cascade capable of detecting the region of interest.

Once the region of interest is located, it is separated into three RGB channels, generating a spatial average on all the pixels of the region and thus producing the three signals: Red, green and blue. The generated signals are decomposed into three other independent source signals using ICA (Independent Component Analysis). ICA is a technique for discovering signals from independent sources of a set of observations that are composed of linear mixtures of the underlying sources. This technique is used because it contains a great ability to reduce artifacts by movement in PPG signals.

Fig. 3. Example of pulse measurement system

The underlying signal of interest that ICA uses, is the cardiovascular pulse wave that spreads throughout the body. During a cardiac cycle (cardiovascular pulse) the facial blood vessels change volumetrically by modifying the length of the incident light path, so that these changes in the amount of reflected light indicate the time of cardiovascular events. The RGB sensors that compose a camera can collect a mixture of plethysmographic signals reflected by the light. The objective of ICA is to find a separation of the PPG signal in order to collect the independent sources contained in it.

Finally, the FFT (Fast Fourier Transform) is applied to the second resulting signal to obtain the power spectrum. The pulse frequency is designated as the frequency corresponding to the highest spectrum power within an operating frequency band, so an operating range of [0.75, 4] Hz corresponding to [45, 240] bpm, thus providing a wide range of heart rate measurements.

Figure 3 shows the system running through a wireless webcam. The software recognizes the region of interest located in the frontal region of the head (in green color) and through the analysis of the images, determines the pulse of the user.

The alarm system is based on the detection of any anomalous values collected by any of the sensors that make up the platform. The system considers any value to be anomalous if it is outside of the normal limits which were previously defined in the system. These limits must be defined by a medical professional for each patient because the configurations can be different depending on the individual. Some of the elements that must be taken into consideration when defining these values are age, sex or weight. But these are not the only data that must be taken into account; to begin, it is essential to analyze the patient's health problems thoroughly in order to properly determine the normal range values for the data collected by each sensor.

4 Results and Conclusions

The result of this work is a wireless sensor device capable of monitoring the possible risks of SIDS in an infant. A web application has been developed to control and visualize all the parameters collected by the sensor system. Figure 4 shows a capture of the developed web interface, in the very center of the image we can see the baby in real

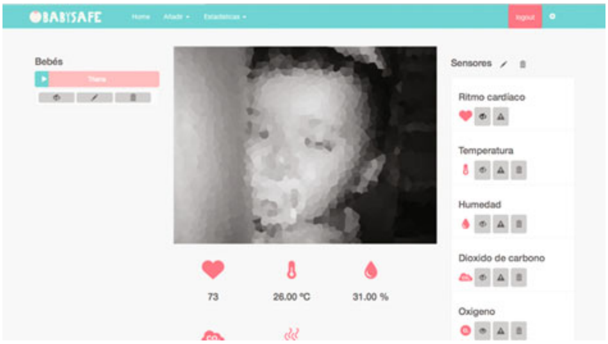

Fig. 4. System web interface

time. For security reasons this functionality is only available if the user accesses the application from the same home network in which the camera is located. At the bottom of the image, real-time values are being measured by the different sensors. To the right of the image you can see the different sensors installed in the device. Through these components it is possible to define the threshold values, on the basis of which, different warnings and alerts are triggered. It is also possible to disable or activate sensors individually or display the data history recorded by them.

In order to notify the parents and caregivers of the neonates of the incidents produced to the parents and caregivers of the infants, an application has been developed for mobile devices. This application, shown in Fig. 5, consists of a simple interface through which the user can enter the access credentials to identify themselves. Once identified, the remote server will notify the user when an anomaly occurs within previously defined values in the web application. In this way, if the anomalous values are registered in the environment in which the infant is resting, the parents or caregivers can perform a quick intervention.

In the future, we will study another of the risk factors such as the baby's position while sleeping, this would also be done by analyzing the images obtained by the camera, as we could see if the baby drinks/sleeps in a risky position. Another possible

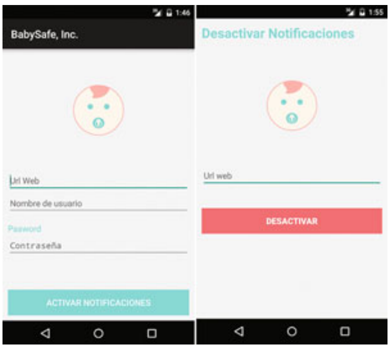

Fig. 5. Mobile application to monitor alerts

study in the future would be the application of expert systems such as CBR (Case-based reasoning), for the automatic detection of anomalies on the basis of data recorded by the devices. By creating a system that learns over time, the system's decision making will improve, yielding better results.

In conclusion, this work proposes a multi-agent system based on the PANGEA platform that manages a non-intrusive environmental monitoring system for the prevention of SIDS in newborns. These data are captured through a system of low cost sensors (less than 80 €) in combination with an open source hardware system such as Arduino. In addition, a real-time analysis of the images captured by an IP camera located on the baby's crib. The combination of environmental data and non-intrusive system, which monitors cardiac pulse, allowing for the detection of possible anomalies in the baby's health.

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We@Home: A Gamified Application for Collaboratively Managing a Smart Home

Danilo Caivano[1], Fabio Cassano[1(✉)], Daniela Fogli[2], Rosa Lanzilotti[1], and Antonio Piccinno[1]

[1] Dip. di Informatica, Università di Bari "Aldo Moro", Bari, Italy
{danilo.caivano,fabio.cassano,rosa.lanzilotti,antonio.piccinno}@uniba.it
[2] Dip. di Ingegneria dell'Informazione, Università degli Studi di Brescia, Brescia, Italy
daniela.fogli@unibs.it

Abstract. Nowadays, the low cost of smart objects and their variety in the mass market is resulting in a more and more pervasiveness of Internet of Things in our houses. This paper describes We@Home, a mobile application for smart home control that enables the collaboration within a group of people (e.g., a family) living in the same environment and interested in setting up complex and coordinated behaviors of their smart devices. Gamification elements are included in We@Home to foster the collaboration and motivate family members to help each other create the trigger-action rules managing the smart objects in their smart home.

Keywords: Internet of Things · Gamification · Smart home · Trigger-action rules · Event-condition-action paradigm

1 Introduction

With the progress of technology, smart objects are more and more pervading our houses. This leads to a new concept, Internet of Things (IoT), which refers to the extension of the Internet to the world of objects and concrete places. These smart objects, connected to a common network, can be controlled by users and can help improve the management of the environments in which they are. The recent development of IoT has led to the creation of different solutions to control smart devices, allowing users to coordinate the operation of these devices. In particular, some literature studies have revealed that the user interfaces of most of these solutions are based on the event-condition-action (ECA) paradigm [1, 2], or, more simply, trigger-action rules [3].

Users are usually supported in setting up the different parts of the rules with the help of available lists of events, conditions and actions (filtered lists), virtual puzzle pieces (jigsaw composition) or components to be put in a network (wired composition) [4]. For instance, the filtered lists metaphor is adopted in several commercial applications, such as IFTTT, Tasker, Locale, and Atooma. In [5], an environment, based on the jigaw puzzle metaphor, is proposed to support end users to create mobile

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applications for managing their smart devices. Other examples of graphical interfaces for ECA rule creation in the context of smart spaces are provided in [6]. However, most of the applications implemented so far are not yet able to support the collaboration among users sharing the same environment. Recently, Coutaz and Crowley have presented AppsGate, an environment for managing a smart home, which combines rule-based and imperative programming [7]. This system consists of a server and a set of web-based clients that can be used by different family members on a variety of devices. But, even though AppsGate provides a high expressive power in terms of programming facilities, it appears as more oriented to computer experts rather than real end users ("user engagement in programming takes time and effort" [7, p. 37]), and, above all, it does not include any mechanism to foster participation and support collaboration among family members.

The application presented here aims at filling this gap. Specifically, in this article we focus on the collaboration among family members for the management of IoT objects in their home. The application, called We@Home, has been developed as a mobile application implementing gamification techniques to foster collaboration and provide a rich user experience.

2 Gamification

Gamification is "the use of game design elements in non-game contexts" [8]. The term "gamification" is sometimes controversial, but the definition given above and the survey provided in [8] clarify that "gamified" applications are different from (video) games, serious games or just software applications that provide a playful interaction, like those considered in [9]. Gamified applications are systems aimed at fostering user motivation in the use of a product or a service through mechanisms that usually belong to games.

To deeply understand user motivation in a gamified application, intrinsic and extrinsic motivations should be clarified. *Intrinsic motivation* leads people to carry out an activity for their own satisfaction, for fun or challenge, with no interest in external rewards. On the contrary, *extrinsic motivation* refers to doing something because it leads to a separable reward [10].

Deci and Ryan in their Self-Determination Theory identified three principles that are connected with intrinsic motivation: *relatedness*, *mastery* and *autonomy* [10]. *Relatedness* is the feeling that an individual is not alone; according to this theory, by learning from others who are engaged with the same setting, the individual can feel better in accomplishing the task. This is a key point in the scenario of gamification, as it is important to connect the user to a community sharing the same interests; intrinsic motivation is usually enhanced by the social relationships that give more confidence in the player [11]. The second principle is *mastery*: it indicates the need of users to participate in ongoing challenges to increase their understanding of the game [11]. In fact, the interest of users in a game derives mainly from their desire to master the system functionality; it is therefore important to create well-defined objectives and rules or leave users the ability to define their own goals and their rewards [9, 12]. The last principle is *autonomy*, where participants can choose their own paths, so that they feel they are in control, rather than doing what someone else desires. In addition to increase autonomy, and then the intrinsic motivation that derives from it, it is important to give users the opportunity to make choices.

On the basis of the Self-Determination Theory principles, Nicholson developed a theoretical framework, called Organismic Integration Theory (OIT), stating that when people perform tasks pushed by intrinsic motivation they have a better perspective on the activities to be carried out than when they are moved by extrinsic motivation, e.g. through external rewards [13]. As a consequence, if gamified systems focus on the distribution of external rewards to increase extrinsic motivation, this will work as long as rewards keep coming [14], and sometimes this will be not even sufficient. Indeed, one of the most famous gamified platforms is Foursquare, which allows users to get rewards such as medals, if they share their location with their contacts by making check-ins in particular places. However, many Foursquare's users are leaving the service because they realized that there is no advantage in participating in the game than to get medals. On the contrary, Stackoverflow, a gamified platform of questions and answers on the theme of programming, has a community linked by the same interests and goals [12]. Rather than considering if motivation is intrinsic or extrinsic, OIT tries to understand what external controls are associated with the desire to carry out activities. If there is a big external control through rewards, some aspects of that external control will be internalized as well. On the other hand, if there is little external control, then the activity will be more self-regulated.

A theoretical model for designing gamified applications, widely accepted by the industry of game design, has not been defined yet. One example is MDA (standing for Mechanics, Dynamics and Aesthetics) proposed in [15]. Whilst, Werbach proposes a gamification framework encompassing dynamics, mechanics and components [16]. In particular, components are the low-level tools that allow making the mechanics concrete; they include a variety of elements that are usually introduced in the user interface of a gamified system, such as badges, leaderboards, levels, points, quests, and many others [17]. The We@Home mobile application presented in the following is enriched with some of these components for controlling and managing a smart home in a collaborative way.

3 We@Home

We@Home is an application for mobile devices that implements gamification techniques with the aim of empowering users to take advantages from the use of IoT devices. Usually IoT devices are managed and controlled by only one user at a time, through his/her own app, in a one-to-one relation. In We@Home mechanisms allowing the collaboration among the home inhabitants have been introduced. Family members exchange requests for the creation of event-condition-action (ECA) rules controlling IoT devices in the home. Thus, collaboration among family members is primarily based on the relationship between requests and responses to such requests, i.e. the ECA rules. A user can create a textual request, which will be notified to the other family members, who can create different ECA rules to satisfy the request. The requester can choose the most satisfactory rule and, after making this choice, s/he can select a reward among those in the wishlist of the rule author.

In the following, a scenario is reported. It illustrates the main aspects regarding the collaboration among end users belonging to the same family using We@Home.

Giovanni is 35 years old and he is the father of two children. He mainly uses the computer for work and the smartphone with few apps installed. He has to manage the IoT objects installed in his house, thus he downloaded "We@Home" app from Google Play store. He uses We@Home for requesting to his family to switch on the oven at 9:30 a.m. for 2 h when he is at work. The system sends a notification to his family members, who get the request and may propose their rules. Both his son Marco and his wife Laura create a rule as a response. Giovanni believes that Marco's rule is the right one and selects it. To reward him, Giovanni chooses a gift from Marco's wishlist.

3.1 Interacting with We@Home

In We@Home the family is the set of individuals living in a smart environment. Each user is a member of the family. If a user is the first to sign up to the system, after registering and personalizing his/her profile s/he will create a new family. During the family creation, the user also selects the IoT objects of interest in a list of the available objects that can be updated at any time. On the contrary, s/he can search other family members through their emails. If the family is already registered, its members are shown along with their names and avatars, and s/he can easily join the family.

As already said, We@Home aims at fostering collaboration among family members in creating trigger-action rules to manage the smart objects in their smart home. To reach this goal, each family member can propose a *challenge* to the others asking to comply with a specific need of managing certain smart devices. At the same time, each family member can propose rules in response to the given request. The creation of the rules can be from scratch or by modifying an existing one. Given the previous scenario, through the Navigation Drawer on the main screen, Marco, Giovanni's son, accesses the family request screen ("Richieste famiglia" in Italian, in Fig. 2 left), where all the family requests are shown in a list. For each of them, a number of information and actions are available, such as, the textual request, the name and the avatar of the requester, the button for the creation of a new rule or for modifying an existing one. Among the requests, Marco finds the Giovanni's request for switching on the oven at 9:30 a.m. for 2 h.

Marco then, answering to his father's request, initiates the creation of a new rule by clicking on the relative button (circled in Fig. 1 left) and create the rule by choosing conditions and actions associated to smart objects of interest (Fig. 1 right). Similarly, Laura creates another rule to satisfy her husband's request.

In creating the rules, We@Home supports the family members by showing a list of all owned objects with tools for managing them, e.g., radio buttons, spinners and TimePickers for turning on/off and setting time and duration (see Fig. 2).

Subsequently, Giovanni can access the rules proposed by his relatives, see for example in detail the Marco's one (Fig. 3 left) and select it. By accepting the rule, Giovanni has to choose a reward for Marco from his wishlist (for instance, mouse, sunglasses, etc.), as shown in Fig. 3 right.

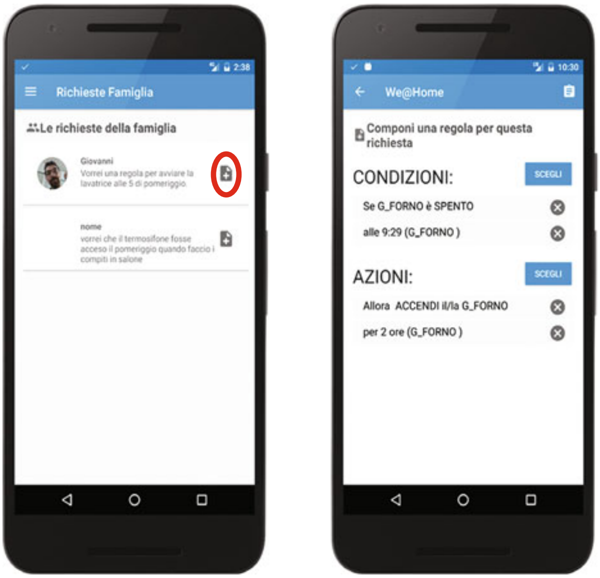

Fig. 1. Requests from the family (*left*) and rule composition (*right*)

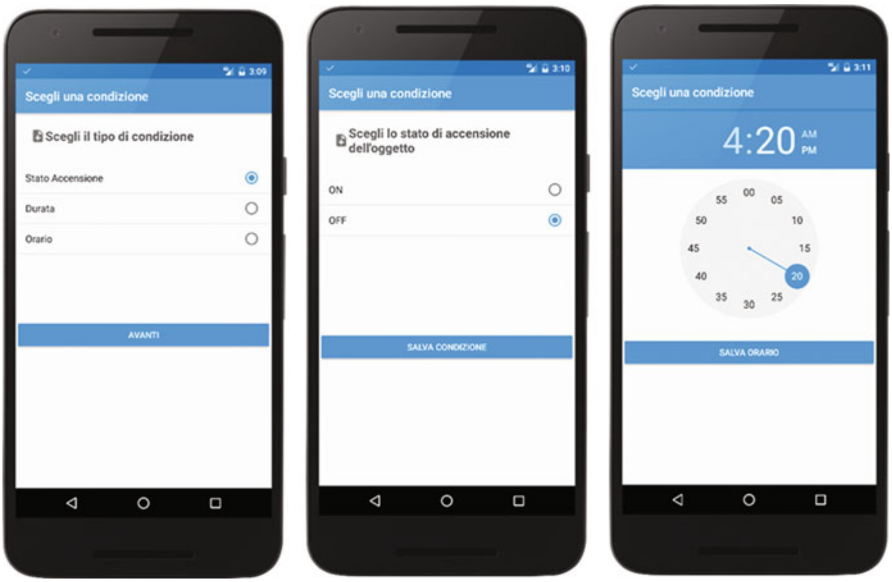

Fig. 2. Example of tools for rule creation in We@Home

In addition to challenges and rewards, the following gamification elements have been adopted: (i) *points* aiming at increasing users' motivation for interacting with the application; (ii) *leaderboards* increasing competition between users; (iii) *medals* obtained by collecting points for stimulating a persistent users' participation.

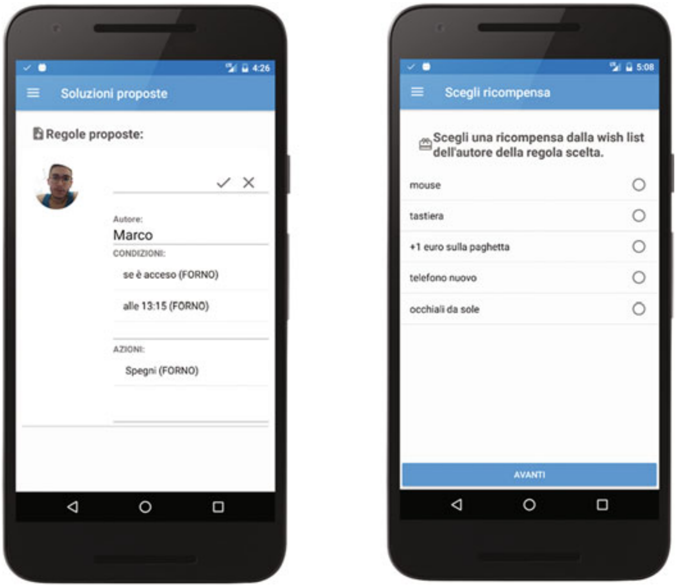

Fig. 3. Proposed rule to satisfy a request (*left*) and wishlist of a user (*right*)

Points can be earned by both the single user and the family. The single user earns points (1) through daily accesses to the application and (2) through challenges. The decision to assign points to a certain number of daily accesses is due to the fact that the user, driven by the desire to "easily" earn points, will use more frequently the application and the possibility to respond to the family requests increases. Points earned by overcoming the challenges are collected and contribute to the position in the overall leaderboard. The leaderboard is determined by the sum of points earned by each family member in completing the challenges and through his/her daily accesses. The top three ranked in the leaderboard are awarded by the gold, silver and bronze *medal*, respectively. Medals are used to highlight the user successes and are shown in the user dashboard along with the corresponding month in which they are earned. The dashboard makes available to the users all statistics on earned points, created rules, proposed rules, requests, and overcome challenges (see Fig. 4).

We@Home is an Android application; Firebase Cloud Messaging is used for handling and receiving push notifications; Volley is adopted for handling the HTTP requests to the server and the JSON format is used for the data exchange. After analyzing platforms for creating rules, such as Workflow and Event-processed, an ad hoc platform, which favors the integration between front and back ends without any further layer, was developed for the creation and the management of rules.

Fig. 4. The We@Home dashboard

4 Conclusion

Today, in the Internet of Things era, almost all smart objects available in the mass market are usually oriented to a single user, i.e., the administrator. The same problem occurs with smart home control by IoT devices where the home "administrator" has to control and manage them alone. The idea of We@Home is to favor the participation of all home inhabitants in the configuration and management of their shared environment and smart devices. Such activity is carried out by a simple visual interface supporting the creation and modification of trigger-action rules. However, we have hypothesized that not all the users may be interested in this activity or willing to learn how to create rules; therefore, to foster participation and sustain collaboration among users, we have enriched We@Home with gamification elements, such as challenges, rewards, points, and medals. A formative study was carried out to evaluate the usability of the We@Home application involving six users. They were enthusiastic about the application, finding it both easy to use and satisfactory. However, we are planning to test the application with real families, in order to demonstrate that gamification may actually contribute to motivate people to participate. In addition, we are currently working on gamification mechanisms to increase the users' interest in participating in the smart home control by introducing competitions among families, for example, living in the same building or in the same neighborhood or city.

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A Task Recommendation System for Children and Youth with Autism Spectrum Disorder

Margarida Costa[1], Angelo Costa[1(✉)], Vicente Julián[2], and Paulo Novais[1]

[1] Centro ALGORITMI, Escola de Engenharia, Universidade do Minho, Braga, Portugal
margaridafsc@gmail.com, acosta@di.uminho.pt, pjon@di.uminho.pt
[2] Departamento de Sistemas Informáticosy Computación, Universitat Politècnica de València, València, Spain
vinglada@dsic.upv.es

Abstract. Current studies indicate that 1 in 68 children have Autism Spectrum Disease. It is known that early diagnosis and intervention can alter the course of development and significantly improve the prognosis of the disease. It is our intention to develop a task Recommendation System, which will use a Case-based Reasoning machine learning technique, in order to supplement the child's regular therapy. Besides the tasks' recommendation, this application will allow a closer monitoring by parents and a better coordination with the therapists, contributing to improve the results on child's development.

Keywords: Autism · Case-based reasoning · Decision support system · Mobile computing

1 Introduction

Autism Spectrum Disease (ASD) is part of a group of complex disorders in brain—neurodevelopmental disorders [1]. This disorder is mainly characterized by verbal and non-verbal communication problems; difficulties in relating to people, things, and events; and repetitive body movements or behaviors [1]. Although those are defined criteria by the Diagnostic and Statistical Manual of Mental Disorders (DSM-V), autism differs from person to person, in severity and combinations of symptoms and there is not a medical test that can diagnose it [2].

In 2014, the CDC (United States) has released a study that found that 1 in 68 children aged 8 years had ASD [3]. In Portugal, the prevalence of ASD in 2007 estimated 10 per 10,000 children [4].

Although there is still no cure for autism, is known that early diagnosis and intervention can alter the course of children development. That is why therapy

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and a regular training and support from parents can significantly improve the prognosis of the disease [2]. Children with autism often need external stimulus to initiate, maintain, or terminate an activity [5].

Technological advancements gave devices the ability to deliver visual, tactile and mechanic feedback, which can be used for children with autism, since this kind of stimulus are generally better received than human stimulus [5].

Combining the technology advantages with the necessities of an autistic child, the motivation for developing this application arose. This paper presents a prototype of our idea. The next section presented the related work. In Sect. 3 is presented the relevant state of the art. Section 4 makes a brief description of the application architecture. The visual interfaces are described in Sect. 5. Section 6 is dedicated to the CBR and the Recommendation System. The last section is dedicated to the conclusions and future work.

2 Related Work

Published in 1992, by Boston University, the Pediatric Evaluation of Disability Inventory (PEDI) was a paper-pencil survey, which asked the caregivers of children and youth with disabilities about their difficulty in doing an extensive list of activities [6]. Later, a Computer Adaptive Test (PEDI-CAT), has been created to increase efficiency and reduce the respondent burden. This survey enables clinicians to construct a description about the current functional status or progress in acquiring functional skills for children between 1 and 21 years of age [6]. The PEDI-CAT has a "item bank" that is an extensive list of 276 activities in the domains of Daily Activities, Social/Cognitive, Responsibility and Mobility [6].

After the completion of one PEDI-CAT, a score report is available for each domain administered, which includes three distinct types of scores: the *scaled scores*, the *normative scores* and the *item-maps*. The scaled scores are the result of the caregivers responses to the questioned items, calculated through a statistical model. The item maps are tables (one for each domain), that define the expected level of difficulty/responsibility for each activity, based on the child's obtained scaled score [6].

PEDI-CAT-ASD, is an adaptation of PEDI-CAT for children and youth with autism spectrum disorders. The results have shown that PEDI-CAT-ASD is appropriate to assess children and youth with ASD among an heterogeneous range of age and severity [7].

3 State of the Art

Currently, there are a huge variety of applications in this area, which can be categorized according to their target audience: if is for children with ASD or their caregivers; their main propose: learning skills or logistic and organizational issues; and the domain of learning skills to explore. Regarding applications directed to the education of children with ASD we present some examples available in the market:

MITA was developed by a group composed by a neuroscientist, an early-child-development specialist, artists, developers and therapists. Mental Imagery Therapy for Autism (MITA) is based on Pivotal Response Treatment which have as target three critical areas of development: response to multiple cues, motivation and self-management. This application includes nine adaptive games that, over time, get more difficult and aim to improve the child's development specifically in the areas of language, attention and visual skills [8].

Social Skills for Autism has been developed by the Shine Centre for Autism, in Ireland, and is based on the Personal and Life Skills Programme (PALS) [9]. This application has 17 individual lesson plans, each one covering a required social skill. When children complete one plan it gives them a reward [10].

Choiceworks aims to help caregivers provide their children clear and easy rules and timetables which allow them to be more independent and to adapt their emotions and behaviors according to different situations. This application is provided with three customizable boards and a multimedia library. It allows the creation of profiles, managing multiple users and saving boards. It can also be adapted for the usage of teachers in a school environment [11].

Autism Tracker by Track and Share Apps company, allows users to explore autism, tracking and analyzing a large collection of data such as sleep, stress, sensory arousal, happiness, activity level and behavior. It has a visual calendar that can summarize totals, averages and statistics over a select period of time, as well, scheduling activities. It also give the possibility to share data with the other users through social networks [12].

Pathfinder is the result of the merge of specialization in strategies for simplification of behavioral data and health-care and autism therapy practice. It was specifically developed to provide technology solutions for administrative and data collection issues, for behavioral health providers. It has easy interfaces for the data store and the creation of documents and shows the therapies progress. Besides that, it organizes therapy teams and schedule and notify therapists about their work day [13].

4 Architecture

The main goal of this project is to improve the interaction methods through technology, thus improving the results of therapy [14,15].

A client-server system have been developed: an Android Application that aims to improve the communication between therapists, children and parents, as well as help the children doing their tasks in a fun way; and a Recommendation System for suggesting activities that are appropriate, necessary and enjoyable for each children, using Case-Based Reasoning (CBR) [16,17].

We have based our data on the PEDI-CAT-ASD repository. The autistic sample includes the scaled scores, per domain, for the ages of 5, 10 and 15 years, obtained through a questionnaire made to 105 parents of autistic children.

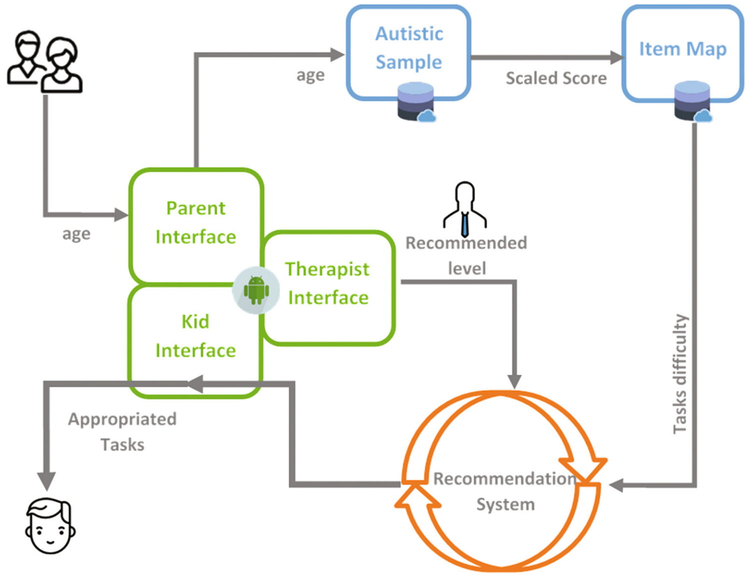

Fig. 1. Client-server system architecture

The system described in Fig. 1 operates in the following way:

1. The user Parent introduces the age of his child in the system;
2. Based on the inserted age, the system selects the predicted *Scaled Score* in each one of the domains, according to the autistic sample;
3. The difficulty/responsibility level for each incorporated activity in the system is given, according to the previously obtained *Scaled Score* and the item-map;
4. The user Therapist introduces the difficulty level in the system;
5. With the previous information, and other external data, the Recommendation System is fed and is ready to start operating. In Sect. 6 it is explained in detail;
6. The user *Kid* receives the assigned tasks.

5 Visual Interfaces

The mobile application has three profiles, as seen in Fig. 2a: *Parent*, *Kid* and *Therapist*. The *Kid* account is authored by the parents and require the children data and one of the therapists available in the system (Fig. 2c).

After login, parents and therapists are received with a list of their children. The Fig. 3a shows the main page for *Kid* and for his *Parent* and *Therapist* (b). The *Kid* profile has tasks and rewards in an effort of increase the interaction with the system. In the Tasks interface, children have a list of suggested activities, which they can select and mark as done or undone. When a task is marked as "done" it is removed from that list and, pending the parents approval, is moved to the "Tasks to approve" list on the parents interface. Each task has

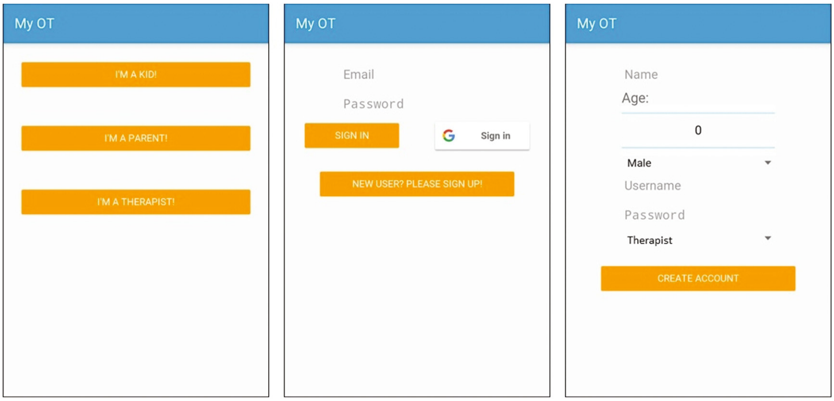

Fig. 2. **a** Choose type of user, **b** login and **c** Create kids account interfaces

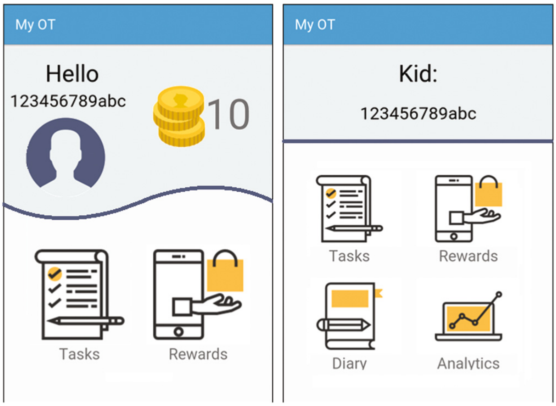

Fig. 3. **a** Kids Application mains page; **b** Parents/Therapists main page

a symbolic value which is given according to the activity difficulty. After the parent's approval, the child receives that value. The main interface for parents and therapists has the following options: Tasks, Rewards, Diary and Analytics. In Tasks the parents are able to propose new tasks for their children, either automatically chosen by the Recommendation System, or manually chosen from the item bank. It has two separated lists of tasks: "Tasks to do" and "Tasks to approve" (Fig. 4a); the second list marks the "done" and "undone" tasks. In case of "done" the parent can classify the difficulty on doing that activity (Fig. 4b). The therapists' interface for Tasks is similar, but without buttons to propose new tasks or the classification option. Therapists have access to the tasks lists, to follow the work done by the patient. In the Rewards interface, parents and therapists can add new prizes to the rewards list. The Diary button, opens a log book, where therapists may register the most important and worked goals of each session. Thus, parents are able to see their child's progress.

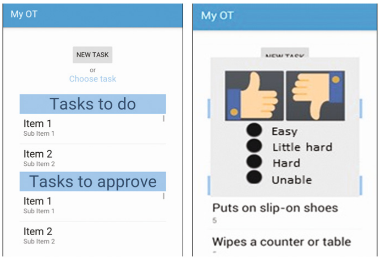

Fig. 4. Tasks activity interface

The Analytics interface for parents and therapists is able to show a domain that the user wants to analyse. The statistics show the frequency of each difficulty level for the selected domain.

6 CBR Methods

To provide more accurate suggestions a CBR system was adopted [18].

Following this approach we have defined first the set of attributes that form our proposed case. In this platform our problem is described by the age of the child, the gender, the day time (morning/afternoon), the week time (week/weekend), the therapist ID and the level of difficulty; and the solution is represented by one task ID. In some cases, some attributes may have missing values, but we foresee that the system should be able to handle incomplete information.

In Table 1, an example for the case *c0001* is shown. The *gender*, *dayTime* and *weekTime* are binary attributes. In *gender*, 0 represents "female" and 1 "male"; In *dayTime*, 0 means "afternoon" and 1 "morning" and in *weekTime*, 0 represents "weekend" and 1 "working days".

The first phase of the cycle—the retrieval phase—retrieves similar cases from the stored ones. For the retrieval algorithm, the most similar cases are selected by means of a k-nearest neighbour algorithm using the local similarity measures to compute the similarity among cases.

For the *age* attribute a *threshold* function has been applied.

The value of the threshold was defined as 2, in order to cover all ages in the autistic sample.

Table 1. A Case base example

Description							Solution
CaseID	Age	Gender	Daytime	Weektime	TherapistID	Difficulty	TaskID
c0001	5	0	1	1	thera@gmail.com	4	DA001

For the *difficulty* attribute, an *interval* function. This function returns $1 - \mid difficulty_{new} - difficulty_{caseBase} \mid / k$, where k is 4, the number of stages in our difficulty scale. In the rest of the attributes an *equal* function was used.

The global similarity is calculated through a weighted average function with the values of the local similarity and the respective weights of the attributes. In consensus with a team of occupational therapists, we have decided to give more importance to the age and difficulty attributes, weighing 1, while the other attributes receive a 0,5 weight. The global similarity retrieves a value between 0 and 1, where 1 means a perfect match.

After a solution has been applied, the user must indicate to the system whether that solution is optimal to the problem or not, which is done when parents confirm that his child has done the task and its difficulty. Each time that one solution is used, its suitability degree is increased and the difficulty value is updated averaging the old and new values. That is how the system learns the degree of suitability of the solutions that the CBR engine provides, by means of the revision and retention phases. Finally, if the similarity of the stored cases is below the acceptance threshold, the system selects the most similar solution and saves it as a new case, gathering the acceptance information in the next cycle.

7 Conclusions and Future Work

This work presents an initial implementation of a therapy support system for children and youth with ASD. Our aim is to produce a companion system that is used as a reinforcement for the therapy sessions that the children attend. We believe that our system will increase the interaction and responsiveness of all users involved, thus optimizing the therapy procedures, and give the opportunity to parents and clinicians to monitoring their children more closely. Comparing with other solutions available in the market, our application is very complete once it provides skill learning trough an automated system, and also data collecting and analysis for caregivers.

Our team of occupational therapists indicate that this application may improve the results of therapy, although validation with real users is needed to confirm these allegations. Also, after conducting a survey on the usability of this application, we have data indicating that the idea is being very well received by health and education professionals dealing with autistic children.

As future work, in order to make our Recommendation System more efficient, it would be important to improve the quality of the cases in the CBR. We also want to adapt the language of the activities to a more appropriated one for children and to illustrate every possible activity. Finally, we want to test our application in a representative sample of children and youth with ASD, in Portugal.

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Content-Based Image Retrieval in Augmented Reality

Leszek Kaliciak(✉), Hans Myrhaug, and Ayse Goker

Ambiesense Ltd., Aberdeen, UK
{leszek, hans, ayse}@ambiesense.com

Abstract. In this paper, we present a content-based image retrieval framework which augments the user's reality and supports the decision making process as well as awareness and understanding of the local marine environment. It comprises a real-time intelligent user interface combined with the 360° real-time environment display in the virtual reality headset. The image retrieval utilizes a unified hybrid adaptive image retrieval model. The presented system provides the user with a unique solution combining the virtual reality real-time headset, 360° view, and augmented reality to remotely monitor the surface and underwater marine environment. The objective of the proposed framework is to enhance the user interaction with the remote sensing and control applications. To our knowledge, it is the first system that combines real-time VR, 360° camera, and hybrid models in the context of image retrieval and augmented reality.

Keywords: Virtual reality · Augmented reality · 360° cameras · Content-based image retrieval · Hybrid models

1 Introduction and Related Work

Augmented reality (AR) is a live view of a physical, real-world environment augmented by computer-generated information. It has applications to navigation, commerce, captioning, among others [9]. Augmented reality is especially well suited for the environment surveillance purposes, for example surface and underwater ocean monitoring. Immersive virtual reality (VR) is often not considered augmented reality because the user is not exposed to a real but a virtual world. We, however, use the virtual reality headset to directly stream the real world information in real time and augment it with computer generated content. The presented use-case is a part of the bigger project which aims at developing a design environment for Cyber Physical Systems. The new type of marine robot with surface and underwater surveillance capabilities is presented in Fig. 1.

In terms of related work, a 360° camera with the virtual reality headset was also used in [10] to provide the users with novel and intuitive means to view the imagery of the Antarctic Ocean from a vessel. By applying the alignment and

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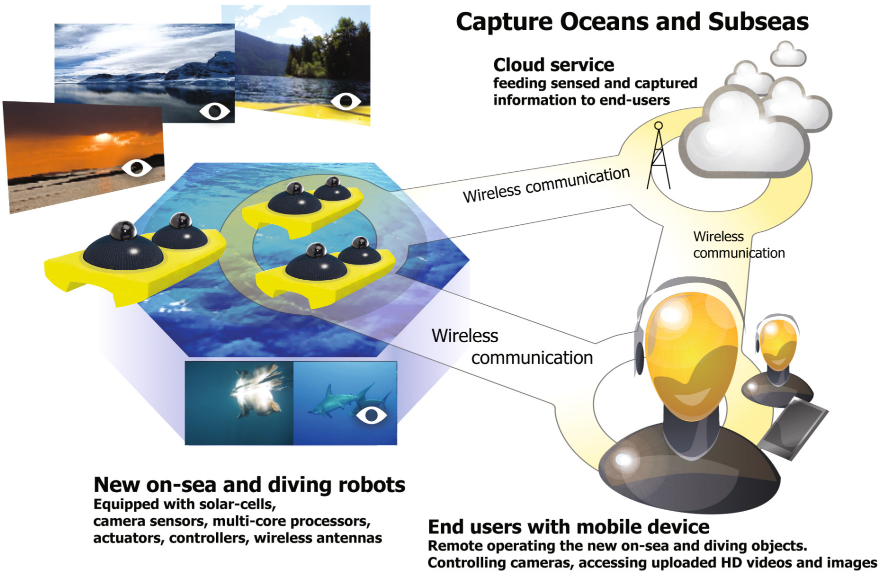

Fig. 1. The marine robots - new cyber-physical systems with immersive remote sensing capabilities

re-projection technique, the 3D image of the vessel's environment is produced in Unreal Engine. This allows for a seamless movement in 3 dimensions.

Another related system taking advantage of the 360° real-time camera and VR is the one introduced in [2]. The presented idea is a vision of the augmented reality real-time 3D environment for robotic operations in space. The astronauts, with the help of VR headset, would be able to quickly and easily move through a virtual reality enhanced 3D model of the International Space Station validated and augmented with real-time camera video.

Our marine robot augments the real-time surface and underwater data stream with the information about similar (previously encountered) information objects. The retrieval of similar objects is based on the fusion of different types of features in order to reduce the semantic gap, the difference between machine representation and human perception of images.

The main challenges in data fusion are currently related to incorporation of correlation and adaptivity into hybrid models [11]. Different feature spaces are correlated because they often represent the same information object. Moreover, the importance of different feature spaces varies, it is dynamic in nature. Standard widely used data fusion strategies (e.g. linear combination of scores) do not take this correlation into account and use fixed weights associated with the importance of feature spaces [1,7].

The presented framework integrates our prototype unified tensor-based system consisting of the user interface, the hybrid model for the combination of visual and textual features, and the hybrid adaptive model for the combination of features in the context of relevance feedback. We address the main challenges in data fusion by utilizing the inherent visual-textual (inter) and visual-visual, and textual-textual (intra) relationships between visual and textual feature spaces. Moreover, the hybrid relevance feedback model adapts its weights associated with the importance of visual and textual features based on the interactions with the user - user relevance feedback.

2 Augmented Reality User Interface

One of the forms of interaction of the user with the robot is via the virtual reality (VR) headset Fig. 2. The VR headset displays the surface and underwater 3D environment captured by the 360° spherical cameras mounted on the marine robots. The experience becomes even more immersive with the head-tracking like feature. All of this offer the user a natural, real-time marine monitoring capability. Moreover, the real-time visual image of the marine environment is augmented by additional digital information. When using the select button on the VR control pad, the on-the-fly image capture and retrieval presents the user with the visual and textual information related to similar information objects. A pop-up window is used to display the retrieval results which can be freely browsed. The user can further narrow down the presented top retrieval results by highlighting the relevant images with one of the control pad buttons and pressing the select button. When using the select button on one of the top result images, the associated textual information will be displayed.

The augmented reality user interface is shown in Fig. 3.

Fig. 2. Marine robot engineer accessing the remotely sensed imagery in VR glasses

Fig. 3. The augmented reality user interface

3 Implemented Models

In this section we present the advanced hybrid image retrieval models used in conjunction with the augmented reality VR headset.

Our models combine different types of visual information representing a specific information object (image), and also textual and visual information for the search refinement process providing the textual information is available in the database of similar images.

3.1 Image Representation

The visual features implemented in our prototype model comprise global and local methods: edge histogram, homogeneous texture, bag of visual words features, colour histogram, and co-occurrence matrix. The textual features used in the search refinement process are based on the standard vector space model with the tf-idf weighting scheme.

In addition, the extracted visual representations of the information objects incorporate the absolute spatial information in order to focus on the middle part of the 360° images. Because the user has the freedom to look around the environment in the VR headset, he/she will focus his/her gaze on the most interesting areas of the 360° image.

In order to implement the aforementioned absolute spatial information, we divide an image into two regions. The central circular region represents the user's focus, and the remaining region represents his/her peripheral vision. We use both regions in the retrieval process by extracting the same visual features from each region and concatenating the representations.

3.2 Hybrid Adaptive Image Retrieval

The data used in Multimedia Retrieval is often multimodal and heterogeneous. Tensors, as generalizations of vectors and matrices, provide a natural and scalable framework for handling data with inherent structures and complex dependencies. There has been a recent renaissance of tensor-based methods in machine learning. They range from scalable algorithms for tensor operations, novel models through tensor representations, to industry applications such as Google TensorFlow, Torch and Tensor Processing Unit (TPU).

We have developed and implemented two tensor-based hybrid models in our prototype system: a hybrid model for the combination of visual and textual features [4], and a hybrid adaptive relevance feedback model for the combination of features in the context of user relevance feedback [5].

In the first tensor-based model we utilize a specific combination of the Euclidean distance to measure the similarity between visual representations, and the cosine similarity to measure the similarity between textual representations. The Euclidean distance, in the case of our mid-level visual features, performs better than cosine similarity. It is due to the fact that normalization of our local features hampers the retrieval performance. On the other hand, cosine similarity in textual space performs better than other similarity measurements [6]. This specific combination of scores has an interesting interpretation in the form of the Euclidean distance calculated on tensor-ed representations [4].

Thus, we combine the distances as

$$\sqrt{s_e^2\left(d_1^v, d_2^v\right) s_c\left(d_1^t, d_2^t\right) - 2 s_c\left(d_1^t, d_2^t\right) + 2} \tag{1}$$

where s_e denotes the Euclidean distance, s_c represents the cosine similarity measure, d_1^v and d_1^t denote visual and textual representations of the query respectively, d_2^v and d_2^t denote visual and textual representations of an image in the data collection respectively, and $\otimes$ is the tensor operator.

It can be shown that the aforementioned combination of measurements is equivalent to

$$\sqrt{s_e^2\left(d_1^v, d_2^v\right) s_c\left(d_1^t, d_2^t\right) - 2 s_c\left(d_1^t, d_2^t\right) + 2} = s_e\left(d_1^v \otimes d_1^t, d_2^v \otimes d_2^t\right) \tag{2}$$

Thus, the implemented model is equivalent to computing the Euclidean distance on tensor-ed representations.

The second tensor-based implemented hybrid model is the hybrid relevance feedback for image refinement. It utilizes the correlation and complementarity between different feature spaces and has been extensively evaluated against other state-of-the-art models [5]. Moreover, because query can be correlated with its context to a different extent [3,8], the implemented model adapts its weights based on the user relevance feedback.[1]

[1] In this paper, the textual and visual terms refer to image tags and instances of visual words, respectively.

The model is defined on a Hilbert space (a complex space with an inner product) which can be thought of as a natural extension of the standard vector space model, with its useful notions of subspaces and projections. It was inspired by the mathematical tools utilized in Quantum Mechanics (QM) and is based on the expectation value, the predicted mean value of the measurement. The model also uses the notions of co-occurrence and the tensor operation. Co-occurrence matrices can be treated as density matrices (probability distribution) because they are Hermitian and positive-definite, and the tensor operator can be utilized to combine the density matrices corresponding to visual and textual feature spaces. The tensor product of density matrices of different systems represents a density matrix of the combined system.

Thus, the intra-feature correlations are captured by density matrices corresponding to individual feature spaces, and inter-correlations are modeled in the form of the tensor product - resulting in a density matrix of the composite system. The projection of the query onto the subspace of the composite system can then be considered as our similarity measurement.

Let tr denotes the matrix trace operator, $\langle\cdot|\cdot\rangle$ represents an inner product, M_1, M_2 are co-occurrence matrices corresponding to different feature spaces (a subspace generated by the query vector and vectors from the feedback set), $\otimes$ denotes the tensor operator, a, b are different representations of an image in the collection corresponding to M_1 and M_2, q_v, q_t denote the visual and textual representations of the query, c^i, d^i denote visual and textual representations of the images in the feedback set, D_q^v, D_f^v denote the density (co-occurrence) matrices of the visual query and its visual context (feedback images), D_q^t, D_f^t denote the density matrices of the textual query and its textual context, and n denotes the number of images in the feedback set.

$$
\begin{aligned}
&tr\left((M_1 \otimes M_2) \cdot \left(\left(a^T a\right) \otimes \left(b^T b\right)\right)\right) = \\
&\left(str_v \langle q_v|a\rangle^2 + (1 - str_v)\frac{1}{n}\sum_i \left\langle c^i|a\right\rangle^2\right) \cdot \\
&\left(str_t \langle q_t|b\rangle^2 + (1 - str_t)\frac{1}{n}\sum_i \left\langle d^i|b\right\rangle^2\right)
\end{aligned} \tag{3}
$$

where

$$
str_v = \frac{\left\langle D_q^v \middle| D_f^v \right\rangle}{\left\|D_q^v\right\| \left\|D_f^v\right\|} = \frac{\sum_i \left\langle q_v|c^i\right\rangle^2}{\langle q_v|q_v\rangle \sqrt{n \sum_i \langle c^i|c^i\rangle^2}} \tag{4}
$$

and

$$
str_t = \frac{\left\langle D_q^t \middle| D_f^t \right\rangle}{\left\|D_q^t\right\| \left\|D_f^t\right\|} = \frac{\sum_i \left\langle q_t|d^i\right\rangle^2}{\langle q_t|q_t\rangle \sqrt{n \sum_i \langle d^i|d^i\rangle^2}} \tag{5}
$$

Let us assume that the relevance feedback is provided after the first round retrieval to refine the query. The adaptive weighting can be interpreted in a following way:

1. small $\langle D_q|D_f\rangle$; weak relationship between query and its context, context becomes important. We adjust the probability of the original query terms; the adjustment will significantly modify the original query.
2. big $\langle D_q|D_f\rangle$; strong relationship (similarity) between query and its context, context will not help much. The original query terms will tend to dominate the whole term distribution in the modified model. The adjustment will not significantly modify the original query.

