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Fernando De la Prieta · Zita Vale
Luis Antunes · Tiago Pinto
Andrew T. Campbell · Vicente Julián
Antonio J.R. Neves · María N. Moreno *Editors*

Trends in Cyber-Physical Multi-Agent Systems. The PAAMS Collection - 15th International Conference, PAAMS 2017

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Preface

PAAMS'17 Special Sessions are a very useful tool in order to complement the regular program with new or emerging topics of particular interest to the participating community. Special Sessions that emphasized on multi-disciplinary and transversal aspects, as well as cutting-edge topics, were especially encouraged and welcome.

Research on Agents and Multi-Agent Systems has matured during the last decade, and many effective applications of this technology are now deployed. An international forum to present and discuss the latest scientific developments and their effective applications, to assess the impact of the approach, and to facilitate technology transfer has become a necessity.

PAAMS, the International Conference on Practical Applications of Agents and Multi-Agent Systems, is an evolution of the International Workshop on Practical Applications of Agents and Multi-Agent Systems. PAAMS is an international yearly tribune to present, to discuss, and to disseminate the latest developments and the most important outcomes related to real-world applications. It provides a unique opportunity to bring multi-disciplinary experts, academics, and practitioners together to exchange their experience in the development of Agents and Multi-Agent Systems.

This volume presents the papers that have been accepted for the 2017 special sessions: Agent-Based Social Simulation, Modelling and Big-Data Analytics (ABM); Advances on Demand Response and Renewable Energy Sources in Agent Based Smart Grids (ADRESS); Agents and Mobile Devices (AM); Computer vision in Multi-Agent Robotics (RV); Persuasive Technologies (PT); Web and Social Media Mining (WASMM). The volume also includes the papers accepted for publication in the Doctoral Consortium (DCAI, DCAI-DECON, ISAMI, MIS4TEL, PAAMS, PACBB 2017 conferences).

We would like to thank all the contributing authors, the members of the Program Committee, the sponsors (IEEE SMC Spain, IBM, AEPIA, AFIA, APPIA, Universidad Politécnica de Madrid, Polytechnic Institute of Porto, and CNRS), and the Organizing Committee for their hard and highly valuable work. Their work

contributed to the success of the PAAMS 2017 event. Thanks for your help—PAAMS 2017 would not exist without your contribution.

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Fernando De la Prieta
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Agent-Based Social Simulation, Modelling and Big-Data Analytics and Persuasive Technologies.
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Agents and Mobile Devices, Computer vision in Multi-Agent Robotics.
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Special Session on Agent-Based Social Simulation, Modelling and Big-Data Analytics (ABM) + Persuasive Technologies (PT)

A Network-Oriented Modeling Approach to Voting Behavior During the 2016 US Presidential Election

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Abstract. In this paper a network-oriented computational model is presented for voting intentions over time specifically for the race between Donald Trump and Hillary Clinton in the 2016 US presidential election. The focus was on the role of social and mass communication media and the statements made by Donald Trump or Hillary Clinton during their speeches. The aim was to investigate the influence on the voting intentions and the final voting. Sentiment analysis was performed to check whether the statements were high or low in language intensity. Simulation experiments using parameter tuning were compared to real world data (3 election polls until the 8th of November).

1 Introduction

The United States presidential election of 2016 was a much-debated subject. On November 8 Americans elected, in contrast to what was expected, Donald Trump as the 45th president of the United States. Such processes and the role of social and mass communication media are more and more investigated; see, for example, [1, 3, 4, 6, 8, 11]. In particular, statements in speeches of Donald Trump or other candidates can have an influence on the voting behaviour of the American citizens. For example, PoliZette states that (based on the LA Times/USC daily tracking poll) Trump jumped 10 points with black voters after his Milwaukee speech on the 16th of August.[1] In this speech, Trump said: "I am asking for the vote of every African-American citizen struggling in our country today who wants a different future". Presidential candidates use different language intensity in different situations and the effects of these depend on each other [2]. During times of economic hardships, people consider a presidential candidate trust-worthier and more presidentiality when he uses high intensity language and during stable economic times, the use of low intensity language will make the candidate seem trust-worthier and more presidential. Language intensity depends on directness toward the audience and emotionalism of word choice. High intensity language is personalized, specific, assertive and explicitly directed at the audience and low intensity language uses indirect messages that are more ambiguous, unclear and imprecise. In [5] the resonance model is discussed,

[1] https://www.lifezette.com/polizette/milwaukee-trump-jumps-10-points-black-voters/.

F. De la Prieta et al. (eds.), *Trends in Cyber-Physical Multi-Agent Systems. The PAAMS Collection - 15th International Conference, PAAMS 2017*,
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which considers the relationship between the message content (of a presidential campaign) and the receivers' predispositions. A predisposition is for example party identification. In this model it is the interaction between the content of a message and the predisposition that controls the reinforcement or 'polarization' effect. Intense partisans will not need a lot of reinforcement, will resist messages that are counter attitudinal and accept consonant messages. Less-intense partisans however will move the most between parties during campaigns. The voters' partisanship extends beyond the mere fact that Republicans will be more responsive to the Republican candidate and vice-versa. Voters also acquire beliefs about the groups served by the political parties and the issues or problems on which they will deliver.