The adaptive model can be naturally expanded to accommodate other features, e.g. various visual features

$$tr\left((\otimes_n M_n)\cdot\left(\otimes_n\left(a_n^T\cdot a_n\right)\right)\right)= \prod_n \left\langle M_n|a_n^T\cdot a_n\right\rangle \tag{6}$$

Thus, for 3 features (e.g. two visual and a textual feature) the adaptive model becomes

$$\begin{aligned} tr\left((M_1\otimes M_2\otimes M_3)\left(\left(a_1^T a_1\right)\otimes\left(a_2^T a_2\right)\otimes\left(b^T b\right)\right)\right)=\\ \left(str_{v1}\langle q_{v1}|a_1\rangle^2+(1-str_{v1})\frac{1}{n}\sum_i\left\langle c_1^i|a_1\right\rangle^2\right)\cdot\\ \left(str_{v2}\langle q_{v2}|a_2\rangle^2+(1-str_{v2})\frac{1}{n}\sum_i\left\langle c_2^i|a_2\right\rangle^2\right)\cdot\\ \left(str_t\langle q_t|b\rangle^2+(1-str_t)\frac{1}{n}\sum_i\left\langle d^i|b\right\rangle^2\right) \end{aligned} \tag{7}$$

Here, for example, M_1, a_1 and M_2, a_2 may correspond to different visual features (density matrices and vector representations of images from the database), and M_3, b corresponds to the textual feature.

4 Conclusions and Future Work

In this paper we have presented the integrated ocean monitoring system for surface and underwater ocean surveillance. The main objective of the proposed framework was to enhance user interaction with remote sensing and control applications. The system offers the user an immersive monitoring experience by combining the augmented reality and the VR real-time real-life 360° view.

The augmented reality incorporates the hybrid image search model to retrieve similar images from the database of previously encountered marine environments to provide the user with supporting information.

The discussed unified tensor-based hybrid retrieval system comprises combinations of various visual features, combination of visual and textual feature spaces, combination of visual and textual feature spaces in the context of search refinement, and the user interface. The implemented models address the key challenges in data fusion, specifically correlation and adaptivity.

To our knowledge, the proposed framework is the very first to combine real-time VR, 360° camera, and hybrid models in the context of image retrieval and augmented reality.

Although our current efforts are focused on the marine robot, another interesting application will be the adaptation of the presented framework to the Mars rover use case which is also a part of the large R&D project. In that scenario, the 360° spherical cameras can be used to take pictures of Martian environment which can be later viewed in the VR headset with the help of additional search functionality.

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Envisaging the Internet of People an Approach to the Vulnerable Road Users Problem

Bruno Fernandes(✉), José Neves, and Analide César

Centro Algoritmi, University of Minho, Braga, Portugal
bruno.fmf.8@gmail.com, {jneves,analide}@di.uminho.pt

Abstract. Internet of Things has been presenting new solutions for the benefit of the human being. However the focus goes towards the thing, leaving aside people as an active and participative element. Literature shows that a new paradigm, entitled as Internet of People, is now emerging. Our envisage of such paradigm consists in a dynamic global network where things and people understand each other, being crucial for problems where the human being is a central part, such as in the Vulnerable Road Users (VRUs) problem. One's intention is to clarify its meaning and postulate essential properties that will help enabling the Internet of People. Based on such assumptions, we propose a high-level architecture which is then applied in the conception of a Multi-agent System on the specific context of the VRUs problem.

Keywords: Internet of people · Internet of things · Vulnerable road users · Multi-agent system · Ambient intelligence

1 Introduction

Internet of Things (IoT) is a paradigm that can be postulated as a global network of physical objects and devices that are capable of self-organization, share data and information, act and react to changes in the environment [1]. However, as the name implies, IoT focuses on the thing. Now is the time to complete the puzzle with one missing piece: the people. In essence, merging people with IoT would allow the creation of the Internet of People (IoP). IoP consists of a dynamic global network where things and people communicate and understand each other; where everyone and everything can sense the other and the world, and act on such knowledge and information, aiming to enhance people's quality of life. In order to bring people to this global network, and to make them an active, reactive and proactive element, one is required to promote the citizen sensor [2], consisting in providing people with sensing capacities. Therefore, the IoP may be of the utmost importance to help those who, because of specific characteristics, are more vulnerable on the road. These are commonly known as Vulnerable Road Users (VRUs) and their vulnerability may arise from lack of external protection, age, physical impairments, visual or hearing disabilities, and so on. The VRU problem is still a major problem and definitive solutions to this problem are still to emerge. However, with IoP new solutions can emerge where things and people are able to recognize one another's presence and thereby cooperate to prevent accidents, injuries and, eventually, save lives.

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This article intends to clarify this new paradigm, focusing on the elaboration of a set of essential properties to guarantee the IoP. In addition, with these properties in mind, we have designed a high-level architecture for the IoP in the specific context of the VRU problem. This architecture was then applied in the design of a Multi-agent System (MAS). Therefore, the rest of this article is organized as follows: the next section will focus our view of an IoP; the following one will center on a high-level IoP architecture and a MAS on the context of the VRU problem; finally, we assemble one's conclusions and point out important directions for future research.

2 The Internet of People

Being IoP an emerging paradigm, there is a clear lack of hypothesizing meanings and properties, i.e., one's intention is to provide some help in order to get in-depth information on its meaning and properties, and strengthen its foundations.

2.1 Definitions of the Internet of People

When searching the literature for possible definitions for the IoP one will find this term being used with different meanings and purposes. Hence, one interesting study focusing the IoP is that of [3] which proposes a theory of the Humanized Internet of Things (H-IoT). According to this understanding, IoP is just a node of H-IoT and its definition for IoP consists of "*interconnect growing population of users while promoting their continuous empowerment, preserving their control over their online activities"*. Such work focused on studying the extent of Fiske's psychological work, which identified four common forms of sociality used by people in their relationships, to their idea of an H-IoT. Without a doubt, our view of an IoP recognizes the existence of an ecosystem of people and things, and, therefore, studies like that of [3] are useful in helping to define hierarchies, sources of reliable information and rules among this emerging ecosystems.

Another interesting study is [2] where it is described an infrastructure that uses smartphones as a key to improve the integration of people with IoT. Here, the smartphone should be seen as a people's extension. In 2011, [4] proposed three pillars to define the future Internet, namely IoT, Internet of Services and IoP. They took the opportunity to come up with an interesting definition for the IoP, very close to what we are describing in this work, i.e., "*envisaged as people becoming part of ubiquitous intelligent networks having the potential to seamlessly connect, interact and exchange information about themselves and their social context and environment*".

2.2 Envisaging the Internet of People

One's vision of an IoP may be postulated as a dynamic global network of things and people who are able to communicate and understand each other, act autonomously and react to changes in the environment. Basically, one is now in the presence of an ecosystem composed of things and people. With the objective of strengthening its foundations, the following lines describe a set of three properties that, when complemented with IoT, should be seen as essential in the development of a truly IoP:

- *Interoperability*: within the context of the IoP, ensuring that things and people are able to understand each other is crucial. Not just communicate but understand what is being communicated. A possible definition of interoperability corresponds to the ability of heterogeneous systems to exchange information transparently, in order to obtain mutual benefits [5]. It presupposes the use of open and well-defined standards and protocols, rather than having each manufacturer using proprietary technologies, which considerably increases the difficulty of articulating the IoP;
- *Citizen Sensor*: the exponential use of smartphones and wearable devices will empower the IoP. Devices that have exceptional detection capabilities. It would be important to harness this potential to empower the citizen sensor [6], allowing people to interact with things and other people, always taking into account emotional, physical and persona features. Thus, one would finally be in a position to make people an active and proactive element, and then begin to propose contemporary solutions to the problems in which the human being has the actor's role; and
- *Ambient Intelligence* (AmI): it consists of an environment, incorporated with sensors and actuators, being sensitive and responsive to the presence and needs of a human being in a non-intrusive way [7]. As devices become smaller, integrated and autonomous, they tend to go unnoticed, which is crucial for the success of AmI. As an example, AmI systems in carriage should consider the car, its surroundings, the conditions of the driver and how to deal handle such information [8]. Thus, combining IoT and AmI with the citizen sensor will lead one to the IoP.

The properties referred to above must be seen as crucial for the actual existence of an IoP. However, there are other properties and challenges that must be studied to have a secure, powerful, open and evolved IoP, as described below:

- *Intelligence, Analytics and Dashboards*: IoP systems are expected to be able to gather important information and produce crucial knowledge from the data collected. Relevant information should be shared with people in order to create comfort, well-being and reduce stress. The implementation of analytics and dashboards should be seen as essential for the creation of user's awareness and sensitivity;
- *Cloud Platforms*: IoP nodes must be able to communicate with a centralized platform in case they require on-demand access to specific services, storage, reporting, among others. Although it is known that cloud services may be somewhat fragile, it is also known that they offer many benefits for distributed applications [9];
- *Unique Identification*: IoP ubiquity raises a great deal of concern related to the unique identification and virtual representation of physical devices [10]. It was underlined that IPv4 addresses are not adequate and so new solutions are emerging, focusing on the use of RFID or an Object Name Service. Within the IoP, identification of each node is crucial for a reliable communication;
- *Device Authentication, Privacy and Security*: privacy and security of things and people is a major issue, ranging from the collection of information to its exposure. Sensors, actuators, and other devices typically tend to delegate their authentication

to reduce their exposure [11]. Securing the IoT is being extensively studied, focusing on techniques such as cryptography and proactive identification [10];

- *Transparency, Monitoring and Auditing*: communication among things and people should follow open and robust standards and protocols for transparency purposes. Users should be able to define their privacy policies and to monitor how their data is being used [11]. The audit should be a constant. In addition, new proposals are emerging such as classification systems on the safety of wearable devices [12]; and
- *Scalability, High-Availability and Efficiency*: IoP systems should be scalable and as flawless as possible. Possibilities such as the use of asynchronous communication or the Multi-agent Systems paradigm would be interesting solutions to support scalability, availability and fault tolerance [13]. Moreover, an IoP solution must be efficient in terms of cost, processing and energy.

3 Architecting an Internet of People for Vulnerable Road Users

Examples of IoT architectures have already been proposed [4, 9] or [14]. However, there is a clear shortage of proposals that include the citizen as an active, proactive and reactive element. In contrast, our approach to an IoP architecture focuses on merging citizens as sensors with IoT in the specific context of VRUs. Such users have been defined as "*non-motorized road users, such as pedestrians and cyclists as well as motorcyclists*" [15]. Improving their safety would allow people to be safer on the road with the main benefit of lessening injuries and saving lives. The VRU is part of the problem and should be considered as part of the solution. Thus, our approach takes people into account as a crucial element and, when combined with things such as vehicles or road-side infrastructures give rise to the IoP. With the VRU problem in mind, we conceptualized an architecture for the IoP that is compatible with the properties defined before. Such architecture, as depicted in Fig. 1, has three layers. The lowest one consists of a *Backend*, which should ideally be built on a cloud platform for scalability and availability factors. It should also contain a set of modules, namely:

- an *Intelligence module* responsible for providing the platform with reasoning capabilities and with the additional responsibility of implementing trust mechanisms, reputation algorithms, and others;
- an *Analytics and Dashboard module* focused on the analysis and production of accessible information for people and entities, allowing, for example, the measurement of sustainable factors and the creation of user awareness;
- an *Authentication and Control module* responsible for protecting the platform, controlling the registry of things and people, its authentication, executing housekeeping, self-auditing and by controlling and guaranteeing privacy settings;
- a *Communication module*, the only entry point to the backend, which is not only responsible to communicate and disseminate information among things and people but also to ensure the use of the correct ontologies, protocols and standards.

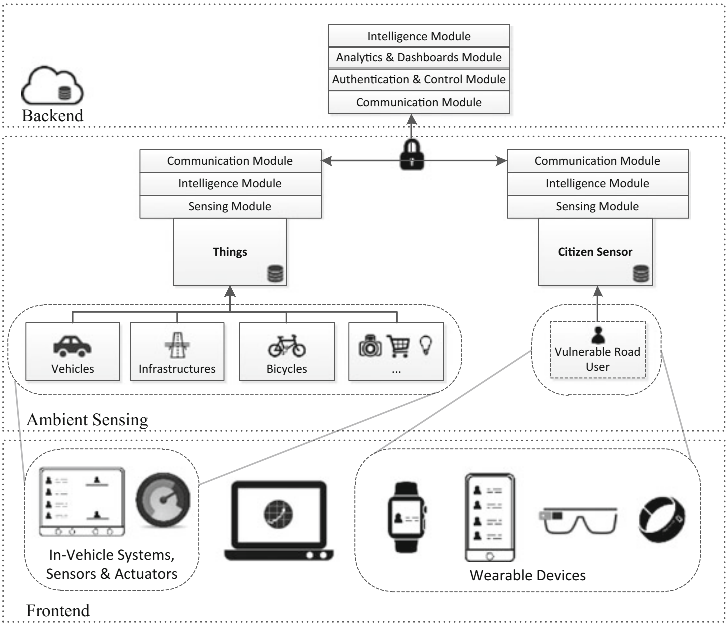

Fig. 1. High-level IoP architecture in the specific context of the VRU problem

In the middle layer, entitled *Ambient Sensing*, is where one can find the IoP nodes, i.e., Things and People, the latter in the form of citizen sensors. Additionally, it is in this middle layer that the environment is felt and where one can act and react to any critical information that it can gather or be informed. Things and people are ideally equipped with three distinct modules, specifically:

- a *Sensing module*, which is responsible for the use of sensors and techniques to sense and understand the environment and the others;
- an *Intelligence module*, which intends to work on the data gathered by the first module and categorize the information, employing models for the prediction of VRU erratic behaviour and dangerous situations. It should also make use of Affective Computing techniques to consider VRU's mood and emotional state;
- a *Communication module* responsible for sharing relevant data with others and for communicating with the backend. It is crucial for things and people to communicate directly among them as it allows a VRU to understand the presence of vehicles (and vice versa) and be informed of possible problematic situations in real time.

Finally, the last layer consists of a *Frontend*, where information is visible to people and to the community, in the form of dashboards or in the form of relevant information alerts and real-time decision making. Vehicles include In-Vehicle systems that are able to display this information. On the other hand, the VRU holds wearable devices such as Smartwatches or Smartbands, which function as a sensor in the middle layer and as a display unit in the Frontend. Therefore, such devices should be seen as crucial enablers of the citizen sensor, allowing VRU to join things in the IoP.

The possibility of designing a MAS for the architecture shown in Fig. 1 is real when considering the characteristics of the one and of a MAS, which consists of a set of Intelligent Agents, being especially suitable for the development of complex and dynamic systems. Agents communicate with each other and with the environment with a focus on understanding the latter and reason upon intelligent models, coordinating their efforts to achieve their goals and the one of the ecosystem where they live. As shown in Fig. 2, it is proposed an open MAS for the IoP, based on the architecture conceived in Fig. 1 and the VRU problem:

- the *Backend* should be composed of four different types of agents, each one with its specific mission. Agents in the Backend may multiply, with the main objective of reducing the workload of each agent and guaranteeing efficiency and availability. Within this layer agents should focus on reasoning and modeling;
- the *Ambient Sensing* layer is, in turn, populated with *Things Agents* and with *People Agents* (labeled *VRU Agents*). It is important to note that more agents can be easily developed and added to the MAS. These agents are required to authenticate and to be compliant with the ontologies and rules being followed. They share similar foundations and should focus on sensing the environment, reason, understanding the presence of others and cooperating with each other, thus enabling the IoP;
- Wearable devices used by people in their daily routine will be, at the same time, hosting the VRU agents and will work as a *Frontend*. These agents should make use

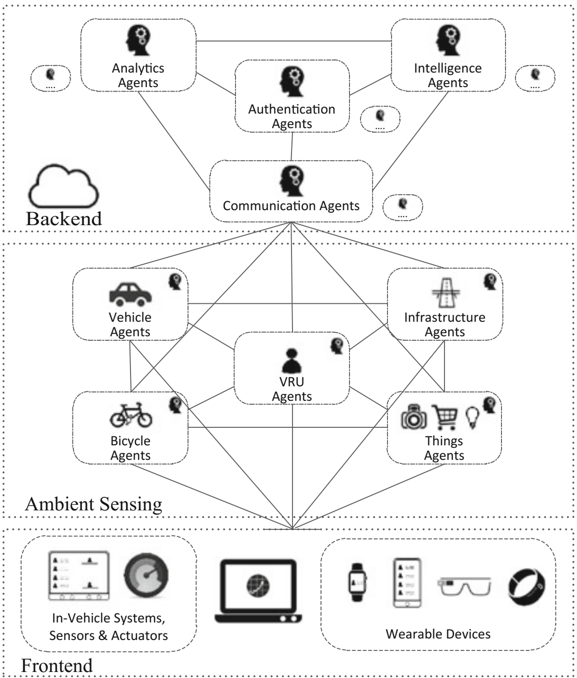

Fig. 2. Designing a MAS on the proposed IoP architecture on the VRU issue

of suitable mechanisms to adapt to people's mood and personality. The development of such agents should focus on emerging technologies to facilitate the integration with people, such as *JADE for Android* [16] or *JavaScript for Agents* [17].

4 Conclusions

As the Internet of People is an emerging paradigm, it still lacks some detail in terms of meaning and properties. Our vision of such paradigm consists of a global dynamic network, an ecosystem, of things and people, able to communicate, organize, understand each other, and act and react automatically to changes in the environment. It is the novelty of including the Citizen Sensor as an active and proactive element that enables IoP. In this context, Wearable devices should be seen as crucial citizen sensor facilitators. IoP allows the proposal of new and contemporary solutions for problems where the human being is a crucial part, as in the VRU problem, an important problem of our society. Therefore, we are committed to design a high-level architecture for the IoP on the context of the VRU problem. Such architecture, together with the properties one envisaged as essential, allowed the design of a MAS focused on the IoP enablement for VRU. Each VRU and each thing (e.g., vehicles, bikes, etc.) has its own agent focused on sensing the environment, reason, understanding the presence of others and cooperate to achieve mutual benefits. The main goal is to prevent injuries, prevent accidents and save lives.

New guidelines for future research should be highlighted, focusing on the study of the implementation of this architecture in the form of the designed MAS. Further studies are needed to clearly define the nature of each agent as well as the definition of ontologies for interoperability purposes, without neglecting important trade-offs such as latency, precision, accuracy and cost. Particularities of the VRU problem should also be addressed, namely the unpredictable behaviour of some of its units or the dissemination of contemporary technologies among the elderly population.

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Intelligent Smartphone Audiometry

Alexander Kocian[1(✉)], Carmelo Ienco[1], Stefano Chessa[1], and Wilko Grolman[2]

[1] Department of Computer Science, University of Pisa, 56123 Pisa, Italy
{kocian@di.unipi.it}
[2] Department of Otorhinolaryngology, Brain Center Rudolf Magnus, University Medical Center Utrecht (UMCU), 3508 Ab Utrecht, The Netherlands

Abstract. The continuously aging population in the majority of industrialized nations challenges the healthcare providers to maintain quality of healthcare services at status quo. To make health care sustainable, the paradigm Ambient Intelligence can be used to exploit information and telecommunication technology for the development of autonomous healthcare services. Following this approach, we design and implement a virtual audiologist dubbed ViA, performing air-conduction and bone-conduction hearing tests based on a standard in contrast to existing solutions. The software platform is Android. In this paper, we present the system architecture of ViA with focus on the Android platform and discuss calibration issues. First test results in office environment indicate that a large range of hearing thresholds can be reproduced on different smartphones within a band of 9 dB. ViA has the potential to identify individuals with correctable hearing loss without putting extra load on the healthcare providers.

1 Introduction

Ambient intelligence (AmI) is an emerging discipline that brings intelligence in physical world environments. Sensors and processors are on the way to be integrated in everyday objects, predicting users' behavior, satisfying their needs and interacting with them without attracting attention. AmI systems must be context aware, personalized, anticipatory, adaptive, pervasive, and transparent [2]. So far, AmI has been applied successfully to several physical world environments such as smart homes, ambient assisted living, healthcare and well-being, intelligent transport systems, and so on.

Focusing on healthcare and well-being services, the majority of industrialized nations are facing severe difficulties, to maintain quality at reasonable costs. As the population is continuously aging, it is expected that even more patients will face multitude of chronic diseases, translating into higher demand for various healthcare and well-being services. To use the limited economical resources more

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efficiently, information and telecommunication technology can be used, to implement pro-active health-care services in an autonomous fashion. In recent years, a number of smartphone applications have become available for physiological status monitoring [2].

During the last years, smartphone based applications were developed for personal use as a screening tool for hearing loss. In 1976, Meyer presented in [6] a first algorithm for automated pure-tone audiometry. This work remained unnoticed over decades. Only recently, the company Unitron, NY, USA developed an automated pure-tone testing application, dubbed uHear® for iOS Apple operated devices. The application requires Apple-accredited insert earphones. A comparison with conventional audiometry reveals that the application and the audiometric values agree in 24 out of 26 cases [1]. Similarly, Praxis BioSciences, CA, USA built the application EarTrumpet®. In contrast to the previous, this application allows selection of a headphone transducer. An initial assessment in [4] shows that the hearing thresholds of 96% out of 42 patients obtained using the automated test were within 10 dB of the corresponding threshold values using conventional audiometry. On the Android side, there is hearscreen™by the University of Pretoria in South Africa. This app offers accurate AC audiometry according to an ISO calibration standard [9]. Another app, dubbed HearingTest® by http://www.e-audiologia.pl, provides audiograms with accuracy of 8.8 dB for 200 ears [8]. All three applications apply air-conduction (AC) audiometry where pure-tone sound pressure is applied to the ipsilateral ear. EarTrumpet and HearingTest mask the contralateral ear with narrowband noise if applicable. None of the above applications apply Bone-conduction (BC) audiometry where a pure-tone vibrating force is placed on the ipsilateral mastoid. All results are stored locally on the smartphone, only. No public documentation of the underlying diagnosis techniques is available.

As the audiometric test results have significant influence on the educational, occupational and social life of the patient, it is critical that the diagnostic techniques and procedures are standardized. There are three standardized diagnostic techniques that are used by the majority of the audiologists: (i) by ASHA (American Speech-Language-Hearing Association), (ii) by BSA (British Society of Audiology) and (iii) by IHS (International Hearing Society) [3]. This paper presents the system architecture of an Android application that allows the user to perform a low-cost automatic audiometric hearing test based on the BSA hearing standard. In contrast to existing solutions, the software application performs AC *and* BC hearing tests with commercial off-the-shelf (COT) components following a *standard*. The paper is the result of a larger project funded by the University Medical Center Utrecht (UMCU), Utrecht, The Netherlands [5].

The paper is organized as follows. Section 2 reviews the BSA diagnostic technique. Section 3 uses the BSA algorithm to design and implement the system architecture of the virtual audiologist ViA. Calibration issues are tackled in Sect. 4 followed by Discussion and Conclusions in Sect. 5.

2 The BSA Audiometry Technique

In this section we outline the BSA hearing test algorithm to be implemented in the smartphone.

We start with AC audiometry at the better ear. Having instructed the patient about the test procedure, ViA asks the patient to place and connect the insert earphones. The applied level is 0 dB HL at 1000 Hz. If there is no response, the level of the tone in increased in 10 dB steps until a response occurs. Then, the level of the tone is reduced by 10 dB and increased in 5 dB steps until a response occurs again. When the patient confirms the threshold level twice, the next test frequency is chosen. Otherwise, the procedure is repeated. The test frequencies are 1000, 2000, 4000, 8000, 500 and 250 Hz, and then, for the first ear only, 1000 Hz another time. The duration of the test tone and the interval between two test tones vary between 1 and 3 s at random. After the AC hearing thresholds on the better ear have been determined, the worse ear is tested in the same way.

Unmasked BC audiometry is required when the AC hearing thresholds are outside the limits of the normal hearing ear. In case they are, the patient is now requested to place the bone conducting headphones as near as possible behind the visible part of the ears (a.k.a. *pinna*) without touching them. ViA determines the worse ear by averaging the AC thresholds between 500 and 4000 Hz. The preferred test order is similar to that used in AC audiometry starting at 1000, 2000, 4000 Hz, but then only 500 Hz. No retest is done at 1000 Hz this time. Duration and interval of the test stimuli are identical to that in AC audiometry. When the BC thresholds on the worse ear are determined, the better ear is tested analogously.

Cross-hearing may occur when the hearing threshold of the two ears is very different. In this case, a test tone applied to the worse may be detected by the better ear due to the interaural attenuation. For insert earphones, the minimum interaural attenuation is $\alpha = 55$ dB provided the earphones are inserted correctly [7]. With BC the interaural attenuation is near 0 dB. When cross-hearing occurs, the following rules for masking apply [3]:

- **Rule 1**: AC masking is needed at any frequency if the difference between the left and right not-masked AC threshold is more than α.
- **Rule 2**: BC masking is needed at any frequency where the unmasked BC threshold is more acute than the AC threshold of either ear by 10 dB or more.
- **Rule 3**: AC masking will be needed additionally where Rule 1 has not been applied, but where the BC threshold of one ear is more acute by α or more than the not-masked AC threshold attributed to the other ear.

The masking procedure is as follows. Starting from the interaural attenuation plus the BC threshold in the non-test ear, the masking level is increased in 10 dB steps. At each masking level, ViA measures the (masked) hearing threshold in the test ear. As soon as a further increase in masking intensity does not cause a further increase in stimulus intensity, the masking plateau is reached. The

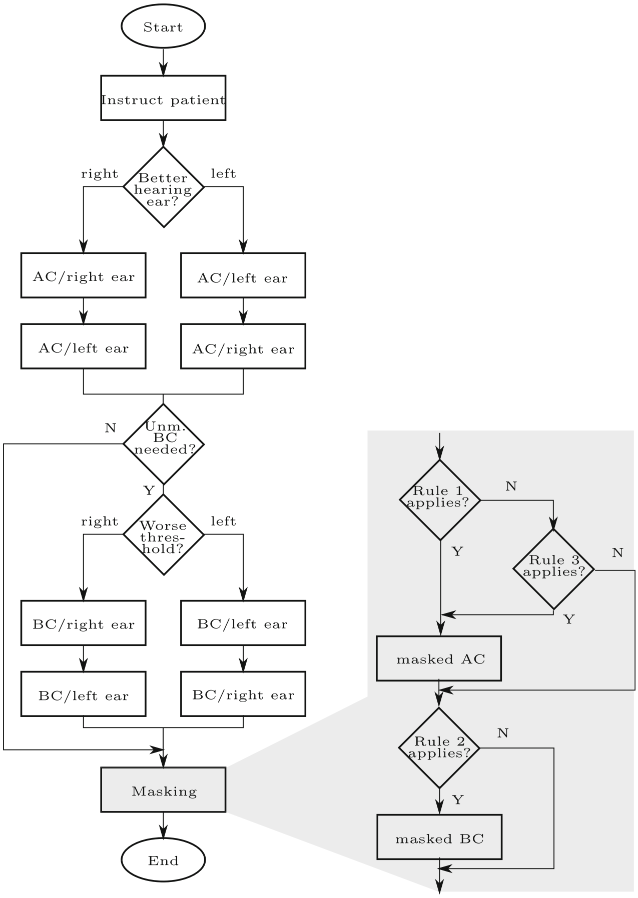

Fig. 1. Pure-tone audiometry according to the British Society of Audiology

corresponding stimulus intensity is the true hearing threshold in the test ear. A flowchart of the diagnostic technique is given in Fig. 1.

3 System Architecture

The high-level system architecture, presented in Fig. 2, highlights the work flow in the software of ViA. The system architecture is composed of five units: the Graphical User Interface (GUI), the Application Manager (AppMgr), the Database Manager, the Tone Generator, and a SQL database. To create modular code components that can be reused by different Android activities with their own life cycle, Android introduces the concept of Fragments.

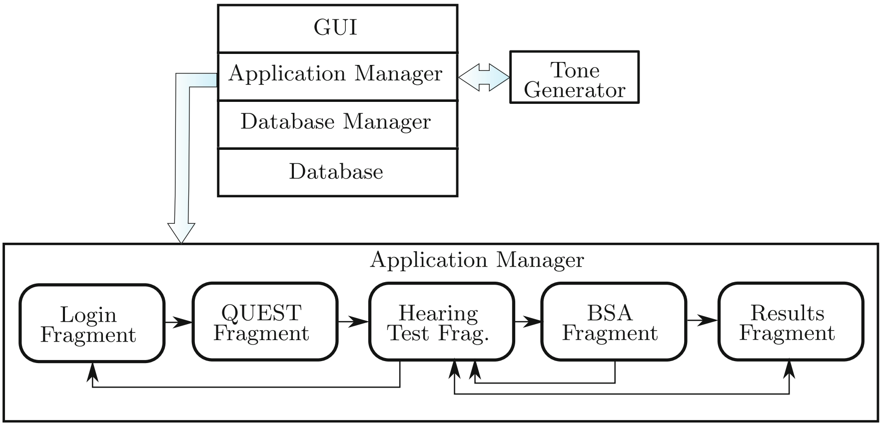

Fig. 2. Architecture of the virtual audiologist with focus on the application manager

The core of our application is the **BSA Fragment**. According to the flowchart in Fig. 1, the BSA Fragment starts with instructing the patient and then handles user feedback from the GUI. Note that Android does not support audio through jack and Bluetooth® at the same time. Consequently, bone-conducting masking is only feasible if headphones *and* bone-conducting headphones are connected to the same audio interface. When the user touches the `Tone Heard` button in the GUI, an event is triggered and forwarded to the BSA. This feedback information is then used to adjust the audio parameters frequency, volume, type (pure-tone or masking noise) and channel (left/right) which are forwarded to the Tone Generator. Note that the BSA Fragment only accepts `Tone Heard` feedback information from the GUI through the flag `Window open` that is set when the Tone Generator is active. When the hearing test is completed, the underlying AppMgr switches to the next fragment which is the Results Fragment. Alternatively when the user does not respond to one audiometric frequency point, the AppMgr proceeds with the next one until the hearing test is completed. When the median environmental noise level exceeds the current HL, the test point is repeated. Finally when the user interrupts the hearing test, the AppMgr returns to the Hearing Test Fragment.

The **Tone Generator**, running as individual thread, plays PCM audio managed by the Android public class AudioTrack. Having defined sample rate and audio bit depth, the audio buffers are filled with audio data and flushed to the audio hardware. The buffers are specified by the sample rate R and the modulation M. With the audio parameters sent by the BSA fragment, either pure-tones or masking noise is synthesized. The former is implemented as sinusoidal signal with particular frequency, duration, and quantization level $Q^2/2$ with $Q \triangleq Q(f, \mathrm{HL})$ which is a function of frequency *and* hearing level (HL). The HL refers to the hearing threshold of normal hearing young individuals. The latter is implemented as white noise, filtered through a FIR filter with 256-taps. The resulting noise is Gaussian with 1/3-octave bandwidth. The integral of the power density spectrum of band-limited Gaussian noise is Q. The tone is played between T_1 and T_2 seconds at random. That pause between two tones varies between T_1 and T_2 seconds, as well. When the tone is played, the flag `Window open` is set equal TRUE and forwarded to the BSA Fragment in the AppMgr. In particular, above parameters are set equal $R = 22050$ samples/s, $T_1 = 1\,\text{s}$, $T_2 = 3\,\text{s}$, and $M =$ 16-bit PCM stereo, implying that Q ranges from 0 to $2^{15} - 1 = 32767$ levels. Finally, we want to point out that the sound volume depends on the particular smartphone hardware.

The **GUI** corresponds to the XML part of the AppMgr. The GUI is composed of the Login screen (username, password), the Questionnaire screen (questions related to daily noise exposure), the Hearing test screen (start new test, load previous tests, logout), the BSA screen (tone heard? stop test) and the Results screen (audiograms). The GUI communicates the user's choice to the AppMgr and reads the status of the flag `Window open` from the Tone Generator thread.

The **Application Manager** (AppMgr) is composed of five Android Fragments that interact directly with the GUI and are connected to the Database Manager. They all implement several listeners that are passively notified of some event such as `Button pressed`. The first fragment in the sequel is the Login fragment; it verifies the user credentials and denies or grants access to the user. In the latter case, the Login fragment asks the AppMgr to switch to the Questionnaire fragment. The Questionnaire fragment reads the user profile from the GUI and stores the result in the database. The Questionnaire fragment asks then the AppMgr to switch to the Hearing Test fragment. Here, the AppMgr moves ahead to the BSA fragment or the Results fragment when the Start button is pressed or the results of an already finished test are displayed, respectively. Alternatively, the Logout button requests the AppMgr, to return to the Login Fragment. Once the hearing test is finished, the BSA fragments asks the AppMgr to proceed with the Results fragment, showing the resulting audiograms.

The **Database Manager** is the only entity that provides direct access to the database. It exposes all the functions that are needed to put, retrieve and modify data. The database manager interacts with the standard SQLite database, a very light weight database, which comes with Android OS.

The **Database** comprises three tables: (i) `AudioProfile` containing calibration data and the FIR filters for generating masking noise; (ii) `Users` containing the user's credentials and response to the questionnaire; (iii) `TestResults` containing the recorded audiograms. Currently, the database is stored locally. The next version of ViA will store the database on a cloud computing platform so that the corresponding audiologist has access to it 24/7. Only authorized audiologists and the user will have access to the data.

4 Calibration

To make sure that the measured audiograms are reproducible, our ViA needs to be calibrated at the earpiece. The calibration set-up comprises a smartphone, earphones, and a calibrated artificial head. To calibrate AC and BC testing, Sennheiser™ HDA 200 supra-aural headphones and Radioear™ B-71 bone-vibrator are connected to the jack of the smartphone, resp. The earphones are placed on top of an self-made artificial head with Brüel and Kjær™ 4955 microphones in place of the ears. The artificial head got calibrated in a certified sound-proof room at the University Hospital in Utrecht (UMCU) [5]. Calibration has to be performed in stwo steps: first, at the output of the smartphone and then, at the earphones.

In the **smartphone** the application software generates a pure-tone with quantization level Q at frequency f and sends the result to subsequent audio amplifier with gain G. In Android, G can take values between 0 and 15. The linearity of the audio amplifier depends on its class. Consequently, calibration has to be performed in two dimensions, namely w.r.t. frequency *and* HL. In particular, $f \in [250, 500, 1000, 2000, 4000, 8000]$ Hz and HL $\in [10, 15, \ldots, 90]$ dB. As an example we considered the smartphone Archos 40 Neon.
The **earphones** are specified by their sensitivity $S_{[\text{dB}]}$ [dB/mW] and their electrical impedance Z [Ω]. To analyze the impact of the earphones on the HL, let us model them as electrical load for the software platform. Consequently, the sound pressure level SPL at the earpiece is the product of sensitivity S times electric power in Z. In the log-domain, it follows

$$\text{SPL}_{[\text{dB}]} = S_{[\text{dB}]} + 10 \log_{10} \frac{2V_{\text{FS}}^2 Q^2}{Z}, \tag{1}$$

where V_{FS} denotes the full-scale audio voltage at the output of the jack. By weighting the sound pressure level in (1) with the ISO 389-7 sensitivity curve of the average human ear θ [dB] for diffuse-field, we obtain the desired HL. Solving (1) with respect to Q, it follows for the quantization level that is necessary to achieved the target HL

$$\log_{10} Q = 0.05(\text{HL} - C(S, Z) + \theta) \tag{2}$$

where the short-cut $C(S, Z) \triangleq S_{[\text{dB}]} + 10 \log_{10}(2V_{\text{FS}}^2) - 10 \log_{10} Z$ is constant for a particular set of earphones. Inspecting (2), it can be seen that an earphone with hardware constant $C'(S', Z')$ causes a linear shift in $\log Q$. Hence, ViA can be factory calibrated with respect to any reference point. When the user connects a particular earphone set, a normal hearing young individual has to determine the reference point e.g., 0 dB HL at 1 kHz, for this particular set, to determine the offset $C(S, Z)$.

5 Discussion and Conclusions

In a first experiment we retested the calibrated smartphone Archos 40 Neon in office environment, using the same headphones and artificial head. The noise floor was at 20 dB HL for 250 Hz and 10 dB HL, otherwise. The absolute value of AC HL error is plotted in the left part of Fig. 3. It can be seen that the error is bounded within a band of 2 dB. This error is mainly caused by the residual

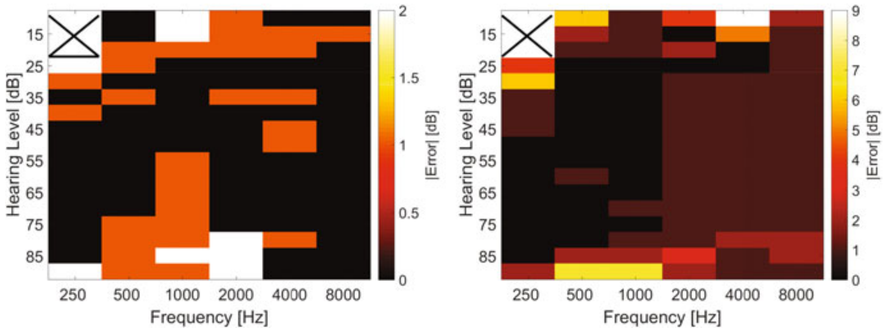

Fig. 3. Absolute error of hearing level for two smartphone models (*left* Archos 40 Neon; *right* Motorola XT 1068)

noise floor in the office. As an representative example for many smartphones, Fig. 3 shows the absolute value of AC HL error for the Motorola XT1068. It can be seen that the error bounded within 9 dB HL with an offset of 6 dB due to the different hardware architecture. Errors less than 10 dB are tolerable.

In cooperation with the University Medical Center Utrecht (UMCU), The Netherlands, we designed the virtual audiologist ViA. ViA is an Android based smartphone application, performing automated AC and BC hearing tests using the standard defined by the British Society for Audiology. Target users are patients with early stage hearing loss who hesitate to consult an audiologist, and users living in medical underserved areas.

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Smart Computer-Assisted Cognitive Rehabilitation for Visually Impaired People

Miguel Oliver[1(✉)], Mario García[1], José Pascual Molina[1,2], Jonatan Martínez[1], Antonio Fernández-Caballero[1,2], and Pascual González[1,2]

[1] Universidad de Castilla-La Mancha, Instituto de Investigación en Informática de Albacete, 02071 Albacete, Spain
{Miguel.Oliver, Mancha.oliver}@dsi.uclm.es

[2] Universidad de Castilla-La Mancha, Departamento de Sistemas Informáticos, 02071 Albacete, Spain

Abstract. The emergence of new devices that allow tracking body movements, such as Microsoft Kinect, has motivated the creation of different rehabilitation systems that allow people with disabilities to improve and recover some lost physical or cognitive capabilities. In general, the use of Kinect sensors to control the patient's movements is the most common solution. In this case, the use of visual capabilities is needed because the patient must recognise the meaning and the objective's location using the visual channel. Thus, current proposals based on Kinect are not useful for visually impaired people and must be adapted through replacing or enhancing the visual information with other stimuli that can be perceived by people with this disability. In this paper, we introduce an adaptation of a previous proposal including some vibrotactile stimuli that allow visually impaired people to determine the type (meaning) and the location of a specific object, allowing them to carry out a series of rehabilitation exercises.

1 Introduction

Life expectancy has strikingly increased and produced the need of offering new technological solutions that allow people to live a better old age. Ageing reduces the perception capabilities and also entails some cognitive and physical problems. Nevertheless, the lost or impairment of some sense, such as the sense of sight, is not only due to ageing. There are other reasons that provoke this impairment. Moreover, as noticed in a recent paper [1], physical activity, cognitive training and social engagement improve the quality of life and reduce cognitive decline in older adults. Thus, in order to provide solutions that improve the quality of life of these impaired people, assistive technologies bring technological proposals that allow them to improve or reduce the effect of their disabilities. These technologies offer new ways to rehabilitate their lost capabilities or to carry out some physical or cognitive exercises in a funny and engaging way, just as when playing video games.

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In general, the rehabilitation process could involve the movement of bones and joints (physical) or brain processing (cognitive). Nevertheless, despite the fact that cognitive rehabilitation includes some movements necessary to carry out the task, these movements are not meant to improve other physical disabilities. Thus, merging these two types of rehabilitation in one tool is a promising field. In any case, although these technological proposals show high potential in the rehabilitation process [13], they must take into account other troubles, such as the loss of abilities in the perception of external stimuli.

This paper presents an improvement of a previous system [9] designed to aid in the cognitive and physical rehabilitation of elderly people, combining in one therapy the two disabilities. The main advantage of the new proposal is the incorporation of multisensory stimulation. In this case, the inclusion, not only visual information but also aural and haptic, enhances the perception of the object included in a specific therapy. With this new information, the therapist can adapt the sensory cues that the user could use to successfully complete the therapy. Thus, after reviewing the assistive technologies used in cognitive and physical rehabilitation, as well as some others that use vibrotactile information to guide the user, we present this new proposal. First, the supported cognitive therapies are described. After that, we describe our multisensory proposal explaining how the specialist configures the therapy, including several senses cues, and how the user carries out the therapy by using these new stimuli. Finally, some conclusion and future works are presented.

2 Use of New Technologies in Rehabilitation

The use of technology applied to human activities is increasingly frequent. It offers support and facilitates the completion of daily tasks. Rehabilitation is not an exception. In fact, the use of technology in rehabilitation offers not only the possibility to control its execution, but it also allows carrying out these activities without the physical presence of the therapist. Moreover, the patients can accomplish their rehabilitation activities at home. In the context of cognitive impairment, there are already some systems that help patients in their rehabilitation process. The cognitive impairments faced may be due to the degradation resulting from age, or from an injury or stroke that affects cognitive abilities. It is impossible to define a unique way of dealing with these problems. Indeed, each type of brain disorder requires different methods and specialists for its treatment [8].

Although the use of Kinect to control the patients' movements in a cognitive rehabilitation therapy is not so frequent, some examples are available. The Tango:H system [4] focuses on hospitalised children with disabilities. It offers some funny games in which children must use some body parts to select objects that allow them to achieve the correct answer. In the older people rehabilitation domain, a system uses Kinect to improve memory by performing mental activities and physical exercises at the same time [?]. The authors design several exercises of different levels of complexity that are adapted depending of the mental state of the patient. Moreover, the effectiveness of this rehabilitation therapy has been analysed [14]. It is concluded that, although this evaluation does not show an improvement of the cognitive impairment measured by means of the Mini–Mental State Examination, cognitive performance does not decline and the impairment progression is slow. A very recent work [3] presents a system for the rehabilitation of stroke-affected patients, which includes four immersive games. One of them is a quiz activity, which not only makes the person perform the physical exercise, but also focuses on cognitive aspects to answer a basic set of general knowledge questions. Finally, the base of the work introduced here presents a tool for designing cognitive therapies that allows the therapists to design from scratch their own cognitive therapies associated with pair and multiple association or categorisation exercises [9]. The capability to design their own exercises allows the therapists to adapt the therapies to each specific patient. In addition, these cognitive exercises are complemented with physical movements of the patient, this way combining cognitive and physical rehabilitation in one single therapy.

3 Haptic Guidance for Visually Impaired People

As noticed recently [10], there are only a few proposals in the rehabilitation domain that include haptic cues for improving the task. As an example, a novel rehabilitation system is presented [12]. It includes a glove that has several vibration motors to increase the feeling of immersion. The proposal uses a Kinect sensor to track the movement of the hand and several bend sensors to control the specific movement of the user's fingers. In this approach, a glove is used to place the vibration motors on the hand. The system locates the different actuators by creating a grid that is used to transmit some movement feeling. Although this proposal locates several vibration motors on the user's hand, the actuators are used to improve the user's perception when interacting with virtual objects, but for guiding the interaction they only use the visual cue. A rehabilitation system that uses a vibrotactile armband communicating with Kinect wireless has been created [10]. The vibrotactile actuators are only used to instantly notify when the selected body part is raised to the required angle of elevation during a physiotherapy session.

Moreover, vibrotactile actuators are also used to guide user movements. Thus, a paper [2] presents a vibrotactile system that measures arm motions using a Kinect sensor and provides vibration feedback when the user deviates from a desired trajectory, indicating the movement. The vibration algorithm is designed so that the user moves toward the stimulus or away from the stimulus. Each band consists of four actuators. The system activates them to indicate that the arm has to be relocated in a correct place. In another work [6], a system that uses accelerometers and gyroscopes to control the patient's movements is introduced. In addition, it includes two coin eccentric mass pager motors for transmitting the vibrotactile stimulus. The user is instructed to move in the direction of the vibrotactile sensation until the vibration is eliminated. Also, a wearable haptic system, in which the user wears a full body suit, densely embedded with vibrotactile actuators, has been presented [5]. The movements of the user are tracked through a motion capture system. When the user deviates more than a predefined distance from the target, actuators on the associated limb segment provide feedback. It helps the users to move that part of his/her body toward the correct configuration. In this case, the vibration feedback from each actuator is intended to be a repulsive cue to push the user away.

As we have noticed, although there are previous proposals that provide support to the user when he/she has to imitate a specific movement, these proposals are all dedicated to the domain of physical rehabilitation therapies. Moreover, in general, they include several actuators distributed in different body parts. Finally, the goal of these systems is only to guide the user in his/her movements, but in our system we need to include some vibrotactile stimuli that allow the user to identify the specific element reached with the movement of his/her hand. Thus, in the next section we present our proposal, highlighting its main contributions.

4 Vi-SMARt: Our Cognitive Rehabilitation System

The proposed system (Vi-SMARt) is basically aimed at cognitive rehabilitation of people. In addition, it combines cognitive rehabilitation with physical exercises. Thus, together with exercising the brain, the user also moves some parts of his/her body, as defined by the therapist, to improve his/her rehabilitation. To achieve this goal, an open rehabilitation system has been created, in which the therapist designs all the rehabilitation exercises from scratch. This allows creating exercises based on well-known therapies, albeit adapted to the specific impairments of each particular patient.

Each exercise incorporates a series of meaningful elements with specific locations in the interaction space. During the design of an exercise, the therapist locates in the interaction space as many elements as he/she wants and selects some features for each element, such as size, position, orientation and colour. Thus, the patients should recognise the meaning of all these elements and carry out a specific cognitive process to successfully complete the exercise. Currently, our system allows designing three types of exercises: *Pair Matching*, *Multiple Matching* and *Categorisation*. These exercises have been selected as they are widely applied in rehabilitation of many cognitive deficits of the front executive function of the brain [8]. In addition, Vi-SMARt offers a possibility of free exercise, in which the therapist can design other types of exercises by freely defining all the available options.

When a patient wants to carry out an exercise, he/she should be located in front of a Kinect sensor that captures his/her body joints. In the previous version of our system (see [9,11]), an image of the user body and the elements defined by the therapist appear on the monitor. In addition, the instructions that guide the patient in the performance of the exercise are also displayed on the screen. The patient's mission is to select several elements by taking into account a specific rule defined by the therapist. To select each element, the patient places on it a particular part of his/her body. The allowed parts of the body used to select an element are set by the therapist at the moment of creating the exercise. As it can be seen, the visual channel is very relevant in this previous version, so that visually impaired people have enormous problems to use it.

4.1 Cognitive Exercise Authoring

The *Cognitive Exercise Authoring* component allows the therapist to design all the steps of a specific task or exercise. When the specialist creates a new exercise, the four types of exercises supported by the system appear. After selecting the desired type, the exercise edition screen is displayed (see left of Fig. 1). The *exercise composer* interface is divided into five areas. At the top, the therapist introduces the name and the goal of the exercise. These labels should be descriptive enough so that the patient can understand what he/she should carry out to successfully solve the exercise. At the bottom, the elements that the therapist can use to design the exercises are shown (numbers from 0 to 9). In this case, due to the fact that the exercise represented in Fig. 1 is *Pair Matching*, when the user selects one number at the bottom of the screen, two elements with the same image appear in the working area. On the left side of the screen, the elements already located in the working area appear. The user can assign several specific properties by selecting one element of the list (see right part of Fig. 1). Finally, the right side of the screen shows the *Steps* that make up the exercise. An exercise may consist of one or more steps. At each step, the elements displayed are totally different from the other steps.

To select an element from the working area, the patient must locate a part of his/her body on it and maintain the position at least for 1 s. As we use Kinect for tracking the user body, the allowed joints are those controlled by this

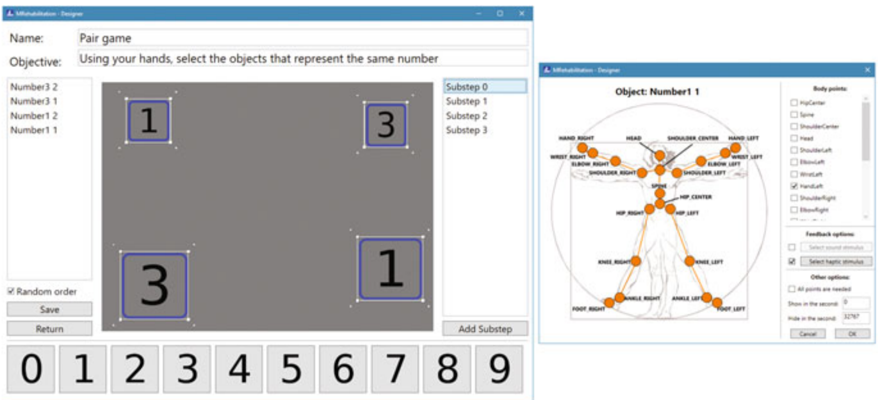

Fig. 1. Exercise edition interfaces. *Left* Exercise composer. *Right* Object properties

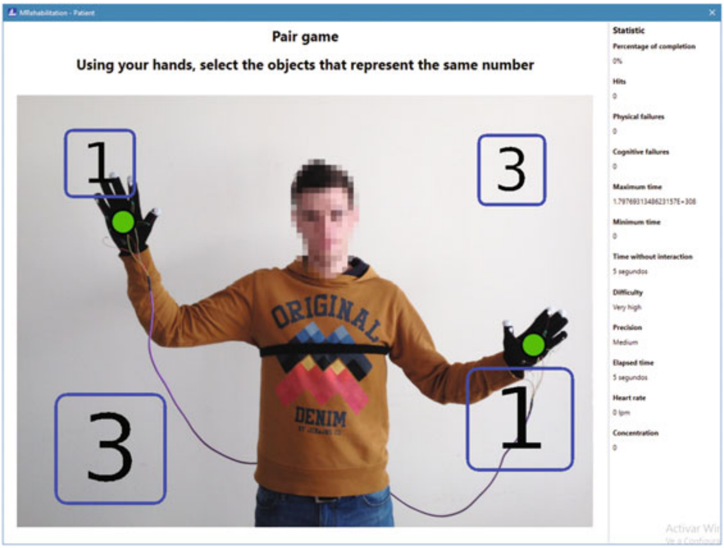

Fig. 2. Patient performing an exercise

device. Thus, the therapist must define for each elements which joint should be monitored to activate its selection (see Fig. 1).

As this system is required to be used by visually impaired people, other stimuli different from the visual one are needed. In this case, we need to assign an additional meaning to each object, in order to provide an additional way to identify each object. As it can be seen in Fig. 1, our system allows the therapists to define two additional meanings to each object. They can add a specific sound and/or and specific haptic feedback to each object. Thus, each object could be represented by an image, a sound, a haptic feedback, or a combination of them. In addition, the therapist can define other options to establish the way the user must carry out the exercise.

In the case that the rehabilitation specialist determines that one object must have sound, he/she selects a representative sound for it. When the patient enters into this object, the sound assigned to this object is reproduced. In this way, the visually impaired patient is able to determine the object. For example, in the exercise illustrated in this paper (see Figs. 1 and 2) the sound assigned to the element is the number represented in the visual image.

4.2 Therapy Execution Environment

The Vitaki system [7] is used for the sake of designing and providing haptic sensations to patients. This system, which is composed of a software and a hardware component that are described below, has been created in our lab.

4.2.1 VITAKI Hardware

The VITAKI hardware is used to bring haptic sensations to the user. VITAKI is connected to a computer via Bluetooth protocol, and the computer sends the haptic stimulation that the actuator must reproduce. In this way, it has the lowest possible latency, since it only has to adapt the signal to stimulate the haptic actuators. This device has 9 outputs to which a haptic actuator can be connected. For our rehabilitation system, we use 8 outputs of the device, 4 for each haptic glove. These actuators are placed on the patient's hands, using haptic gloves. In addition, the device uses a battery in order to get a minimal intrusion when a user is performing an exercise. In this way, the user should not worry about any wire connection between PC and VITAKI, so he/she performs the exercise totally free.

4.2.2 VITAKI Software

The VITAKI software is used to design the haptic feedback, so it can be used by the therapist to design a specific stimulus for each object. With this application, we can design the haptic stimulus that the user will receive when entering into an object. We can create complex stimuli by designing their waveforms. An example of this program is shown in Fig. 3. The system allows us to perform any desired waveform for stimulation. The therapist may create complex waveforms from the simple waveforms that are in the system or use previously defined ones. In addition, he/she can also create waveforms libraries for later use.

Although this allows us to provide haptic feedback to the user with greater accuracy, the therapist may wish to provide simple haptic signals to the patient. For this, we can use the rehabilitation system itself, instead of the Vitaki Software. In this way, the therapist will only have to define the duty cycle (period and pulse duration) to create the haptic stimulus instead of designing the waveform. Using this method, we can create distinctive stimulus for each object in the scenario in a simple way.

The patient's part is simpler than the therapist's one. At the beginning of the exercise, the user is offered the name and the objective set by the therapist at the top of the screen (see Fig. 2). Moreover, this information is read out by the system, allowing the visually impaired people to understand what they have to do during that exercise. This explanation must be sufficiently clear so that the user does not need any additional information for carrying out the full exercise. In the central part of the screen, the first *Step* created by the therapist appears, as well the figure of the patient in the background, are displayed. This image is captured by a Kinect sensor placed in front of him/her. On the right side of the interface, the number of hits, cognitive and physical failures, the duration of the exercise, and the patient's physiological data (e.g., heart rate or concentration) are also highlighted.

In order to sense the haptic stimuli, the user has to place the Vitaki device on his/her chest or waist, and a glove with haptic actuators on each hand. When the

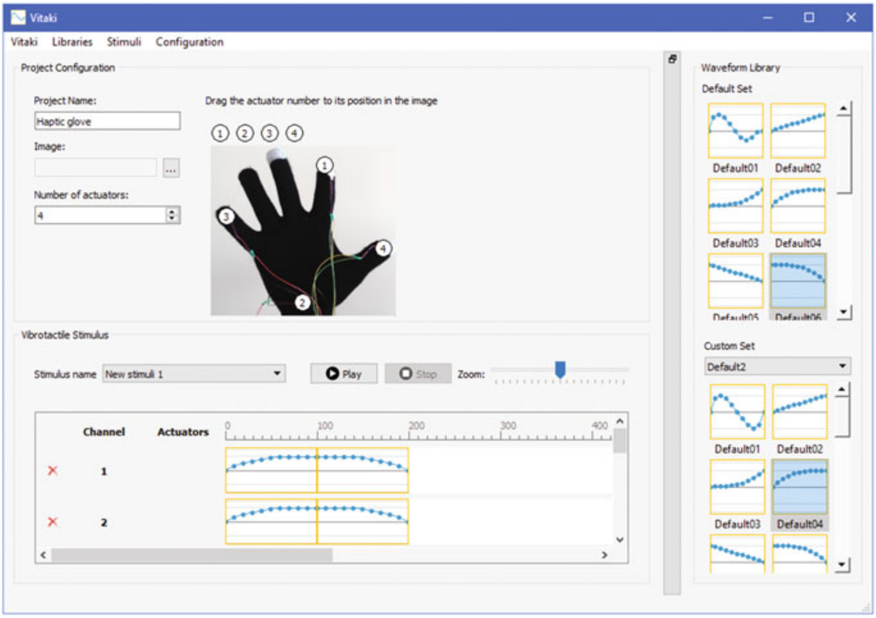

Fig. 3. VITAKI software

exercise starts, the patient receives a haptic stimulus at each of his/her hands, indicating the location of the nearest haptic elements of the working area.

On the gloves (see Fig. 4) 4 vibrotactile actuators are placed. They are located on the thumb, on the index finger, on the pinky and on the palm of the hand. This actuators' situation allows the user to draw a cross, pointing to the four possible movements of the user's hand to find an element in the working area (see Fig. 4). The vibration of these actuators indicate in which direction the patient should move his/her hand (i.e., the vibration of these actuators on the patient's right hand indicates that he/she has to move the hand to the left, up, to the right or down, respectively). The vibration of the actuator becomes lower when the patient's hand comes close to the object. This helps visually impaired people to find objects in the interaction area.

Secondly, the patient receives a specific pulse when he/she enters inside each object. The pulse is created by using the VITAKI tool discussed in the previous section. The haptic pulse is provided at the same time in the 4 actuators of the hand, and the intensity of this pulse is defined by the size of the object in the virtual world.

The relation between the 'haptic object' and the stimulus is not necessarily representative, because there is no direct relation between object meaning and haptic sensation in most cases. However, there are some exceptions to this fact. This is the case, for example, in *Categorisation* exercises, where the user has to sort the objects. In this type of exercises, the number of pulses can be used to

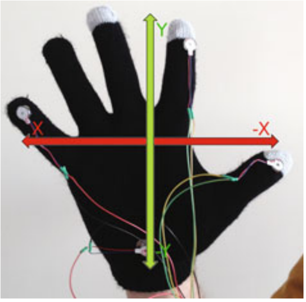

Fig. 4. Haptic glove

identify the number of the object. In this way, the patient receives a pulse for the first 'haptic object', two pulses for the second one, and so on. In the exercise used as an example in this paper (see Figs. 1 and 2), the haptic pulse assigned to each object can be a single pulse for objects with number 1, and three pulses for objects with number 3, and the pulse being more intense in large objects, and less intense in small objects. In this way, haptic meaning is assigned to objects in the virtual world, which enables patients with visual impairment to distinguish one object from another.

5 Conclusions

In this article, we have presented a multimodal cognitive rehabilitation system for visually impaired patients. After introducing some current computer-aided rehabilitation systems and their target patients, the rehabilitation system implemented in our research team has been described. Due the wide range of cognitive injuries that may occur, it is impossible to design a system that covers all of them. Therefore, the developed system has been focused on a small group of exercises, namely *Pair Matching*, *Multiple Matching* and *Categorisation*.

After choosing the type of exercise, the therapist just needs to put some elements in the working area and specify the stimuli associated to each one. As described in the paper, besides the visual sense we can send information to the user by aural and haptic channels. In the first case, standard PC peripherals such as display and speakers are used. But, in the second one, we use the VITAKI system developed in our laboratory, which allows us to manage several vibrotactile actuators that transmit a previously designed signal. As for the patient's view of the system, we have tried to minimise the cognitive load. In fact, the patient only needs to move his/her body to select some elements of the working area. In addition, to knowing where the elements of the working area are, we have design a glove composed by four actuators that guides the user in the exploration task. Finally, this glove allows the user to receive some information about the meaning of the each element.

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Electric Vehicle Urban Exploration by Anti-pheromone Swarm Based Algorithms

Rubén Martín García[1(✉)], Francisco Prieto-Castrillo[1,2(✉)], Gabriel Villarrubia González[1], and Javier Bajo[1]

[1] University of Salamanca, BISITE Research Group, Edificio I+D+i, 37008 Salamanca, Spain
{rubenmg,franciscop,gvg}@usal.es, jbajo@fi.upm.es, fprieto@mit.edu

[2] MediaLab, Massachusetts Institute of Technology, 20 Amherst St, Cambridge, MA, USA

Abstract. In this work we show how a simple anti-pheromone ant foraging based algorithm can be effective in urban navigation by reducing exploration times. We use a distributed multi agent architecture to test this algorithm. Swarm collaboration is analysed for different scenarios with varying number of units and map complexity. We show how an increase in the number of robots results in smaller exploration times. Also, we measure how the complexity of the map topology affects the navigability. We validate our approach through numerical tests with both synthetic random generated maps and real bicycle routes in four cities. Also, by monitoring the dynamics of three real prototypes built at the laboratory, we check both the feasibility of our approach and the robustness of the algorithm.

Keywords: Smart cities · Route optimization · Swarm intelligence · Robots

1 Introduction

A major challenge in Smart Cities (SC) [1] is the dynamic optimization of routes under different criteria. The objective is to manage a flood of electrical vehicles (EV) efficiently and in a sustainable way. The problem can be solved with different strategies, one of the most common found in literature is the use of a bio-inspired algorithms [2].

In this work we provide an implementation of a well-known bio-inspired meta-heuristic to analyze the collaborative routing of EV in cities. Moreover, we investigate the behavior of a swarm of robots in real environments.

The main difficulty in coordinating a robot swarm lies in the communication among units. In this regard, previous works can be split into implicit/indirect and explicit/direct communication. Implicit communication—also known as *stigmergy*—is based on the context and some of its most typical uses can be found in [3–6]. In this regard, the Pioneer work of Pierre-Paul Grasse in termite colonies revealed the communication mechanisms of these insects by means of chemical signalling and in particular by pheromones [7]. These observations resulted in an ant-based exploration algorithm [8]. Here, each ant leaves a pheromone trail in its foraging activity. This trail persists for some time and it is followed by other ants in the search of food resources.

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Also, the pheromone approach has been widely adapted to several artificial intelligence problems in its converse flavour (i.e. anti-pheromones) [9–11]. In particular, some researchers have used anti-pheromone (APH) proxies to optimize robot exploration [12]. The main advantage is that each unit accesses a different region fostering the diversity of the solutions by means of indirect and decentralized communication.

On the other hand, the efficient exploration and target localization in urban environments is gaining more and more attention [13, 14]. However, bio-inspired algorithms tailored to optimize robot exploration and dynamic route generation in SC are somewhat separate research fields. Therefore, in this work we propose an APH-based robot swarm exploration strategy to optimize routes in SC. In particular, we merge robotics knowledge with the SC paradigm to analyse intelligent routing of cooperating electric vehicles. We describe how a simple APH-based algorithm can be effective in locating targets in different cities. To this end, we use both numerical simulation and real physical exploration with three prototypes.

This paper is organized as follows. In Sect. 2 we present the APH-based algorithm and Multi-Agent architecture for SC exploration. We apply the strategy in Sect. 3 for a case study of 4 different cities with different spatial complexity. The main outcomes from this study are summarised in Sect. 4 and we conclude in Sect. 5.

2 An Anti-pheromone Swarm Algorithm for Exploration

In the following we describe both the proposed architecture and the Anti-pheromone based algorithm.

2.1 Proposed Architecture

For the distributed execution of the Anti-pheromone swarm algorithm we have used the multi-agent architecture PANGEA [15], previously developed in the BISITE research group. This Multi-Agent System (MAS) allows the implementation of embedded agents in computationally limited devices, allowing a simple communication among the different elements. The information transfer is based on the use of the ISO/IEC 20922: 2016 protocol, which allows flexible communication with optimum battery consumption.

Virtual agents in a MAS cooperate with each other, aiming to solve a problem or reach a goal. In PANGEA, agents with the same goal are grouped into virtual organizations (VO). Figure 1 shows an interaction diagram of the different virtual organizations implemented in our study. Below we describe the virtual organizations in this work.

- **Mobility:** Includes mobile agents for environment exploration.
  - **Robots**: mobile entities that move around the environment and eventually find targets.
  - **MQTT**: is the technology used for receiving and resending robot messages by means of the MQTT (MQ Telemetry Transport) protocol [16].
- **Conflict**: includes the following agents:

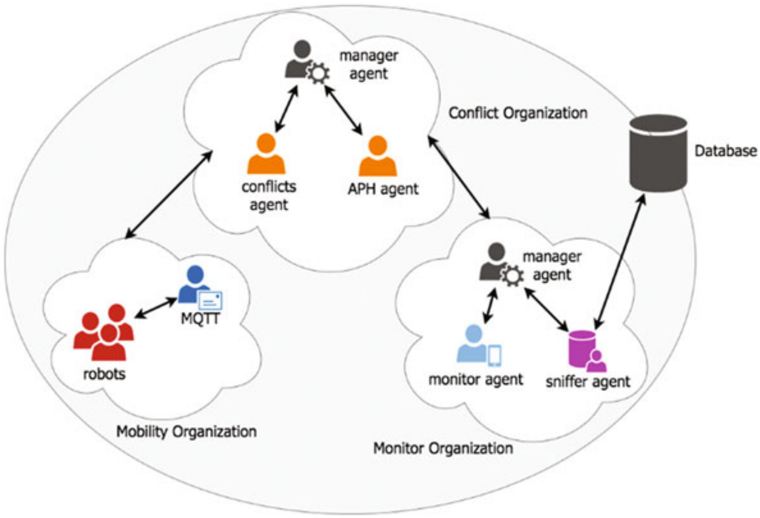

Fig. 1. MAS architecture. Three virtual organizations (Mobility, Conflict and Monitor) of agents cooperate in the navigation process. The robots of the Mobility VO communicate through the MQTT agent. The Conflict VO manager receives the robot information and sends it to the conflicts and APH agents. He also sends back mobility instructions to the robots. All these messages are also monitored in the VO Monitor and finally stored

  - **APH agent**: it holds the virtual map and is responsible for counting the anti-pheromones at every location and time.
  - **Conflicts agent**: Aimed at solving potential emerging conflicts among agents when two robots coincide at the same location.
- **Monitor**: to monitor the process and store the information in a database. These agents do not interfere in the main process. This group is composed of:
  - **Monitor agent**: controls the life cycle of other agents and enables the interface to display the general state of the communications, organizations and agents. This agent is responsible for starting the agents of the platform in case of failure.
  - **Sniffer agent**: manages the message history and filters information by controlling communication initiated by queries.

In PANGEA the Manager agent verifies the creation and elimination of agents and the assignment of roles. Also, he is the communication hub among organizations.

2.2 Anti-pheromone Algorithm

The navigation algorithm we present in this work (pseudocode in Fig. 2) is an adaptation of the classical two-dimensional APH gradient [4] to a 1D gridded world. This world consists of a set of parallel and perpendicular lines arranged in a way that mimics urban topologies.

In the following section we apply this strategy to different scenarios.

```
while current location ≠ target do
    if current location = intersection then
        [paths] ← get all paths with the lowest and same level of
          anti-pheromones;
        if size (paths) > 1 then
            angle ← angle of random path in [paths];
        else
            angle ← angle of the path in [paths];
        end
        turn ( angle );
        go on;
    else if current location = dead end then
        turn ( 180° );
    else
        drop anti-pheromone;
        go on;
    end
end
```

Fig. 2. Anti-pheromone navigation algorithm. Each time a robot reaches an intersection which is neither a target nor a dead end, a negative APH gradient based route is followed

3 Simulation

In this section we describe both the numerical simulations and the laboratory robot prototype based tests.

3.1 Numerical Simulation

Our simulation consists of an N × N gridded world where robots move along paths generated according to a modification of the random walk algorithm as we explain below. In this setting we define the following parameters:

(1) N_{robots}: number of robots
(2) $R_{maze} = N_{path}/N \cdot N$ proportion of path units (N_{path}) with respect to the total number of cells.
(3) $Pers_{rate}$: pheromone evaporation time (i.e. number of time units a pheromone takes to evaporate). At every time step the robots leave a pheromone unit.

There are two phases in our tests. Firstly, we generate synthetic topologies with parametrized complexity. Here the path generation algorithm is a simple adaptation of a 2D random walk with jumps of varying lengths. We however constrained the algorithm to avoid adjacent lines and prevent robot collisions. With this strategy we generated a population of 22×10^6 samples by sweeping parameters as follows: $N = 40$, $N_{robots} \in [1,\ 10]$ with $steps = 1$, $R_{maze} \in [0.1,\ 0.6]$ with $steps = 0.05$ and $Pers_{rate} \in [1,\ 100]$ with $steps = 1$. For each parameter combination we repeated the tests 50 times. At every run, a synthetic topology is generated and both the target and robots' initial positions are selected randomly among the path locations.

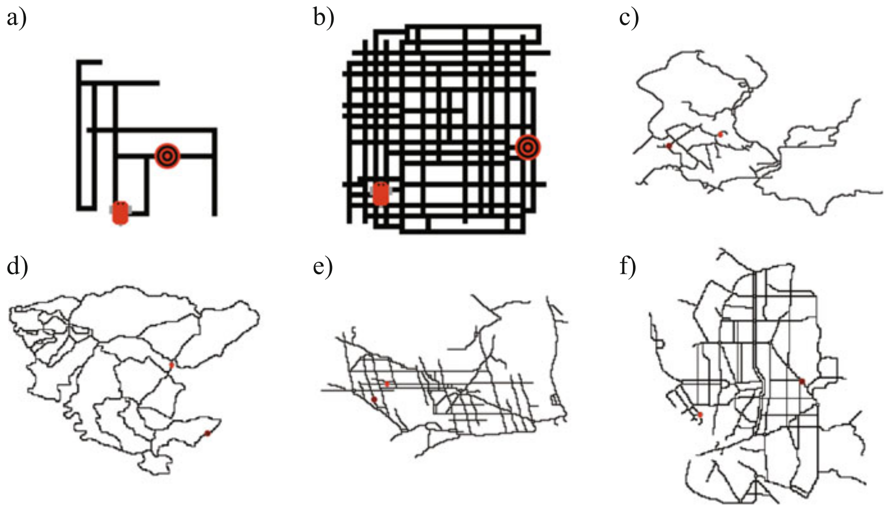

Fig. 3. **a** Synthetic topology with $R_{maze} = 0.1$. **b** Synthetic topology with $R_{maze} = 0.5$. **c** Map of Gijon with NM = 2.01. **d** Map of Castellón with NM = 2.02. **e** Map of Barcelona with NM = 0.6. **f** Map of Madrid with NM = 0.5

In the next phase we have used real EV maps from four Spanish cities. In particular, the bike routes from Madrid, Barcelona, Gijon and a mountain bike trail in Castellón have been adapted to our simulations.

For each of these maps, we ran a parameter sweep with $N = 200$, $N_{robots} \in [1, 5, 10]$, and $Pers_{rate} \in [10, 250]$ with $steps = 10$.

As before, every combination of parameters has been repeated 50 times and the target and robot initial positions are chosen randomly at every iteration.

In both analyses (synthetic maps and real routes) we have obtained the following metrics:

(a) *firstTime*: defined as the first time of arrival to the target by any of the robots,
(b) *totalTime*: elapsed time until all the robots reach the target.
(c) *robotPath*: the number of discrete locations (i.e. patches) covered by the robot along its path.

As stressed, every topology is parametrized by its spatial complexity. This is simply defined as the mean of the neighbourhood (Von Neumman) size of every path cell. The resulting complexities for Gijón, Castellón, Madrid and Barcelona are respectively: 2.01, 2.02, 2.05 and 2.06 (Fig. 3).

3.2 Robot Swarm Simulation

We have also built real robot prototypes in order to test the APH navigation strategy in the laboratory. The reason for using real robots in our experiments is that, as electric vehicles, they are subjected to events which are similar to those commonly found in real EV scenarios. In particular, the measurement errors of position in a real

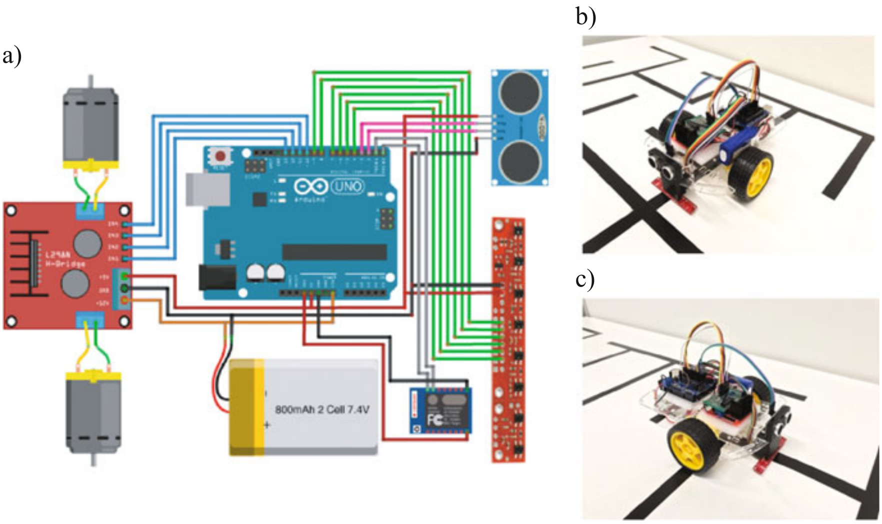

Fig. 4. **a** Schematics design of robots. Electronic components and design of the robot connections. **b** and **c** Robots in lab controlled environment. Here the robots move along black strips by means of an 8 sensor array located at the front side (*red component*)

environment map to our prototype setting. Moreover, the lab tests allow us to explore the robustness of our approach, which is the major concern in real implementations.

To this end, the electronics division of the BISITE research group of the University of Salamanca has built a set of three robots following the schematics shown in Fig. 4a. An Arduino board is used as microcontroller. The rotors control is enhanced through a driver based on the chip L298n. The sensing system consists of two parts: (a) an infra-red sensor array for edge line detection and an ultrasound sensor to track distances. The WiFi communication has been enabled through an ESP8266 board. The robot holds a 2 cell Lithium 800 mAh based battery.

The laboratory tests have been implemented with the MAS design proposed earlier in this work. The map has been constructed by printing connected segments of black lines on a white surface according to the general patterns in our simulations.

Each robot moves forward through the lines until it reaches an intersection. Then it sends an MQTT message to the Conflicts and Monitor VOs to determine the next move. This is done by counting the current APH level of the possible paths at the cross and by selecting that with the minimum APH amount. Once the path is selected the APH level is updated. The agent states and decisions are stored in a database for its posterior statistical analysis.

4 Results

In this work we analyse the mean first time of robot arrival to the target averaged over the 50 runs for every parameter combination. We use this observable as a proxy for robot collaboration. In Fig. 5 we show this metric for a value of 60 $Pers_{rate}$ and

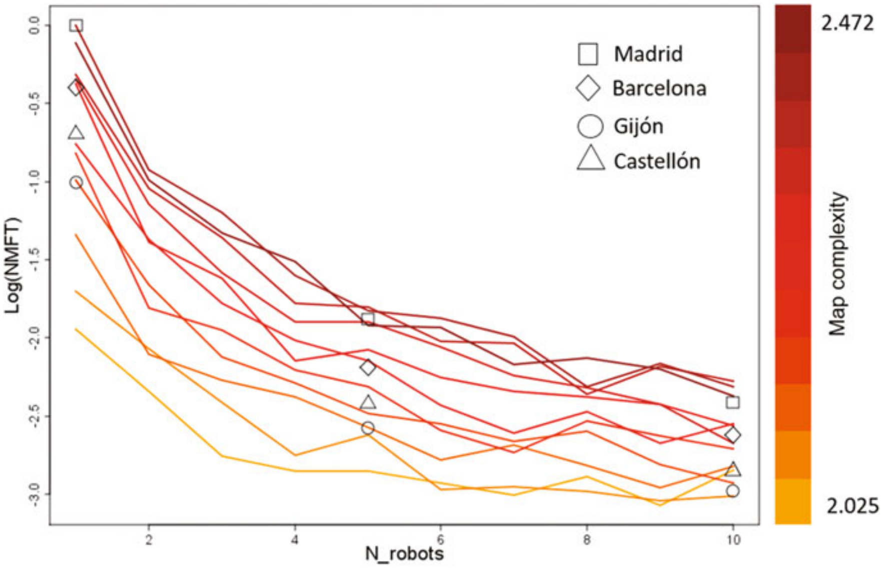

Fig. 5. Normalized first arrival times to the target for different number of robots and levels of map complexity. Data points represent the simulation on real bike routes in four Spanish cities

increasing number of robots and for different levels of map complexity in a log scale. Here the times are normalized with the maximum time and the map complexity is computed as described above. Also in the plot we show data points corresponding to simulations with 5 and 10 units for the bike routes for Madrid, Barcelona, Gijón and Castellón (Fig. 3).

It is observed that arrival times decrease with the number of robots. This result shows that swarm collaboration is actually happening. Also, as expected, the complexity of the map topology augments the exploration time for a fixed number of robots. For 10 robots the NMFT for Gijón, Castellón, Barcelona and Madrid are: 0.051, 0.057, 0.073 and 0.089 respectively. The complexities of Gijón (2.01) and Castellón (2.02) are similar, which is also the case for Barcelona (2.06) and Madrid (2.05). This is consistent with the disposition of the data points in Fig. 5. Interestingly, Madrid is slightly less optimizable than Barcelona, although its complexity is smaller.

In our setting, we predict that APH based navigation in Gijón-like cities is likely to be around 57% times shorter than Madrid-like cities only due to the differences in spatial complexity (see Fig. 3) regardless of city size.

These simulations have been validated by real tests at the laboratory with physical prototypes. In particular, the dynamics of three units have been monitored to ensure the time reduction found in simulations. Due to limitations of space a comparison between simulations and real time measurements this part of work is left for the future.

5 Conclusions and Future Works

In this work the classical anti-pheromone ant foraging algorithm has been adapted to the problem of optimal routing in Smart Cities. We have validated our approach both by numerical simulations and by real laboratory tests. The simulations were performed with random-walk generated maps and with real bicycle routes of four Spanish cities with parametrized spatial complexity. In both cases, swarm collaboration is results in a significant reduction of the arrival times. Also, it is found that these times increase with map complexity.

We have validated the possibilities for a real implementation of our strategy in the laboratory facilities of the BISITE research group at the University of Salamanca. To this end, three prototypes have been constructed to check the proposed MAS architecture and the robustness of the APH based strategy in real conditions.

From the statistical analysis of the experiments the collaboration among robots has been quantified in terms of the elapsed times to reach a target. We have shown how an increase in the number of units and in map complexity results in higher exploration times. The swarm collaboration mechanisms of our design has shown to be effective both in simulations and laboratory and can be implemented in real Smart City scenarios.

Regardless of the topology of the city, the proposed decentralized collaborative navigation strategy can be valuable to the design of new routing patterns without compromising efficiency. At its current stage the navigability improvement is only shown when compared with the non-swarm limit. Due to limitations of space and time the comparison with other mobility solutions is left for future work.

In future works, we will also consider combinations of different bio-inspired algorithms to improve city navigability under different factors. In particular, a suitable combination of different virtual signalling communication mechanisms (e.g. pheromone and anti-pheromone) can lead to significant improvements.

Although in this paper the real laboratory tests have been used only as a proof of concept for our APH MAS design, in a future work a systematic analysis of the prototype dynamics will be performed in order to verify the numerical simulations.

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A Pilot Study on Personalised Coaching to Increase Older Adults' Physical and Social Activities

Rebecka Janols[1(✉)], Esteban Guerrero[2], and Helena Lindgren[2]

[1] Department of Community Medicine and Rehabilitation, Umeå University, 901 87 Umeå, Swedenrebecka.janols@umu.se
rebecka.janols@umu.se

[2] Department of Computing Science, 901 87 Umeå, Sweden
esteban.guerrero@umu.se, helena.lindgren@umu.se

Abstract. The aim of this research is to conduct a pilot study of a prototype that provides feedback using theory-based motivating messages developed by older adults, in a context of every day activities that include both physical and social activities. The prototype mobile application integrated the messages, a motivational model, and a personalization module that selects motivational messages based on preferences, motivational profile and the situation. The four participating older adults used the application for planning and following up social and physical activities. They found the messages entertaining and appreciated the dialogues with the application. They used the dialogues primarily to reinforce their satisfaction regarding conducted activities and did not necessarily tell the truth about conduced activities in the interaction with the application. The results are preliminary, but give valuable implications for further development of the personalisation module towards more purposeful use of ambient information, and aspects to explore in future user studies.

Keywords: Behaviour change · Persuasive technology · Personalisation · Ambient intelligence · Physical activity · Social inclusion · Older adults

1 Introduction

Personalised coaching through digital systems, sometimes called Behavior Change Systems (BCS), or Persuasive Technology (PT), is motivated mainly for improving the wellbeing and health in an individual [1,2]. In few cases theories about humans' motivation are applied [3,4]. This research aims to evaluate a mobile application that adapts theory-based motivating messages in a context of every day activities that include both physical and social activities. A

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prototype mobile application aiming at promoting physical and social activity was developed and evaluated. The prototype was developed as an extension to an existing web application for assessments of ability with the aim to support older adults in planning physical and social activities, and evaluate these (Fig. 2). The user was reminded to plan activities, encouraged with messages, and was given feedback on their performance. Earlier developed applications for baseline assessments and sensor-based assessment of location, balance and strength through the mobile phone were also further developed and applied [5].

The output of the adaptive intelligent system that the older adult receives needs to fulfill expectations, make sense and be useful to the user, in order to have a positive impact on behavior [2]. Therefore, this pilot study was conducted to qualitatively assess the participants attitudes towards the motivating messages selected based on theory and user characteristics, and delivered by the coaching application. The set of messages were developed by older adults in a participatory design process [6].

2 Methods

The prototype was evaluated in a formative and qualitative pilot study involving four older adults. Different aspects were studied regarding how a supportive application in the form of a personalised persuasive coach could be designed to increase motivation.

The primary focus of the user study was on the functionalities of the extended mobile Android version of HemmaVis [5] (*mHemmaVis*), developed as part of this research, and the seniors' experiences using the system while conducting their activities during a period of use. Research questions included to what extent the system was seamlessly integrated into their daily activities, whether they were able to interact as intended, whether they followed their plans and the reasons for not complying to their plans of activities, and whether they found the system's messages tailored to their motivational profile appropriate, useful and encouraging. Four seniors volunteered to test the system for two weeks after the initial baseline assessment. One female and two men 84–85 years old volunteered, who lived in a residence home. One of these had both computer, smart phone and touchpad, one person had none of these. The third person had own computer. A fourth senior aged 70 living in her own house volunteered also, who had an own computer. Consequently, three of the seniors had no experience of smart phones or touch pads before the study. All four were found being highly active, both physically and socially.

HemmaVis was used by the senior as instrument for the baseline assessment (Fig. 1) and mHemmaVis was used by the senior for planning activities, setting and adjusting goals, and follow up activities through self-assessment (Fig. 2).

The setup of the user study was organized as follows. The participant was either visited in their homes or contacted by phone in totally five occasions during a three week period, every 4–5 days. This frequency was chosen with the consideration of the seniors' low experience with such technology. During

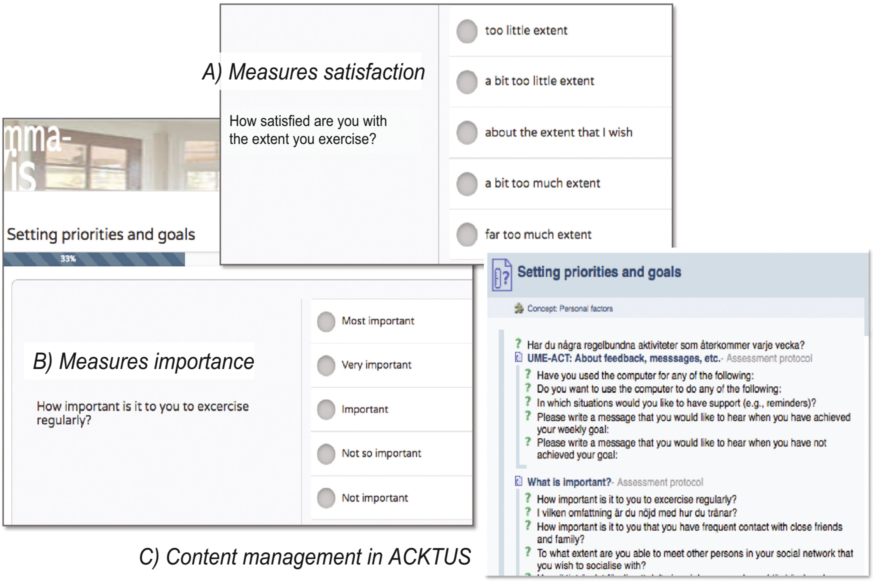

Fig. 1. Screenshots from the baseline assessment application HemmaVis and the content management system ACKTUS [8]

the first visit an introduction was given, a pre-assessment was done and the program was presented. The main purpose was to identify significant limitations in functioning, environment or timing in their personal life, and involve the person in the design process. Thus, aspects of design and interaction identified at this occasion were also fed into the development of prototypes. During the second visit 2 the baseline assessment was conducted and the participant made their first plan, both by using HemmaVis. During the following three occasions follow-ups were done either as interview by phone, or visits when the researchers interviewed and observed the participant using the application for following up activities and revise their current plan.

3 The mHemmaVis Application

The mobile application developed and used in the pilot study integrates (i) a knowledge-based *motivational model* incorporating different person-centric factors, (ii) a *personalization module* for generating the adaptive behavior of the system that aims at motivating the individual, and (iii) a set of *motivational messages* categorized based on theory targeting primarily physical and social activities, which forms the motivational content of dialogues between the user and the system. The motivational model and personalization strategies are presented in detail in [7].

The system initiates the interaction between the user and mHemmaVis by a push notification through a smart phone or tablet as an invitation to engage

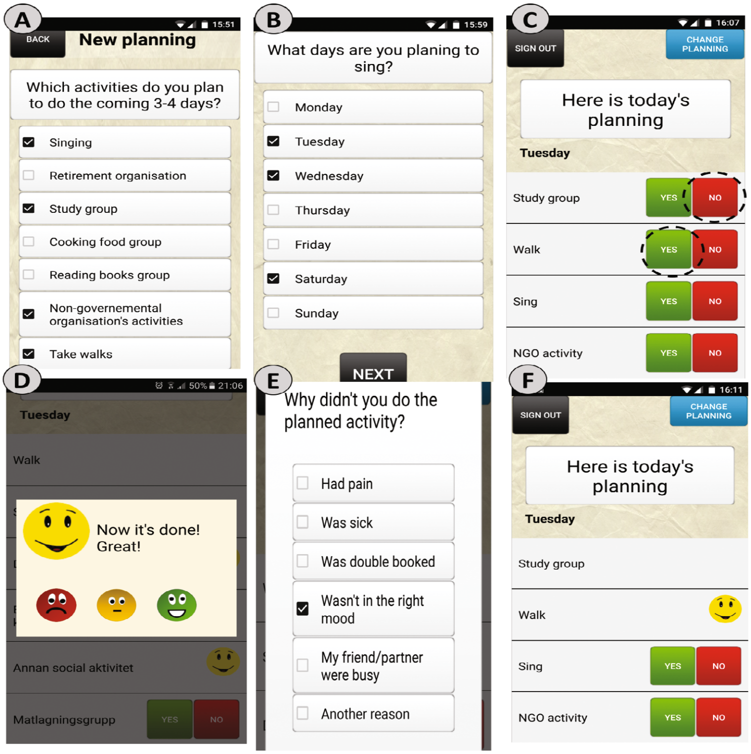

Fig. 2. mHemmaVis interface: **a** selecting activities, **b** selecting days to do the activity, **c** plan of the day, **d** the response by the system if the activity has been performed, and **e** a question about reasons when an activity has not been performed

in a dialogue. During the user study there were three dialogue situations with different purposes: (i) to outline planned activities for the current day (breakfast time) (Fig. 2c), (ii) to reflect on the activities of the day and evaluate these (dinner time) (Fig. 2c–f), and (iii) to revise the plan of activities (dinner time every third day) (Fig. 2a, b).

The planned activities for current day are presented to the user as a checklist with the possibility to mark whether they have performed the activity or not (Fig. 2c). After the user has reported if (s)he has performed an activity, the activity is augmented with a happy green face for reinforcing the accomplishment in the list of activities, and no face for activities not performed as planned (Fig. 2f). In both cases an encouraging message is provided and if not conducted, the question about the reason/s for not doing the activity (Fig. 2e). Each message can be evaluated by clicking one of the three coloured smileys in Fig. 2d.

During the baseline assessment conducted using HemmaVis, the client specifies for each category of activity the following:

1. **Importance**: the degree of importance to the client following a five item scale ranging from *not important* to *most important* (Fig. 1a),
2. **Satisfaction**: to which extent the activity is currently being performed in a satisfactory way. The categories of degrees relate to satisfactory or not satisfactory, here distinguished between *too extensively*, or *too little* (Fig. 1b),
3. **Intervention**: whether or not the client wants to have support from assistive technology to manage the activity, and thereby define a goal relating to this activity (*Intervention* and *Desired goal* in Table 1).

In addition, the following information is collected:

- **Personal information**: gender, age, social factors, living conditions, etc.,
- **Daily routines**: daily and weekly habits,
- **Activities**: specific prioritized physical and social activities,
- **Health**: pain and sleeping conditions.

This information can be used for generating a *personalized model of each activity*, exemplified in Table 1.

The ACKTUS platform was used for application development [8] (Fig. 1c), and the ACKTUS core ontology was extended to include classes of motivation based on the different motivational levels in Self Determination Theory (SDT) [9] (*amotivation*, *external* regulation, *identified* regulation, *introjected* regulation and *intrinsic* regulation). The content of the baseline assessment application HemmaVis was developed by modeling structured questions, which were associated with the motivation-related concepts. Content of the applications such as motivational

Table 1. Activity Models of different activities for the same person, depending on how the activity is valued by the individual. The example is based on one of the participating seniors (User D in Table 2). Mot RAI and Mot SIMP are two assessments of motivation

Category of activity	Physical activity: take walks exercise prog.	Maintain relations: meet friends	Social events: leisure events	Keep up with society
Importance	Very imp	Very imp	Not that imp	Very imp
Satisfaction	Too little	Too little	A little too little	Satisfactory
Desired goal	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Mot RAI	Intrinsic	n/a	n/a	n/a
Mot SIMP	Intrinsic	Intrinsic	Extrinsic	Intrinsic
Intervention	Yes	Yes	Yes	No

messages were also categorized and formalized by associating each to a type of motivation.

A generic algorithm for the adaptation of messages was implemented in the system [7]. This includes the identification of the individual's situation in which (s)he conducts an activity, fetch relevant set of messages based on the current situation and information from the user model, create the motivational model relating to the current situation, set goals for the coach agent, select and apply a decision-making strategy for adaptation, return a decision that includes the motivational message tailored to the person and her/his situation.

4 Results from User Studies

During the test period the four seniors made four plans each for the next couple of days (3–4 days). They all planned both social and physical activities. Table 2 shows the four participants' plans for the first week. The most common activities were taking walks, and attend different kind of events, e.g., theatre or concert.

The results showed that they did not necessarily tell the truth about their own performance. Two of the participants told that they almost always replied "yes", that they had performed the activities, even if they may not have actually done the activity. The two participants rather changed today's schedule than saying "No". Reasons were that (i) they did not like to admit that they have not performed according to their plan, and (ii) that they did not know what will happen in the system if they reply "no". The conclusion was drawn that this was partly due to a lack of transparency in the system, and partly due to that the system was perceived as filling the function of the "therapist" with expectations, and not as a tool that they control themselves.

One participant added a larger number of activities to his plans compared to the other three persons, and completed only a few of them each time period (User A in Table 2). Based on the observations and interviews, it was concluded that he perceived the plan more as a wish list of things he would like to do, than being a realistic plan. Reasons for why activities were not conducted were often that a friend did not join, or that the organizers of an activity did not schedule the activity the particular days, i.e., external reasons that he had no control over.

The results showed also that the participants' dialogues with the system including the messages were appreciated. They found the messages and dialogues entertaining, and used features in the design for continuing the dialogues for reinforcing their activities. They perceived the messages as being "great" and that they were looking forward to add the information that they have done the planned activity. One said that the messages made her laugh. The participants also liked the faces. It was observed a positive response and increase in interest at the first meeting when they were informed that the messages were created by other seniors.

It was observed that three of them always pressed the happy green face as if they liked all messages (Fig. 2d), and seemed to not follow the instructions to

Table 2. The seniors in User Study 3 made an individual plan for the first week. Their plans were made during the baseline assessment and each contain both social (So) and physical (Ph) activities that they regularly do

User	Type	Activity	Mon	Tue	Wed	Thu	Fri	Sat	Sun
A (m)	So	Bingo					x		
	So	Organization			x	x			
	So/Ph	Play pool	x	x	x	x	x	x	x
	So	Event	x						
	So	Sing				x	x	x	x
	So	Meet friends	x	x	x	x	x	x	x
	So	Retirement org.				x			
	Ph/So	Walks	x	x	x	x	x	x	x
	Ph	Golf	x	x		x	x	x	x
	Ph/So	Grocery shop.			x				
B (m)	So	Bingo					x		
	Ph/So	Walks	x	x	x	x	x	x	x
	Ph/So	Grocery shop.		x					
C (f)	So	Meet friends					x		
	So	Event				x		x	
	Ph/So	Walks	x	x	x	x	x	x	x
D (f)	So	Organization					x	x	
	So/Ph	Play accordion					x	x	
	Ph	Exercise strength	x	x	x	x			
	Ph/So	Walks	x	x	x	x			
	Ph	Gardening	x	x	x	x			

evaluate each message. Based on the observations of the participant's behavior in these situations the conclusion was drawn that they considered the faces as a way to continue the dialogue with the system about their activity after receiving a motivational message. In activity-theoretical terms, they did not shift focus from the targeted activity that they were evaluating towards focusing the system feature [10]. As such, the smileys served a different non-intended, however in this context, important role as means to reinforce the individual's own goals. Consequently, it was concluded that the initial purpose to use the smileys for evaluating each message was not a reliable method.

5 Discussion and Future Work

The purpose of the mobile application mHemmaVis was to provide personalised coaching to increase older adults' physical and social activities, which is accomplished through the outputs of the system adapted to each individual's preferences and type of motivation. The qualitative results from the pilot study revealed unexpected behaviors and attitudes in the participants that leaded to new research questions interesting to explore further in future user studies. Firstly, the profound value in being provided acknowledgement of achievements; secondly, the apparent value in being able to give responses to the system's responses, similar to when having dialogues with other humans; thirdly, the value of being able to modify plans to fit the reality; fourthly, the value of making "wish lists", rather than realistic plans; and lastly, the value of being entertained, having fun while using the application. Consequently, the purpose of context-based information obtained by sensors may need to be reconsidered. Typically, the goal is to measure activity levels and patterns, in order to provide information about healthy routines and fulfillment of goals, as a means for self-monitoring. In the case of the four study participants, the main purpose of such information would be to provide the individuals reasons for acknowledgements of achievements, reinforce by extending the dialogues to give responses to responses, and have a bit of fun while doing this. On the other hand, also monitor the ability to continuously adjust the plans to fit the reality, and the habits of making wish lists, while still being able to accomplish a satisfactory amount of the desired activities. The task to monitor these aspects and act upon decrease in achievements and in satisfaction would in this context be a primary goal by the ambient intelligent system for promoting and increasing physical and social activity in older adults.

Future work includes user studies involving a larger number of participants, and over a longer period of time, for the purpose to explore the importance of these aspects further.

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Environment Mapping with Mobile Robot Guided by a Markers Vision System

Juan Pablo Ángel-López and Santiago Murillo-Rendón(✉)

Universidad Autónoma de Manizales, Manizales, Colombia
jangel@autonoma.edu.co, smurillo@autonoma.edu.co

Abstract. A Markers vision system is a set of infrared cameras capable to distinguish little spheres made of reflective material. These systems usually have been employed to study bio-mechanical processes, and as a tool for animating characters in virtual worlds, for instance in animated movies and video games. In this work, this tool is used as a positioning system for a mobile robot in a closed room. The robot is a prototype made over Arduino®, it consist of a two motor control provided with a proximity sensor for monitoring the space around. The control of this robot was designed to be automatic, in other words it is conditioned to walk in a delimited space and to report the objects found in its way. To control the mobile robot, an algorithmic framework was built in Matlab®. The idea with this framework is to receive the data obtained by the motion capture system to locate the robot in the delimited area. Otherwise, the framework is used to build the virtual map of the place and to produce the control orders to guide the robot. The aim of this work is to evaluate a set of strategies for environment mapping and the performance of the robot in the identification of the hidden space and its reconstruction in a virtual representation. In the other hand, this work is used to teach techniques of artificial vision, algorithm writing, digital signal processing and control to undergraduate students. Furthermore, this project is proposed to identify new lines in mobile robots research and in the development of automatic machines that works in cooperative schemes.

Keywords: Robotics · Motion capture · Environment mapping · Spatial coordinates

1 Introduction

Mobile robots (MR) are systems designed to work in an autonomus way, it is, a MR itself has a set of systems that provide it with energy, locomotive properties, environment recognition, positioning and specific tools to do the task for which it was designed. This kind of robots have been developed to resolve a lot of tasks as: disperse fertilizer [1], collecting plantation crops [2], locate and distribute products in warehouses [3], among many others applications. In the first

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example, the robot has to rove the plantations providing fertilizer, in its way the robot must avoid the obstacles to optimize its work [1]. The second example corresponds with a harvester robot, this MR is capable to identify apples and collect them, it is accomplished by means of a system of artificial vision (AV), the robot captures an image of the place and segments the apples' shapes, then, an algorithm locates each apple in a matrix. The MR is guided by this matrix to the apples' position and a robotic manipulator harvest it. Other example is the Amazon® robots, used by this enterprise to trace the customer orders. The Amazon® warehouses are distinguished for their big dimensions, so the MRs use have optimized the tracing procedure and have reduced the operation cost over 20% [3]. The positioning ability in mobile robots is provided by different systems as: gps, proximity sensors, stereoscopic vision cameras, motion capture technology and others. Most of these are based in AV [4]. The AV consist in programming an electronic system to recognize a scene and its elements. In mobile systems can also allow the robot to identify and navigate around its environment. In general an AV system consist of five stages: the data acquisition, preprocessing, segmentation, feature extraction and classification, but depending of the complexity of the application some of these stages can't be included or modified [5]. An example of positioning is showed in [6]. Here the target is to place a disk in a hole. Given that the disk position related to the hole is unknown, it is necessary to use an illumination set to project points to the disk surface, then the lights are detected by the control cameras and the disk location is estimated. The algorithm makes a triangulation process to determine the disk disposition. Other application of MR is the exploration of hostile places like the ruins after an earthquake, places with chemical contamination or in the extraterrestrial exploration in the same way as Curiosity in Mars [7]. The previous scenario is possible to achieve in most cases thanks to the incorporation of environment mapping and route planning systems and strategies. First, the environment mapping consist in building a surroundings virtual representation [8], this representation enables the robot to identify obstacles for its navigation. In [8] the desing of a 3D sensing system for a Unmanned Ground Vehicle (UGV) is described. The autors reviewed different technologies for mapping, including Ultrasonic based systems [9], RADAR (Radio Detecting And Ranging) systems [10], systems based on stereoscopic cameras [7] and LIDAR systems (Light Detection And Ranging). After this review, the authors described the UGV designed, and the technology used for mapping is a LIDAR System. The work showed by [11] uses a stereoscopic vision system to obtain a 3D matrix, the dimension of this matrix is $264 \times 264 \times 64$ in order to build the representation of a space with 6 by 6 by 2 m. The crayfish algorithm allows one to define camera 3D rays, through this rays it is possible to found displacements that corresponds with object location. This work allows the representation of the environment with full definition and it is useful for high perception robots. In [12] the authors present the development of a MR under the Open Unified Process methodology. The robot works with a stereoscopic vision system to identify the place around, whit this the robot identifies obstacles and determines routes from 2D images. Other strategies to route planing are the use: of potential fields, Brownian particles and Dijkstra algorithm for multi-target routes. In general, the route planning strategy depends of the localization and mapping system. In this work, a MR developed over an Arduino® board is showed. This robot uses a localization system based on motion caption and is provided with an infrared distance sensor which permits the environment mapping. The control system is centralized in a PC, where the algorithms to calculate orientation of the robot are implemented in Matlab®. The Matlab® implementation also supports the algorithms for calculating the best route obtained after the surroundings mapping, and the virtual map is built too. The communication protocol was implemented with WiFi technology and the robot mechanical behaviour corresponds to a differential architecture. Forward, the article is organized in this way: First, in Sect. 2 the equipments and methods are presented, then in Sect. 3 the results are showed, finally in Sect. 4 there will be the conclusions of this research.

2 Equipment and Methods

The main goal of this research is to develop an environment mapping by tracking the position and orientation of a mobile robot inside a controlled area. For the detection of position and orientation of the robot a (Motion Capture) MoCap System is used, which broadcasts the current status of the vehicle to a main control script written under the Matlab® Environment. The mobile robot is communicated with the main PC via WiFi in order to constantly send and receive data.

2.1 MoCap System

This research takes place thanks to a MoCap System composed by twelve infrared Flex 3 cameras and the software Motive©, both manufactured by OptiTrack™. The cameras are placed on a rectangular frame of 3.8 by 7, 3.5 m above the ground. Figure 1 shows the laboratory setup, where it is possible to appreciate the rectangular frame and the capture area where the cameras are aiming to. This capture area is 2 by 3 m approx (Fig. 2).

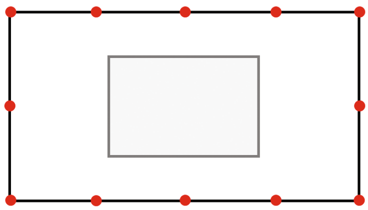

Fig. 1. The external *filled circles* represent the cameras and the *inner rectangular* area represents the capture volume

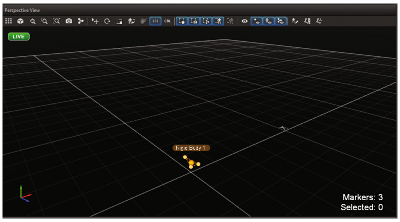

Fig. 2. Motive© live capture interface and rigid body creation

The cameras used for this study have a capture rate of 100 *FPS*, a video resolution of 640 × 480 and a maximum range of detection of 11 m [13]. On the other hand, the software which the cameras where connected to, gathers the information sent by the cameras to create a 3D data set. Motive© builds a tridimensional matrix that contains the xyz coordinates from each one of the markers placed inside the capture volume [13]. In order to track the robot in "Real Time", Motive© broadcasts the 3D data of each rigid body and the markers attached to it, to an interface named *NatNet* [14] written in Matlab®, provided by OptiTrack™. The original *NatNet* script was modified so it could send to another PC the raw data needed to calculate position and orientation of the vehicle. For the detection of the vehicle, three markers are placed on its top, forming an isosceles triangle aiming to the front of the robot. The reason of this setup is that the MoCap software needs at least three markers for crating a rigid body, and a rigid body is needed for broadcasting data via *NatNet*. As a result of the creation of the rigid body, Motive© creates a virtual marker placed at the geometrical center of the object, which is also transmitted by the *NatNet* interface.

2.2 Mobile Robot

The robot used in this research has a differential architecture (Fig. 3), which means that its movement is generated by two independent wheels placed in the rear of the car, each one attached to a DC motor, and a free wheel in the front. The vehicle is controlled wirelessly by an ESP8266 WiFi module attached to an Arduino® board, from a PC using Matlab®. The Arduino® script receives orders from the PC like going forward, going backwards, rotating clockwise (CW), rotating counter-clockwise (CCW) or stopping, which results in the control of the direction of rotation of the actuated wheels. The vehicle is also equipped with an infrared sensor placed at its front, in order to detect and avoid obstacles ahead of it. In the case and obstacle is detected, the robot stops and sends data about the distance between itself and the obstacle to the PC so the main algorithm could be able to build a mapping image of the environment.

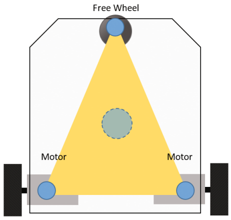

Fig. 3. The schematic representation of architecture used for the mobile robot and the location of the markers

2.3 Robot Tracking and Environment Mapping

The origin $(0, 0)$ of the controlled area's coordinate system is placed at the exact geometrical center of that area so all the coordinates and vectors are measured relative to that point. The *NatNet* interface sends the 3D coordinates of the geometrical center and the front marker of the robot, relative to coordinate system mentioned before, to the main Matlab® script and then, with that information, an algorithm calculates the position and orientation of the mobile robot. The main task of the mobile robot consist in defining a target xy coordinate to achieve, enclosed in a certain area. When the destination is determined, two vectors are created in order to determine the orientation of the vehicle relative to its target. The first action is to align the robot with the desired destination by rotating clockwise or counter-clockwise and the next action is to achieve the target by moving straight forward. Here, the problem is to determine what kind of rotation (CW or CCW) must be done by the vehicle. To do so, a coordinate system transformation is needed. The coordinates of the target are transformed to a local coordinate system centered at the geometrical center of the robot, whose $X\ axis$ is the vector created between the center of the car and the front marker (Fig. 4). If the target is placed in the first or second quadrant of the local coordinate system, the robot must rotate CCW, and in the other case, the robot must rotate CW. To determine the quadrant where the target is placed, it is only necessary to calculate the y (vertical) coordinate according to the car, as shown in Eq. 1, where β is the angle between the vehicle's system and the reference system, θ is the angle between the vehicle and its destination and r is

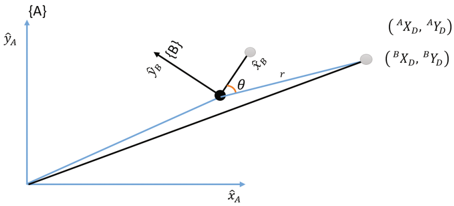

Fig. 4. Local coordinate system determination for the robot rotation

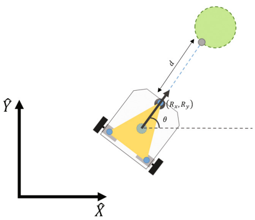

Fig. 5. Environment mapping representation

the distance between the center of the car and the target.

$$^{B}Y_D = r \sin\theta \cos\beta - r \cos\theta \sin\beta \tag{1}$$

When the robot finds an obstacle on its path, it stops by a certain distance before the object. The obstacle and that distance are detected and measured by an infrared distance sensor placed under the front marker, so the detected object is aligned with the direction vector of the vehicle. The main tracking and control PC is able to determine if the robot has stopped, in which case it is asked to the vehicle for the measured distance. The xy coordinate of the obstacle is calculated with the measure given by the robot and its position and orientation, detected with the MoCap system (Fig. 5). A monochrome image is built for representing the controlled area and the objects detected inside it, where every black pixel corresponds to an obstacle or a point from the frontier of the navigation area, and its resolution equivalent is one pixel per squared centimeter. Every time the robot sends a distance, a coordinate is calculated and then its corresponding pixel of the image is filled black.

3 Results

As a result of this research, a differential mobile robot was built and two Matlab® Graphical User's Interfaces (GUIs) were created in order to control the robot via WiFi connection (TCP/UDP). One GUI performs a manual control by push buttons and keyboard entries (Fig. 6) and the other GUI performs an automated control by giving a desired destination xy coordinate, while making a live tracking of the vehicle via *NatNet* (Fig. 7).

The manual control GUI has five different movement actions: straight forward, straight backwards, rotate CW, rotate CCW and to stop. There are also manual increasing and decreasing speed buttons for both motors independently. All these previous actions were also mapped with the keyboard, following this equivalence:

- W: Straight forward
- S: Straight backwards
- A: Rotate CCW
- D: Rotate CW

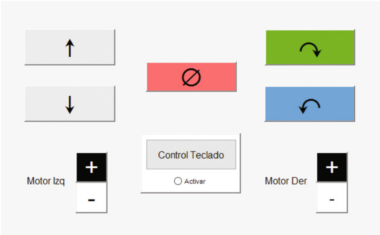

Fig. 6. Manual control GUI

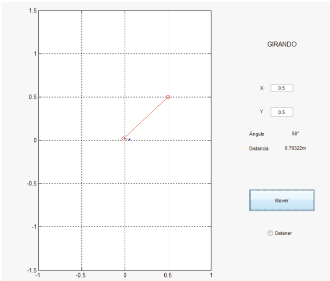

Fig. 7. Live tracking control GUI

- Q: Stop
- I: Increase Left Motor speed
- K: Decrease Left Motor speed
- O: Increase Right Motor speed
- L: Decrease Right Motor speed

The live tracking control GUI asks the user to enter the target xy coordinates for the vehicle to achieve, if the user gives a point outside the defined area, the GUI will ask for another pair of coordinates. The mobile robot's movement control is a simple iterative proportional approach with hysteresis. When the vehicle is not aligned with its target, the control algorithm decides the direction of rotation (CW or CCW) in order to place the robot aiming to the destination and then proceeds to move straight forward. This process is not made in this two basic steps given that the robot is not able to move exactly in a straight line. The vehicle has to recalculate and to correct its trajectory several times before arriving to the destination point. According to the environment mapping, the vehicle stops at the presence of an obstacle placed in front of it. The main PC detects this state of the robot by calculating the standard deviation between the last positions of the car, and when this parameter is close to a minimum value, it will be considered that the robot has stopped. After this detection, it will be asked for the car to send via WiFi the value of the distance between itself and the detected object. With this information and with the position and orientation of the robot, the exact coordinate of the object is calculated and then,

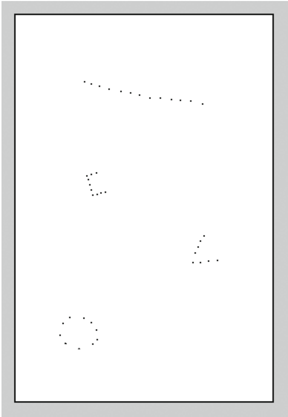

Fig. 8. Example of constructed map for several objects

this coordinate is filled in the monochrome map of the controlled environment (Fig. 8).

4 Conclusions

The main difficulty with the robot is to achieve a straight trajectory, since the inherent difference between both motors, in spite of having the same reference and manufacturing. To resolve it, various strategies were used: first, the evaluation of different chassis was useful to determine the most appropriate structure to accomplish the wheel proper alignment. Moreover, it was necessary to evaluate the used wheels, because the MR traction depends on the materials and dimensions. Other guideline was the use of gearboxes, facilitating the speed control. Nevertheless the gearboxes increase the current intake. The most remarkable improvement was the implementation of opto-interrupter speed controllers. This system senses each wheel spin, then by means of interruptions in the Arduino® board, it is possible to synchronize the motor speed. Even, after the described improvements, the straight movement it is still not too accurate. Taken into account the idea to build a MR with the lower cost, other relevant aspect was the communication system. In that sense, it was evaluated the option of using HC-05 and HC-06 bluetooth modules, broadly used in embedded systems. The lower transmission range and its unstable connections contributed with the exploration of other modules. The use of the ESP8266 module proved a better performance, and for this reason the communication protocol was implemented over UDP and TCP/IP standards. The current communication protocol sends to de Arduino® board a string composed by only the word "dat" followed by a three digits number. This protocol has proven to be useful but also to be so simple. It is necessary to improve this method by adding, for example, another combination of letters at the end of the sent word in order to assure a correct received string. This strategy can also be improved by ordering the board to write a certain speed (by a PWM signal) to the motors and not only to increase or to decrease such value by a predefined increment/decrement on the Arduino® algorithm. Given that the vehicle requires for a user to give it a destination coordinate so it can detect and map several obstacles, the need to implement an autonomous trajectory algorithm to navigate the environment is evident, in order to achieve a complete mapping of the obstacles placed inside the controlled area. The mobile robot's technology is as simple as it can be (not the markers system), so its performance is not perfect. The automatic positioning approach has a success rate of approximately 60% because of the poor mechanical performance of the vehicle; it is necessary to improve the motors control and speed. Another issue with this system is the required time for the robot to get to its destination. The selected control strategy requires several iterations for the robot to achieve its goal; sometimes it takes almost 5 min to travel a distance of 2 m when the robot is not properly aligned with its destination, so this could be accomplished by programming a PID (or a more complex) control strategy.

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Decision Support System for the Negotiation of Bilateral Contracts in Electricity Markets

Francisco Silva[1], Brígida Teixeira[1], Tiago Pinto[1,2(✉)], Isabel Praça[1], Goreti Marreiros[1], and Zita Vale[1]

[1] GECAD - Knowledge Engineering and Decision Support Research Center, Institute of Engineering - Politechnic of Porto (ISEP/IPP), Porto, Portugal
[2] BISITE - Research Centre, University of Salamanca, Salamanca, Spain
{fspsa, bccta, tmcfp, icp, mgt, zav}@isep.ipp.pt
tpinto@usal.es

Abstract. The use of Decision Support Systems (DSS) in the field of Electricity Markets (EM) is essential to provide strategic support to its players. EM are constantly changing, dynamic environments, with many entities which give them a particularly complex nature. There are several simulators for this purpose, including Bilateral Contracting. However, a gap is noticeable in the pre-negotiation phase of energy transactions, particularly in gathering information on opposing negotiators. This paper presents an overview of existing tools for decision support to the Bilateral Contracting in EM, and proposes a new tool that addresses the identified gap, using concepts related to automated negotiation, game theory and data mining.

Keywords: Automated negotiation · Bilateral contracts · Data mining · Decision support systems · Electricity markets · Game theory

1 Introduction

Since the beginning of the 21st century, the EM have undergone a profound restructuring, proceeding to its liberalization. Therefore, EM became more competitive, but also more complex, resulting in increased unpredictability [1].

Nowadays, new challenges arise regarding the increasing usage of energy from renewable sources. The European Union (EU) has defined a set of policies and standards that contribute to the large-scale implementation of distributed generation, in order to encourage and increase the use of this type of energy. An example would be the "20-20-20" program [2]. However, the usage of this energy type introduces a new source of unpredictability in the sector, due to its intermittent nature. As such, the unpredictability and risk in the EM are increasingly higher, considering the great complexity of the interaction between its participating entities and the large number of associated variables, which hinder the decision-making process. In this context, EM simulation proves to be a great

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tool for decision support, through the study of the inherent mechanisms of these markets as well as the relations between the entities (players), by analysing their profiles, behaviours and strategies [3]. Although there are several EM simulators, few are the ones that provide support for negotiation among players.

This paper intends to address the identified gap, aiming to propose a solution that allows participating agents to obtain the best possible results, considering their objectives. As such, it's considered a Decision Support System (DSS) for bilateral contracts, including methodologies for the pre-negotiation phase, particularly in the profile analysis of opposing negotiators. This way, it allows adaptability of the negotiation strategies, which together with a contextual analysis, gives the capability to analyse and identify different contexts of negotiation.

This paper is divided into five sections: Bilateral Contracts in Electricity Markets, Multi-Agent Simulators as Decision Support Systems in Electricity Markets, Proposal, Experimental Findings and Conclusions.

2 Bilateral Contracts in Electricity Markets

EM are constantly evolving and adapting. Currently, most countries have their own market or participate in regional markets, together with neighbouring countries [4]. EM are composed of several market types [5,6], based on three different models, which are (I) day-ahead spot, (II) intra-day, both usually auction based, and (III) bilateral contracts models.

In the scope of EM, bilateral contracts are long-term contracts established between two entities, buyer and seller, for energy transaction, without the involvement of a third entity. The transaction is usually carried out several weeks or months after the contract is made [7] and usually has the following specifications: start and end dates and times; Price per hour (€/MWh) and amount of energy (MW), variable throughout the contract and, finally, a range of hours relative to the delivery of the contract. Players can use customized long-term contracts, trading "over the counter" and electronic trading to conduct bilateral transactions [8]. There are four types of bilateral contracts: the first type are Forward Contracts, that consist in energy exchange between a buyer and a seller for a future date, for the price negotiated at that moment; the second type are Future Contracts, which are similar to Forward Contracts except that they are managed by a third party responsible for ensuring compliance with the agreement; the third type are Option Contracts, that are similar to the Forward and Future contracts with the difference that the two entities only guarantee a buy/sell option; the last one are Contracts for Difference, that allows entities concerned to protect themselves from the energy price change between the date of establishment of the agreement and the agreed date of exchange.

With the exception of Contracts for Difference, this type of negotiation allows players to control the price at which they will transact energy, in contrast to what happens in spot markets, due to the proposals' instability. In establishing a Forward or Future contract, players are committing themselves to transact energy for a given price at a future time, with the risk of making a transaction at a lower price than the expected and lose competitive power. Option Contracts or Contracts for Difference can avoid this risk. The first allows the player to choose not to go through with the exchange while the second ensures that the transaction is carried out at the market price. However, the first option also has the risk of not guaranteeing whether or not the other party will exercise their option to exchange and the second option does not allow better prices than the market. This way, it is possible to understand the risk associated with the negotiation of bilateral contracts and the need that players have of tools that help them reduce this risk and even optimize their profits.

3 Multi-agent Simulators as Decision Support Systems in Electricity Markets

The vast majority of EM simulators are focused only on market analysis and are void of mechanisms that allow their users to get support for direct negotiation. Particularly with bilateral contracts, there are gaps in decision support systems, namely in obtaining information about the opposing party [9]. This leads to an urgent need to acquire new methods that support the decision process, such as the definition of suitable models, choice of the best candidates to close the deal, analysis of the previous transactions of these candidates and strategies to employ to get the best deal possible. One of the main advantages of using MAS for the implementation of these simulators is that they have software agents that, by definition, interact with each other autonomously in order to meet an objective [10].

In the literature, it is possible to find references to systems that allow the simulation of bilateral contracts in the context of EM. Some examples are The Electricity Market Complex Adaptive System (EMCAS) [11], The Multi-Agent Negotiation and Risk Management in Electricity Markets (MAN-REM) [9] and The General Environment for Negotiation with Intelligent Multi-purpose Usage Simulation (GENIUS) [12]. These simulators are based on phased negotiation approaches, following the ideology of automated negotiation (see Table 1), namely in the definition of the pre-negotiation, actual negotiation and analysis of the results in order to adjust future proposals. However, these simulators do not respond to the problem already identified, that is, in the pre-negotiation phase, a detailed study of the characteristics of possible opponents does not occur, in order to perceive which are best suited to their objectives and which negotiation strategies should be used with each one of them, in order to close the best possible deal.

Table 1. Phases of automated negotiation problems (Adapted from [9])

Group	Component or dimension
Preliminaries	Social conflict (detection and exploration)
	Negotiating parties (number of parties)
Pre-negotiation	Structuring of personal information (definition and execution of key pre-negotiation tasks)
	Analysis of the opponents
	Protocol and selection of the initial strategy
Actual negotiation	Exchange of offers and feedback information
	Argumentation (threats, promises, etc.)
	Learning (in negotiation)
	Dynamic strategic choice (new strategies)
	Impasse resolution
Renegotiation	Analysis and improvement of the final agreement

4 Proposal

This DSS focused on the Pre-Negotiation phase, joining the Preliminary and Pre-Negotiation phases of automated negotiation. This union simplifies the system given the proximity of the two phases, being joined in most models. The DSS is intended to support an agent who intends to transact energy with other agents through bilateral contracts. The agent supported by this system may be any type of entity interested in transactions within the electricity markets. The agent will use the system whenever it intends to enter new bilateral contracts and wish to guarantee the maximum possible gain. When an agent pretends to enter into a bilateral contract market, it can find more than one competitor. Weighted competitor choice is very important when maximizing profits. Moreover, this decision does not necessarily fall on the competitor who can offer the best proposals. The competitor's ability to comply with the agreement is a very important factor. The fulfilment of agreements, however promising they may be, with competitors who fail to do their part ends up being a great waste of time for the agent and compromising his management.

For decision support in this stage of negotiation, the system uses a scenario analysis method based on game theory. The outputs of this method are the choice of the most favourable competitors, the distribution of the amount of energy, to be negotiated with each of the selected competitors, which guarantees greater profit, and the price that each competitor is expected to show.

As can be seen in Fig. 1, the proposed method is composed of three parts: Scenarios Definition, Possible Actions Definition and Decision Process. The Scenarios Definition consists in the specification of the different negotiation scenarios that the supported agent can find. The results of the potential competitors in the past are analysed and, by means of forecast algorithms, the prices of the

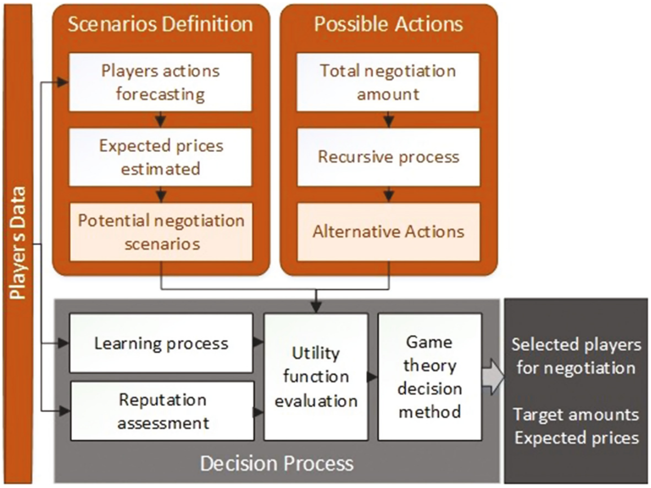

Fig. 1. Diagram of proposed methodology

competitors, for different amounts of energy, are forecast. When there is not enough history to make forecasts, an estimation process is necessary. The Possible Actions Definition are the generation of all alternative actions that the supported agent can take. The total energy to be negotiated with each competitor is determined through a recursive process to exploit all possibilities. The last part, Decision Process, is composed by the choice of competitors to negotiate with, the respective amounts of energy and the expected prices. For this purpose, a game theory approach is used to evaluate the potential outcome of each scenario-action combination through a utility function. The appraisal also considers the reputation of each competitor and also uses a learning process, which allows to know which scenarios are most likely to occur in each context.

Concerning the user's interaction with the system, a graphical interface is available, allowing the user to enter his objectives and his possible competitors, obtaining the ideal solution (the quantities to be negotiated with certain competitors and the expected prices) coupled with an explanation of the results.

5 Experimental Findings

This section presents a case study that allows the evaluation of the proposed tool's operation. In order to facilitate the analysis of results, it's considered a simple scenario in which the supported player intends to buy 10 MW in a weekday context. In order to obtain decision support on the opponents to negotiate, and corresponding quantities, the supported player indicates the 5 players that it can negotiate with. From his point of view, the calculation of each opponent's reputation should have as much importance to his personal opinion as the social opinion. The social opinion itself will be calculated giving the same weight to the supported group's members' opinion, as well as the group of each target player. The decision method to be used is the Most Probable, which selects the action with the highest utility of the most probable scenario, determined by the learning module. Finally, regarding the risk value, several tests will be carried out in order to perceive its impact.

In the first stage, a forecast is performed to obtain the price that each opponent may propose, considering their contracts history. In case of unsufficient data to forecast the price for a given quantity, a value is estimated, considering the price forecasts for the other quantities. Figure 2 shows the forecast results.

Supported by the data in the application's database, it was possible to forecast the expected prices for all quantities for all opponents, with the exception of the 10 MW quantity. The estimation made for this quantity shows prices close to those presented in the remaining amounts of energy, except for the estimated price for Player 4. In this case, there is a deviation from his normal behaviour due to forecasts of quantities exceeding 10 MW, which presented a significant downward trend. Taking into account the results of the forecast phase, Player 4 presents the best selling price, precisely for the amount of energy that the supported player intends to acquire. However, the final decision will also depend on each opponent's reputation (see Table 2).

As it can be seen in Table 2, the player with the highest reputation is Player 2, followed by Player 5 and then Player 4 (player with the best selling price). Depending on the player's propensity to risk, reputation may not favour Player 4 against Players 2 and 5 who, despite not having such attractive sales prices, are more secure due to their reputation. To determine the best choice the supported player can take, all possible actions are generated and the utility value of each one is calculated. The range of possible actions are the maximum number of different

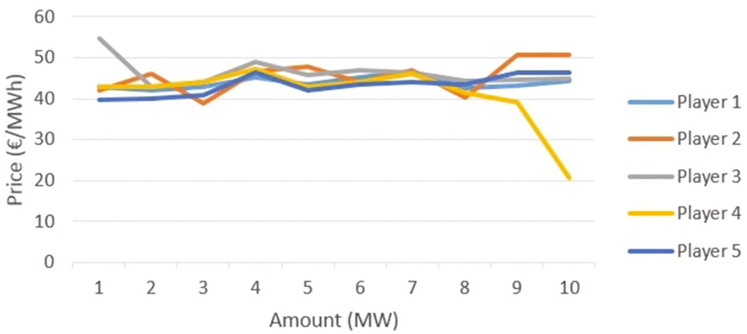

Fig. 2. Opponents expected price per energy amount

Table 2. Reputation of the opponents

Player ID	1	2	3	4	5
Reputation	0.275	0.575	0.125	0.325	0.425

power distributions by the various opponents, from trading 10 MW with only one player, to trading the same amount, but divided by several players (Example: 6 MW with one player and 1 MW with each of the remaining). The actions' utility value combines the reputation of the players to trade in that action, with the economic advantage it can bring to the supported player. The two components' weight varies depending on the supported player's risk propensity. The risk value ranges from 0 to 1 where 0 is the minimum risk and only the reputation component is considered and 1 is the maximum risk, where only the economic component is considered. The number of possible distributions of 10 MW per 5 players is 1001, a very high number, considering the amounts of energy and possible opponents in question. Through the Most Probable decision method, it was possible to obtain the negotiation recommendations presented in Fig. 3, for different risk levels.

Figure 3 shows that in case of risk 0, that is, each action is evaluated only by the reputation of the players involved, it's recommended to transact all the energy with Player 2, the player with the highest reputation. By increasing the risk to 0.25, it's no longer advisable to negotiate all power with Player 2. The supported player should only transact 8 MW with Player 2 and 2 MW with Player 5 (second highest reputation). In this case, some security is abandoned in favour of a more economically advantageous transaction. This is followed by a case where the risk value is 0.5, where the reputational component is as important as the economic component. In this case, since Player 4 has a superior advantage in the economic component than Players 2 and 5 in the reputation component, he's selected to transact the 10 MW. Being Player 4 in advantage, the risk increase, favouring the economic component, will keep the recommendation in his favour.

Through this case study it is possible to perceive the advantages that a player, intending to make bilateral contracts, may have when using this decision support system. The system presents the expected results according to the supported player's expectations and presents the best solution in the middle of a very high number of possible actions in a large number of scenarios that would otherwise be practically impossible to achieve.

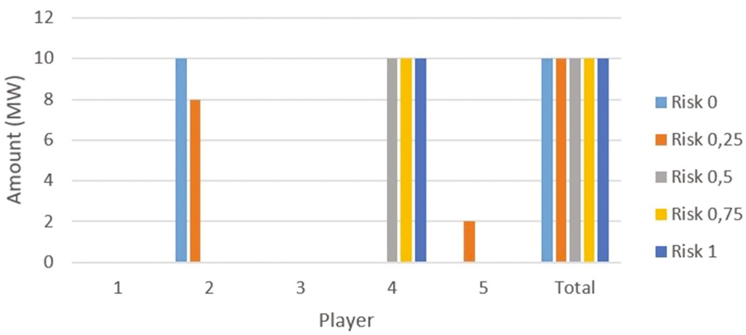

Fig. 3. Actions for different risks

6 Conclusions

The paper presents a state of art for bilateral contracting in EM as well as acknowledgement of automated negotiation as the main strategy for modelling this type of simulators. It was concluded that the simulators seek to follow the automated negotiation phases, but present weaknesses in not exploring the information of the opposing traders in the pre-negotiation. Thus, a DSS that proposes a solution to the identified problem is presented, which uses data mining techniques and game theory to select the players with whom they intend to negotiate, fulfilling their requirements. A study was performed in order to demonstrate the advantages of the tool for the decision maker.

As future work, alternative approaches to the Possible Actions phase will be considered, to present an higher performance while keeping the quality of results.

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T2*—Personalized Trip Planner

Joao C. Ferreira[1(✉)], Ana Lucia Martins[2], Jorge Vieira da Silva[3], and João Almeida[3]

[1] Instituto Universitário de Lisboa (ISCTE-IUL), ISTAR-IUL, Lisbon, Portugal
joao.carlos.ferreira@iscte.pt
[2] Instituto Universitário de Lisboa (ISCTE-IUL) Business Research Unit (BRU-IUL), Lisbon, Portugal
almartins@iscte.pt
[3] Card4B – Systems S.A., Lisbon - Portugal/MASAI Mobility Community, Brussels, Belgium
mta@teleticketing.eu, joao.almeida@card4b.pt

Abstract. In this research work we describe the framework for a Personalized Trip Planner identify as T2* (Travel to Anywhere) towards a digital concierge in everyone's pocket by a tailor made aggregation of features and services. The mission is to empower key stakeholders in the travel and tourism industry (Travelers, Concierges, and Service Providers) to develop seamless travel experiences. This work is integrated with the MASAI H2020 project with the goal to serve in all stages of the travel process, including changes in travelers' mobility patterns, associated local travel, long-distance travel, and business as well as to be used for leisure purposes. A personalized travel advice is produced based on the user' profile created based on the user' Facebook information extracted through a semantic approach. The quality of the service provided is measured and high-level service is promoted by an implemented reputation service.

Keywords: Multi-Modal · Journey planner · Ticketing · Personalized travel planner · Transportation data integration · Integration · Concierge

1 Introduction

Consumers regularly search for, purchase and share travel information online. According to the Google Travel Study 2014, about 80% of business travellers and 78% of leisure travellers use online sources in their travel planning and for their eventual purchases [1], where 25% of total global travel sales are done online, and this percentage is rapidly increasing [1]. Air transportation comprises 46% of total online travel sales while online travel accommodation sales comprise 23% [1]. The US and Europe are the regions accounting for most of these sales, while the Asia Pacific region is expected to double its online travel sales by 2017. In Europe, online hotel sales are experiencing a rapid growth. By 2017, Western Europe is expected to reach a rate of 40% of total sales, while Eastern Europe is expected to reach 24%. Online Travel Agents (OTAs) offering superior site tools and options (e.g. Expedia, Priceline or Sabre) are increasingly consolidating the traveller market, leading to stiff competition

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with direct suppliers. OTAs from emerging markets are expected to expand in advanced markets in the near future [2]. According to the World Travel Monitor in 2015, about 70% of international travellers are active social media users. Social media is now influencing the decision making process of approximately 25% of all international trips, with destination choices (about 40%) and accommodation choices (about 30%) being the most common. Nearly 50% of travellers are posting their experiences on review sites (e.g. TripAdvisor) and travel blogs/forums [2]. The trend in sharing travel related reviews and content on social media in recent times is expanding into a level ahead where the sharing of travel services (e.g. Airbnb, BlaBlaCar and Vayable) merge with active consumers providing apartments, cars, meals and tours. Shared usage platforms are changing the travel economy, giving people new options about where to stay, what to do and how to get around. Adapting to this new reality by monitoring user-generated content and cooperating with social media is of great importance for the tourism market and its destination management. Big Data, which is increasingly gathered from cities and public organisation by digital sensing devices and networks, allows Concierge and Service Providers to supply customers with targeted options and personalised offers for a more tailored travel experience. The customer's demand for real-time services is rising with services required to be easily accessible via multiple devices (desktop/tablet, smartphone) with a 24/7 availability. Since poor site experiences often lead to negative impacts on companies and brands, a flexible technological architecture is required to reach consumers on all screens. Concierge and Service Providers need to adopt a holistic approach capable of following customers through all stages of their travel process (dreaming, planning, booking, anticipating, en route, destination) [2].

The creation of seamless travel requires a closer cooperation between large varieties of industry and policy makers to design services involving integrated ticketing/pricing and infrastructures responding to all travellers' needs. Multi-stakeholders governance models require the alignment in a multi-stakeholder environment (authorities, citizens, and private sector) as well as supported implementation based on a suitable standard that can perform as a major driver of innovation for making travel more comfortable, efficient, and sustainable [3].

Drivers of this approach—The travel and tourism industry is changing due to consumer demand and new possibilities brought advances in technology. This is providing new business opportunities at a fraction of the cost that they were years ago. The future of travel is based on an open ecosystem providing a seamless multimodal door-to-door travel experience. The economics of innovation is altered with cloud based applications. New opportunities can be tested and piloted without major start-up costs. The mobile app ecosystem and connected services are suitable for immediate adaptation, allowing purchasing resources in real time. The cloud has the ability to dynamically scale up or down the infrastructural commitment when demand changes on a pay-as-you-go. This ability has an enormous impact on the service provider's costs. Risks can be reduced thereby increasing potential return [4]. Alongside of this there is a growing API [5] economy that is making our world even more than ever plugged in. Highly complex technical products, which have a development technique in the R&D and IT field based on the need of sharing information and enabling transaction processing APIs, are able to close the gap between business and IT and are supported by the trend of integration in sophisticated ecosystems—elevated to become business model drivers [6].

This work is integrated with the MASAI H2020 project (http://masai.solutions). The MASAI idea originates from the classical concierge model—introducing the conceptual role of a concierge between the traveler and the Service Provider, which can, in principal, be taken on by anyone in the ecosystem. This model, in fact, already exists in the form of hotel concierges and travel agencies as well as in the electronic form of OTAs and travel product related search engines. Tech Start Ups, betting on fully artificial intelligence enabled concierges [7] are continuously being launched. International companies like BMW with their Concierge Start-up Challenge (http://www.bmwstartupgarage.com) are supporting this trend by creating the most advanced humanoid artificial concierge.

2 Travel Planner Phases

Figure 1 shows that the traveler goes through different stages during every travel. Travel planning and booking is a process similar to a puzzle. The traveler often starts using search engines with only a vague idea in mind, before refining it based of further inspiration. At the beginning of the decision making process the traveler relies heavily on consumer reviews and social media. During the different stages, the customer switches devices, interfaces, apps and websites on many occasions in order to research destinations, to compare prices and then to book transportation or additional services. While according to some sources, travelers visit about 6, 5 different websites on average per booking [8], Expedia research shows that average segment travelers visit up to almost 40 pages during the booking stage [9]. Some professionals quote an average of 80–100 clicks used to organize an accommodation solution. Travelers rely on the internet at all stages of the traveling experience, but some devices are more frequently used in certain phases than in others. Using smartphones and tablets for research, consumers often switch to their laptop or computer to make their final booking [9]. Statistics show that nearly half of those who use their smartphone for leisure travel information do not use this device for their booking [9]. The problem is that, as seen above, the traveler has to choose from many alternatives and has to put a lot of effort in the booking process. He can use different devices, encounter a variety of touch points and can choose from a large number of distribution channels, websites and apps. The fragmentation of the travel and tourism market described above is faced by the traveler who is then required to deal with this complexity, often feeling alone and overwhelmed by the process. Our proposal is an integrated solution, based on the usage of standardizations and complements to them in order to aggregate the services of the many Service Providers in the travel and tourism market. The aim is to provide a seamless intermodal travel experience for travelers through all stages of travel.

As suggested in Fig. 2, this integration task is performed through a domain ontology definition for travel where local public transportation operators' databases are mapped and integrated with PoI (point of interest) and information from blogs, twitter and facebook, through a retrieval engine that collect information and creates representative profiles. This facebook information can be the basis for the creation of users'

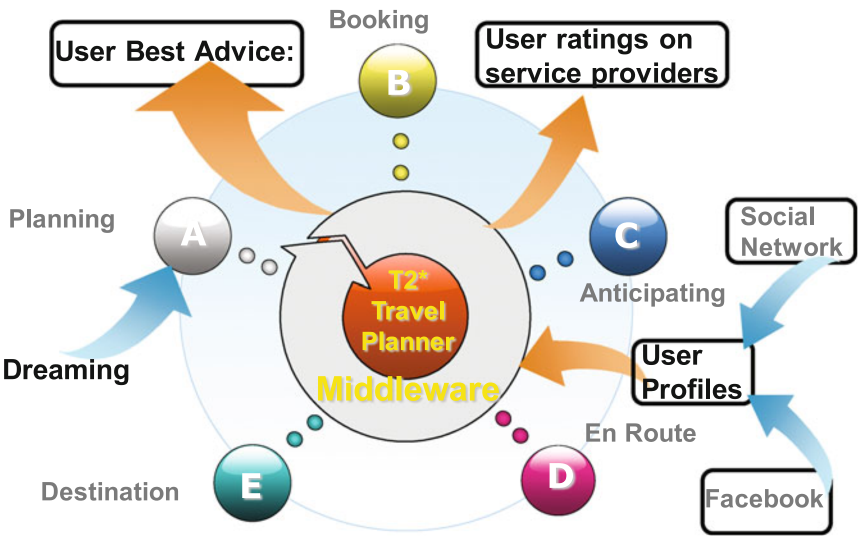

Fig. 1. T2*, a personalized travel planner

Profiles stored in the MASAI folder (helps to organise travelling and to manage personal data such as preferences, payment details and tickets), which can be divided into two categories: positive and negative. Positive is used to retrieve travel topics that users are interested in and negative profile is used to avoid past relevant travel topics that users manifestly demonstrated their dissatisfaction with or past topics that th e user is no long interested in. This profile can be built directly (the user provides the information) or indirectly by the system, through the extraction of user's facebook using their authorization and avaliable API. This user profile information can be aggregated in user communities. This process is performed through a semi-automatic process based on the clustering of the user profile description (positive profile) for communities. Clustering is based on a distance function within an N dimensional space. The similarities measured by the distance will be evaluated based on experience and on the singularity of treated subjects. Communities are only effective after a human authority decision. Every time a new member arrives, all partners of the community and in their neighbor communities should be notified through an automatic notification service. Feedback from the partners on judging this classification will contribute to a better define the community in a collaborative way. A central profile is used as community representative and will be identified as the nearest to the geometric centre of the community. The user's communities will provide useful information to different systems' stakeholders.

Mobile tourist guides have been in the spotlight for the past decade and are becoming increasingly available in various forms to tourists visiting places. The majority of these mobile tourist guides are to be used via a constant network connection and some as proprietary standalone mobile applications installed on-device. Some are solely navigational assistants using positioning technologies for large cities offering

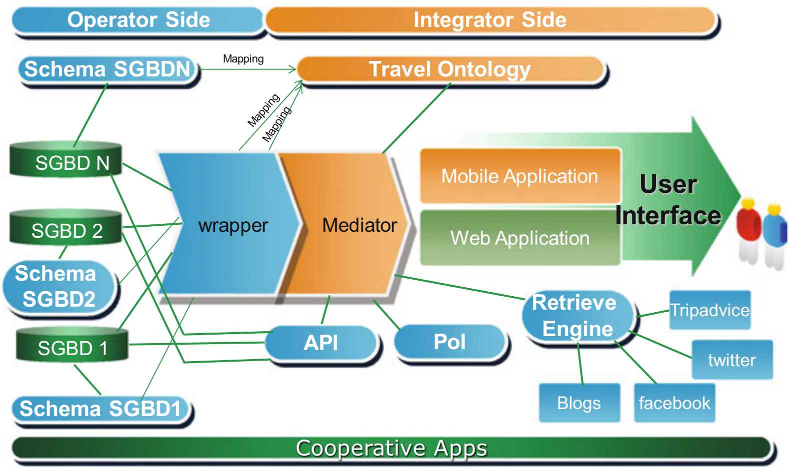

Fig. 2. Information and data integration process

exploratory services and others are used indoors, for example as museum guides. There is difficulty in obtaining information about traveling to, from and within a region, even in the same city due to the diversity of transportation operators. Most of these operators have their own system and plan the routes and schedules independent from nearby operators. Still, public transport systems differ from region to region. It is therefore understandable that when reaching at a destination, even for the most traveled person, it becomes difficult to use local public transportation due to poor organization of information and especially due to language barriers. This context denotes the scarcity of appropriate information systems to assist travelers in these destinations, including providing practical information essential to understanding the operation of the means of transport.

From several Public Transportation data base of consortium partners and standard specification, such as SIRI [10] and IFOPT [11], a common schema data was created. Figure 3 shows the main entities of the domain model. Travel Ontology is built on top of RDF using OWL (Ontology Web Language). Also in Fig. 3 (on the right) it is represented the relationship between the Operator, the Service and the Contact entities. Public transport operators are represented by the Operator entity. This entity is associated with the entity that represents the Service(s) provided by a particular operator. For example, in the Portuguese case, it indicates the case in which the operator Carris offers two services: bus and tram. The relationship with the entity Contact is due to the need that exists to represent the contacts provided by operators of public transport. The Contracting Service represents the services provided by an operator of public transport that can be, e.g. rail, road, air or water (sea, river or lake). Each service will be linked to a type, represented by the entity Type, which represents the categories within each mode, e.g. rail, bus, plane or ship. Within these types may still exist variants, the Variant entity. The Contact entity, represents the contact types, such as: electronic mail (email), telephone, address and website. This authority is shared by all entities Operator and POI (points of interest), because both the transport operator and points of interest have similar types of contact. POI entity are divided into categories which highlight, for example, Academic (Academic), Rest (Restoration), Monument (Museums) and others. Also Fig. 3 (left), illustrates the relationship between the entities Schedule, Stop, POI, Interface and Contact. Stop entity include the attributes: name of the stop, geographical coordinates (Latitude, Longitude) zone (taking the subway as an example verifies the existence of two areas, one inside the city limits and another in the vicinity). The association of the entity with the entity Stop with POI should be relevant to the fact that giving information about the area around the station so that users from other countries have tourist information. The relationship between Stop and Schedule justified with the representation of a schedule. T2* performs the role of a Concierge, both human and artificial to connect the aggregated mobile service offers with the traveler through personalized interaction. The touch point for the traveler is, at any one time, only one Concierge App used on the traveler's preferred device. To provide the Concierge App with full functionality several modules with data integration were developed to cover Fig. 1 main process of travel activity. From the first phase of dreaming and inspiration, the traveler can use the T2* Concierge App to get new ideas through interaction with the Concierge group. He can interact through one interface with his friends or travel experts who are also part of the group in order to discuss and plan upcoming journeys. As the final booking approaches, the digital Concierge will recommend hotels and look for the best prices. All of this is automated and requires no effort on the part of the traveler. To do this in a customized way and to respect personal preferences, the Concierge App accesses, with the traveler's permission, the traveler's personal data. All personal data from previous trips are saved and stored in the user's personal T2* Folder available in the defined midleware, which, for reasons of security and data protection, is in full control of the traveler at all times. The more information and travel preferences the traveler provides, the more accurate the ensuing search results and offers will be. With T2*, booking is quick, simple and convenient. The offered proposal of the T2* Concierge needs only to be confirmed and booking is finalized automatically. T2* uses a payment solution provider who handles the billing and distributes the payments. There is no need for the traveler to go through several transaction processes or to take care of many clearings or bills. Additionally, T2* allows recurring business trips to be easily booked with only one click. Ticket Organization and Travel Management with T2* After booking, all tickets are stored in the T2* Folder and displayed

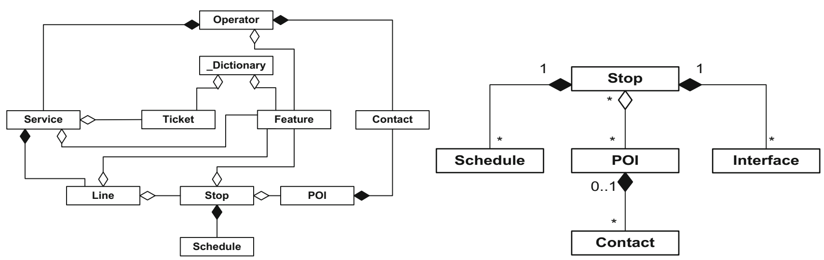

Fig. 3. Travel Ontology: entities in the domain model (*left*) and stop hierarchy (*right*)

in the Concierge App in one central place, according to trip and date. This provides an easy overview of all tickets, and avoids issues with printed tickets or with the need to check several apps.

3 Services Providers Reputation System

A reputation system collects, distributes, and aggregates feedback about participants' past behavior, helping users to decide whom to trust and encouraging trustworthy behavior [12]. There are many empirical studies concerning reputation systems, see Resnick et al. [13] for an overview. Various trust and reputation systems have been proposed or implemented in different areas. Some proposed classifications use their application areas [14], algorithms [12] or some combined characteristics [15] as criteria. These classifications allow looking at trust and reputation systems from different perspectives always from zero development phases. Since there are common modules and strategies among different systems, the idea is to build one based on a modular structure using a service approach. The reputation levels' system is inspired from videogames like World of Warcraft [16], which needs exponential requirements to level up.

Our system provides an input for users to express their opinion related to the experience with the service providers in the context of T2*. The information quality is rated by the as being helpful or not helpful (+1, −1). This range allows a less ambiguous evaluation, since it will influence the reputation of those who submitted the item. Using this schema, it is possible to filter and organize information by its quality and, at the same time, indirectly rate the user who submitted that information. In order to calculate the service provider quality itself, our system also provides an input for users to express their mobility experience quality by a quantitative rating from 1 to 5 stars, plus comment (output of Eq. (1) in Fig. 4). User reputation is based on their activity expressed by Eq. (2) in Fig. 4.

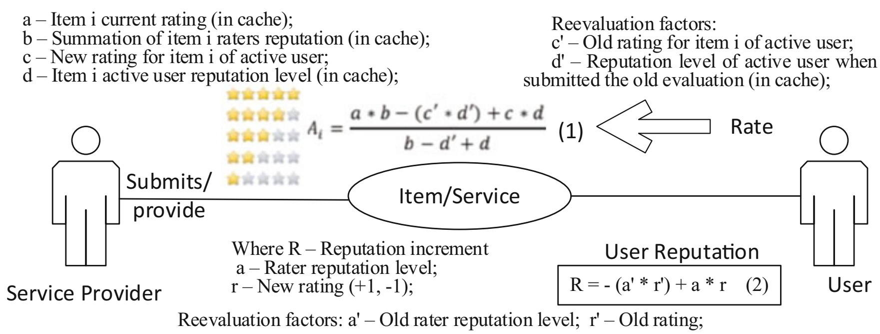

Fig. 4. Implemented service provide and user reputation

4 Conclusions

This work addresses the interconnection of digital services in order to facilitate mobility in heterogeneous and diversified environments. The core idea originates from the traditional personalized concierge services offered by hotels. Here the Concierge is a digital concierge linking up the traveler's demand with the products and services offered by all Service Providers connected to the MASAI community. The traveler enters contacts a MASAI Concierge Provider by using his favorite MASAI Concierge App. In order to provide the traveler with a convenient and compliant offer, the Concierge Providers' module is then linked to the modules of the multiple Service Providers participating in the MASAI community.

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Smart Management System for Electric Bicycles Loan

Jorge Revuelta Herrero(✉), Juan Francisco de Paz Santana,
Gabriel Villarrubia González, and Juan Manuel Corchado Rodríguez

Computer Science, Salamanca University, Plaza de la Merced s/n, 37008 Salamanca, Spain
{jrevuelta, fcofds, gvg, corchado}@usal.es

Abstract. Nowadays, in many urban areas we can find vehicle renting services, whose members can rent and deposit a vehicle. These services operate both nationally and internationally and the most commonly rented vehicle is the bicycle, this is because it is more personal, the hiring cost is low and it has no negative impact on the environment. This work presents an optimization method that seeks to minimize the time a bicycle user has to wait until they can travel to their desired destination; this will be done by adapting the stations at which the users deposit their bikes at the end of their trips.

Keywords: Bicycles · BSS · Electric bicycle

1 Introduction

The main problem facing bicycle rental services is providing service and satisfying the demands of a great numbers of platform users.

In the literature, the main way of tackling this problem is the use of a bicycle carrying trailer of a particular size, that would be in charge of redistributing vehicles at the service's rental stations throughout the day.

This work focuses on the creation of an optimization method that will help minimize the time platform users have to wait in order to rent a bike. This will be done along the day, by altering in a controlled way, the parameters of a series of trips known by some users. The method is based on the implementation of two individual algorithms: a heuristic that allows to alter the destination of the trips made by the users and a second heuristic that allows to alter both the place of origin and destination of the trips made by the users. Alterations that can cause an unforeseen shift in the user's trip, should be minimal, since they penalize the performance of the solution which must be able to satisfy user needs in a short period of time.

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In the Sect. 2, we review previous work related to optimization in the field of bicycle rental services. The Sect. 3, presents the proposed methods, the theoretical bases that underpin it and the methodology they conduct. In the Sect. 4, the proposed methods are applied to a specific problem. The Sect. 5 presents the results of the application of the proposed methods on the case study, as well as the conclusions made.

2 State of the Art

In the literature there are numerous works and articles related to optimization problems in the field of bicycle rental systems. Each of them deals with the same issue: the optimization of resources so that the service provided to the users could be more efficient and have less setbacks.

The work proposed by Chira et al. [3] raises the problem of Urban Bicycle Renting Systems. The infrastructure of the vehicle routes that connect the different stations and storage centers requires optimization. In the study, it is proposed to solve the *VRP* (Vehicle Routing Problem) with multiple storage areas, to which a fusion of evolutionary, nature inspired algorithms are applied, [2] with *Ant Colony Systems* [5].

The work proposed by Kadri et al. [11] addresses a crucial factor in the optimization of bicycle rental systems; the user's ability to pick up the bicycle at any station that he chooses as the point of origin and deposit the bike at any station that is the closest to the desired destination. To achieve this, the authors apply balancing systems to the *VRP* problem, considering a static case. The vehicles make routes through the stations and they must return to specific locations that are known a priori, and each and every station can be visited only once by each vehicle. The problem is addressed as a *traveling salesman problem* [10] with additional constraints.

In the work of [4] the authors propose the rebalancing of a bicycle rental system through an algorithm of destruction and repair. The metaheuristic of destruction and repair is combined and with a constructive heuristic and several local search procedures. The proposed algorithm is adapted to solve the *one-commodity Pickup and Delivery Vehicle Routing Problem with Maximum Duration (1-PDVRPD)*, which is the variant of the *Bike Sharing Problem* where the main restriction is the maximum duration for each route.

Other works, such as the one proposed by Frade and Ribeiro [6], also focusing on the lack of resources in the bicycle renting systems, approach the issue by constructing the stations from a series of maximum resources available, optimizing their locations according to the demands of the particular geographic location, so that the quantities of bicycles distributed are adequate to the demands in that area. The proposed method can be used on a restricted budget and makes use of optimization in order to maximize user demand coverage in bicycle rental systems. It uses strategic decisions in order to locate bicycle stations and define the size of the system (number of stations and bicycles) combined with operational decisions (bicycle relocation). The final model determines the optimal location of the stations and the number of bicycles per station.

The article by Alvarez-Valdes et al. [1] divides the bicycle rental problem into two main phases: the first phase makes an estimate of the future unfulfilled demands at each of the stations, for a certain period of time, and the possible number of bicycles at the beginning of each period. The second phase uses these estimates to guide the proposed redistribution algorithms. The proposed quality of service parameter uses known data which is provided by the rental system and which, given the initial number of bicycles in the establishment, performs approximations and statistical predictions for the future. This quality information measurement is applied in the second phase, a *VRP* in which the routes of the carrying trailers, which relocate the bicycles, so that they first reach the stations with the highest bicycle demand, they also collect the damaged bicycles and return them to the store.

3 Proposed Method

In this section we describe the methods and algorithms proposed, in the light of their limitations and the different points of view on the problem that we are dealing with and which has already been discussed in the previous section.

The main issue that impedes the implementation of the proposed method is the fact that the search in the solution space is discrete. Only the coordinates of the search space that correspond to stops in the different temporary instants (which are also discrete), are possible solutions or steps in the resolution of the problem.

In the same way, the time component that adds one more dimension to the problem causes the application of some of the previously presented algorithms to be discarded. The dependencies between the different solutions made for each set of trips are propagated in time in a chained way until the final solution is obtained.

It is for this reason, that the heuristic proposed by the method must be implemented iteratively, so that the solution to the problem does not belong to a single instance of the algorithm (local solution) but to a finite set of them, be solved in parallel and be able to obtain the best solution among all of them as a global solution to the problem.

The method used may be similar to the one applied by *Scatter Search* [7–9], since the solutions belong to the discrete point domain of the search space (coordinates of the service stops) along with a discrete-space search implementation similar to that proposed in *Swarm Particle Optimization* [12], where it is the set of particles that individually looks for candidate solutions problem and not the individual knowledge of the swarm of each where the solution to the problem is found.

The basic idea of the optimization procedure is that a set of users who make a specified route, at predetermined departure hours, can travel to their destination in the shortest time possible, and even though all routes will be executed, situations where the user cannot find a bicycle at the point of origin of their route, will be avoided.

The system can be modeled in the form of a fully connected graph, in which each of the nodes is a bicycle station and links the possible routes that can be traveled by users.

Each of the nodes on the graph, which represents a station in our system, contains information about its status, as well as the inclusion of states derived from the demand of the users when making routes. It is for this reason that the nodes contain a table of resources and demands that allow to manage the system's capacities for each one of the stations so that the best global solution is obtained. Resources and demands are represented are always represented in relation to the time frame which allows the system to place in discrete time units the arrival and departure of both resources and demands.

As can be seen in the Fig. 1, each of the stations is defined at the initial point of the route traveled through the demand made by the user on the travel platform, where the starting point and the finishing point of the trip can be seen and an established departure hour. In addition, the stations have bicycles that each user of the platform travels from a Point to an end point at a specific time at the beginning of the route. In addition, the stations have bicycles available for temporary use for the members of the platform.

It is easy, therefore, to be in a situation where a user who wants a trip at a given time, finds that there are no bicycles available at their place of origin. The objective of the proposed method is, therefore, to minimize the users' non-useful time, understanding non-useful time when a user has to wait for an available bicycle; sum of the waiting times of the users who do not find a bicycle in their place of origin at the moment of demand and the time it takes them to reach a different station, recommended by the system.

As can be seen in the Fig. 2, the proposed method allows the system to send users to stations that do not match the preferences chosen by the user in their route, thus allowing the system to restock the bicycles at other stations which have high demands and minimizing global waiting times. This movement produced by the adjustment of the method considers that takes into account that the user must travel by default more slowly between the user preference and the system recommendation, so that time cost is also used as a measure to be minimized in the algorithm.

The algorithm is based on a three-dimensional space where the two-dimensional spatial planes (x, y) are parallel to the third dimension (t), rep-

Fig. 1. Example of resource and demand tables for a stop in the system

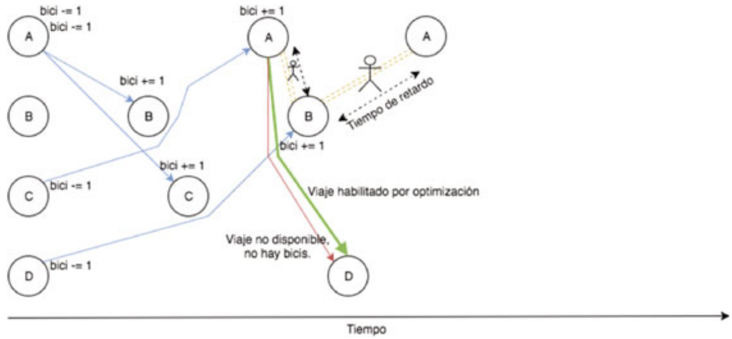

Fig. 2. Graphical representation of the proposed method

resenting the geographical locations of the stations in our problem as seen in Fig. 3. Each demand of a user generates a service request layout coinciding with the user's route demand and intends to find a P' for each P result of completing the trip and that it sums up the successive delays produced iteratively for each demand.

The result of the algorithm is the set of demand plans $P_0, \ldots, P_n$ and target plans $P'_0, \ldots, P'_n$ representing the destinations chosen and summing up all the delays produced T_d.

The first of the proposed methods only considers the change of the destination to which the user is guided, for each of the system demands, as shown below:

1. A $2D$ space is generated, of size $m * n$ (where m and n are the dimensions of the coordinate system) in which stations are placed randomly k with b of initial bikes each.

$$\begin{pmatrix} (k_i|b)_{0,0} & \cdots & (k_i|b)_{0,n} \\ \vdots & \ddots & \vdots \\ (k_i|b)_{m,0} & \cdots & (k_i|b)_{m,n} \end{pmatrix}, k_i \in K = k_0, \ldots, k_k \tag{1}$$

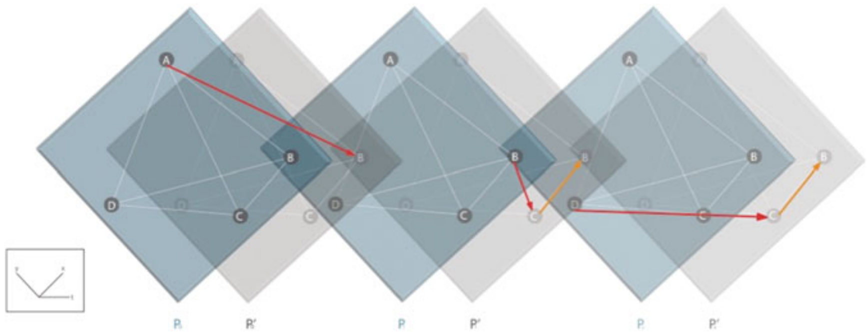

Fig. 3. Graphical 3D representation of the proposed optimization method

2. A vector of a defined size is generated with d demands on coordinates (x, y) corresponding to any of the $k_n \in K$ stations.

$$D = d_0, \ldots, d_n, \qquad d_i = (x_i, y_i), t_i \tag{2}$$

3. Also, a discrete instant is generated t for each $d \in D$ which represents the discrete instant in which the request for the trip is made.

$$\forall d_i \in D \,\exists\, t_i \in \mathbb{N} \tag{3}$$

4. The algorithm must therefore optimize, so that the delay time in the demands is minimal in D taking into account the limitations of b_k bikes available at the k stations and the experienced changes in time due to the execution of the requests in D.
5. For each demand $d_i \in D$.
6. Choose the layout $(P|P')_k$ nearest temporally prior to layout P_i as the initial state or choose the initial state P_0 if no other exists.
7. If it is possible to travel from $d_i \exists\, k_d \mid b_d > 0$ this means, available bicycles, it is used as origin and subtracts a bicycle from k_d.
8. A random deviation coordinate, as shown in Fig. 4, is generated on the ideal destination coordinate for the request, following a Gaussian distribution with center components x, y of the destination coordinate and configurable deviation, and obtains the closest station to the generated coordinate.
   If the obtained station has enough resources (parking spaces available), it is used as a destination. In the case of the lack of spaces, the standard deviation configured in one unit of the Gaussian distribution is expanded and another coordinate is obtained.
   This step is repeated until a station with sufficient resources is found, different from the origin of the request or until a maximum number of iterations u is made.
   In case of not having obtained solution in the search of destination, the raised solution is discarded like candidate solution.

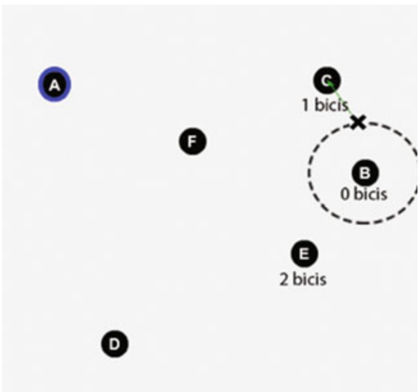

Fig. 4. Random generation of locations by standard deviation ranges

9. The deposited resource (the bicycle left at the station) is added to the destination station chosen and the destination is verified so that it matches the destination chosen by the user. If the destinations do not match, the travel time is obtained (by the Manhattan distance in the location matrix) from the selected destination to the desired destination, by multiplying the speed difference factor between cycling and walking, and it is added to T_d or global *delay time* of the problem.

$$\begin{aligned} T_d &= T_d + Tv_{fd_i,fe_i} * k_{pedestrian\text{-}bicycle} \\ \text{where } fe_i &= \text{chosen destination to} \quad d_i \\ \text{where } fd_i &= \text{ideal destination to} \quad d_i \end{aligned} \tag{4}$$

10. The time taken to travel from the origin to the selected destination is calculated using Manhattan and the layout P_i' is located at the time instant with respect to the origin P_i plus the calculated travel time.
11. Once steps 5 … 10 are performed for each d_i the final value to be reduced T_d is obtained.

In addition, an alternative to the previous methods is proposed which allows to adjust the location origin of the set of travel requests made by the users.

The following are the steps that comprise it:

1. Steps 1–4 are applied in the same way as in the previous method.
2. In the main loop that travels $d_i \in D$, a random coordinate is generated first, following the same rules as those used to generate the target. The restriction applied in this case is, that there are enough bicycles at the chosen station of origin.
3. The travel time is calculated for the station which is different to the one selected by the user, as done in step 10 of the previous method.
4. The remaining steps are performed identically as in the previous method.

4 Case Study

In order to validate the methods proposed above, a simulated case study has been developed with plausible data which could correspond to reality.

Variables:

- Number of trips: 50, 100, 150.
- Period of time in which they occur: 12 h.
- Number of stations: 12.
- Initial bicycles per station: 7.
- Maximum bicycles per station: 12.
- Number of particles per problem: 100.

The implementation of the methods has been done using the programming language *Python*, the 2.7 version using a plane of dimensions 100 × 100 as we can see in the Fig. 5 on which the distances are calculated using *Manhattan* (for its resemblance to apples in a city).

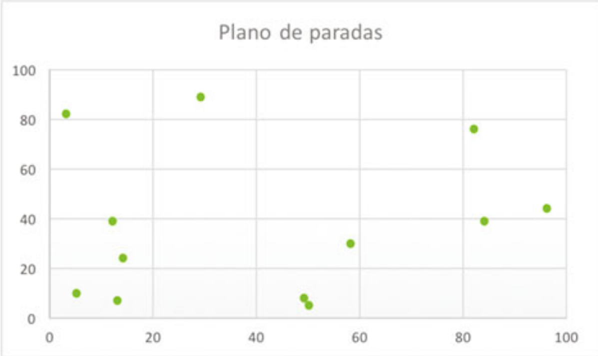

Fig. 5. Locations of the case study stations

5 Results and Conclusions

The generation of circle trips was the first case that was tested in order to verify the validity of the proposed methods. That is, to generate a number of trips equal to the number of available bicycles, all destined to the same station and from that stop to generate the same number of trips, thus passing by all the stations and finishing with the starting one. The optimum result is that for this type of travel arrangement, cumulative delays should not occur in any case, since there will always be sufficient resources and any alteration that would cause the user to walk, would penalize the result.

The results were satisfactory, obtaining a $T_d = 0$ in all cases.

Also, in order to test both of the methods proposed, they have been applied to the same data set for implementation and in different amounts of routes requested, ranging from 50 to 150 trips.

The generation of the data for the execution of the different tests shown below is the generation of N trips within the available time range in seconds (therefore, for this case: $[0, 43200]$) with random origin between the set of stations described in the previous section and random destination different from the origin between all the stops of the defined set and that is identical for all tests executed.

Five pairs of tests have been performed for each set of trips of the same number and the same random data have been generated for each pair, the pair composed being the best solution for the data of the algorithm *Destination* and the best solution for the data of the algorithm *Origin-Destination*.

Also, it should be noted that the pairs of tests have been ruled out in cases where neither algorithm offers a solution (i.e., infinite solution).

As can be seen in the Figs. 6, 7 and 8, the method that considers the different route destination requests and their modification, achieves better optimization results in all cases, in this regard, the method also allows to change the point of origin of the request, according to the needs of the system.

Likewise, the Table 1 shows the results of the Student T-Test, which allows us to determine if there is a significant difference between the means of the

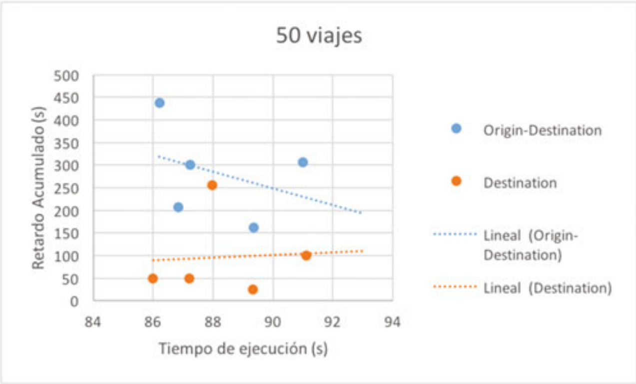

Fig. 6. Results for 50 trips

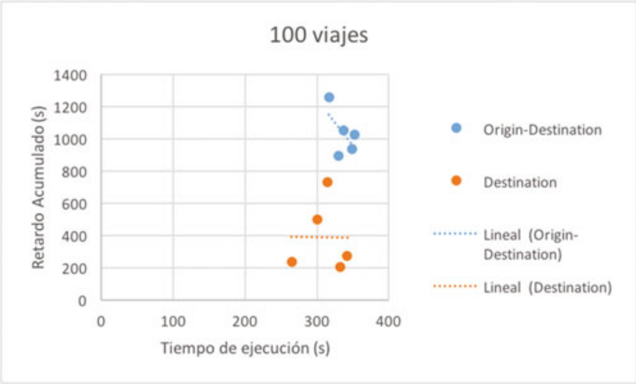

Fig. 7. Results for 100 trips

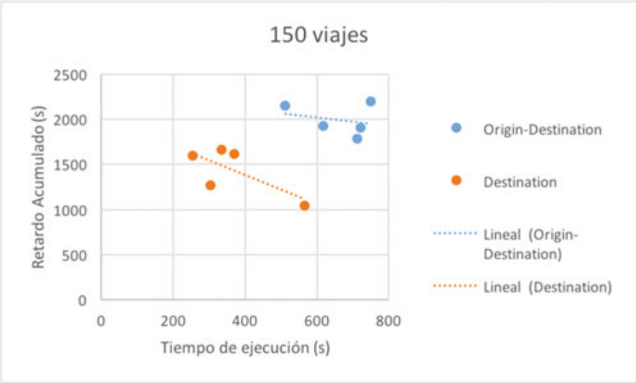

Fig. 8. Results for 150 trips

Table 1. T-Test results for performance in different sets of trips

Viajes	50	100	150
T-Test	0.0186	0.0006	0.0047

performance values calculated by the groups that shape the execution of each of the two variants in the proposed method, through the probability that two results of the different groups are identical.

The null hypothesis H_0 would therefore, confirm that the results delivered for each number of trips and for the two methods proposed are similar. Since the values obtained are all <0.05, we can reject the null hypothesis H_0 and assert that the two samples are significantly different and that therefore the results delivered by the two methods differ from each other (take H_1 as true).

It should be noted that as the number of journeys is increased, the *Destination* method may not find a valid solution (i.e., infinite solution) to the problem due to constraints caused by the lack of resources available at stations), while the *Origin-Destination* method yields results (albeit with a lower efficiency) in all the problems generated. Another aspect to consider is the execution time of both methods, for a reduced number of trips (which does not exceed the number of global resources of the system) the end solutions of both methods have very proximate time margins. This, however, is not adhered to when the number of resources in the problem are less than the number of demands in the problem; in this case the Destination method obtains results (when it is able to obtain them) in a shorter time than the Origin-Destination method as shown in Fig. 9.

The goal of future works will be to develop the methods by expanding shared knowledge, as applied in the *Ant Colony Optimization*, whose ants in addition

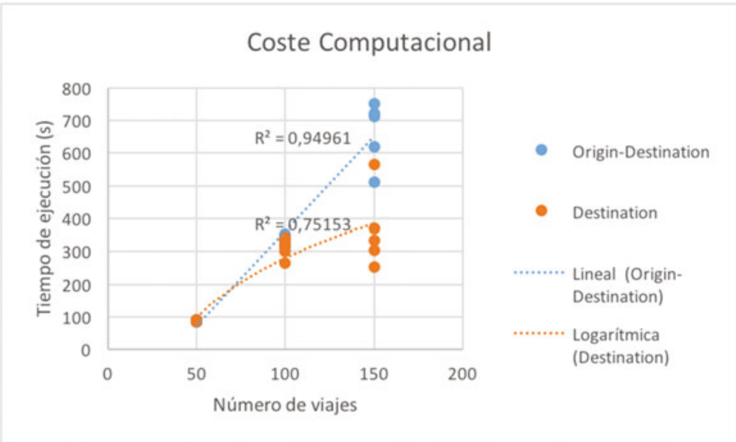

Fig. 9. Computational cost for executions

to possessing individual and private information also share information about the acquired general knowledge and generate valid candidate solutions based on local minimum solutions.

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Multi-agent System for the Control and Monitoring of Shared Bicycle Fleets

Luis Méndez(✉), Daniel Hernández, Gabriel Villarrubia, and Juan F. de Paz

Department of Computer Science and Automation, University of Salamanca, Plaza de la Merced, s/n, 37008 Salamanca, Spain
{luismendez,danihiglesias,gvg,fcofds}@usal.es

Abstract. The use of rented bicycles as an alternative means of transport has increased relatively in the last years. This increase sets a challenge to the management of shared bicycle fleets that can now be found in the majority of European cities. The main objective of this work is to design a comprehensive system which will monitor bicycle fleets using low-cost sensors. The system allows for the detection of anomalous situations, detecting possible robberies, vehicle abandonment and use of bicycles in prohibited areas. To this end, the use a multi-agent architecture is proposed for the management of the different hardware devices, for tracking, messaging and alerts that are produced by the system.

Keywords: Intelligent transport systems · Fleet management · e-Bike · PANGEA

1 Introduction

The daily movement of vehicles in cities results in the consumption of 75% of world energy [1] and the emission of 80% of greenhouse gases [2]. The increase in human mobility and transport in urban environments is a great challenge for today's society, as it is one of the main causes of city crowding and logistic and energetic inefficiency, as well as pollution to some extent [3, 4]. To tackle this problem, we need innovative solutions in communication networks, information processing and transport, which would enable us to make a more efficient use of the resources (vehicles, energy, roads, etc.), at the same time, providing free and flexible mobility. The growing idea of intelligent cities implies new challenges and requires new solutions in relation to transport. In the last years, the use of vehicle-sharing systems has spread, one of them being public bicycle services [5, 6], as well as the shared use of cars [7] and motors. "Free" drivers' systems like Uber or; in the goods distribution sector, "flexible" fleets which are formed "on the go" and offer novel systems on the basis of new technological opportunities and dynamic demand [8].

The main goal of this work is to create a geolocation system of bicycle fleets which will allow to calculate the position of different bicycles through low-cost hardware systems. Using the information collected by the system, it will be possible to obtain information about the routes travelled by the different users. This data will provide

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knowledge of the most commonly travelled routes by the users, the places visited by the vehicle, performance statistics and areas with least visitor frequency.

The hardware device employed in this work uses GPS technology [9] in combination with a mobile communication system called GPRS [10]. This study will focus on a low-cost device which will be easily installed in the bicycles that are already present on the market. For the management of data and all the events produced in the system, a multi-agent architecture based on the PANGEA [11] platform has been designed, enabling the integration of software agents in hardware devices of low computational capacity, as in the case of the tracking device used.

The rest of this work is organized as follows: Sect. 2 reviews similar works, Sect. 3 explains the architecture and its application in the case study. In Sect. 4 we will present the results and conclusions obtained in the research.

2 Background

The existing types of transport are of great importance in our everyday life, since citizens spend a large part of their lives travelling, both within their own cities and when travelling to other places. The train stations, buses and other vehicles (like cars and bicycles), can be equipped with technology that could provide basic knowledge on how the system can react at each moment. Based on this knowledge, the use of this type of systems in a preventive and effective way, would improve people's daily lives. Additionally, the public transport system can benefit from new technologies, such as the sensor systems, vehicle identification and image processing, which would help achieve a more fluid, efficient and above all, safer transport.

As for vehicle fleet management in urban environments, in the current literature, it is possible to find various works. As in the case of work [12] where the authors present a revision and classification of the intelligent stocking methods for electric vehicles, in accordance to their location. Also, work [13] tackles the problem of bicycle fleet management in the renting systems, analyzing the location of the stations for a more dynamic management; providing high availability to all of the users. Various works also examine this topic, for example in [12, 14] the authors propose different techniques that intend to solve the problem of design, and location of the different stations in the renting and restocking of bicycles in the cities. Other works, such as [15] propose the use of geolocation systems based on GIS for the calculation of potential travel demands to create specific distributions, locate the stations using location assignment models, determine station capacity and define the demand characteristics of the stations.

In the literature we can find numerous works that tackle the problem of integrating software agents in hardware devices of low computational capacity, such as [16]. The work [16] is based on the PANGEA [11] architecture, just like the architecture proposed in this study. This is not the only work where we can find PANGEA, in [17] authors also propose the use of this architecture, integrated in a series of medical sensors for the remote monitoring of patients. Other examples, [18–20] where we can also find the integration of sensors in multi-agent architectures. All these works have in common the use of integrated architectures in hardware systems, however, this has not been applied to real-time tracking systems for vehicle fleets based on low-cost hardware and MAS systems. The following work is proposed after a thorough examination of the present literature and the lack of studies in this particular area.

3 Proposed Tracking System

In this section we present the architecture designed in this work, to track and monitor shared bicycle fleets. We describe the low-cost hardware used and the final system implemented in the development of this work.

A MAS (multi-agent system) architecture system is proposed, based on the PANGEA [11] platform for the tracking and monitoring of shared bicycles in the renting system, implemented in the city. In Fig. 1 we show the designed virtual agent organization.

In the first place, the **Bicycle Tracking System** is formed by the agents: alert, monitoring, coordinator and GPS, embedded in the low-cost hardware system. The agent with the GPS role will be in charge of obtaining data through the GPS antenna. These data reach the coordinator, who is responsible for passing them on to the monitoring agent. If the monitoring agent detects values which are out of the permitted tracking range, he interacts with the alert agent. The alert agent is in charge of sending the incidents to the server which is in charge of its management.

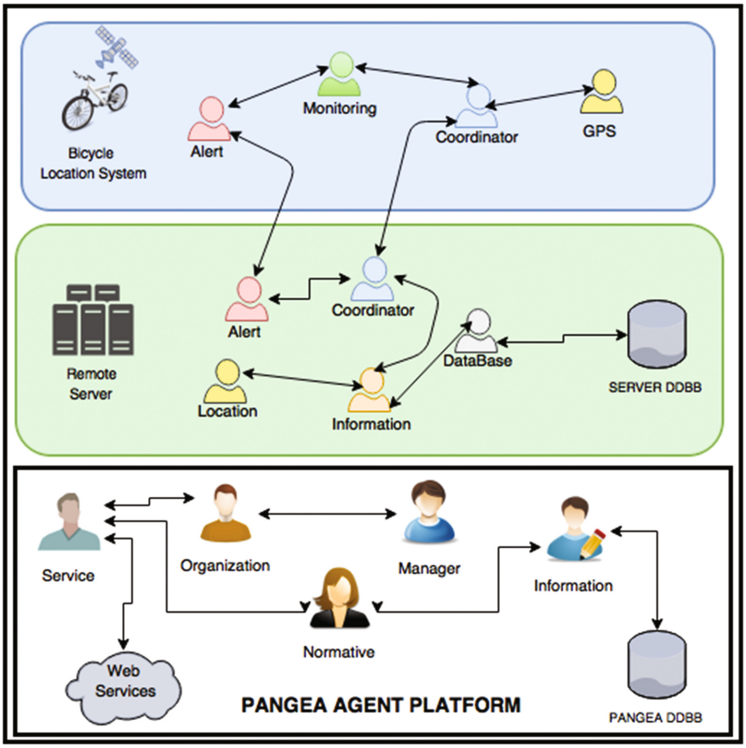

Fig. 1. Virtual organization of the system based on PANGEA platform

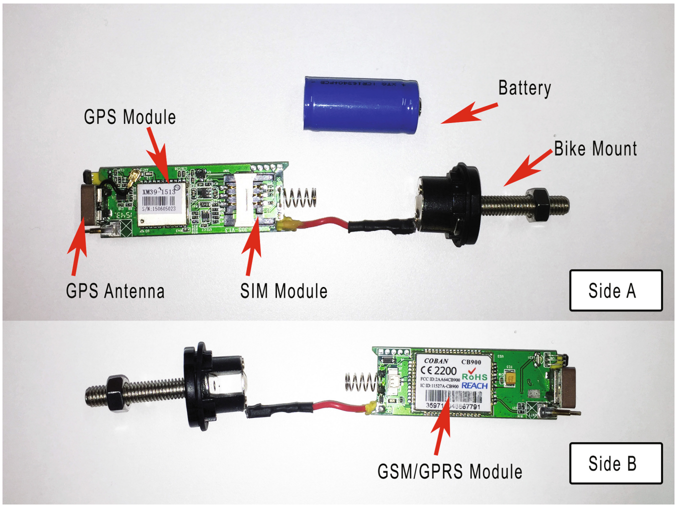

Fig. 2. Bicycle tracker device

The organization **Remote Server** includes the agents: Coordinator, information, alert and database. The agent with the coordinator role is in charge managing information that is received from the tracking device. The agent whose role is information is responsible for regulating the data received and subsequently sending them to the database agent which is in charge of its persistence in the DB. The agent with the alert role is responsible for analyzing the different alerts which are sent form the tracking device. The tracking agent obtains tracking data from the different bicycles, with this information a knowledge base is constructed on user habits, analyzing the repeated locations and frequent routes made. This information is stored again through the database agent in the DB and will be used in future works for system optimization and pattern extraction and statistics on cyclist's behavior in the city.

3.1 Hardware Device

The commercial device used costs less than 30 € and can be installed in any bicycle by placing it in the head tube of the handlebars. In Fig. 2 the device board can be seen, it is composed of the GSM/GPRS communication module, it operates through a telephone line, for that, a SIM card reader module is provided. It has a GPS tracking chip and an antenna with which triangulation data are received. The device also has a compact and light battery of 1400 mg capable of functioning during 6 months and sending data to the central server.

3.2 Final System

An image of the proposed system infrastructure is shown in Fig. 3. Firstly, the GPS device described in the previous section can be seen. It is used to obtain the

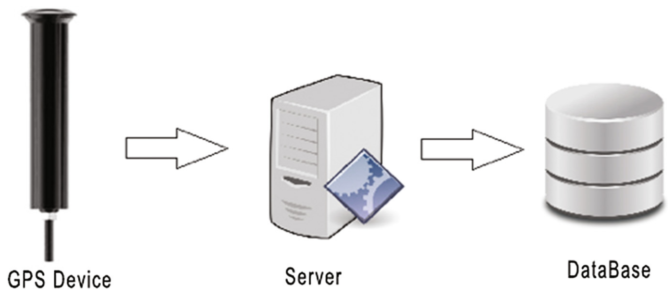

Fig. 3. Diagram of the tracking system

geographical coordinates which are then sent. These data are collected by the central server in which they are received, treated and stored in a database.

The central server identifies each of the devices through their IMEI (International Mobile Station Equipment Identity). This helps to differentiate clearly which bicycle send each tracking message at any time and if the connection has been lost or if the device doesn't have enough battery. The central server also processes all the data in real-time in the search of anomalous values which can indicate some type of problem, such as robberies, vehicle abandonment or if the device is being altered.

4 Results and Conclusions

The main outcome of this research is the multi-agent architecture which is able to communicate with computationally limited devices, such as the autonomous micro-controllers which are connected to low amperage batteries. The use of PANGEA helps save battery as opposed to SOAP type architectures through the use of MQTT protocol.

The device designed in this case study allows for the geolocation of vehicle fleets and its cost is below 30 €, making it a bearable price for the companies in the sector. The information collected from the routes made by the users, enabled us to obtain behavior patterns and information relevant to the owners of the bicycle renting system. As for the administrative user, we can view the km travelled or the condition of each bicycle, so that we know the exact time at which bicycle should go through a checkup.

The tool gives information on the city areas to which the users most often travel. Verification test carried out in the city council can provide information on where more bicycle lanes are needed. In the case of a robbery, the position of the bicycles can always be checked. The end-user of the service can find out which stations have high-bicycles availability and which stations have no bicycles available at a given moment.

Images of the application developed are presented below (Figs. 4, 5, 6 and 7)

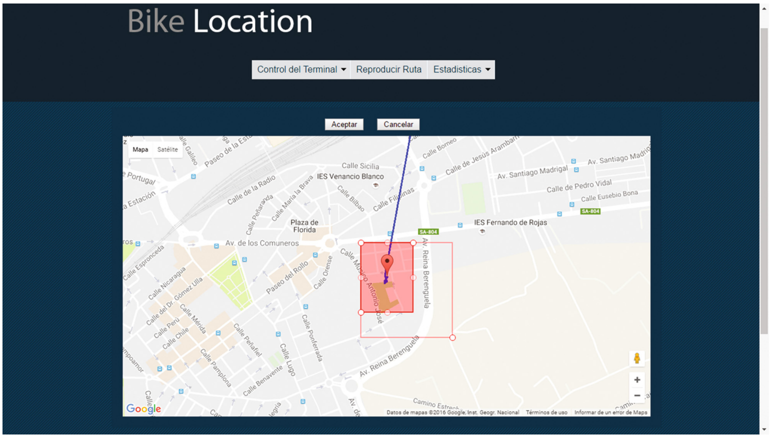

Fig. 4. Geo-boundary configuration to detect robbery and unauthorized use of vehicles

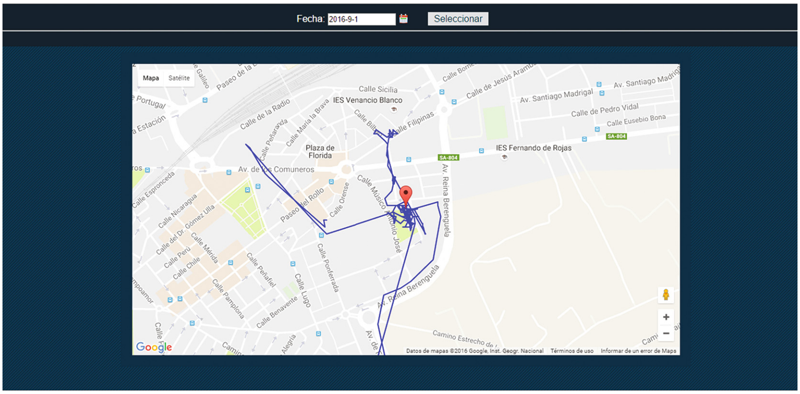

Fig. 5. Retrieved route

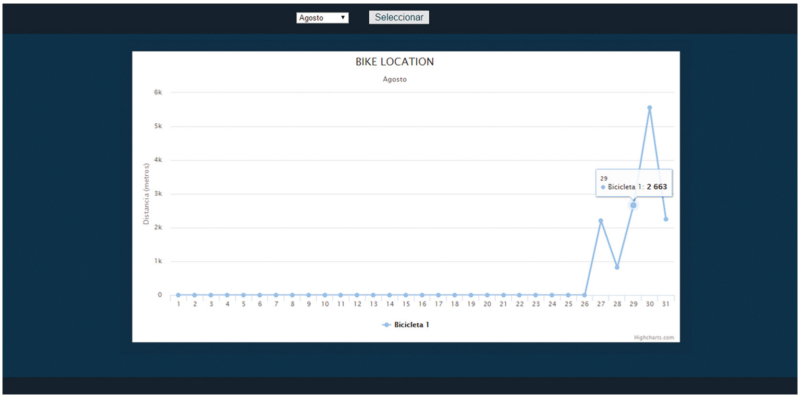

Fig. 6. Distance graph that shows the distances traveled by the user and the total kilometers traveled by the vehicle

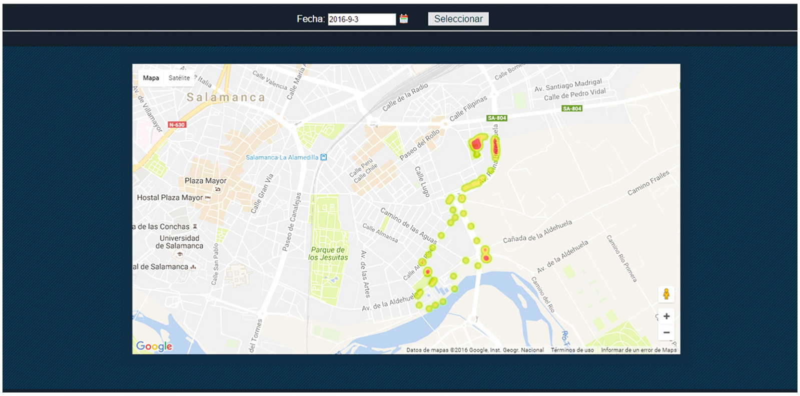

Fig. 7. Heat map indicating the most traveled areas by a vehicle

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Adapting the User Path Through Trajectory Data Mining

João Ramos(✉), Analide César, José Neves, and Paulo Novais

Department of Informatics, Algoritmi Centre, University of Minho,
Braga, Portugal
{jramos, analide, jneves, pjon}@di.uminho.pt

Abstract. The pervasiveness of location based services such the GPS on mobile devices enabled the gathering of massive spatial-temporal data. These databases enabled the mining of new data in order to calculate frequent patterns and predict the movement of the objects. In the development of our system for guiding the user with cognitive disabilities (CogHelper) we are applying a trajectory data mining to adapt and adjust the path to user preferences. Indeed, the guiding process may be more useful and it increases the quality of life of the user through this new functionality (conciliated with the speculative computation module). Thus, instead of the user having to adapt to the application we are developing a system that adapts the path to the user. Rather than being guided through the shortest path he may be oriented by a longer but preferred path. The main contribution of this paper is the specification of the trajectory data mining which is incorporated in CogHelper system.

Keywords: Trajectory data mining · Frequent patterns · Sequence mining · Clustering

1 Introduction

Location-acquisition technologies are becoming more embedded in people's daily life. Examples of such systems are mobile devices with GPS or GSM, and computers that if connected to the Internet may be founded through their IP address, just to name a few. This data acquisition results in larger amounts of location-based information and the need to treat and obtain results in such collected data becomes imperative. By mining the frequent trajectory patterns in the spatial-temporal database one may detect the regularity of moving objects (e.g., people or vehicles). Thus, it is possible to define frequent patterns and, with this data, predict the movement of objects.

Several authors have studied and developed different algorithms/methods for mining spatial-temporal data [1,8,10,11,16]. The different algorithms are described in more detail in Sect. 2. The spatial-temporal trace generated by a

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moving object is defined as spatial trajectory [17] and is represented by a set of chronologically ordered points. Each point is constituted by its coordinates (latitude and longitude) and a timestamp. According to Zheng [17] there are four sources of data: mobility of people, mobility of transportation vehicles, mobility of animals, and mobility of natural phenomena. In our case (as described in Sect. 4) we are focused on the mobility of people and the data gathering may be subdivided in active and passive recording. The former is related to the GPS acquisition whereas the latter is collected by GSM connection using the cell towers. Despite the method for acquiring the data and before using the trajectory data there is a fundamental step where the data is preprocessed [17]. Here a number of issues are considered in order to prepare the data for the data mining. Thus, it is important to filter the noise (points where the GPS error is bigger than the usual), to segment and to compress the data (without removing its utility), and to do a map matching in order to have a more accurate path.

Considering our previous work (CogHelper, see [14,15]), we intend to implement a module of trajectory data mining where the goal is to adapt the path to the user preferences. Thus, instead of guiding the user through the shortest path, the system may suggest a longer but preferred traveling path.

This paper is organized as follows: in Sect. 2 it is presented the related work regarding the existing algorithms and their use in trajectory data mining. In Sect. 3 it is provided a brief description of our system and its main goal. In Sect. 4 we detail the goal of applying a data mining algorithm in our system considering the adaptation of the path to the user. Finally, in Sect. 5, the main conclusions are drawn.

2 Related Work

There are several models and methods to efficiently query spatial-temporal databases in order to obtain different types of information like frequent trajectories, the type of trajectory, among others.

Alvares et al. [1] changed the usual paradigm of considering a trajectory as a set of ordered points to a semantic point of view. Thus, the authors provided an extraction method to obtain the frequent movements between two places. Instead of knowing the exact trajectory between place A and place B, Alvares et al. tried to know to which place the user would travel considering his origin. In their work the authors considered a trajectory as a set of stops and moves, in which stops are important places where the moving object has not moved. The moves are delimited by two stops and by a time interval and are part of the trajectory. Indeed, the authors are able to detect frequent stops during a time interval, frequent moves, duration of stops, among others. The main goal was to find the frequent moves between two stops, for example, detect that if the user is on place A he will travel to place C.

To Giannotti et al. [8] a trajectory pattern is a set of trajectories where the moving objects visit the same places in the same sequence and the traveling times are very similar. Indeed, the authors define regions of interest and the typical travel time of the moving objects. Like Alvares et al. [1], in Giannotti et al. [8] the trajectory pattern establishes the pattern that if the object is in A it will most likely travel to B, disregarding the particular route between the two places. In their trajectory method, the authors initially convert the raw data (sequential spatial-temporal data) into a sequence of regions of interest and then, in a second phase, the trajectory data mining algorithm is used to detect the movements between two places. A region of interest represents an area where the number of collected raw data is very significant, meaning that the moving object has not change too much its position.

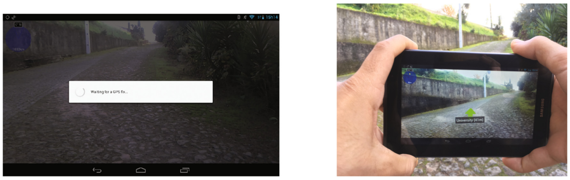
To Ye et al. [16] the goal was to detect people's life patterns. The authors, in a first step, convert the GPS raw data into a sequence of stay points, which are geographic regions where the user stays for an amount of time (pre-established threshold). Then they apply a density-based clustering method (in their case the OPTICS [2] was used) to obtain a sequence of location history, i.e., sequence of clusters that represents points where the user stays for a period of time. With these sequences, the authors are able to treat the data and get results such as the user habits during the week or in the mornings, among others.

WhereNext is a location predictor from Monreale et al. [11]. Like the other described works, here the authors convert the GPS log data to trajectory patterns. To obtain these patterns the authors adapted the algorithm proposed in [7] and they represent sequences of dense spatial regions. Then, the authors build a tree considering the previously generated patterns and their connections. Using the tree the authors are able to predict the next movement of an object by applying different prediction strategies. To create the initial trajectory patterns Monreale et al. [11] use the total set of points that are within a given region. Thus, instead of using just the historic data of a given object, they use the data of all moving objects to create the patterns in a region.

In [10], Lee et al. try to find trajectories that are frequently repeated, being able to analyze and predict the next movement of the objects. The authors use the spatial and temporal attributes of the collected data to mine the frequent trajectories. In their approach the authors initially convert the raw data to create a graph from which they create trajectory lists. These lists (in the form of a tree) indicate to where the moving object usually travels when it is on a specific location (represented by a node in the tree). After this step Lee et al. transverse the mapping graph through a developed graph-based algorithm and detect frequent patterns.

3 CogHelper: System Description

CogHelper is an orientation method for people in the earlier stages of cognitive disabilities, i.e., with mild and moderate disabilities. In the advanced stages of this condition (severe and extreme) the person may not be able to use a mobile device, thus the orientation is not viable. Being an on-going work the main features of the system have been described in [13–15]. The goal is to guide the user by using an augmented reality interface (Fig. 1b) in which we try to



(a) Waiting for a GPS signal

(b) Informing the path to the user

Fig. 1. Orientation method for people with disabilities—Augmented reality interface

minimize the cognitive effort needed to understand the direction that should be followed. While the system is calculating the best traveling path a screen appears informing the user to wait (Fig. 1a). Through a speculative computation module the system is able to predict and anticipate possible user mistakes however, as described in Sect. 4, the adapted traveling path is obtained through a trajectory mining module.

Although not being the main users, caregivers are also another type of people who may need to execute the application. Indeed, we have developed a localization feature in order to let caregivers know, in real time, the current location of the person with cognitive disabilities. This feature is very important since caregivers may develop a different activity while knowing the location of the person under care, not having to physically be with him.

To add more functionalities to the system it is also possible to connect to external services such as iGenda [4]. Through this external system whenever the user has an appointment the guidance process may be remotely started in order to guarantee that he will not arrive late. Thus, by applying the concept of Ambient Intelligence (AmI) it is possible to provide better assistance to the patients [5]. Indeed, sometimes the care may be more effective if the patient is in his home environment instead of being relocated to a nursery home [3].

4 CogHelper: The Trajectory Mining Module

CogHelper [14,15] is a system where the main goal is to guide people with mild or moderate cognitive disabilities. In more extreme cases of this diagnosis the person may not learn how to use a mobile device, thus his orientation is not possible. The development of the system has also a parallel goal that is to provide a localization feature for caregivers, which let these type of users to know in real time the current location of the person with disabilities.

To guide the user the system has a speculative computation feature that is able to predict a user mistake and alert him in advance. Thus, instead of turning into the wrong path the system may ensure that the user is traveling in the correct one. The speculative computation module, in order to anticipate user mistakes and assure the correct traveling path, needs to be fed with the traveling route. With the goal of adapting the traveling path to the user preferences we

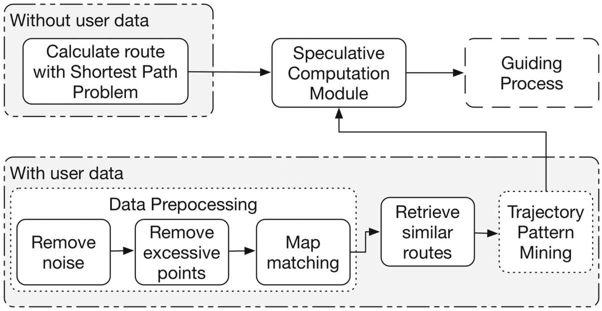


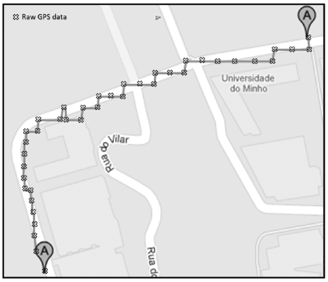
Fig. 2. Process for generating adapted routes

are implementing and testing a trajectory data mining. Thus, instead of guiding the user through the shortest path he may be oriented by a longer but preferred (and more familiar) trajectory.

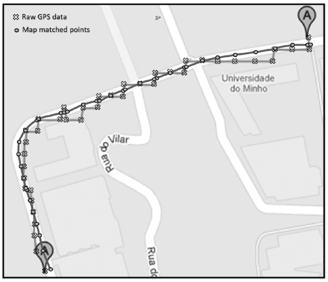
A trajectory of a person with cognitive disabilities (also defined as user) is a sequence of time-stamped locations obtained by the GPS of the mobile device. The location is composed by Cartesian coordinates, i.e. latitude and longitude, and the timestamp. The active recording of the user location (from the GPS) is done whenever the user is receiving the necessary aid from the application. The process for mining the trajectories are depicted in Fig. 2. When there is no information about the user (e.g., the person is using the application for the first time) the system calculates the shortest path and retrieves it to the speculative computation module. The shortest path is calculated using an external tool named GraphHopper [9]. When there is previous information about the user, i.e., there is spatial-temporal data from previous trajectories the system uses the available data in order to provide the best trajectory to the user.

To adapt the path it is necessary to do a pre-processing step in order to prepare the available raw data for the mining process. Indeed, and as depicted in Fig. 2, it is necessary to remove the noise of the data, remove points that may not increase the detail of the trajectory and do the map matching. The first step of this pre-processing phase (noise removal) eliminates locations whose GPS error was notorious, i.e., points that for some reason (like the reflection of the GPS signal in a building) have an error bigger than the usual GPS error. Then locations that may not have added value to the mining are also removed, e.g., locations that are in the middle of a straight line. Finally, the map matching is the process of getting the remaining data and match it to the roads defined, in our case, in Open Street Map[1] database. Figure 3a represents the raw data recorded from the GPS of the mobile device whereas Fig. 3b is the final step of the pre-processing stage (including noise removal and map matching). For this pre-processing phase we use GraphHopper Directions Api [9] which has a map matching feature and is an open source tool.

[1] Open Street Map, available at http://www.openstreetmap.org/.



(a) Route obtained from database raw data



(b) Error removal from raw data

Fig. 3. Trajectory data pre-processing [15]

After the pre-processing step we are able to apply the trajectory data mining method in order to extract the frequent trajectories (patterns) from the data. For this process and in our preliminary tests we are experimenting, with good results, two different methods: the PrefixSpan algorithm [12], which mines frequent sequential patterns; and OPTICS [2], which is a clustering algorithm that groups the locations in clusters. Both methods are based on an open-source API named SPMF [6], which provides an implementation of such algorithms. Through PrefixSpan algorithm we may extract frequent trajectories from the entire traveling paths that the user has done. The trajectories obtained from the execution of the algorithm (frequent trajectory) consider an input value that defines the support of a sequential pattern (indicating the minimum percentage of sequences where the pattern occurs, considering the total patterns). In our case we use the mining method with the data from the user that the system is going to guide. Thus, the path is adjusted to the user preferences. The execution of the algorithm searches for patterns in the dataset according to the defined threshold. The returned patterns may represent an entire trajectory, i.e., may start near the user current location and end at the intended destination; or be part of a trajectory. In this case we use these trajectories and we try to create new traveling routes using the mined patterns. If the recently created trajectory is much longer than the shortest path, the system uses the shortest one, using the other option otherwise. Using the clustering method (i.e., the OPTICS) the data is grouped into clusters considering some input parameters such as the minimum number of points that a core point need to have in its neighborhood and the radius ϵ that the recorded locations may be from the core of the cluster, which defines the neighborhood of a point. In a rough comparison the patterns detected by PrefixSpan are equivalent to the clusters defined by the execution of the OPTICS algorithm. However, by using this mining method it is necessary to create connections between the clusters in order to obtain a trajectory that guides the user between his current location to the intended pre-selected destination.

In the case of using the shortest path or in the case of applying the trajectory data mining method the obtained trajectory needs to be converted in order to be used in the execution of the speculative computation.

5 Conclusions

Location based acquisition methods, due to their pervasiveness, have allowed an easier access to the user location (through, for example, the smartphone) which enabled the access to new data about the user. Through this information one could know the user frequent behaviors and frequent trajectories, e.g., the usual traveling path from home to work. We are developing a system to guide people with cognitive disabilities (the main users of the application) and, at the same time, providing a localization feature to caregivers. Considering the specificities of the target population of the system, it is important to develop methods that adapt the system to the user preferences and not otherwise. Thus, using a speculative computation method the system is able to predict the next movement of the user and anticipate possible mistakes. However, to use this module it is necessary to have input values which are obtained by applying a mining method. Through this paper we describe how the trajectories are adapted to the user through two different trajectory data mining methods. This process is very important since a longer but preferred (or more familiar) path is better than the shortest one, as the user may feel more comfortable traveling along the longer path and the risk of getting lost is minimized.

As future work we intend to define which of the mining methods have better results in adapting the traveling path by doing more exhaustive tests and by enlarging the spatial-temporal data about the users under test, since the preliminary results do not allow the definition of the most suitable method.

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A Review of Multi-agent Based Energy Management Systems

Amin Shokri Gazafroudi[1(✉)], Juan F. De Paz[1], Francisco Prieto-Castrillo[1,2], Gabriel Villarrubia[1], Saber Talari[3], Miadreza Shafie-khah[3], and João P. S. Catalão[3,4,5]

[1] BISITE Research Group, University of Salamanca, Salamanca, Spain
{shokri, fcofds, franciscop, gvg}@usal.es
[2] MediaLab, Massachusetts Institute of Technology, Cambridge, MA, USA
[3] C-MAST, Universidade da Beira Interior, Covilhã, Portugal
[4] Faculty of Engineering, INESC TEC, University of Porto, Porto, Portugal
[5] INESC-ID, Instituto Superior Tcnico, University of Lisbon, Lisbon, Portugal
{saber.talari, miadreza, catalao}@ubi.pt

Abstract. This paper proposes a review of Energy Management Systems (EMSs) based on Multi-Agent Systems (MASs). Also, goal, scale, strategy and software are discussed as different characteristics of the EMSs. Then, multi agent-based structure of the EMSs is described. Finally, challenges and future discussions related to the EMSs are presented in this paper.

Keywords: Energy management system · Multi-agent system · Smart grid · Power market

1 Introduction

Smart Grids (SGs) improve energy efficiency in power and energy systems through intelligent control and automation technologies. Also, SG is accounted as an appropriate solution to utilize intermittent energy resource. However, these energy resources create challenges due to uncertainty of its power generations in the system. Moreover, restructuring causes to appear new agents in the power system. Hence, all in all make power systems as complex ones. Different technologies have been used in SGs to realize these aims e.g. MASs. While there is no any unique definition for agents, MAS is a set of independent units that can make decision and interact with other ones [1]. Hence, MASs can make a possible environment for SG's players—e.g. electrical generation, consumers, system operators, aggregators, etc.—to act autonomously and communicate with each other [2].

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Various researches have been presented for energy management of power system, and different methods have been represented based on their goals, scales, strategies, and software. For instance in [3], the scale is considered to be power grid. Also, the goal is to minimize the operating cost. besides, the hierarchical and decentralized strategy is presented based on MAS. Moreover, CPLEX [4] and JADE [5] are used to implement the problem in a real system. Also, multi-micro grid system has been operated cooperatively in [3]. In [6], the authors have reviewed how SGs are modeled as MASs. Besides, they compared some projects based on their view and objects related to the system in. In [7], the authors have reviewed the agent-based technologies of large-scale energy systems and SG projects. A hierarchical central approach of Micro-Grids (MGs) has been presented in [8]. The primary control is done in level of distributed energy resources, while the secondary control is done in the level of MG by an Automatic Generation Control (AGC) to control frequency and voltage. Also, the tertiary control is applied to provide the ancillary services for load regulation in the host-grid level. In [9], a new method has been presented to solve AC optimal power flow problem in the multi-agent decision-making framework. In [10], the multi-objective problem has been defined to minimize energy costs and estimate state based on bottom-up approach.

In [11], each smart home has been considered as an autonomous agent that can buy, sell, and store electricity. Furthermore, the uncertainty is modeled through generating the random data and functions in [11]. In [12], a MAS has been demonstrated in the distribution network scale, while agents consist of home agents and retailer agents. In [12], the purpose of the authors was to minimize the payment cost of the electricity. In [13], home energy management problem in connection with transactive energy nodes has been discussed. Moreover, co-simulation of smart homes and transactive energy market has been studied in [13]. In [14], economic dispatch problem has been solved by decentralized and self-organizing strategy. The proposed strategy of [14] is non-hierarchical, and the operation costs is minimized locally and then applied to the system globally. In [15], an energy management system has been presented based on integration of smart meters. The authors have proposed the hierarchical method to manage the energy in [15]. In [16], an intelligent method has been demonstrated to manage energy dynamically in the MG. The proposed method of [16] has been defined to optimal or sub-optimal. Besides, providing the critical loads continuously is the purpose of [16]. In the model of [16], intelligent dynamic energy management system is responsible to send dispatchable control signals of energy. Moreover, forward-looking network is responsible to evaluate the dispatched control signals. The main aims of [16] are to maximize the reliability, utilization of renewable energies, and consumers' welfare. Moreover, the operating cost has not been considered in the decision-making problem of [16].

In [17], the agent-based approach has been represented to optimize the operating cost of the SG and the Residential Energy Management System (REMS). Also, Particle Swarm Optimization (PSO) method has been used to maximize welfare and energy efficiency in [17]. In [18], authors has discussed about the necessities of using Computational Intelligence (CI) in REMSs. CI has been applied to three parts of the REMS in [18]. These parts consist of the prediction of building required power, forecasting the purchasing electrical load from the power grid, and ANN-based controllers. Minimizing the building energy cost is the goal of controllers. Also, PSO has been utilized for optimization problem of BEMS. In [19], building energy management has been defined as an intelligent MAS. Energy management system includes two parts: demand-side management and supply-side management. Furthermore, the JADE has been used to implement the model of [19]. In [20], an adaptive and integrated method has been presented for Demand Response (DR) and REMS based on real-life conditions. In [21], the method is proposed to apply the local energy resources optimally through minimizing the loss of energy. Also, in [21], authors had studied comparatively different battery control strategies. The main purpose of [21] is to minimize the purchasing cost of the electricity. In [22], the scheduling problem of the REMS has been solved considering DR. The objective function of [22] was the trade off between the purchasing cost of electricity and dissatisfaction of the consumers.

In this paper, a review of multi-agent based energy management systems, its features and challenges are provided. The rest of this paper is organized as follows. Section 2 describes the features of multi agent-based energy management systems. Multi agent-based structure of the EMSs is described in Sect. 3. Then, challenges and benefits of these systems are discussed in Sect. 4. Finally, conclusions are given in Sect. 5.

2 Features of Multi-agent Based Energy Management Systems

As highlighted before, Multi-Agent based Energy Management Systems (MAEMSs) can be classified based on different characters. In this paper, goal, scale, strategy and software are introduced as characteristics to compare different MAEMSs.

Main purpose is one of important characteristics of Energy Management system (EMS). Goal is presented as an objective function in the energy management problem. Goal of EMS can be maximizing profit, minimizing cost, maximizing reliability, etc. In other words, goals of the system is its virtual feature that indicates its desired strategy. Scale of EMSs is another characteristic that represents the system's level that optimum decisions are make for it. Scale of EMSs can be system-wide, MG, Local, Home. etc. It is clear that according to the scale of the system, complexity of the energy management problem can be changed, and different tools can be utilized to solve it.

Strategy is another important characteristic of EMSs. Strategy is defined as a decision-making path to obtain optimum amount of objective function. Centralized, decentralized, and hierarchical are more common strategies in EMSs. As mentioned before, in MASs, a platform is required to provide interaction and communication between autonomous agents in the systems. There are different software and platforms—e.g. JADE, MATLAB, etc.—that are chosen based on goal, scale, and strategy of the proposed MAEMS.

3 Agents of Energy Management Systems

EMSs consist of different agents that each of them has different tasks. In this section, all agents of the EMS will be introduced and their task will be described. Moreover, the physical system of the MAEMS is seen in Fig. 1. MAEMS includes three layers. First layer is the electricity system which is displayed by black lines. However, second layer is the communication system that is shown by blue lines. Third layer presents interaction between users and other agents that is displayed by green line.

Electrical Loads (**ELs**) are a group of agents that consume electrical energy in the MAEMS. Generally, ELs are classified into different types of loads such as shiftable, controllable, Must-Run Services (MRS), etc. Therefore, ELs can be considered as an organization of different types of agents in the MAEMS.

Distributed Energy Resources (**DERs**) is a set of agents that is responsible for electrical energy generation. DERs are intermittent energy resources, so they inject uncertainty in the system. However, increasing the prediction accuracy of these stochastic variables can decrease the corresponding uncertainty in the system.

Energy Storage Systems (**ESSs**) are the agents in the MAEMS that can store electrical energy such as batteries. Batteries can help to smooth the electrical demand profile and improve the performance of energy management system based on demand response programs.

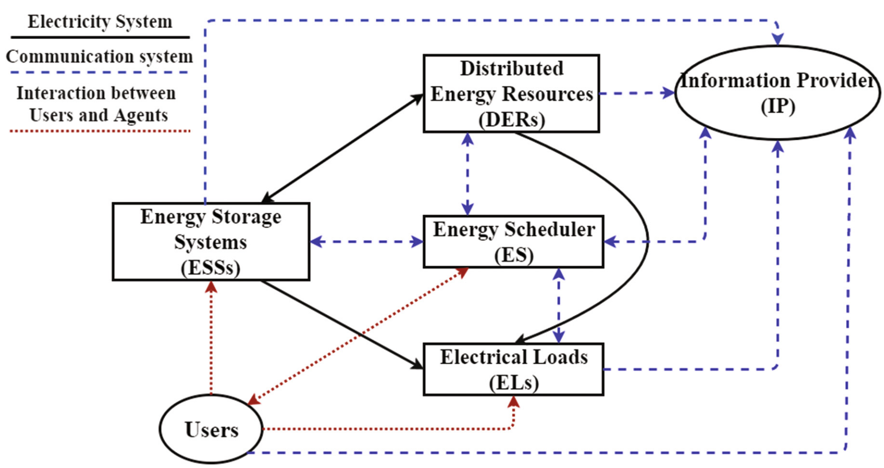

Fig. 1. MAS design of energy management systems

Information Provider (**IP**) is an agent that is in charge of providing real-time and historical data information. It senses and records information from all the agents as well as environmental conditions.

Users are residents of a home. Each of these residents are an agent of the MAEMS. Therefore, Users is defined as an organization of this group of agents. Users has direct effects on the ELs and EVs. Furthermore, the objective function of the decision-maker system is determined based on the desired of the Users. All interactions of the Users are illustrated in Fig. 1.

Energy Scheduler (**ES**) is a virtual organization of agents who plays as a system operator in the MAEMS. The ES consists of two agents in the MAEMS: Prediction Engine (PE) and Decision-Maker System (DMS). The tasks of both are described in the following:

PE provides accurate prediction of all stochastic variables of the system such as wind speed, solar radiation, weather temperature, electricity price and electrical unshiftable loads for the DMS. Hence, the outputs of this agent will be the inputs of the DMS. As the DERS utilized in the MAEMS are non-dispatchable resources, the forecasting of its power output will be very important for the DMS. Hence, accurate forecasting of PE can assist the DMS to make optimum decisions.

DMS makes optimum decisions in the MAEMS. Therefore, after the Objective Function (OF) is defined in the system, this agent should make an optimum decision. In this case, DMS faces a discrete optimization problem under uncertainty of the PE's outputs. This uncertainty causes some problems for the DMS, such as increasing the operating costs of the MAEMS and computational overload. There are different methods to model the uncertainty in the optimization problems such as stochastic programming [23], interval optimization [24], robust optimization [25], etc.

4 Challenges

SGs provides more flexibility for the energy systems and increase energy efficiency of them. For instance, MASs cause platforms that agents can act autonomously. Hence, it increases reliability of the system. Moreover, MAS can be applied to decentralized energy management methods that decreases computational burden of the system. However, there are some challenges to implement these systems. As highlighted before, there are independent agents in this structure. Hence, real-time operation is very important in this case. In real-time, system should be able to connect all devices and exchange all information—this information can be historical and measured data, or real-time decisions—between them. Since balancing between power generation and consumption is vital in the power systems, real-time operation plays as a huge concern in them. Moreover, cyber-security is another challenges in SGs. Another challenge in decentralized energy management systems is related to the optimum decisions of these systems. While local decision-makers decrease computational burden of the system, their decisions are not globally. Hence, a trade-off between local decisions and global optimization is one of main research concepts in these systems.

5 Conclusion

The paper presents a review of multi agent-based energy management systems. Different characters of these systems based on MASs have been discussed. Also, agents of the energy management systems have been described. Finally, paper concludes by expressing challenges and discussion topics related to the decentralized energy management systems.

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Modelling an Intelligent Interaction System for Increasing the Level of Attention

Dalila Durães[1,3](✉), David Castro[2], Javier Bajo[1], and Paulo Novais[2]

[1] Department of Artificial Intelligence, Technical University of Madrid, Madrid, Spain
d.alves@alumnos.upm.es, jbajo@fi.upm.es
[2] Algoritmi Center, Minho University, Braga, Portugal
pg30465@alunos.uminho.pt, pjon@di.uminho.pt
[3] CIICESI, ESTGF, Polytechnic Institute of Porto, Felgueiras, Portugal

Abstract. Learning activities using technologies is one of the common education methods. Its advantages allow that students can learn with concepts more practical's. However in this environment not all the students can be attentive. In this research an Ambient Intelligent System has been designed using biometrics behaviors for detecting learner inattentiveness. The learning attentiveness of a student can be determined precisely and the teacher has access to these results and might improve news strategies.

Keywords: Level of attention · Technology in learning · Ambient intelligent systems

1 Introduction

In a traditional learning environment student and teacher are the key elements in the classroom. In environments in which technologies exist, the teacher plays an essential role in providing an engaging learning and teaching environment. Together, they take a set of physical, social, emotional, mental characteristics, and needs to the classroom. These influence the way one relates with the other and consequently affect the way the learning process will progress. Teacher is able to learn about the necessities and the educational philosophy as well the nature of his/her students; this will improve teacher's position in order to facilitate student's learning.

For these reasons, education, training, skills development, and learning are processes that are continuously performed since we are born. These characteristics and the ability to learn and teach, allow us to grow as a person. The learning concept is described as the act of acquiring knowledge, behaviors, abilities, standards or preferences and the study of learning has been closely linked to the development of psychology as a science [1].

The school must create systems that are capable of involving students and capture their attention. Advances in computers and wireless technologies have also had an impact on the educational setting, thus generating a new approach for Ambient Intelligent (AmI) systems. The rapid development of these technologies combined with

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access to content in a wide variety of settings, allows learners to experience new learning situations beyond the school's wall.

In the last years, school has introduced news technology with a set of computers, networks and access to the Internet in order to improve learning. These systems have implemented two important features: context awareness and adaptively. Context awareness denotes that the pedagogical progress and the context that are provided to the learning environment should be aware of the situations in which the learner actually is. Context of adaptively refers to the idea that different learning context should be adaptable to the particular setting in which the learner is situated [2].

Being a cognitive process, attention is strongly connected with learning [3]. When it comes to acquiring new knowledge, attention can be considered one of the most important mechanisms [4], where the level of the learner's attention affects learning results, and the lack of attention can define the success of a student.

Teaching should be solidly grounded to the absolute understanding of how the process of learning occurs, so that instructional strategies could be efficient and lead to persistent knowledge. This is especially true when learning activities involve the use of technologies, as they are more likely to be inattentive due to exposure to other sources of distraction. This may affect the acquisition of knowledge [5].

This paper deals with the issue of attention monitoring, with the aim of proving a non-intrusive and non-invasive system, reliable and easy tool that can be used freely in schools, without changing or interfering with the established working routines.

This paper is organized as follows. In the next Section the state of art of technology in learning and ambient intelligent where scientific literature is reviewed. Section 3 contains the proposed architecture, Sect. 4 presented the methodology applied with data acquisition and in Sect. 5 preliminary results are presented. Finally, in Sect. 6 some conclusions of this work are presented and future directions are suggested.

2 State of Art

Learning is a skill used in all of the human's lifetime, and it can be defined as the art or process of acquiring knowledge or skill. It is very linked with attention as without attention the learning ability is severally impaired. Another theory associated is: less attention causes less information retained by the brain [6].

2.1 Technology in Learning

Technology is shown to help low performing students to increase their results and attitudes towards the classroom [6]. The stimulus provided by the technology is more advantageous than disadvantageous [5].

Although the difficulties of having technology in classroom are disappearing some strongest factors can proved that they can still be felt. This is especially true when we consider the lack of training and disbelief in the role of technology, the necessary time spent, and the costs of equipment.

The classroom contains not only students but also teachers, so the use of technology in learning also changes the role of these teachers. It is required that the teacher have more training, time available to study and explain the technology that will be used in the classroom.

There are many technologies that can be used to learning like online collaboration tools, presentation software, tablet, course management tools, clickers and smartphones, lecture-capture tools, and audio tools. These technologies have many advantages to help students to learn faster and better, by allowing teacher to adapt the students learning style. However, there are many distractions that can disrupt attention present in these technologies. With the emergence of social networks and games, it can be very difficult for the teacher to know if the students are really working on the pre-defined tasks or if they are wasting their time and attention on other tasks [7].

2.2 Ambient Intelligent

The collection, storage, management, and anticipation of contextual information about the user to support decision-making constitute some of the key operations in most AmI systems.

An AmI system is an environment in which technology is embedded, hidden in the background, sensitive, adaptive and responsive to the presence of people and objects. This system also preserves security and privacy while using information when needed and with an appropriate context [8].

In the case of this work, adaptive systems aim at supporting and enhancing a student's learning process [9]. In their supply of adaptability, adaptive systems generally consider the student's knowledge, background, interest, goals, targets and/or choices [10].

3 The Proposed Architecture

In this section it will be presented the proposed architecture approach. The modules will be developed following the notions of encapsulation, inheritance, polymorphism, association, and abstract classes. The technologies applied for this system are JavaFX, SQL, and REST. The architecture is presented in Fig. 1.

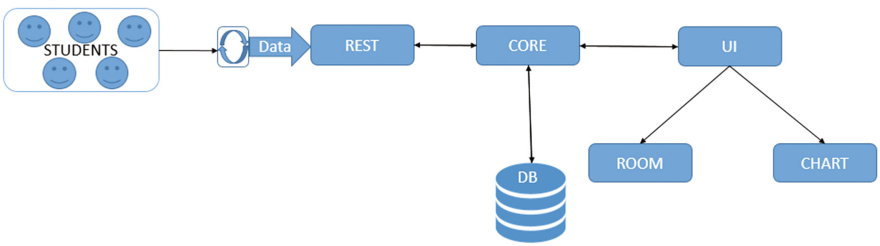

Fig. 1. The proposed architecture of the AmI system

The proposed architecture contains a rest service (REST) that receives data in real time from computer student's. This data contains the peripheral behaviors biometrics student's features. This rest service (REST) sends the data received to the core module (CORE) of the application. In this field, all processing will be made and compare with previous data stored in database (DB). Finally, the database (DB) will be updated.

Then there are some graphical modules that allow showing the information in an intuitive way to the user. These graphical modules stand out the user interface (UI) that allows the teacher to control the application. This graphical module user interface (UI) is composed by a module that allow the creation of charts (CHART) and the layer that allows the creation of virtual classrooms (ROOM) so that the teacher may view intuitively the students behavior.

3.1 REST

As previously mentioned, this module will deal with the transportation of the data of the peripheral behaviors biometrics student's features. The requests have a defined Json format that allows exchanging information with the classifier.

This application will be send information about what should be considered as a task and which students it will be applied to. Then it'll receive the attention data about the global class and each student. The technology used in the making of this layer is REST and Java.

3.2 CORE

This is the module where all the business logic will be located, so all the required processing will be done in this layer. This module provides powerful tools for performing analytics and statically analysis in real-time. This layer simplifies the code and limits resources requirements. It is important that in this process some values are filtered to eliminate possible negative effects on the analysis. The system calculates, at regular intervals, an estimation of the general level of performance and attention of each student.

Here it will be tested for input errors from the application users and received errors from the received data, it will be also the module responsible for managing the sync time with the REST layer. This module it will be a Java based module.

3.3 DB

In this module the raw data received from the data generating devices is stored in a data store engine. Here it is acknowledged the supporting database and it will store the students' attention profiles, the class attention profiles and the previous made classroom tasks, it will also store the information linking the students to the correct class and the possible classrooms plants.

The classifier will also interact directly with the database, this is helpful to reduce the needed quantity of data to pass through rest and speed up that process. For the construction of this module it will be used MySQL for this module.

3.4 UI

The system will need to interact with the teacher, so this module will provide that. It will contain the window to order: introduction of the classroom tasks; ordering to starting collect data; button to authorization to create news classrooms; and button to choses students, and tasks.

This module needs to follows the known aspect of usual applications so that it would be easy for the teacher to use. For the construction of this module it will be made using JavaFX.

3.5 CHART

This module will allow the teacher to see the data into charts that help him to concentrate information and study the student's behavior in classroom, instead of the attention, and other reference indicator being displayed in a non-intuitive and non-invasive way.

This layer allows the teachers to make all the charts that they feel the need to, so it would have to be highly adaptive to every user and it is built with JavaFX.

3.6 ROOM

Here it will be made a classroom designer, to allow teacher to display the student's attention so that he can see in little time what students or sectors of the classroom are not attentive.

This module needs to allow the teacher to design where the seat students of the room where in the classroom. This system has some pre-designed room, which the teachers can use. If the design room proposed didn't exist the teacher can created or adopted a notation to persist the created rooms, and it is built with JavaFX.

4 Methodology

In this work we compare the class from the sciences and technology course while performing an activity based on Microsoft Excel at the High School of Caldas das Taipas, Guimarães, Portugal. We want to determine how the class reacts during the lesson and the effect on mouse and keyboard dynamics, and attention level.

For this purpose one group of 28 (19 girls and 9 boys) students were selected to participate in this experience. Their average age is seventeen years old. In the lesson, they have access to an individual computer and 100 min to complete a task. Students received, at the beginning of the lesson, a document with the goals of the task.

4.1 Data Acquisition

The first stage of the proposed system is the collection of the relevant data. The data collected by the logger application characterizing the students' interaction patterns is aggregated in a server to which the logger application connects after the student logs in.

The privacy of the students is ensured, since the necessary data that is collected to perform the login and the registration are an ID that does not personally identify of the student. They also need a password, and specify the gender.

This application runs in the background, which makes the data acquisition process, a completely transparent one from the point of view of the student. The system was developed to acquire data from normal working routines, compiling information from the students' activities through the mouse and the keyboard, which act as sensors. The Mouse and Keyboard Sensing layers are responsible for capturing information describing the behavioral patterns of the students, and receiving data from the events generated by their mouse and keyboard [11]. These data are further processed, stored and then used to calculate the values of the behavioral biometrics.

As previously mentioned [11], the early version of this system acquired data describing the interaction of the user with the computer in terms of the mouse and the keyboard.

This raw data includes all the important interaction events: when keys were pressed down or released, when the mouse moved (and where to), when clicks started or ended and when the user switched to a given application. This data is then transformed by the server as described in [11], to generate 15 features that describe the performance of the interaction with the computer.

5 Preliminary Results

During the lesson with the class, the monitoring system was used to assess the interaction of the students with the computer and to quantify their level of attentiveness as well. To quantify attentiveness the following methodology was followed. Asides from capturing the interaction of the students with the computer, the AmI system also registers the applications with which students are interacting.

Attention is calculated at regular intervals, as configured by the teacher. The teacher may also want to assess, in real-time or a posteriori, the evolution of attention of the whole class. If necessary, the teacher may also click on a student to analyze the temporal evolution of the attention for that specific student during the class. Figure 2 presents the evolution of attention for four students in the lesson.

Theoretically, the lesson began at 8:15 a.m. and finished at 9:55 a.m. However, the students need to set down and the teacher must explain the content of the lesson. After that the student need to turn on the computer, open the session, and run the application.

In case of Fig. 2 we have four students that were monitoring the level of attention. In these cases, the background application received data after 24 min of the lesson had begun. This mean that students only begin to open the application task at 8:39 a.m., although there are a student that only begun after 32 min, at 8:47 a.m.. After finished the task, the student turn off the computer, before the lesson had finished. Some students have finished the task in 50 min after the lesson begun at 9:05 a.m., and other after 66 min at 9:21 a.m..

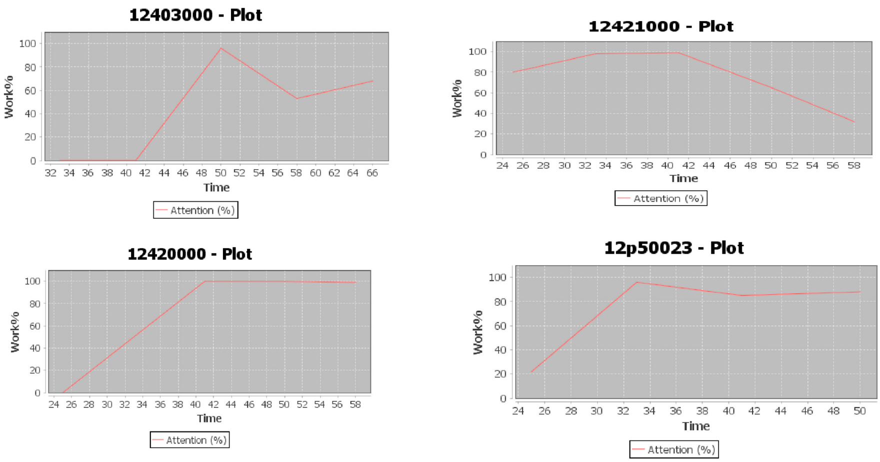

Fig. 2. Evolution of the level of attention for four students

In term of attentiveness, we can see that each one reacts differently and had different evolution of the level of attention during the lesson. For example the student 12421000, has a good level of attention until the minute 41, after that his level of attention in the task as decrease continuous until a lower level of attentiveness (around 30%).

6 Conclusions and Future Directions

The work developed so far resulted in a very useful system for the teachers, which can monitor, in real-time, the level of attention of their students. However, in this moment, the architecture of the proposed AmI system can only analyze the student's level of attention from the percentage of time spent interacting with work-related applications and don't compared with the biometrics behaviors captured of the students. It also necessary having a larger amount of data in order to analyze the profile of students and predict how they react in different types of lessons.

With the proposed system it is possible to detect potentially negative factors dynamically and non-intrusively, making it possible to foresee negative situations, and to take actions to mitigate them. This may, in turn, minimize issues such as stress and anxiety, which can negatively influence the students' results and are closely related to the occurrence of conflicts.

In future work we will implement a tighter integration between the monitoring of the interaction of the users with the keyboard and the mouse (biometrics behaviors) and the performed tasks. With the data of biometrics behaviors it'll be possible to know all the actions that each user performed both with the mouse or the keyboard, and at what time. We will thus generate a new feature that will quantify the level of activity of each user throughout time. This new feature will allow a more contextualized analysis of attention, improving the performance of its classification and quantification.

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A Hospital Service Kiosk in the Patient's Pocket

Marta Serapicos[1(✉)], Hugo Peixoto[2], and Victor Alves[1]

[1] Algoritmi Centre, University of Minho, Braga, Portugal
martaserapicos23@gmail.com, hpeixoto@chts.min-saude.pt
[2] Information Systems Department, Centro Hospitalar do Tâmega e Sousa E.P.
E., Penafiel, Portugal
valves@di.uminho.pt

Abstract. Nowadays, with the use of upcoming technologies such as augmented reality, organizations can improve their services more intelligently. Customer service continues to be an important factor for improving quality in healthcare units and, for this reason they are providing self-service systems, such as kiosks, as an option. Therefore, and having also in consideration the current use of mobile devices in day-to-day life, an augmented reality solution that takes advantage of mobile technology was advised. The goal is to optimise the process of customer service in healthcare units. The main element of this solution is a mobile application that provides an augmented reality experience to the user due to its self-awareness about his location and about the tasks that the he is performing. This application complements the current kiosks system in which it is integrated, providing most of its functionalities.

Keywords: Customer service · Self-service kiosks · Augmented reality · Mobile · Indoor location system

1 Introduction

In the last decades, technological advances have occurred at an exponential rate and everyday innovations appear in different sectors of activity and in the most basic daily activities of society. Technologies such as wireless networks, allow constant communication and exchange of information, anytime, anywhere, between multiple objects, services and people. This set of different interconnected physical and digital systems constitutes the Internet of Things (IoT) [1, 2]. Cyber-Physical Systems (CPS), are a new generation of powerful mechanisms based on embedded devices, with computational and physical capabilities. The potentials of CPS can be boosted by the benefits of IoT, enhancing the modalities that enable interaction with humans or other machines [3, 4]. IoT and CPS establish the basis for the Industrie 4.0 (I4.0). The I4.0 concept was first introduced during the German Hannover Mess in 2011, due to all the advancements in digital technologies as an inevitable future scenario of challenges and opportunities, with big economic and favourable social transformations. It is described

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as a promising age of "smart industries", in which humans, devices, objects and systems combine intelligently, to form dynamic, self-organizing networks of production [5–7]. With this fourth industrial revolution sooner or later different companies, as well as their respective components, will be able to link their strategies in order to achieve common goals that are beneficial for all involved. This process can be facilitated through the use of upcoming technologies that afford a better interaction human-human, human-machine and machine-machine, like Artificial Intelligence (AI), Virtual Reality (VR) and Augmented Reality (AR) [5, 6].

Organizations must be aware of all social transformations and technological developments and adapt accordingly, in order to attend the needs and increasing expectations of the customer and consequently manage to survive in such a competitive environment. In addition to technologies that improve health care, healthcare institutions should also not forget technologies like Information Systems (IS), which allow a better organization of patient data as well as an increase in the efficiency of all the surrounding processes [8, 9].

Medical institutions have been using the combination of the usual over-the-counter service with self-service kiosks to improve the efficiency and celerity of patient service. These kiosks systems allow patients to check-in for their scheduled appointments, take tickets for the services offered by the healthcare unit, make payments, check medical appointments and overdue payments and access other kind of relevant information. Self-service technology has been increasingly used due to the advantages mentioned above and also because they allow a personalized service, adapted to the particular needs of each user as can be seen from the offer of numerous IT companies [10–12]. Some of these companies are taking the next step and are starting to invest in technologies that combine self-service with mobile technologies [13, 14].

By its very nature, the hospital environment is difficult to change because of all the legal, organizational, technological and social issues that need to be overcome [8]. Therefore, in certain procedures or situations it would be easier and more interesting if the perception of reality could be extended. A system based on AR can make this option feasible, since it allows presenting, directly or indirectly, the real world complemented with computationally generated objects through the display of common mobile devices, such as smartphones. These virtual objects are usually interactive. [15]. In addition, as described in [16] a healthcare unit can perform more than one thousand medical appointments in a daily basis. Combining these medical appointments with non-medical ones such as nursing care, radiological and laboratory examinations, this number can be even higher. The use of AR can also improve the flow of patients within the healthcare facility. Not only the patient user experience can be improved but also the global management of people inside a healthcare unit can become a simpler task.

In this context, the main goal of this work was to conceptualize and implement an AR solution that combines existent self-service kiosks systems with mobile technology, in order to optimize the process of customer service in healthcare units. Maintenance of the confidentiality and security was mandatory during the system development.

2 Augmented Reality Solution

The Augmented Reality Solution (ARS) (Fig. 1) was designed to be easily integrated with kiosks systems installed at healthcare units. The main component of this solution consists in a mobile application that communicates with some of the healthcare unit informatic system elements. The target is the user of the respective healthcare unit that will have access to the mobile solution by installing the developed Application (App) in his mobile device.

As most of the existent AR applications are related to the overlapping of virtual images in the real world [17, 18], one can fall into the error of thinking that AR is limited to the sense of sight, which is not true. The AR cannot be restricted to a particular technology nor to any sense [15, 19]. In the case of this solution the notion of AR lies in the capabilities of the mobile App to react to the state in which it finds itself and provide a User Interface (UI) that depends on the identified state. The different App states, and, therefore, the different UIs presented, are consequence of its self-awareness about the location of the user within the healthcare unit and about the tasks that he is performing. In addition, the UI of the App offers the core existing kiosks systems functionalities. Summing up, as the user moves through the physical environment of the healthcare unit, the mobile App presents new information and functionalities. The user has the kiosk literally at his fingertips and, instead of going to the equipment, it is the equipment that comes to the user. The mobile device location is computed through a developed indoor location algorithm based on the wireless signal features.

2.1 Functional Architecture

For the system implementation, an architecture based on client-server concepts was idealized (Fig. 2). The Hospital Information System (HIS) enables the connection between the healthcare unit itself and other healthcare units via RIS (the Portuguese health informatics network). Among other components, the HIS is connected to the kiosks system and to the mobile App through the respective application servers.

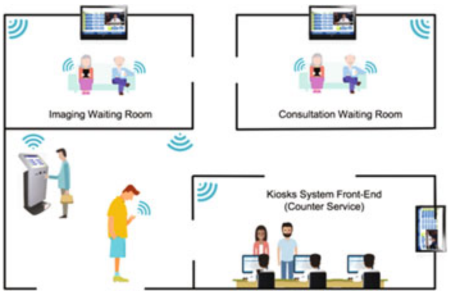

Fig. 1. Augmented reality solution

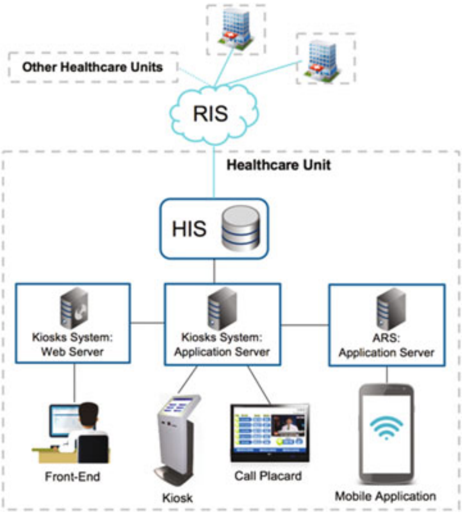

Fig. 2. Functional architecture

The kiosks system is constituted by 3 distinct software modules that provide information based on the application server database and knowledge:

- The first one is installed on each kiosk equipment and ensures the performance of its features.
- The second one is installed on a computer to command the call placards. It manages the priorities system and waiting queues, and also ensures the transmission of information related to the order of service.
- The last one is in charge of the overall management of the system and is installed on the healthcare unit service computers which are the system Front-End.

The mobile App, developed as main element of the ARS, makes requests to the kiosks system, about tickets, queue lines and any available information of the patient using the application. These requests and the respective responses are handled by the application servers.

3 Development

3.1 Indoor Location System

An indoor location system was developed (Fig. 3) in order to locate the mobile device inside the healthcare unit building. This system is based on methods described in [20, 21] and takes advantage of the Wireless Local Area Network (WLAN) existent in the healthcare unit infrastructure. Each access point (AP) of this network broadcast a wireless signal that has two interesting components, the Basic Service Set Identifier (BSSID)—formed by the AP MAC address and a network identification—and the Received Signal Strength Indicator (RSSI)—the relative power of received wireless

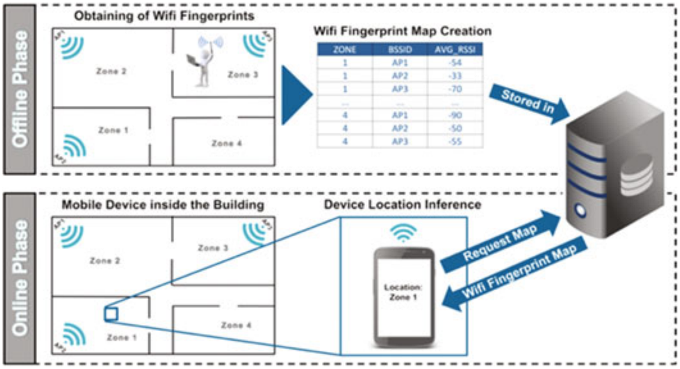

Fig. 3. Offline and online phases of the indoor location system

signal, which decreases as the distance to de AP increases. These features can be scanned by most mobile devices (currently iOS based mobile devices does not provide this information), so if a device has access to a WiFi Fingerprint Map (WFM), i.e. a map where the wireless signals features for each relevant zone of the building are represented, it can infer about its location.

The developed indoor location system has two phases (Fig. 3):

- The offline phase consists in the creation of the WFM of the building. For this purpose, a program was developed that uses the airport command line wireless tool of the Mac OS to perform a wireless broadcast scan and build the WFM. This program receives as input the zone identifier and then collects the WiFi Fingerprints, i.e. the BSSID and the respective RSSI for each wireless signal picked up in the respective zone. At the end of this process, a database is created and stored on a RESTful Web Service, making it available for the mobile devices to use in the online phase. This phase is executed only once or every time the WiFi network AP grid is changed.
- During the online phase, the mobile device is supposed to locate itself inside the building. A similarity algorithm (Fig. 4) that compares the RSSI values scanned by the device with the information contained in the WFM was developed. The similarity algorithm returns the most probable location of the mobile device. The map is downloaded and stored in the device, in order to avoid a server overload and errors in case the wireless connection fails.

3.2 Mobile App States

The mobile App states and UIs depends on its location and on the tasks that the user is performing. Table 1 provides an overview of some system possible states, showing the relationship between the *User Type*, the *User Enabled Actions*, the *Correct Zone,* the *State*, *UI Contents* and the *UI Possible Actions*. The *User Type*, which depends on whether the user has a *Scheduled Appointment* (*SA*) or not (*Other*), also influences the application states, since a patient with a *SA* must have access to more information than a user who does not have it (*Other*). The sub-states are not presented.

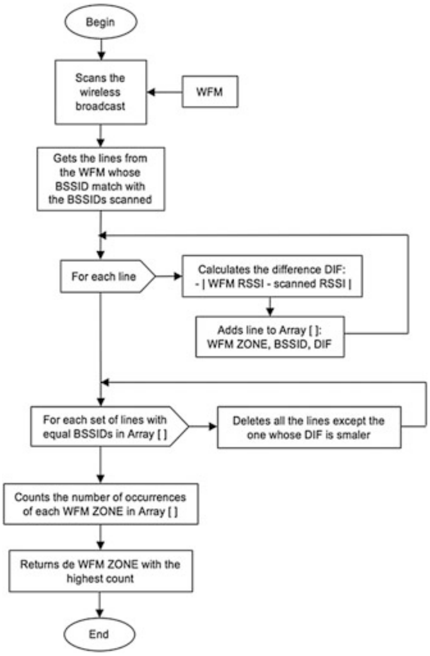

Fig. 4. Similarity algorithm flowchart

In some cases, the user needs to be in the *Correct Zone* for the user to be able to access the next consequent state and respective *UI Contents* be presented. When a patient is not in the correct zone (e.g. he should be in the dermatology waiting room but is in another room), the App notifies him, indicating the location he should go to.

The different actions are presented in Table 2; Table 3 describes the contents presented on *UI Contents Main Page*. Note that depending on the *User Type*, in some cases, there are differences in the *UI Contents*, namely the *Side Menu* that is displayed, e.g. State 6, whose *UI Contents Side Menu* is the 1, is reached only by users with scheduled appointments (*User Type SA*), while State 6.1, whose *UI Contents Side Menu* is 2, is reached only by users without any scheduled appointment (*User Type Other*).

The *UI contents* presented in the two different *Side Menus* are a set of options. *Side Menu 1* is presented only for the user who has scheduled appointments and provides the actions: *c*, *d*, *e*, *f*, *g*, *h*. *Side Menu 2* is presented to the other users and provides the actions: *b*, *c*, *d*, *e*, *f*, *g*, *h*.

After *State 2*, *4*, and *4.1*, the user receives a notification to go to the correct room number. The notification appears when the physician calls the user to its consulting room or, in the case of *State 3* and *3.1* the call is made by the individual in the counter service.

In Fig. 5, *State 0* provides to any type of user a *Login Form*. If the user has a scheduled appointment the App moves to *State 1*, whose UI includes the *UI Contents*

Table 1 Overview of some system possible states (* independent; - no or not done or not exist; √ yes or done; / one or another)

User Type		User Enabled Actions (during one session)								Correct Zone	State	UI Contents Main Page :: Side Menu	UI Possible Actions
SA	Other	a	b	c	d	e	f	g	h				
*	*	-	-	-	-	-	-	-	-	*	0	Login Form :: -	a :: -
√	-	√	-	-	-	-	-	-	-	*	1	Welcome1 :: 1	b :: [b, c, d, e, f, g, h]
-	√	√	-	-	-	-	-	-	-	*	1.1	Welcome 1.1 :: 2	c, d :: [c, d, e, f, g, h]
√	-	√	√	*	*	*	*	*	-	Consultation's Waiting Room	2	Consultation Info :: 1	- :: 1
/	/	√	*	√	*	*	*	*	-	Counter's Service Room (Front-Office)	3/3.1	Front-Office Info :: 1/2	- :: 1/2
/	/	√	*	*	√	*	*	*	-	Medical's Service Waiting Room	4/4.1	Medical Service Info :: 1/2	- :: 1/2
/	/	√	*	*	*	√	*	*	-	*	5/5.1	Overdue Payments Info :: 1/2	i, j :: 1/2
/	/	√	*	*	*	*	√	*	-	*	6/6.1	Scheduled Appointments Info :: 1/2	i, j :: 1/2
/	/	√	*	*	*	*	*	√	-	*	7/7.1	Other Info :: 1/2	i, j :: 1/2
*	*	√	*	*	*	*	*	*	√	*	8	Login Form :: -	a :: -

Table 2 Actions

User Actions	
a	Authentication
b	Check-in for scheduled appointment
c	Take ticket for front-office
d	Take ticket for medical service
e	Check overdue payments
f	Check scheduled appointments
8	Check other info
i	Cancel
j	Ok
h	Logout

Table 3 Description of UI Contents of the Main Page

UI Contents Main Page	Description
Login Form	Allows the user to login to the system in order to gain access and unlock all the App features. It can be made using an appointment code that is associated to the patient
Welcome1	If the user has a scheduled appointment in a near time (in the next hour) is provided a welcome page with informations about the consultation and with options for check-in
Welcome1.1	If the user does not have a scheduled appointment in a near time is provided a welcome page with options that correspond to actions c and d
Consultation Info	Detailed information about the appointment is provided to the user, such as schedule, specialty, doctor and room. The ticket identifier is also displayed
Front-Office Info	It is provided information about the zone where the respective front-office is located and the ticket identifier is also displayed
Medical Service Info	They arc provided information about the medical service required by the user and the ticket identifier is also displayed
Overdue Payments Info	For the user has access to his overdue payments he has to identify himself. The user can cancel this option and return to the previous page or press ok and access to more details
Scheduled Appointments Info	For the user has access to his scheduled appointments he has to identify himself. The user can cancel this option and return to the previous page or press ok and access to more details
Other Info	The user can access other informations such as waiting times, queue numbers, healthcare unit zones, information about the institutions and other medical information

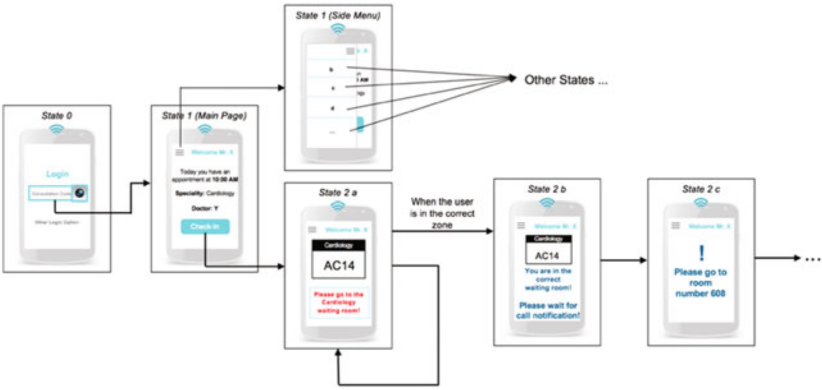

Fig. 5. Illustrative example of an UI flow

Main Page Welcome1 and the *Side Menu 1*. After the user makes the check-in the App reaches the *State 2* that, as well as the other states, can be divided into sub-states according to the UI contents. E.g. in the sub-state *a* of *State 2* the App presents a notification to the user indicating that the he is not in the correct location.

4 Discussion and Conclusions

Regarding to the ARS planning, the use of AR and mobile technologies was chosen to avoid impacts on the normal functioning of the healthcare unit. Furthermore, this approach allows the main component of the solution, i.e. the App, to be installed on the users own mobile device, which is an advantage for the institutions because there is no need to invest in specific hardware. Other companies are already applying this kind of technologies, as the best solution to improve customer service [13, 14].

With the implementation of the ARS, the user experience is enhanced because he can handle his own service more comfortably, without having to go to a specific place to do it. The global management of people inside a healthcare unit has become also a simpler task. Since the load of the service queues is distributed by three types of locations, i.e., the counters service, the kiosks and the mobile solution installed in several devices belonging to users, the waiting queues are minimized. It should be noted that this is an intelligent application, capable of providing information that the mobile App itself evaluates as most appropriated, according to the location of the user inside the healthcare unit and according to the tasks he performs. The implementation of this solution completes the physical environment around the user with virtual information of interest. Within the institution, where most devices are interconnected, the features of this solution allows constant communication between humans-machines and improves the communication between people e.g., between the patient and hospital staff. One disadvantage of the implemented App is that it does not work on devices which do not allow the scanning of WiFi networks, as is the case of iOS devices.

In the future, the developed similarity algorithm will be improved so that its nature becomes deterministic. With this change some computation errors will be decreased, the calculation of the user location will be more accurate and consequently it will be possible to provide more precise information to the user. Other features such as enabling payments will be added in the future.

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Development of a Hybrid Application for Psychotic Disorders Self-Management

Raquel Simões de Almeida[3,4], Constantino Martins[1,2](✉), António Marques[3], Daniel Benevides[1], Alexandre Costa[1], Cristina Queirós[4], Tiago Sousa[3], Ana Almeida[1,2], Nuno Fonseca[1], and Luíz Faria[1,2]

[1] Computer Science Department, Institute of Engineering – Polytechnic of Porto, Porto, Portugal
{acm,1100863,1090248,amn,nuf,lef}@isep.ipp.pt
[2] GECAD Knowledge and Decision Support Research Group, Porto, Portugal
[3] School of Allied Health Sciences, Oporto Polytechnic Institute, Porto, Portugal
antoniomarques@sc.ipp.pt, tiagojcs1@gmail.com
[4] Faculty of Psychology and Educational Sciences, University of Porto, Porto, Portugal
cqueiros@fpce.up.pt

Abstract. This paper describes iCOPE, a hybrid web/mobile application prototype with the purpose of improving the self-management of psychotic disorders. The development of iCOPE was driven by a multidisciplinary collaboration between mental health occupational therapists and medical computing engineers. A usability test was performed to assess the satisfaction with the technological proposal. Several modules were identified as crucial and were employed in iCOPE: stress management, problem solving, medication adherence, symptoms monitoring and social interaction. Results of a usability survey to therapists and patients revealed general approval of the user interfaces.

Keywords: Hybrid application · Psychotic disorders · Usability · Assistive technology · Ambient intelligence

1 Introduction

Mental illness, particularly psychotic disorders, comprehends a number of clinical conditions associated with several changes that include limitations related with thinking capacity and reality understanding, deficits in communication skills and difficulties in developing appropriate emotional and behavioural responses [1]. One of its core features are cognitive impairments which are present at illness onset and remain relatively stable over the course of illness, jeopardizing psychosocial functionality [2].

Some international guidelines encouraged not only active user's involvement and participation, nuclear values of recovery, as well as the emergence of integrated strategies that contribute not only to symptoms remission, social participation and quality of life promotion [3], but also to establish the need to promote an approach focusing on people and their needs and choices [4, 5].

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Illness self-management is an approach designed to involve people with mental health problems as active agents in their own treatment and recovery, teaching them to monitor their condition and to use appropriate coping strategies. Patients who received self-management education were more likely to improve medication adherence and symptomatology, compared to other patients [6].

Due to recent technological developments, several researchers designed innovative assistive tools that improve the accessibility and quality of care for people with mental health problems [7, 8].

Mobile applications seem to contribute to help their users to engage in health promoting behaviours outside the clinical context [9, 10] or in other activities such as therapeutic homework, facilitating generalization to the day-to-day life of its users [11].

Smartphones framework have come to stand out as interesting platforms for illness self-management, because they are easily accessible, they are mobile and they have internet connection capability [12]. However, applications targeted at people with psychotic disorders, particularly schizophrenia, are scarce and under development [8, 11, 13]. Some studies conducted in Europe and in the United States have sought to counter scepticism in using these technologies for people with psychotic disorders, due the fact that these people are willing and able to engage in such technologies [8, 14]. Nevertheless, individuals with higher prevalence of adverse symptoms or lower intellectual abilities seem to have more difficulty in their use, which requires additional training or the use of specially intuitive devices and software that minimize the number of steps required to perform each task/action [13, 15]. Approaches centred on the user are particularly important during the development of technological systems for people with psychotic disorders, as they often have a set of unique features (e.g., presence of positive and negative symptoms) that can significantly affect how they can get involved in technology-based services [16]. Additionally, it is also essential to ensure privacy and data security and, therefore, adequate access and use of these [17].

Provision of mental health care has been viewed as a public priority due the increased number of people with mental illness, and also because mental illness is one of the main causes of disability and morbidity. Globally, there are a small number of facilities/services in psychosocial rehabilitation field, revealing a clear failure, inadequacy and disarticulation of existing social responses to meet people with mental illness needs. Thus, giving tools for patients' use in community to promote greater well-being and quality of life for its users, is a strategy that contributes to the reduction of health care costs, by better monitoring and eventual reduction in the number of relapses. In addition to the formal effectiveness in terms of health, self-management can also help change perceptions and reduce stigma, presenting people with psychiatric disorders as capable citizens. Low cost technologies promoting independent living and that supports rehabilitation processes should be assessed and disseminated and can play a very important role in the developed and developing world.

This paper aims to present iCOPE, a hybrid web/mobile application prototype developed to improve self-management of psychotic disorders. This innovative tool presents the advantage of gathering the strengths of the existing applications, combining their different functionalities, and also allowing real time information exchange between the rapists and patients.

This paper is organized as follows. Section 1 present's iCOPE System, Sect. 2 presents iCOPE REST API, Sect. 3 presents iCOPE Web Platform, Sect. 4 presents Mobile Application and Sect. 5 presents stakeholders feedback.

2 ICOPE System

The development of iCOPE was driven by a multidisciplinary collaboration between mental health occupational therapists, psychologists and medical computer engineers, based on an extensive literature review about mobile applications for mental health. This process was also a user participatory design approach which advocates a change of perspective: instead of design for users, it is expected to design with users.

One of the From a more abstract perspective, the iCOPE system can be seen as an assortment of tools that may be applied psychotherapeutically through the interaction of different actors and interfaces: iCOPE web platform and iCOPE mobile application. Figure 1 show an overview of the Logical View of iCOPE. Thus, the iCOPE web platform works with a centralized server, meaning that patient's therapeutic progress may be registered and consequently monitored through the therapist's interface. The proposed approach lead to the development of an API based on RESTful principles capable of communicating with the main database. Moreover, the iCOPE mobile application supports the main philosophy of the project to provide a platform capable of assisting the rehabilitation process in psychotic disorders, which allows the patient to follow the therapy course based on computer-aided treatment.

A RESTful API architecture defines a set of constraints and rules used to define Web service communications. It aims to provide a service focused on the data exchange using HTTP requests (Fig. 1). Considering the centralized architecture of the project, the mobile application requires communication with the server in order to acquire, display and record data. The API offers a layer communication with the server

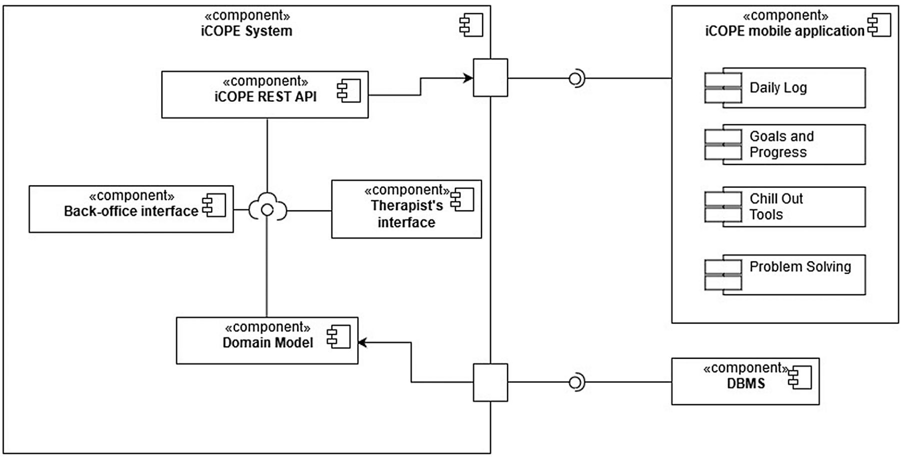

Fig. 1. Proposed overall system logical view

and the database. It is, therefore, a service that allows interaction with the various modules/entities that support the data model. RESTful architectures present several advantages, such as the possibility to build a Web service outline resource easily accessible through different platforms (especially useful for developing mobile applications). It creates a layer of abstraction that separates server implementations from client implementations.

3 iCOPE Web Platform

The web platform has two modules, which are described as: The back-office system for the administrator's interface; The therapist's interface where a professional psychotherapist may interact with the patient.

The administrator interface provides access for the application system's administrators to the user account management tools, allowing them to register new user accounts, alter wrong or outdated data on existing accounts and manage the association between therapists and patients. The interface is presented through a website or portal which requires email and password authentication from an administrator in order to use its functionalities.

The therapist's interface allows the therapists to oversee their patient's inputs in the daily log, objectives and problem solving modules. This allows them to acquire better knowledge about each patient's struggles and goals, helping them adjust the therapy so as to better increase the patient's quality of life. The interface is also presented through a website or portal which requires email and password authentication from a therapist in order to use its functionalities. The therapists may change their account and details once they are authenticated.

4 iCOPE Mobile Application

The mobile application (Fig. 2) implements the features and modules which are considered as crucial for the patient's therapy. It leverages on the advantages offered by mobile applications, such as the capability to easily transmit time-sensitive information, the ability to access remote services from several real world locations and, more important, it may provide immediate therapeutic support. Mental health applications may provide patients with tools that help them overcome their difficulties, increase self-management skills, encourage the definition of goals and improve their overall quality of life.

Apache Cordova is a framework for building cross-platform mobile applications. Its main feature is the ability to build hybrid applications using languages that are part of the web development standards, such as HTML5, CSS3 and JavaScript. This is a great advantage as it removes the dependency on specific API implementations found in the various mobile operating systems found in the marker. This means an application can be compiled and released to multiple devices, without having to maintain native platform code.

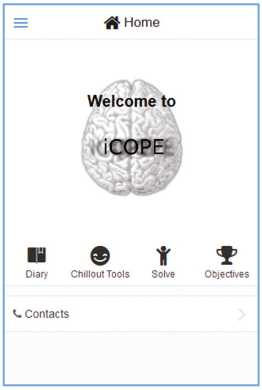

Fig. 2. Main menu

Before any practical development, it was necessary to carry out preliminary research work to determine the best approach to be used in the application's interface design. The main aspect to be consider was the optimization of the experience and interaction with the user, giving emphasis on simplicity while still maintaining full functionality. Some facilitators of use were identified such as being easy to access and use (simple screen, short sentences, few steps to perform an action is essential).

Keeping style consistency across multiple screens and forms was also an additional concern, along with maintaining cohesive positions for the various interaction buttons. This design allows the user to predict where he should click to fire a certain application event, across different screens or forms. In other words, it helps increase the predictability of application events. It was important to choose a pleasant colour scheme in order to emphasize what is important and which elements can be interacted with. In conclusion, ensure that software is user friendly and easy to deal with. Designing software with the goal of treating mental health requires several considerations regarding the sensitivity of the users, alerting for a constant struggle with keeping the interface clean with emphasis on simplicity.

First we must describe which modules are part of the application and are consequently considered as crucial for the patient's therapy.

(i) Daily Log

The daily log is a module in which the patient is able to describe and expose a psychotic experience or event that triggered an auditory hallucination. This module also works as a record of patient's mood over time and allows the review of past entries. For the therapist, it works as a feedback mechanism and may help to determine the best strategies and interventions for symptoms' monitoring. The elements of this module focus on analysing the influence of the hallucinations perceived by the patient and the consequent action taken to supress the symptoms. Medication adherence was also included in this module, involving custom notifications for taking medication.

(ii) Goals and Progress

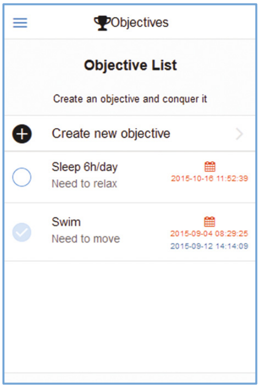

Fig. 3. Objective list

A patient can define a set of goals or tasks (Fig. 3) to accomplish. The main objective of this module is to provide a personal motivation element that the patient can follow. By completing goals or tasks, the patient can show progress in the treatment. Any goals will be visible to the therapist associated with the patient, and a goal may also be supported or executed in collaboration.

(iii) Problem Solving

The problem solving module describes an introspection and self-management tool. As a way to promote problem solving, it is necessary for the user to provide tangible solutions to solve the specific problem. After this process, the patient must evaluate their own solutions and choose the most appropriate, together with an assessment of their success. Social interaction may be difficult for people with psychotic disorders as they may strive to start a conversation or to appropriately communicate through normal gestures with others. Thus, this module can be considered as way of interaction and as place where the patient may vent or describe a stressful situation in a safe space.

(iv) Chill Out Tools

This module (Fig. 4) offers the patient not only stress management skills but also a relaxing environment with access to media files to view or listen. This tool incorporates these features in order to provide a calm setting including guided meditation and relaxation instructions (Jacobson progressive muscle technique, Schultz autogenic training, Mindfulness exercises, Imagery). Multimedia content is available dynamically, meaning content can be managed server-side, avoiding the need to change anything client-wise.

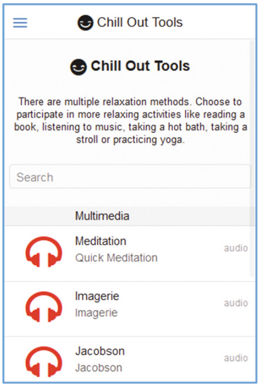

Fig. 4. Chill out tools

5 Stakeholder Feedback and Conclusion

Illness self-management is fundamental for patients, allowing them to take control over their lives and fostering genuine collaboration with professionals in their recovery process. New self-management technologies could change health functioning, symptoms, and progress towards recovery. To validate our proposal we asked our stakeholders. Stakeholder feedback involved both surveys with professionals (occupational therapists and psychologists) and people with psychotic disorders. The survey was carried on with six therapists and six patients who volunteered to use their designated interfaces and to evaluate them. It is important to mention that patients and therapists were paired up, which contributed to the lower amount of samples. The protocols for these studies were approved by an ethic review board, assuring that samples were acquired anonymously, through a predetermined set of questions that did not expose private or personal information.

The survey consisted in assessing: engagement and usability, functionality, aesthetics, information and overall subjective quality. Subjectiveness and aesthetics may be considered as questionable factors, however, it is essential to evaluate the sensitivity of the users (their tastes), in order to understand which directions should the application's design take.

Results (Table 1), both from the therapists and from the patients praised the usability and usefulness of the implemented functionalities, and showed overall satisfaction with the graphic features of the interfaces. However, users felt extra interface customization, such as theming the application's colours, which would be a visually satisfying feature. Regarding therapy usefulness, patients understood most modules to have good potential (Table 1).

The therapists also considered that the application could facilitate their patient's therapy, and that modules were widely useful (Table 2).

The application system developed meets the requirements and expectations of different stakeholders, providing a secure access via responsive interfaces that were designed to present the content appropriately to the screen resolution.

Table 1 Usefulness of the iCOPE's modules according to patients involved in pilot evaluations

Module name/evaluation	Useless (%)	Less useful (%)	Useful (%)	Very useful (%)
Home screen	0	16.6	83.3	0
Diary	0	0	50	50
Objectives	0	0	50	50
Problem solving	0	0	50	50
Chill out tools	0	0	33.3	66.6

Table 2 Usefulness of the iCOPE's modules according to the therapists pair up with the patients

Module name/evaluation	Useless (%)	Less useful (%)	Useful (%)	Very useful (%)
Patient overview	0	0	100	0
Diary	0	0	66.6	33.3
Objectives	0	0	66.6	33.3
Problem solving	0	0	50	50

The surveys among patients, psychologists and occupational therapists, aiming to validate functional requirements, revealed that the prototype is interesting and has the potential to achieve: increased knowledge and communication between therapists and patients; timely responses in the event of crisis; reduced risk of hospitalizations and relapses; and increased patient participation in several areas of their life. The patients' opinion supported the potential of a smartphone application to be an innovative tool to empower patients to develop self-management skills.

Regarding future developments, the iCOPE project has the potential to mature and consolidate through integration with other systems such as electronic health records and physiological measurement systems.

Mobile devices can be a complementary part of assessment and intervention for mental health problems as society increasingly move to a hybrid model of mental healthcare. This hybrid web/mobile application prototype could potentially improve mental health care system and thus, patients' functionality, independence and quality of life.

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An Environment for Studying Visual Emotion Perception

Davide Carneiro[1,2](✉), Hélder Rocha[1], and Paulo Novais[1]

[1] CIICESI, ESTG, Polytechnic Institute of Porto, Felgueiras, Portugal
[2] Algoritmi Center/Department of Informatics, University of Minho, Braga, Portugal
{dcarneiro, pjon}@di.uminho.pt, pg27737@alunos.uminho.pt

Abstract. Visual emotion perception is the ability of recognizing and identifying emotions through the visual interpretation of a situation or environment. In this paper we propose an innovative environment for supporting this type of studies, aimed at replacing current pencil-and-paper approaches. Besides automatizing the whole process, this environment provides new features that can enrich the study of emotion perception. These new features are especially interesting for the field of Human-Compute Interaction and Affective computing as they quantify the effects of experiencing different emotional dimensions on the individual's interaction with the computer.

Keywords: Visual emotion perception · Behavioural biometrics · Keyboard dynamics

1 Introduction

Emotions are one of the most interesting Human mechanisms and serve very important and diverse functions, namely by prompting one for action, providing information about a situation or allowing a more efficient communication with other individuals [7].

While the study of emotion *per se* and of its role in inter-human relationships is not new, in the last years a new field of study emerged that is devoted to the study of emotions in the context of Human-Computer Interaction: Affective Computing [2]. Specifically, this field aims at the development of systems that can recognize and respond to Human emotions.

In this paper we detail the development of a system to facilitate the study of visual emotion perception. Moreover, the system also aims to measure the influence of these emotional dimensions on Human-Computer Interaction.

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The goal is, on the one hand, to facilitate data collection, allowing simultaneous data collection processes and providing the researcher community with access to relevant data in a structured manner. On the other hand, we aim to provide new variables that can enrich this type of studies, eventually leading to new and relevant findings. Namely, this system combines behavioural biometrics and accelerometers placed on the keyboard, to characterize, in a rich way, the interaction of the participant with the computer.

This is, indeed, the key innovative aspect of this system: the non-intrusive collection of new types of information from the environment, that can more thoroughly characterize the participant's state and significantly enrich the work of the researcher and widen the potential findings.

Despite the specific scope of the current work, the developed environment can undoubtedly be used with other aims (e.g. stress assessment, fatigue detection).

1.1 System Operation

The proposed system allows researchers to select (using the Administration dashboard) from a large set of emotionally-evocative color photographs from the International Affective Picture System (IAPS) [4]. The IAPS is a collection of normatively rated affective stimuli, considering tree dimensions: affective valence (ranging from pleasant to unpleasant), arousal (ranging from calm to excited) and dominance (ranging from controlled to in-control).

The researcher selects the desired stimuli and creates and configures a new study, consisting of a sequence of photographs. These photographs are sequentially shown to the participant, either in a pre-determined order or randomly.

The participant is asked to describe (typing in the keyboard) how she/he actually feels while watching each of the photographs. The participant is allowed to look at the photograph while typing and there is no time-limit for this task. In the following screen the participant is also asked to rate each picture in terms of valence, arousal and dominance. A 9-point Likert-scale is used for this rating with the following labels: valence (1—unpleasant, 9—pleasant), arousal (1—calm, 9—excited) and dominance (1—dominated, 9—in control).

After the participant provides this feedback, there is a 30-s interval in which no photograph is shown (only a white rectangle is visible in the space of the photograph) before advancing to the next one. This is done to "reset" the emotional state of the participant between each two photographs.

An extensive amount of data is collected while this process takes place, fully describing the participant's interaction with the computer during each photograph, as described in the remaining of the paper.

2 Behavioural Biometrics and Affective Computing

Behavioural Biometrics is the field of study related to measuring uniquely identifying patterns in human actions. Many of the things we do are done in a unique way: walking, talking, typing on a keyboard or using the mouse [6].

Given the uniqueness of our behaviours, Behavioural Biometrics are often used to implement continuous and post-login methods of security and authentication. Nonetheless, they can also be used to detect significant changes in the user's behaviour, which may indicate a significant change in the user's state. In previous work we have studied the effects of mental fatigue and stress on keystroke and mouse dynamics [3,8].

In this work, the goal is to determine if different emotions (with variations in their valence, arousal and dominance) can have similar effects on the individual's interaction with the computer. Ultimately, this will lead to the development of software and devices that are aware of the individual's emotional state, allowing them to react accordingly. Other researchers have also addressed this topic, albeit considering different features.

Shukla et al. look at the user's typing behavior to identify emotional states [9]. The authors use a total of 8 features: session time, keystroke latency, dwell time, sequence, typing speed, frequency of error, pause rate and capitalization rate. Questionnaires were used to assess the emotional state of the participants. All this data was then used to train classifiers for human emotion recognition from the keyboard typing patterns. In a related approach, the authors of [10] analyze typing behavior against positive/negative emotions. Its main conclusion is that all participants have shown significant differences in typing patterns when under positive and negative emotions, elicited through facial feedback [5].

3 Architecture

The architecture of the system consists of three main components. The *User Area* is where the participant's interaction with the system takes place. It includes a desktop with a mouse and keyboard, and three accelerometers attached to the keyboard. The developed application runs in this desktop, showing the photographs to the participant and collecting the data. This data is sent, in real time (whenever the participant advances to the following photograph), to the server.

The *Server Area* contains a Mongo database where data from the several studies are stored. The database also stores the structure of each research protocol created by researchers through the administration dashboard (e.g. sequences of photographs and other settings). All data is stored in the form of JSON documents.

Finally, the *Data Analysis* component provides a set of tools to automate data analysis and facilitate the work of the researcher. This includes data aggregation (e.g. by emotional valence), data extraction (e.g. to raw .csv files), feature extraction, statistical analysis (e.g. hypothesis testing) and training and validation of classifiers for emotional valence (Fig. 1).

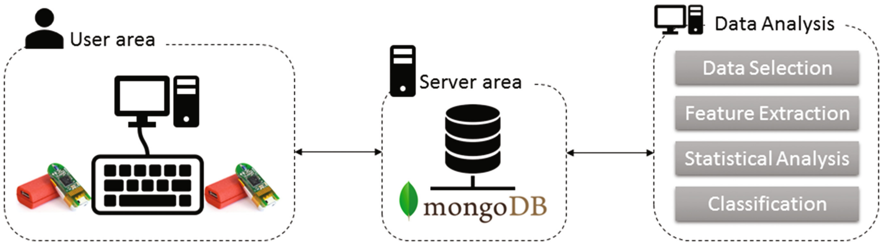

Fig. 1. Main components of the developed system

3.1 Administration

The administration dashboard allows the researcher to manage all the relevant data stored in the database. Specifically, through the dashboard, the researcher or team of researchers associated to a project are able to:

- Manage users—researchers can add/edit/remove participants as well as consult their information (e.g. date of birth, occupation, name);
- Manage research protocols—researchers can add/edit/remove research protocols, that are constituted by sequences of IAPS photograph identifiers, as well as meta-data (e.g. date of creation, responsible researcher, description);
- Manage participations—researchers can assign participants to specific research protocols. The dashboard allows to visualize individuals who have not yet participated in a given protocol;
- Manage collected data—researchers can visualize a summary of the data collected in a given participation (of a participant in a research protocol). Through the dashboard the researcher can also delete this data.

3.2 Data Collection

Different types of data are generated and collected by the system. Namely, we make a distinction between behavioural data and operational data.

Behavioural data includes data collected from the keyboard and the accelerometers attached to it.

Accelerometers are used with the aim to measure the intensity of typing (increased intensity results in larger values of acceleration). For this end, three WAX3 accelerometers are attached to the back of each keyboard: one in the center and the other two closer to the each side of the keyboard.

The WAX3 combines a triple axis accelerometer sensor (± 16 g, 4 mg resolution) with an ultra low power IEEE 802.15.4 2.4 GHz band. The device also integrates a USB 2.0 enabled microcontroller and micro USB connector along with an on-board power source (rechargeable Li-Polymer battery). This enables the device to behave as a receiver or transmitter and facilitates easy charging and reconfiguration using the bootloader application. Additional functionality can be added using the available expansion port and open source code structure.

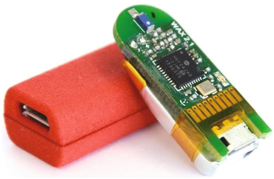

Fig. 2. WAX3 triple axis accelerometer

Each instance of data generated by each accelerometer contains the following elements: the timestamp, the identification of the accelerometer, and three values denoting the acceleration measured in each of the axes.

While pressure-sensitive keyboards could be used for this purpose, this solution is less expensive and can be applied on any keyboard (Fig. 2).

The keyboard, on the other hand, is used by the participant to type the words that describe each image. While the words typed can be useful to understand the participant's emotional assessment of each image (through text analysis), the goal is, at the moment, different: we aim to analyse *how* the participant types when visualizing images portraying different emotions.

To this end, the system registers the events related to pressing or releasing keys while typing, together with the key pressed and the timestamp in which it happened. The generated data thus describe two different types of events:

- KEY_DOWN, timestamp, key
  Identifies a given key from the keyboard being pressed down, at a given time;
- KEY_UP, timestamp, key
  Describes the release of a given key from the keyboard, in a given time.

Finally, operational data describes the actions of the participant throughout the experimental session. This includes the moment in which he/she is shown a new photograph, the moment in which writing starts or the moment in which the photograph is hidden.

Since the emotional rating of each photograph is known, operational data provides the necessary context to interpret behavioural data. For instance, it allows to aggregate and study the participant's behaviour by emotional valence or arousal, eventually pointing out if different levels of valence or arousal consistently result in specific and different interaction patterns.

The features extracted from these sources of data are described in Sect. 4.

3.3 Data Storage

The data collected are stored, in real-time, in a Document-oriented Database. These kind of data stores are designed to store and manage documents. Typically, these documents are encoded in standard data exchange (e.g. XML, JSON, YAML, or BSON). These kind of stores allow nested documents or lists as values as well as scalar values, and the attribute names are dynamically defined for each document at runtime.

In the specific case of this work, MongoDB is being used. MongoDB is a database that is half way between relational and non-relational systems. It provides indexes on collections, it is lockless and provides a query mechanism. MongoDB provides atomic operations on fields like relational systems, supports automatic sharding by distributing the load across many nodes with automatic failover and load balancing. Data are stored in a binary JSON-like format called BSON that supports boolean, integer, float, date, string and binary types. The communication is made over a socket connection.

MongoDB is actually more than a data storage engine, as it also provides native data processing tools: MapReduce and the Aggregation pipeline. Both the aggregation pipeline and mapreduce can operate on a sharded collection (partitioned over many machines, horizontal scaling). These are powerful tools for performing analytics and statistical analysis in real-time, which is useful for ad-hoc querying, pre-aggregated reports, and more. MongoDB provides a rich set of aggregation operations that process data records and return computed results. A significant amount of the features is extracted using either MapReduce or the Aggregation pipeline, as detailed in Sect. 4.

4 Feature Extraction

One of the key innovative aspects of the proposed environment is the extraction of new features to characterize the effects of emotional valence, arousal and dominance on Human-Computer Interaction. Hence, this section focuses on describing these new features, that will significantly enhance this kind of studies when compared to existing approaches.

Features have been organized in two main groups: operational and behavioural. In this section, the term *dimension* denotes one of the three affective dimensions of each photograph: valence (ranging from pleasant to unpleasant), arousal (ranging from calm to excited) and dominance (ranging from controlled to in-control). Indeed, since the aim is to assess interaction according to emotion, all the features described are calculated by participant and by dimension.

For each of the features described below, the following measures are provided (by participant/dimension): raw values, average, median, standard deviation and quartiles.

4.1 Operational Features

Operational features are those extracted from operational data, that describe the actions of the participant throughout the study. The following features are considered:

- Words/characters—expresses the average number of words or characters that the participant types in a given dimension. Perhaps people tend to be more expressive when experiencing pleasant emotions?;
- Time to start typing—quantifies the time spent by the participant visualizing the photograph before starting to type;

- Time typing—quantifies the time spent typing by the participant in each dimension;
- Total time—quantifies the time spent by the participant in a given photograph (time since first visualizing the photograph until advancing to the next one);

A significant number of other features can be considered in the future, namely those related to Natural Language Processing including sentiment analysis. However, these features are at the moment outside the scope of our work.

4.2 Behavioural Features

Behavioural features, on the other hand, are features that describe the manner in which the participant interacts with the computer, during the study. The following features can be extracted from the system:

- Time between keystrokes—describes the time span between two consecutive KEY_UP and KEY_DOWN events, i.e., how long did it take the user to press another key after releasing the previous one;
- Keystroke latency—quantifies the time span between two consecutive KEY_DOWN and KEY_UP events, i.e., for how long did the user press a given key;
- Typing speed—quantifies how fast a participant types, in words per minutes, considering a word as any group of five characters;
- Keystroke force—describes the acceleration measured on the keyboard, in each of the three accelerometers used and in each of the axes.

4.3 Other Features

Additional features are also available, namely through the MapReduce feature and the Aggregation pipeline of MongoDB. Specifically, we consider features derived from the previously mentioned ones by grouping data by participants' characteristics. These characteristics include age, gender, level of scholarship or occupation. These features may be very interesting, namely to understand how these characteristics affect Human-Computer Interaction or if emotions affect users with different profiles differently.

5 Conclusions

In this paper we described an environment for supporting the carrying out of studies focused on human emotion identification. In traditional approaches, researchers rely on a pencil-and-paper approach, generally using the Self-Assessment Manikin (SAM) [1]. The main disadvantages of this approach is that it is susceptible to error (when the researcher inputs the participant's answers into the computer) and depends on the researcher being present.

The significant contributions of this work are two-fold. One the one hand, the proposed system completely automatizes the whole process, making it distributed and structured. Data collection takes place in real-time and results are available immediately after the conclusion of the protocol. Moreover, researchers can easily share and reuse protocols or studies. It also makes it easier for people other than the researchers to apply the instrument, with the same validity.

On the other hand, this system provides new features that are not available in other approaches and may reveal interesting and new insights. Moreover, these new features allow the study of the influence of emotion on Human-Computer Interaction, eventually contributing to the further understanding of one of the most interesting topics in this field: that of understanding and reacting to user emotion.

Concluding, we believe that this system can be of interest for the researcher communities studying Human emotion (notably Psychologists), Human-Computer Interaction and Affective Computing.

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Defining an Architecture for a Ubiquitous Group Decision Support System

Diogo Martinho[1(✉)], João Carneiro[1,2], Goreti Marreiros[1], and Paulo Novais[2]

[1] GECAD, Institute of Engineering, Polytechnic of Porto, Porto, Portugal
{diepm,jomrc,mgt}@isep.ipp.pt
[2] ALGORITMI Centre, University of Minho, Guimarães, Portugal
pjon@di.uminho.pt

Abstract. Supporting group decision-making in ubiquitous contexts is fundamental while developing Group Decision Support Systems (GDSS). Here we propose an architecture that assures ubiquity and allows the development of a system which can be used anywhere at any time and through almost any sort of electronic device. Our approach can be used by developers that intend to build Ubiquitous Group Decision Support Systems (UbiGDSS). It uses three main components that are interconnected and that will allow to collect and preserve the amount and quality of intelligence generated in face-to-face meetings.

Keywords: Group Decision Support Systems · Ubiquitous computing · Multi-agent systems · Intelligent reports

1 Introduction

Over the last years, we have observed a growing necessity for Group Decision Support Systems (GDSS) to include ubiquitous computing in their development [1, 2]. It no longer makes sense to approach the group decision-making problematic the same way as 10 or 20 years ago, and it is now fundamental to provide intelligent and efficient answers in busy environments such as the ones observed in large multi-national organizations [3].

This work explains a system architecture which can be used to develop GDSS while supporting ubiquitous computing and allows every participant to exchange knowledge regardless of time or location constraints [1]. This architecture uses three main components that are interconnected and that will allow to collect and preserve the amount and quality of intelligence generated in face-to-face meetings in a way very similar to the real group decision-making process.

The rest of the paper is organized as follows: In the next section, the system architecture is exposed and each component is detailed. In the following section, it is described how each component was implemented and some screenshots of those components are shown. Finally, some conclusions are taken in the last section, along with the work to be done hereafter.

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2 System Architecture

The architecture proposed in this work is aimed at ubiquitous group decision support systems and therefore should support decision-makers anytime and anywhere. Figure 1 shows the architecture considered for our system.

The main components of the system are:

- A web application which will be the interface between the multi-agent system and the participant. This application allows problem configuration and reports the decision-making results to the participant. Our system is focused towards multi-criteria problems where participants can share their opinion about different alternatives based on existing criteria. Therefore, the interface first allows to define problem data (alternatives and criteria that will be discussed) and select which decision-makers can participate in the decision-making process. After that, each participant that was selected can make personal and problem configurations. After the decision-making process ends, the results will be reported back to the participant via an intelligent report adapted to each participant that is based on all these previous personal configurations. The web application is accessible by desktop and mobile browsers thus being available to almost any kind of electronic device;
- A database where all configurations related to each problem will be stored. These configurations include problem data, personal and problem configurations. The multi-agent system will load these configurations to simulate the group decision-making process;
- A multi-agent system which simulates different group decision-making processes based on the data available in the database. For each personal configuration, an agent will be created and that will use the information provided in that configuration to represent the decision-maker and behave in the most desired way. It is two

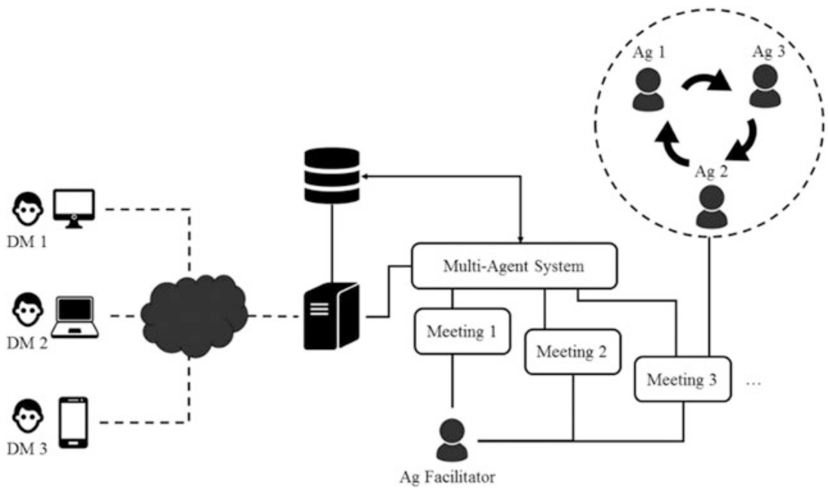

Fig. 1. Proposed system architecture

different types of agents will act in each meeting. There is always a facilitator agent that is responsible for coordinating and analysing the decision-making process, and there will be a group of participating agents that represent decision-makers and that will negotiate and persuade each other to choose an alternative as the solution for the problem.

2.1 Web Application

Defining a configuration environment in which the decision-makers could model a multi-criteria problem is a complex process [4]. It is essential that the interface can support easy and fast configurations specially in the context of making decisions inside organizations. In this context, individuals with a very tight schedule (top managers and executives) should make decisions and it does not make sense to force them to fill extensive and lengthy configurations because they do not have the time nor will to do so [1]. The right idea is to assure some aspects related to interface development such as usability, simplicity, adaptability, and clarity. The interface should be complex enough whenever it is necessary. If the decision-maker does not have much interest in the problem being discussed, he/she will probably not want to look at very complex reports about the problem. On the other hand, if the decision-maker finds the problem being discussed to be very important he will likely prefer access to much more detailed information [5]. In our proposal, we have developed a web application which is the interface between the multi-agent system and the participant.

This application follows a general template that was proposed in [4] and that is divided in three main sections: Problem Data, Personal Configuration, and Problem Configuration. In the first section, it is specified problem specific information that includes criteria and alternatives information. It can also be specified other information indirectly related to the problem such as historical data, finances, statistics, etc. In the second section the decision-maker can model its own personal attributes and how he intends his/her representing agent to behave throughout the decision-making process. For this, the participant can select a conflict style and other participants who he/she considers to be credible and whose opinion should not be ignored. The third section is related to the configuration of problem-specific attributes. The third section is related to the problem configuration where each decision-maker can select: the preference towards each one of the available alternatives; the importance given for each criterion; preferred alternatives and criteria.

The web application was further extended in [5] to provide the results of the decision-making process via intelligent reports adapted to each decision-maker. These reports aim to clarify the decision-maker and show him/her what happened during the decision-making process and are built considering three key factors: expertise level, time, and interest. By combining (or not) these three factors the information provided to decision-makers could be more or less complex.

2.2 Database

The database component stores data related to each multi-criteria problem: problem data personal configurations (data inserted by decision-makers about personal attributes), problem configurations (alternatives and criteria preferences), user data (problems the user has been part of, user profile, etc.). It also collects and store information and results obtained from each decision-making process: alternative chosen, consensus percentages, requests exchanged between agents, average satisfaction level, etc.

2.3 Multi-agent System

Multi-agent systems have been frequently used as a tool to support group decision-making [6]. In this type of systems each decision-maker is represented by an agent that tries to negotiate and persuade other agents to accept his opinion. We have used a multi-agent system with two types of agents: a participant agent that represents a decision-maker according to the configurations that were provided and a facilitator that coordinates and analyses the entire decision-making process.

Facilitator Agent. The facilitator main actions include:

1. Load problem data—The facilitator loads problem data such as alternative, criteria and selected agents which is available to all participant agents;
2. Notify agents before the process begins—After each participant agent has been created it notifies those selected to be part of the decision-making process;
3. Manage participant agents' communications—The negotiation model used between agents follows a communication logic inspired in social networks [7] and there have been considered two types of communication: public and private. For both communications, the facilitator receives and forwards all sent messages to the respective recipients. Besides that, the facilitator analyzes the content of each message to assure that no duplicate messages will be sent towards the same recipient agent or to verify the necessary conditions to end the decision-making process. For communication, the facilitator chooses which participant agent can start a public conversation topic as well as when to close that topic and start another one.
4. Finish the process—The facilitator must end the decision-making process whenever an alternative is accepted by all participant agents or when agents have no more messages to exchange with other agents. As the process ends the facilitator should transmit its results such as the alternative that was chosen which will be stored in the database and be available to all decision-makers.

Participant Agent. Participant agents are the virtual representation of decision-makers. A participant agent will behave according to all configurations provided by the decision-maker and attempts to negotiate and persuade other agents to accept its opinion. It will receive information throughout the decision-making process regarding other agents' preferences and decide if it should make a certain request or receive requests and decide if it should accept or reject that request. shows the internal architecture of the participant agent. Figure 2 details the three layers considered in the participant agent architecture.

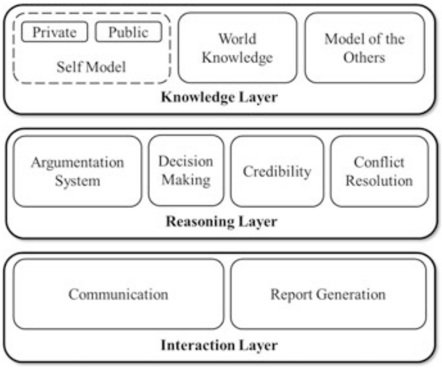

Fig. 2. Participant agent architecture

In the knowledge layer the participant agent has knowledge about the environment surrounding him. This includes information he detains about the problem, information about itself which includes its preferences and goals (public and private model) and information related to the public profile of other agents.

The reasoning layer allows the participant agent to reason about the received information, whether it receives a request or another kind of message. In this layer, it is considered four main components:

- Argumentation system—This system is responsible for identifying and evaluating arguments. The participant agent selects the most appropriate argument at a certain point throughout the decision-making process. It will analyze the current number of agents supporting each alternative as well as their criteria preferences to select the argument that should be sent in the request. The participant agent also uses the argumentation system to evaluate received requests and related arguments;
- Decision-Making—This component is used for the agent to measure its preferences and verify which alternatives are more likely to be accepted throughout the decision-making process;
- Credibility—This module is used with the information provided by the decision-maker regarding whose opinion he/she thinks to be credible. The participant agent will use this information when evaluating the opinion of other agents;
- Conflict Resolution—This module contains all the information regarding the conflict style which is used by the participant agent. This information includes values that were measured for all the dimensions identified for each conflict style and that will be essential to define the behavior of the agent. All conflict styles considered have been proposed in [8].

The interaction layer is responsible for the communication between agents as well as for the generation of reports for each agent after the decision-making process ends which will be provided to each decision-maker and whose content will vary according to the initial configurations provided by him/her.

3 Implementation

In this section, it will be described how which component presented in the system architecture has been implemented.

3.1 Web Application

The web application is a ubiquitous application that can be used in web browser in both desktop or mobile devices. The problem data definition, problem and personal configuration has been developed using JavaScript and Java, ASP .NET and C#. Any user can use the system from anywhere, at any time and from almost any kind of device with the only restriction being having access to the Internet. The meeting organizer should first define problem data and after that each decision-maker can make personal and problem configurations using the template proposed in [4]. The multi-agent system will perform the decision-making process with each agent representing each decision-maker and the meeting results will be sent to each decision-maker via an Intelligent report as seen in Fig. 3.

The content of an Intelligent Report is defined according to the interests of the decision-maker and is divided in two sections. The first section presents global information about the level of consensus (preference given by each decision-maker) towards each alternative. The second section presents information about the self and other group elements. In this section, it is considered information with a higher level of complexity such as forecasts or simulations of different scenarios, identification of different groups (concerning their preferences), as well as explanations about decisions done by the system.

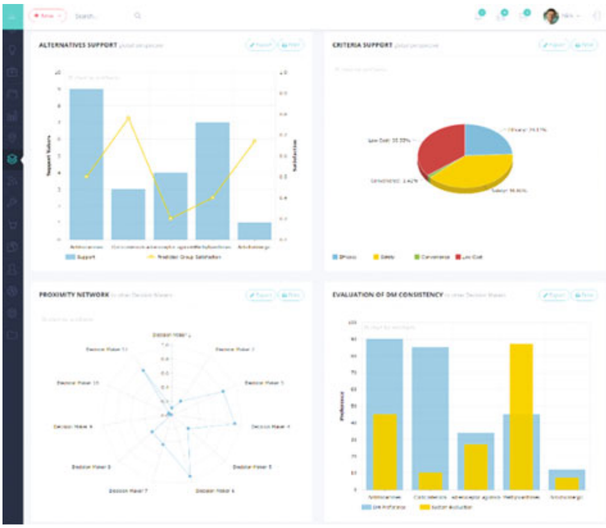

Fig. 3. Intelligent report

3.2 Multi-agent System

The multi-agent system is developed using Java Agent Development Framework (JADE) and offers a set of features which are essential in multi-agent systems development such as synchronous and asynchronous communication between agents, support concurrency, offer security mechanism via SSL and support agent mobility. Some screens of agents' communication can be seen in Figs. 4 and 5.

In Fig. 4 it is shown agents exchanging information regarding alternatives preference. An agent asks other agents what are they most preferred alternatives and they reply stating their most preferred alternative. In Fig. 5 it is shown an example of a private conversation where an agent performing a request to another agent.

Fig. 4. Agents' communication via request

Fig. 5. Agents' communication via statement

4 Conclusions and Future Work

The group decision-making process has evolved over the last decades and it only makes sense that GDSS should also evolve (using the latest technologies) to overcome emerging issues such as the difficulty to gather decision-makers at the same place and time. We now start seeing the development of UbiGDSS that can support users anywhere, at any time and from almost any sort of electronic device.

In this work, we propose an architecture which can be used to develop UbiGDSS and present three main components that will assure ubiquity to the system. Furthermore, we specify each component and show how they have been developed. As future work, we will keep improving the web application and perform usability tests focused on intelligent reports. We want decision-makers to be able to validate reports created by the system and the relevance of information presented in each report.

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An Architecture for Proactive Maintenance in the Machinery Industry

Alda Canito[1(✉)], Marta Fernandes[1], Luís Conceição[1], Isabel Praça[1], Magno Santos[2], Ricardo Rato[3], Gonçalo Cardeal[3], Francisco Leiras[4], and Goreti Marreiros[1]

[1] GECAD - Research Group on Intelligent Engineering and Computing for Advanced Innovation and Development, Polytechnic of Porto, Porto, Portugal
alrfc@isep.ipp.pt
[2] EVOLEO Technologies, Lda, Porto, Portugal
[3] ISQ - Instituto de Soldadura e Qualidade, Oeiras, Portugal
[4] SISTRADE – Software Consulting, S.A., Porto, Portugal

Abstract. Industry currently lives in an environment where change is continuous. Factors such as global competition, economic crisis, technological development and the fact that most products have shorter life cycles lead to this sector being under constant pressure to achieve higher profits. Companies face the need to revise their thinking in order to reshape their work processes. Organizations today are abandoning the reactive processes they have used up until now and are adopting proactive practices such as product life cycle planning and proactive maintenance through constant monitoring of equipment. This constant monitoring and interconnection of systems is called Industry 4.0. In this work, we propose an architecture that facilitates the implementation of Proactive Maintenance in a company that produces custom components for the machinery industry, specially the automotive industry, and helps the company improve its Ecoefficiency, allowing a reduction of costs.

Keywords: Proactive maintenance · Industry 4.0 · Ambient intelligence · Ecoefficiency · Ubiquitous computing

1 Introduction

Digital information and processes are of growing importance in the industrial sector. Information and communication technologies can be integrated into the production cycle, creating an environment of constant interaction between humans and machines —an environment where it is possible for a worker, in any part of the factory, to access a real-time digital representation of the production process and current statuses of the machines in use, in accordance with the principles of ambient intelligence. This 'digitalization' of the industrial sector is referred to as "Industry 4.0" and it's often considered the "4th Industrial Revolution". The installation of unobtrusive sensors is a fundamental part of the digitalization process, being the source of a lot of the data which, after an intelligent analysis process, will generate the knowledge required to make proactive maintenance possible. Sensors can be integrated with an intelligent

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platform that will fulfil the roles of data acquisition, analysis and transmission and open up the potential of the Industry 4.0.

Considering the lower profit margins and difficulties associated with the current economic crisis, the role of maintenance procedures has increased in relevance, impacting directly on availability, safety, product quality and consumer satisfaction levels. Furthermore, maintenance of the company's equipment is also directly related to that company's ability to be competitive in terms of product's cost, quality and performance.

According to Westkämpfer [1], by annually dedicating from 5 to 6% of the product's final price to maintenance activities, it is possible to: (1) achieve better levels of fault prevention, (2) solve issues faster, (3) lower maintenance and management costs, (4) produce a better final product at a more competitive price and (5) develop a more efficient productive cycle.

However, modern maintenance practices such as (1) identification of possible causes behind failures, (2) reduction of failures in the production systems, (3) reduction of unpredicted interventions on equipment that require shutting it down, and (4) improvement of overall quality and productivity aren't widely applied yet. The concept of maintenance has also suffered modifications over time in order to fulfil these roles, going from corrective practices into more preventive and predictive ones. Predictive and preventive maintenance come with the advantage of fixing problems before they come into place, replacing parts only after a certain level of deterioration has been identified, as opposed to fixing the fault after the fact. Maintenance is therefore crucial to companies' competitiveness, which leads to an increased complexity of maintenance processes, further enhanced by the increasing complexity and automation of production processes [2].

Swanson divides management strategies in three categories [3]: (1) reactive maintenance, which deals with the failure after it happened, (2) proactive maintenance, with preventive and predictive approaches, and (3) aggressive maintenance, which relies on the optimization of both the equipment and the processes involved in the production cycle. The reactive approach is historically the most common. However, as maintenance practices grow more sophisticated, a shift to a more proactive strategy has been noted. This paper will focus on proactive maintenance, in particular predictive maintenance techniques, which complement preventive maintenance to achieve a fully proactive approach.

In order to be able to predict failure, it is necessary to gather real-time data from the equipment and have knowledge about the machining process. Predictive maintenance techniques can be implemented through the monitorization of equipment, where data is obtained through a network of sensors, combined with the development of intelligent decision methods.

In this document, we'll be presenting an architecture that allows a manufacturing company to implement Predictive Maintenance and improve its Ecoefficiency. The system's architecture will encompass all the phases the information goes through, from the moment it is captured by the sensors or obtained via the existing management systems, the several transformations and analytical processes it goes through, until it is finally presented to the end-user in the form of notifications and predictions of failure, among others.

This document is organized as follows: (1) Introduction, where the theme, motivations and context are presented; (2) State of the Art, in which are shown several technologies used in predictive maintenance to solve similar problems; (3) Architecture, where the components of the novel approach are presented and explored; and (4) Conclusions.

2 State of the Art

2.1 Predictive Maintenance

When nearing failure, equipment exhibits signs that something is wrong in 99% of cases [4]. This information can be collected by sensors and used with predictive maintenance techniques to avoid unnecessary equipment substitutions, reduce costs, and improve industrial processes [5].

Predictive maintenance indicates the correct time to perform maintenance; that is, when a component is approaching failure but before it actually fails. Performing maintenance only when needed results in machines spending less time offline, and components are only changed when and if necessary. Predictive maintenance performs both prediction and diagnosis of an equipment's condition, providing information about the nature of the problem, where it's occurring and why, and when an equipment failure is likely to happen [4].

Although predictive maintenance technologies have progressed considerably, in many industrial settings time-based maintenance is still common. However, this type of maintenance is imperfect and unreliable [6]. Engineers at the SKF Group placed thirty bearings under stress and measured how long it took for the bearings to fail [5]. Even though these were identical bearings under identical conditions, the time to failure varied between 15 and 300 h. This experiment suggests that it's impossible to know a priori how long a component will last in an industrial setting. The duration of an equipment's stable period is never accurately known and varies according to the type of equipment and the different conditions that equipment is subjected to. To avoid reaching an equipment's end-of-life, some companies substitute equipment periodically based on the bathtub curve. However, when an equipment is substituted prematurely the failure rate tends to increase since new equipment often suffers from infant mortality. Considering time-based maintenance methods aren't particularly reliable, it's unwise to define maintenance plans based on temporal data. Moreover, companies would benefit from using predictive maintenance throughout the equipment's life cycle to detect the onset of degradation and equipment failure [4, 5].

Predictive maintenance usually consists of three distinct phases: data acquisition, data processing and decision-making [7].

Data acquisition may be performed continuously and/or at regular intervals. It de-pends greatly on sensor technologies [4]. Three predictive maintenance techniques can be defined based on their data source [5]:

- Existing sensor-based maintenance technique;
- Test-sensor-based maintenance technique;
- Test-signal-based maintenance technique.

The first technique uses sensors already present in the equipment to measure variables such as temperature, pressure, level and flow. The second type of technique implies installing test sensors in the equipment. Examples of such sensors include accelerometers to measure vibrations and acoustic sensors to detect leaks. Both of these techniques are mainly passive, whereby they don't interfere with the equipment that's being tested and can be performed during working hours. The third technique consists in introducing test signals into the equipment to test for defects such as corrosion and wear of cables, motors and sensors, as well as other equipment [5].

Data processing involves detecting and analysing changes in process parameters such as temperature, motor current, fluid pressure and flow rate among others, as well as performing vibration, oil, thermal and acoustic analysis. Vibration analysis is commonly performed and used mostly in rotating and reciprocating machinery. It is useful in the detection of problems like imbalances, misalignment of couplings and bearings, bent shafts, resonance, etc. Physical and chemical analysis of oils and lubricants can be indicative of the conditions of the equipment (wear) and the oil itself. Thermal analysis is used to detect mechanical or electrical problems that result in abnormal temperatures. Acoustic analysis can provide important information about an equipment's health by identifying changes in the normal sound patterns, which might be indicative of leaks or other types of deterioration. Additional analyses may be performed for specific cases of predictive maintenance [4].

One of the big challenges of predictive maintenance is the ability to deal with large quantities of data. Improvements in system monitoring technologies and lower IT costs mean the resources necessary to obtain knowledge from large volumes of data, often in real-time, are more readily available. New knowledge about the operation and maintenance of equipment can be obtained by combining intelligent analysis of high frequency data in real-time with domain knowledge. It's also important that the information derived from the data reaches the right people, at the right time and in an appropriate format. Predictive maintenance should ultimately be turned into action and direct the maintenance job appropriately [4, 6].

2.2 Ecoefficiency

The concept of Ecoefficiency has existed since the 1970s [8, 9], but the term "ecoefficiency" was invented by the World Business Council for Sustainable Development (WBCSD) and by Stephan Schmidheiny in the book "Changing Course: A Global Business Perspective" [10].

The WBCSD states that Ecoefficiency is achieved through the delivery of "competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life-cycle to a level at least in line with the Earth's estimated carrying capacity." [10].

Ecoefficiency therefore aims to create greater value with less environmental impact. In other words, Ecoefficiency tries to simultaneously increase a company's economic and environmental efficiency. It's a management philosophy that encourages companies to strive for environmental improvements with a positive economic impact,

Table 1 Structure behind the ecoPROSYS© methodology for Ecoefficiency assessment

Domain	Description
Environmental performance assessment	Aims to identify the intensity and significance of the environmental aspects related to the ecoefficiency principles by establishing objectives for each principle. This component is key for the integration of the objectives of environmental protection and economic growth
Life cycle assessment	Aims to quantify and evaluate the environmental influence resultant from the environmental aspects identified for the system under analysis
Cost and value modelling	Aims to quantify the economic performance, as well as determine the importance of each cost to the system under analysis. Value can also be represented by the profit or of the cost using common economic indicators

focusing on business opportunities that strengthen a company's competitive position in an increasingly globalized market [11].

In recent years, several different methodologies have emerged to support the implementation of the ecoefficient concept in companies. The necessity behind this revolution is connected to the fact that the existing tools and methods are often seen as "isolated elements", adding difficulty to performance assessment and complicating the identification of improvement opportunities. EcoPROSYS© (Ecoefficiency Integrated Methodology for Production Systems) is an example of an innovative method-ology that gathers in a single tool different Ecoefficiency domains (**Environmental Performance Assessment; Life Cycle Assessment; Cost and Value Modelling**) to create a flexible and holistic approach that can be applied in production systems [12]. This methodology is based on the following structure (Table 1).

3 Architecture

We present here our proposal of an architecture that facilitates the implementation of Predictive Maintenance in a Mechanical Metallurgy company that specializes in precision parts production, using raw materials, such as aluminium, steel, bronze and technical plastics to produce custom parts for industry clients, particularly the automotive industry. The architecture was also defined with the aim of helping the company improve its Ecoefficiency (Fig. 1).

Furthermore, this architecture will be compliant with the OSA-CBM standard of the Machinery Information Management Open Systems Alliance (MIMOSA) [13]. The OSA-CBM defines an architecture and framework for the exchange of information in a condition-based maintenance system, simplifying the process of integrating different hardware and software components.

The architecture is composed of five main layers, namely: (1) Data acquisition, (2) Data repository, (3) Big Data processing and management, (4) Management software, and (5) Information delivery platform. The management software layer includes

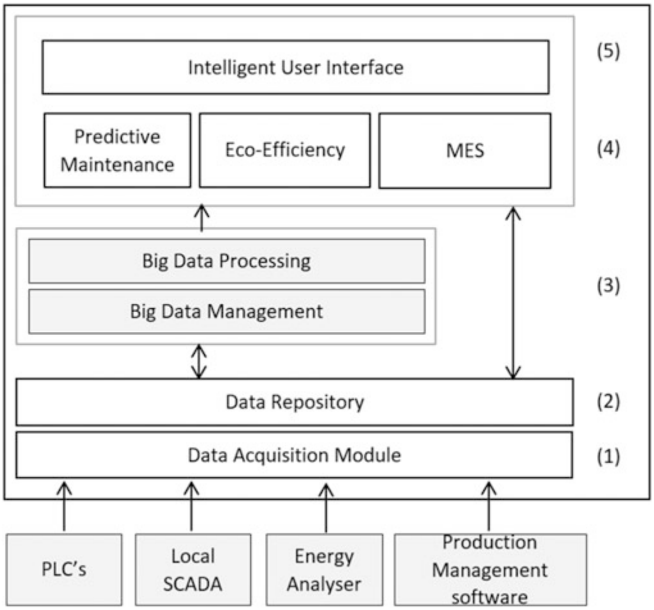

Fig. 1. Proposed architecture

the Maintenance management system, the Ecoefficiency system and the Manufacturing execution system (MES).

To perform Predictive Maintenance and improve the company's Ecoefficiency, the system needs to monitor the manufacturing machines and obtain a large amount of operating data. This task will be executed by the data acquisition module, which will collect data from the machines, as well as from the production management software. The machines monitored by the module may have different ages and technologies and rely on legacy systems, thus requiring different data acquisition approaches. Some of the data is acquired directly by the machines and is available through a bus with a described protocol. This data will be gathered using a gateway. When the machines do not provide, or describe a bus, interfaces to sensors (to their terminals) will be implemented and the data of interest will be sampled by the data acquisition module. Furthermore, if a machine does not have sensors, or if additional sensors are required, they will first be installed. This hybrid approach will allow all machines, new and legacy ones, to be monitored and become part of the system.

Indicators such as noise and vibration are particularly important, considering that fault occurrence is usually preceded by a change in their intensity or frequency. The variables to be monitored include, but aren't limited to those presented in Table 2.

The data gathered by the data acquisition module will be stored in a repository that can be queried directly by the information delivery tier, but will also be used by the Big Data processing module for purposes of data analysis and creation of the predictive models used for Predictive Maintenance and Ecoefficiency.

Table 2 Sample of variables to be collected

Element	Description	Origin
Cutting emulsion	Cutting emulsion levels and concentration of oil and water	Sensor
Cutting tool	Temperature on the cutting tool during the cutting process	Sensor
Spindle load	Power draw on the spindle motor	Sensor
Vibration	Vibration during the cutting process	Sensor
Noise	Noise during the cutting process	Sensor
Lubricant	Measure of the lubricant levels	Machine protocol
Energy consumption	Energy consumption per machine	Sensor
Machine status	ON/OFF	Machine protocol
Program in execution	Each execution program can be identified by a code	Machine protocol
Error information	Information provided by the machine after an error has occurred	Machine protocol
Operating hours	Number of hours the machine has been in use	Machine protocol
Axis load	Load on each of the machine's axis	Machine protocol
Cycle time	Time (in seconds) of each of the machine's cycles	Machine protocol
Tool speed	Speed of the tool during the cutting process	Machine protocol
Calibration data	Information regarding the calibration of the machine for the current operation	Manual

Raw data is "dirty" and "messy" and needs to be transformed and improved before it can be used for analysis. Since the data will be obtained from heterogeneous sources, it will first need to be consolidated. The data will need to be cleaned as well, which consists in solving issues such as missing values, outliers and inconsistencies. Data transformation and dimensionality reduction are also crucial steps of the pre-processing phase.

Artificial Intelligence techniques, such as Machine Learning, Data Mining, or Fuzzy Logic will then be applied to the data with the purpose of identifying components that might be approaching failure, diagnosing failures, and proposing possible corrective measures, thus allowing the system to perform Predictive Maintenance. The data will also be analysed with the aim of suggesting actions that will lead to a decrease in waste production and a reduction of energy consumption. Additionally, storing and applying analytics to large amounts of data will require the system to be integrated with a Big Data platform. This process will be handled by the Big Data management module.

It's essential that the insights obtained by analysing the data reach the right people at the right time, so that Predictive Maintenance can actually be carried out. In conformity with the company's structure, the information delivery platform will have different access levels, meaning the information that will be displayed will vary depending on who accesses the system. While a machine operator might see only real-time information and short-term alarms and notifications, the person responsible for machine maintenance will have access to aggregate information and long-term recommendations, and upper management members will be able to access KPIs concerning maintenance and efficiency. This means staff will be able to visualize information that is relevant to their specific functions and responsibilities. Additionally, users will also be able to view comparative analysis of similar equipment and conduct analytical monitoring of the processed data from different temporal perspectives. This information will be accessible in desktop computers, as well as mobile devices, being therefore available anywhere in the company.

This and other techniques will be used to implement additional functions to a MES system. Coupled with all the other functions already available in the MES and the management software, the proposed system will aid the manufacturer improve his processes, as well as reduce costs and maintenance times.

4 Conclusion

In this paper, we proposed an architecture that aims to help companies increase their Ecoefficiency and shift from traditional maintenance approaches to proactive ones. The rate at which these goals are achieved can be measured in a number of ways.

First of all, when it comes to Predictive Maintenance, it is expected to have (1) a reduction of both preventive and corrective maintenance interventions due to correctly suggested predictive actions. This reduction can lead to (2) an extension of component life: as only the components in the imminence of failure are effectively replaced, components can last for longer than expected; which also contributes to (3) reduced failure rates and downtime due to repair.

As the number of interventions is expected to decrease, there is (4) an increase in the machines uptime, given that failures are prevented and the maintenance time for each failure is reduced (affecting MTBF and MTTR, respectively).

Improvements in Ecoefficiency, on the other hand, can be noticed by (1) measuring the reduction of energy consumptions due to automatically turning off machines during times of inactivity; (2) reducing unplanned plant/production system outages and costs with raw materials, machine components and unexpected production failures; (3) reducing energy, water and oil consumption, reducing machining waste and avoiding breakage of parts.

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A Comparative Cost Study of Fault-Tolerant Techniques for Availability on the Cloud

Altino M. Sampaio[1(✉)] and Jorge G. Barbosa[2]

[1] Instituto Politécnico do Porto, Escola Superior de Tecnologia e Gestão, CIICESI, Felgueiras, Portugal
ams@estg.ipp.pt

[2] Faculdade de Engenharia, Departamento de Engenharia Informática, LIACC, Universidade do Porto, Porto, Portugal
jbarbosa@fe.up.pt

Abstract. The success of ever growing warehouse-sized Cloud data centers built to respond to the increasing demand for computing resources depends on the ability to provide reliability and availability at scale. In order to provide dependable and secure systems and services, one needs to implement security controls capable of avoiding, coping and recovering from failures. However, dependability and security of services at all cost is not a solution for Cloud providers. In this paper, two state-of-the-art fault-tolerance techniques are compared in terms of availability of services to consumers, and energy costs to Cloud providers. The results have shown that proactive fault-tolerance technique outperforms traditional redundancy in terms of cost to Cloud users, while providing available compute environments and services to consumers.

Keywords: Availability · Cloud computing · Virtualization · Fault-tolerance · Power-efficiency

1 Introduction

Security refers to the ability of a system to protect and defend information and system resources with respect to confidentiality, integrity, and availability [1]. In particular, availability assures that a system works promptly and service is not denied to authorized users. Availability is a function of reliability, which is defined as the ability of a system or component to perform its required functions under stated conditions for a specified period of time. An interruption of service results in the inability for customers to access information or computing resources.

Nowadays, with the service oriented economy trend [2], supported by recent distributed computing paradigms such as Cloud computing, there is an increased concern about aspects regarding the quality and availability of the services offered. In order to respond to the progressively adoption of Cloud systems by

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diverse consumers, data centers supporting Clouds continue to grow in scale and in the complexity of their components and interactions. A recent study on the reliability of existing large high-performance clusters is constrained by a mean time between failures (MTBF) of about 1.25 h [3]. Additionally, if one considers that scientific computing requires a massive number of computers for performing large scale experiments, and that some applications take a very long time to execute, the probability of failure during execution becomes significant, as well as the loss of the service.

Egwutuoha et al. [4] describes the major techniques to overcome failures and improve reliability and availability of networked systems and provided services. A full revision of fault-tolerant systems is out of the scope of this paper. Redundancy is a traditional fault-tolerance technique which applies replication of tasks. In turn, proactive fault-tolerance, the new trend on system dependability, leverages failure prediction technique to anticipate failures by migrating a task from a health-deteriorating physical machine (PM) to a healthy PM.

In this paper, one compares redundancy and proactive fault-tolerance, in terms of energy consumption and completion rate of jobs. For that, a set of CPU-bound deadline-constrained jobs is submitted to a Cloud datacenter in which computer nodes are subject of failure. Our objective is to understand to what extend can redundancy deliver reliable and available services to costumers, compared to proactive fault-tolerance, and at what cost to cloud providers.

The remainder of this paper is organized as follows. Section 2 discusses related work based on fault-tolerance techniques in the Cloud. Section 3 presents scenario implemented to conduct tests. Section 4 describes metrics and discusses results obtained. Section 5 concludes the paper.

2 Related Work

Redundancy and proactive fault-tolerance are two well known techniques that intend to provide reliability and availability at scale. Regarding redundancy, Ferreira et al. [5] evaluated the viability of using state machine replication to deal with failure. Redundant copies of Message Passing Interface (MPI) processes, partially combined with checkpointing, provide failover capabilities. Outcomes reveal that state machine replication approach to exascale resilience outperforms traditional checkpoint/restart approaches. Casanova et al. [6] investigated two approaches for replication: (a) entire application instances are replicated; and (b) each process in a single application instance is replicated. Authors have concluded that replication is worthwhile when compared to the no-replication case (instead of using pure checkpoint-recovery approach) in terms of expected application execution times.

In [7], the author investigated and proposed failure-aware compute node selection strategies for the construction and reconfiguration of virtual computing environments. The approach leverages proactive failure management techniques, based on virtual machines (VM) migration, and considers both the performance and reliability status of compute nodes. Later, Sampaio et al. [8] proposed a dynamic power- and failure-ware scheduling algorithm to build high-available virtual clusters to run Cloud consumers jobs. Also Liu et al. [9] have followed a proactive fault-tolerance approach to enhance Cloud service reliability, based on CPU temperature model.

Despite redundancy may be significantly efficient, it my lead to wastage due to replication. In turn, proactive fault-tolerance highly depends on the ability to predict the failure. This study intends to compare these two fault-tolerant techniques, in terms of costs to Cloud providers, and jobs executed to consumers.

3 Fault-Tolerant Cloud Environment

This section provides a formal description of a fault-tolerant Cloud environment.

3.1 System Overview

One considers a Cloud computing environment consisting of a Cloud provider and multiple consumers. The computing infrastructure is composed of h PMs, where M is the vector representing the PMs, such that $M = \{m_1, \ldots, m_h\}$. PMs are homogeneous, in terms CPU capacity C, memory capacity L, network bandwidth N, equal access to a shared storage space S for storing VM disk images, and may have distinct predicted time in the future for the occurrence of failures F_i, such that $m_i = \{C, M, N, S, F_i\}$. In a typical usage scenario, consumers submit jobs to a virtual cluster running on top of PMs. A virtual cluster consists of a set of VMs, and each VM runs on top of a PM at a time. It is responsibility of the Cloud manager component to allocate, manage, and deallocate virtual clusters. Each job J can be seen as a set of independent deadline-driven CPU-bound tasks T_i, $J = \{T_1, \ldots, T_n\}$. A VM encapsulates the task execution environment and is the unit of migration in the system. A VM runs a single task. Multiple distinct VMs can be mapped to a single PM. Consumers specify a deadline for a job, based on job's longest task. The computing environment acts as best-effort, since resources may not be available at submitting time, delaying the start of jobs execution. Job deadlines become activated just after submission.

Migration of VMs is required for proactive fault-tolerance technique. Tasks with deadlines extending past the failure time of their node migrate $\xi = 3\,\text{min}$ before the nodes predicted failure time. Each VM requires a RAM size of 256, 512, or 1024 MB, randomly selected. The migration overhead of the VM depends on the memory size and the network bandwidth, which was set to 1 Gbit/s.

3.2 Nodes Power Consumption

Since the power consumed by the active PMs is mainly dictated by the CPU resource, only the CPU power consumption in our energy model is considered. The power consumption, P, of a PM, i, can be estimated based on the linear power model, $P_i = p1 + p2 \times CPU\%$, where $CPU\%$ is the percentage of CPU utilisation for a given time interval, measured for a PM_i at runtime. The $p1$ (112 W) and $p2$ (48 W) factors are the power consumption when the PM is in idle mode and the additional power consumption from CPU utilisation, respectively. The factor $p2$ is typically proportional to the overall system load.

3.3 Workloads and Failures Description

A set of 100 synthetic jobs was created, totalling 1003 tasks, which workload characteristics followed a Poisson distribution [8]. The average job inter-arrival time was set to 10 min, and each job was composed of an average of 10 tasks. Additionally, the average task length to MTBF ratio varied on a logarithmic scale of {0.01, 0.10, 1.00}. The rationale is to analyse the impact of the average task length to the MTBF ratio on the performance of the fault-tolerance mechanisms. The average CPU utilisation per task was set to 20% of the node capacity. A job deadline equals the deadline of its longest task. The task deadlines are rounded up to 10% more than their minimum necessary execution time, and require a RAM size selected randomly within 256, 512, and 1024 MB.

Regarding nodes reliability, the MTBF was programmed according to [8], with an average value of 200 min. Proactive fault-tolerance was implemented based on a failure predictor tool [7], with an average accuracy around 75%. In this study, failure events stand for any anomaly that preclude computing infrastructure components to work.

3.4 Scheduling Algorithms

To construct high-available fault-tolerant virtual clusters, to which users workloads are scheduled and executed, two scheduling algorithms are used: (a) Common Best Fit (CBFIT) [7]; and (b) POwer- and Failure-Aware Relaxed time Execution (POFARE). A full explanation of these algorithms is out of the scope of this paper. Basically, while CBFIT selects the PM that has the minimum capacity necessary to run a task to optimise energy consumption, and uses redundancy to deal with failures, POFARE considers both predicted failure occurrences and capacity of PMs, and proactively moves VMs away from suspicious machines.

4 Evaluation and Results

This section describes the metrics used to evaluate the two fault-tolerance mechanisms, and analyses the results obtained through simulation.

4.1 Evaluation Metrics

Two main metrics were defined: (a) completion rate of users' jobs (E_J); and (b) energy consumption (E_E). The completion rate of users' jobs, E_J, expressed as Eq. (1), is the ratio of completed jobs J_C (i.e., all its tasks have been executed within their deadlines) to the number of submitted jobs J_S. Its value falls in the interval [0, 1]. The availability of the compute environment and services provided increases as E_J approaches to 1.

$$E_J = \frac{J_C}{J_S} \ . \tag{1}$$

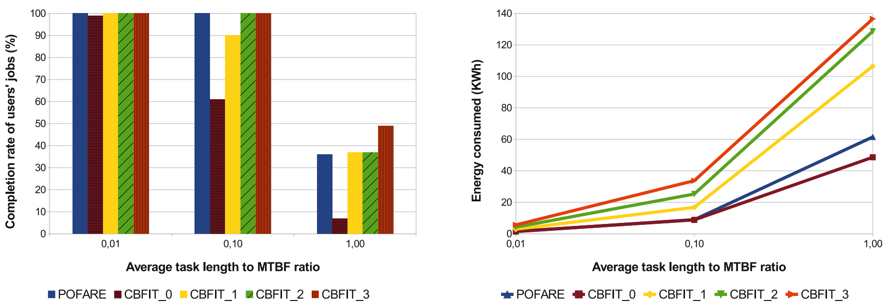
The energy consumption E_E, expressed in KWh, and presented by Eq. (2), is determined by dividing the average power consumption (in Watts) of the computing infrastructure (i.e., for all active PMs u at all sample times f) by 60 (because the power consumption samples are obtained each minute).

$$E_E = \frac{\sum_{s=1}^{f} \sum_{i=1}^{u} \theta_i \times \frac{P_i}{1000}}{60}, \ \theta_i = \begin{cases} 1, & \text{if PM } i \text{ is active at instant } s \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

Since availability and dependability must be protected in a cost-effective manner, E_J and E_E may be used to selected the appropriated security control.

4.2 Results Analysis

A set of simulations was conducted for proactive fault-tolerance (i.e., POFARE), and redundancy based on 0, 1, 2, and 3 redundant copies of tasks (i.e., CBFIT_0, CBFIT_1, CBFIT_2, and CBFIT_3, respectively). Under redundancy, redundant copies of the same task are scheduled in different PMs. The results are show in Fig. 1. These simulations were conducted in a compute infrastructure composed of 100 nodes, with MTBF fixed at 200 min. In Fig. 1a, one can observe that proactive fault-tolerance tends to achieve better completion rate of jobs, as the average task length to MTBF ratio increases from 0.01 to 0.10, being outperformed by redundancy based on 3 copies per task, for the case of 1.00, due to the overhead caused by higher number of VM migrations. In the specific case of redundancy, the results get better as the number of replicas per task increases, however at expenses of high electricity bills for Cloud providers, as shown by Fig. 1b. An important outcome from the results depicted in Fig. 1b is that higher system dependability does not necessarily mean more energy consumed. If one considers the case of average task length to MTBF ratio equal to 0.01 and to 0.10, proactive fault-tolerance (i.e., POFARE) provides better dependability since it successfully completes more jobs and consumes less energy.



(a) Completion rate of users' jobs

(b) Energy consumption

Fig. 1. Impact of the average task length to MTBF ratio in the performance of fault-tolerance mechanisms

Only the case of no replication of tasks (i.e., CBFIT_0) outperforms proactive fault-tolerance in terms of energy consumption, but with consequent negative impact on the number of jobs successfully completed.

5 Conclusion

This paper has evaluated the effectiveness of security controls in providing dependable Cloud services to costumers. Failures represent the threats to dependability and security of a system and services deployed. Unfortunately, with the ever-growing warehouse-sized data centers being built to deal with increasing demand for computing resources and services, component failures become norms instead of exceptions. In order to deal with this issue, different fault-tolerance mechanisms exist to provide dependable compute environments. However, dependability of services at all cost is not a solution, because it may ending up increasing the energy consumption and operational costs to providers.

This study assessed two state-of-the-art fault-tolerance mechanisms, namely redundancy and proactive fault-tolerance. The results obtained based on simulations showed that proactive fault-tolerance outperforms redundancy up to 3 replicas in some circumstances (i.e., the case of average task length to MTBF ratio equal to 0.01 and to 0.10), in terms of jobs successfully executed, and less energy consumed.

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Information Security Maturity Level: A Fast Assessment Methodology

Sérgio Monteiro[1] and João Paulo Magalhães[2](✉)

[1] CIICESI, ESTG, Politécnico do Porto, Porto, Portugal
8140344@estg.ipp.pt
[2] GCC, CIICESI, ESTG, Politécnico do Porto, Porto, Portugal
jpm@estg.ipp.pt

Abstract. In this paper, we propose an entry-level methodology for the determination of an Information Security Maturity Level. The methodology is based on the analysis of three axes and three functional areas (people, processes and technology) and aims to be a first approach, with the simplicity of language and focus on the recipient, for the quantitative measurement of potential security risks. The methodology has been applied in a real context and the results reveals the usefulness of it. The maturity level is simple to understand facilitating the spread of a security awareness culture, while allowing organisations to plan the necessary activities to mitigate the security threats.

1 Introduction

Never as before so much attention has been given to information security. And, never like before, information security has experienced so many threats. The information society is based on the access and valorisation of information, thus providing an exponential growth of competitiveness, innovation and modernisation. Confidentiality, Integrity and Availability are three fundamental and irrefutable aspects to assure the information security, but, keeping these three pillars stable is far from being an easy task. The existence and proliferation of cyber threats, which take the shape of practices such as cybercrime, cyberespionage, cyberwar or hacktivism are witnessing a growth in number, sophistication and impact and making the protection of information a daunting task.

According to the "The Economic Impact of Cybercrime and Cyber Espionage" report [1], cybercrime is responsible for annual losses between $300 thousand million to $1 billion dollars (long scale) in organisations around the World, which corresponds for 0.4–1.4% of the world Gross Domestic Product (GDP). Another report published by Juniper Research [2], predicts that the rapid digitalisation of both consumer data and corporate records will increase the cost of data breaches to $2.1 billion by 2019. Apart from the financial losses there are reputational and trust losses which are more difficult to quantify. The number of attacks as well as the fines associated with the data leaks contributes to an

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increased awareness of the problem. Nevertheless, when the organisations get to the risk analysis stage, they often face doubts regarding the implementation of information security plans. These doubts are a consequence of the difficulties that organisations have in putting a value on their assets and analyse the degree of threat the assets face. These difficulties are particularly significant for Small and Medium-sized Enterprises (SMEs).

In this paper we present a fast assessment methodology for the determination of a Information Security Maturity Level (ISML). The methodology combines technical and non-technical means to provide a quantitate value that represents the level of information security maturity in a given organisation. To achieve this, the methodology should:

- simple to interpret, maintain and operate;
- quantify the level of maturity by means of well defined algorithms;
- replicable across organisations;
- allow the comparison between organisations of the same vertical markets.

To meet these goals and produce an accurate ISML, the underlying methodology considers three main areas of assessment (surveys, social engineering tests and vulnerability analysis) distributed by the three functional areas (processes, people and technologies). Supported by algorithms the methodology produces a score per area of assessment and a global score resulting from the cross analysis. This score represents the level of information security maturity and allows to inform the management structures of their level of information security maturity as well as to provide a vision about the level of risk of the organisation in relation with its peers. With a simple and practical method to calculate the Information Security Maturity Level, and before it is necessary to enter a deeper risk analysis, organisations can better understand their weaknesses, allowing them to adopt preventive/corrective measures to mitigate the identified risks.

The remainder of the paper is organized as follows: Sect. 2 describes the related work, Sect. 3 describes the ISML methodology, Sect. 4 presents the results obtained from a real application and Sect. 5 concludes the paper.

2 Related Work

The information security (or lack of it) is attracting many attention in the last years and in many different fields. Due to a progressive awareness about this matters, countries are continuously improving services to handle the security threats in a more proactive way. Also, and all over the world, organisations and specialists on the subject of cybersecurity, are placing information security issues on the top of their priorities, and considering the cyber threats from the strategic, tactical and operational perspectives [3].

To approach the numerous and complex cyber threats of nowadays, it is suggested the execution of a continuous monitoring system able to operate on four main aspects [4]: (1) Vulnerability and asset management; (2) System and log collection, correlation and reporting; (3) Advanced network monitoring; (4)

Table 1. Comparison of quantitate risk analysis Models

Model	Analysis	Complexity	Description	License
ISAMM	Quantitative	N/A	Risks are evaluated by taking into account the annual loss expectancy	N/A
IRAM	Quantitative and Qualitative	Average	Workshop based analysis with the IT team	Free for subscribers
MAGARETI	Quantitative and Qualitative	Average	Provides more than one approach for risk assessment	Free
MEHARI	Quantitative and Qualitative	Difficult	Analysis based-on surveys, formulas and parameters	Free

Threat intelligence and business analytics. By operating across these aspects it becomes possible to maintain the awareness of information security, discover vulnerabilities in advance and support the organisational risk management decisions [5]. This seems simple but its implementation is complex. At the very beginning of the process it is required a risk analysis, in order to identify the assets, determine the level of threat and define controls to mitigate threats. This task is considered complex and it outcome versus cost of execution is not always understood in companies with lower information security maturity. A quick overview about existing risk management models reveals the existence of at least 27 different information risk assessment models. From those 27, 16 models follow a qualitative risk analysis approach; one is strictly quantitative and three combine the two approaches. We have also identified seven models which cannot be characterised in neither way. In Table 1 we present a fast comparison of quantitate risk analysis models considering the type of analysis it provide, the complexity of implementation and the license type. This analysis is based on previous research [6].

Even though the risk assessment models differ from each other all these models have in common, even the simpler ones, a certain level of complexity on their implementation, which many times makes them difficult to adopt for small and medium organisations which do not have the technical, human and financial means to understand and implement them. On the contrary, the methodology we propose in this paper aims to be a "front door" to this problem, by providing a quantitative analysis which differs from the majority of the models that we have mentioned. It is important to refer that our methodology is not intended to replace the traditional risk assessment method, but complements them.

3 Information Security Maturity Level: Methodology

The methodology here proposed consists on a reference guide which describes the different procedures to implement. It is divided on three analysis areas named by axes: surveys, social engineering, vulnerability analysis. These three axes cover the three vertices of the triangle: processes, people and technology. The main objective of this methodology is guide the security assessment process, producing a quantitative value, representative of the information security level observed in the organisation. With a such methodology it becomes easy to replicate its applications across organisations with little adaptation effort as well as to compare the results across the organisations. The result of methodology is a level or a score representative of the Information Security Maturity Level (ISML). It corresponds to a value between 1 and 5 where 1 represent a low security maturity and 5 a strong information security posture. The determination of a score is particularly interesting to engage boards and the C-suite. It provides a simple indicator of how an organisations is and contributes to defining a roadmap fill the information security gap. To determine the level we have adopted the "Cyber security maturity model" proposed by Deloitte on the "The cyber security imperative - Protect you organization from cyber threats" in [3]. The cyber security model presented by Deloitte is illustrated in Fig. 1.

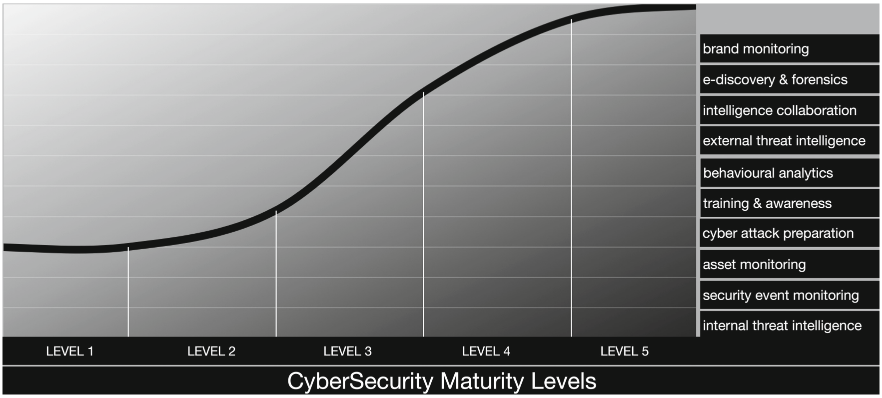

Fig. 1. Deloitte—cyber security maturity model

The cyber security maturity model, illustrated in Fig. 1, is based on ten big operative areas and describes a logarithmic curve between the proactive threat management level (yy axis) and the maturity levels (xx axis). As the level progresses, the underlying criteria to achieve a higher maturity level become tighter. Like this model, there are others in the literature that follow a similar curve. We followed the Deloitte cyber security model by defining eleven areas of risk management and distributing them by the inner boxes. From the number of boxes filled we achieved the upper percentage of each level: Level 1 is between 0 and 38%, level 2 is between 39 and 75%, level 3 is between 76 and 93%, level 4 is between 94 and 98% and finally level 5 is between 99 and 100%. In the next subsections we present the algorithms used to determine the ISML which is then mapped in these levels/intervals.

3.1 Axis Number 1—Surveys

The axis number 1—surveys—is composed by a standard questionnaire and an analysis model. The questionnaire is composed by several questions organised by group under analysis: normal users, board, IT department. The idea is to capture a global vision around questions of interest regarding the information security. As presented in Algorithm 1 the questionnaires phase initiates with a meeting to weight the questions, taking into account their importance/risk (type 1, questions whose negative response is connoted with greater risk or type 2 questions whose negative response does not represent a considerable risk). This meeting is held with the organization management board under the guidance of an information security specialist. The second phase is the conduct of the surveys for each of the three target groups. Finally, in the third stage the surveys are analysed and the ISML is determined.

Algorithm 1 Surveys—weighting process, analysis and ISML determination

procedure 1. WeightingQuestions(set_of_questions)
  1.1. Meeting to segment questions by type: 1—higher risk; 2—lower risk
  1.1.1. Determine the percentage of questions of each type (PQ_i)
  1.1.2. Determine the weight for each type of questions ($P_x = 1 - PQ_i$)
end procedure
procedure 2. ConductSurveys
  2.1. Survey per group under analysis: normal users, board, IT department
end procedure
procedure 3. AnalyzeAnswers(P_x)
  3.1. Determine the percentage of answers per question (R)
  3.2. Achieve the weight value of answers per question ($F_n = P_x * R$)
  3.3. Sum up all the F percentages ($RF = \sum_{n=1}^{N} F_n$; N = number questions)
  3.4. Determine the ISML by positioning the value of RF on the reference curve
end procedure

3.2 Axis Number 2—Social Engineering

The axis 2—social engineering—consists on a set of procedures that allow to test people and users, whose procedures and actions can endanger the organisation. The purpose is to evaluate maturity based-on the level security awareness of the people on the organisation (e.g. open email attachments, phishing, CEO fraud). This ISML is determined by the steps described in Algorithm 2.

Algorithm 2 Social engineering—campaign, admissible behaviours and ISML

procedure 1. Preparation
  1.1. Management meeting to present the campaigns (e.g. phishing simulation)
  1.2. Determine pre-requisites
  1.3. Obtaining clearance
  1.4. Select the type of action (e.g., external phishing attack with cloned page)
  1.5. Collect information from the target (e.g. list of email addresses)
end procedure
procedure 2. DesignAction
  2.1. Build the scenario (e.g. email template, landing page)
  2.1.1. Identify/List possible consequences (LC_i)
  2.1.2. Analysis criteria (with management): LC_i, #occurrences, Level
end procedure
procedure 3. ExecuteAction
  3.1. Launch campaign
  3.2. Collect results
  3.3. Determine the ISML considering the analysis criteria
end procedure

The Algorithm 2 involves three procedures. It initiates with a meeting to present and select the type of campaigns (e.g. phishing attack, malware download). After defining the campaign the action is customised and executed. During the customisation phase are identified and discussed with the management team the list of possible consequences (LC). The LC corresponds to a list of items that can occur as a campaign result (e.g. collaborators opened the email, collaborators clicked on the malicious link). These items are listed and, together with the management team, an analysis criteria is defined (e.g. if one collaborator opens the attachment the security maturity level should be equal to 1).

3.3 Axis Number 3—Vulnerability Analysis

The axis 3—vulnerability analysis—considers the result of a vulnerability analysis (vulnerability assessment) for the determination of ISML. A vulnerability analysis is a technical analysis that involves the identification of vulnerabilities that can be used by hackers to attack the organisation. This kind os analysis provides a list of vulnerabilities with a level o severity (e.g. critical, high, medium, low, informative). The level of severity combined with the number of occurrences per level of severity as presented in Algorithm 3 is used to compute the ISML.

Algorithm 3 Vulnerability assessment—planning, auditing and ISML

procedure 1. PREPARATION
    1.1. Management meeting to define the scope: network, systems, applications
    1.2. Define level of maturity by type of severity (LS_i) (e.g. $LS_{critical} = 1$)
    1.3. Determine pre-requisites
    1.4. Obtaining clearance
end procedure
procedure 2. AUDITING_AND_ANALYSIS
    2.1. Select vulnerability analysis tools according the scope
    2.2. Perform the vulnerability analysis
    2.3. Collect the results
end procedure
procedure 3. DETERMINE_ISML(LS_i)
    3.1. Obtain number of occurrences per severity (RC_i)
    3.2. Initialise $IMSL = 5$
    if ($RC_i > 0$) **then**
        $IMSL \leftarrow LS_i$
    end if
end procedure

The determination of the ISML for the vulnerability analysis is very simple. As presented in Algorithm 3, during the preparation phase is defined the maturity level according to the type of severity. A result of this step can be for example: $critical = 1$, $high = 1$, $medium = 2$, $low = 3$, $informative = 4$, $no_occurrences = 5$. After defining this, the ISML will be equal to the level where the number of vulnerabilities is greater than zero.

4 Experimentation

The proposed methodology was submitted to experimentation in four city councils with a total of 695 people. At the time of this paper we collected the results from the axis 1 (surveys) and axis 2 (social engineering).

For axis 1 we followed all the steps indicated in Algorithm 1. During the initial meetings we presented a list of questions and defined the type of questions (type 1 higher risk, type 2 lower risk). The types were standardised considering the largest number of votes per questions, with inputs from the expert operating the surveys. Three different surveys (one per group of analysis: normal users, board, IT department) were sent using a Google form. A total of 115 people answered to the surveys and the results were analysed. From the analysis process presented the third and fourth procedure presented in Algorithm 1 we determined the ISML. All organisations were ranked at level 2, revealing a low level of maturity. This means that they are highly exposed to risk on functional areas, while the security demands (namely in what refers to users and to policy and procedures definition) are given almost no attention.

For axis 2 we also followed all the steps indicated in Algorithm 2. During the preparation meetings we agreed the execution of a phishing campaign. We registered a domain and used the Gophish framework to support the execution of the campaign. We sent an email message to 50 workers randomly selected. The email included a link to a webpage under control of the attacker. Once the user clicked the link and the page was accessed, the user is invited to click on another link (second level) to download (third level) an excel file containing self-executing macros (fourth level). When the macro is executed an email is automatically sent to the origin. The list of consequences and analysis criteria was the following: level 1—opened email, clicked on link, opened file and activated macro; level 2—open email and clicked on link; level 3—opened and discharged email; level 4—opened and forwarded email to the IT support team; level 5—did not open the email. The ISML will correspond to the level, being 1 the lower and 5 the highest, were one or more of the listed consequences took place. After analysis the results we observed a total of 24 workers in three of the organisations that activated the macro ($ISML = 1$) and in the other organisation a total number of 25 workers who opened the email and clicked on link ($ISML = 2$). These results show that level of maturity in relation to social engineering techniques used on cyber attacks is very low.

5 Conclusion

In this paper we presented a "entry level" methodology to assess the Information Security Maturity Model (ISML) of an organisation. The methodology is distributed on three axes: surveys; social engineering; vulnerability analysis and comprises three functional areas: people, processes and technology.

ISML aims to be a reference guide supported by a set of algorithms that normalise the process of analysis and determination of the information security maturity level. In this context, three ISML algorithms were presented. Through experimentation in real context, two of these algorithms have already been tested and the results obtained were interesting. The acceptance was good, the operationalisation of the methodology was simple and the results useful. Based on the results it was recognised the need to define security policies; promote security training programmes; define a stronger investment on technology; and conduct a more profound risk analysis.

We recognise that ISML still needs more work to become more accurate and widely adopted. As it is now, it already provides a base work that facilitates the adoption of security analysis and contributes to the mitigation of vulnerabilities.

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