The goal of this paper is to present an agent-based computational model to simulate voting intentions over time. It takes into account agents representing persons from different ethnic groups and different mental states within these agents. The computational model was designed by a Network-Oriented Modelling approach based on temporal-causal networks [12]. This is a generic and declarative dynamic AI modelling approach based on networks of causal relations (e.g., [7, 9]), that incorporates a continuous time dimension to model dynamics, as also advocated in [10]. The model was related to poll data of the 2016 US presidential election, specifically the race between Donald Trump and Hillary Clinton, and the influence of statements made by Donald Trump or Hillary Clinton during their speeches. Sentiment analysis was performed to check whether the statements were high or low in language intensity.

2 Domain Knowledge: Polls and Speeches

The speeches of Donald Trump and Hillary Clinton have influenced the opinion people have about these candidates. In a speech, a candidate is able to use high or low intensity language. Depending on the use of language and on their economic situation people consider a candidate as more or less trustworthy and presidential. In this research multiple speeches where analyzed with the use of an online sentiment analyzer tool.[2] The tool computes a score that reflects the overall sentiment, tone or emotional feeling of the speech given as input. The score ranges from −100 to +100 where −100 indicates a very negative or serious tone and +100 indicates a very positive of enthusiastic tone. For now it is assumed that this score reflects the language intensity that is used by the candidate.

Three polls (see the Appendix) conducted by McClatchy-Marist where used to check the voting behavior at different times. The answers (in percentages) on the question "If November's presidential election were held today, whom would you support if the candidates are:" were used to see whom people would vote for. The possible answers were: "Hillary Clinton, the Democrat", "Donald Trump, the Republican", "Gary Johnson, the Libertarian", "Jill Stein, of the Green Party", "Other", "Undecided". The first poll of 1132 was conducted from the first of August through August the third. The interviews were performed by phone. The second poll involving 1298 adults was

[2] http://www.danielsoper.com/sentimentanalysis/.

conducted from September 15th to September 20th. The third and last poll consisted out of 1587 adults and was conducted from November 1st to November 3rd.

Eighteen speeches were analyzed: three for every candidate in the time period before a conducted poll. The first speech on the 22nd of June given by Donald Trump had a sentiment score of 14 (the overall sentiment or tone of the speech was somewhat positive/enthusiastic), for the transcript of the speeches, see appendix. The second speech on the 21st of July had a sentiment score of 9.4 (the overall sentiment or tone of the speech was essentially neutral). The third speech on the 27th of July had a sentiment score of −32.2 (the overall sentiment or tone of the speech was somewhat negative/serious). The speeches given by Hillary Clinton on the 7th of June and the 18th and 28th of July had scores of −4.2, −7.9, −8.8 which means that the overall sentiment or tone for all of these speeches was essentially neutral. The first speech given by Trump during the time period after the first poll and before the second poll, the 18th of August, had a sentiment score of 14.2 (the overall sentiment or tone of the speech was somewhat positive/enthusiastic). The second and third speech on the 31st of August and the 15th of September had a score of −8.2 and −7.3: the overall sentiment or tone of the speech was essentially neutral. For Clinton in the same time period all three speeches were essentially neutral with score of −8.9, −7.0, and −6.9. The first speech given by Trump during the last period, after the second poll and before the third, the 2nd of October, had a sentiment score of 66.8 (the overall sentiment or tone of this speech was quite positive/enthusiastic). The second and third speech on the 13th of October and the 22nd had a score of −8.7 and −6.9 (the overall sentiment or tone of these speeches were essentially neutral). The three speeches given by Clinton during the third period on the 3rd, the 11th and the 26th of October had scores of −8.8, 2.9, and 8.9 (the overall sentiment or tone of the speeches were essentially neutral). The polls will serve as empirical data to check in how far the model is a good representation of the voting behavior.

3 The Designed Temporal-Causal Network Model

Temporal-causal network models can be represented at two levels: by a conceptual representation and by a numerical representation. These model representations can be used to display graphical network pictures, but also for numerical simulation. Furthermore, they can be analyzed mathematically and validated by comparing their simulation results to empirical data. Moreover, they usually include a number of parameters for domain, person, or social context-specific characteristics. To estimate values for such parameters, parameter tuning methods are available.

A conceptual representation of a temporal-causal network model in the first place involves representing in a declarative manner states and connections between them that represent (causal) impacts of states on each other, as assumed to hold for the application domain addressed. The states are assumed to have (activation) levels that vary over time. Three main elements in the Network-Oriented Modelling approach based on temporal-causal networks, and which constitute a conceptual representation of a temporal-causal network model are the following (see [12, 13]):

- **Connection weight $\boldsymbol{\omega}_{X,Y}$.** Each connection from a state X to a state Y has a *connection weight* $\boldsymbol{\omega}_{X,Y}$ representing the strength of the connection.
- **Combination function $\mathbf{c}_Y(..)$.** For each state a *combination function* $\mathbf{c}_Y(..)$ is used to combine the causal impacts of other states on state Y.
- **Speed factor $\boldsymbol{\eta}_Y$.** For each state Y a *speed factor* $\boldsymbol{\eta}_Y$ is used to represent how fast a state is changing upon causal impact.

Combination functions in general are similar to the functions used in a static manner in the (deterministic) Structural Causal Model perspective described, for example, in [9, 14], but in the Network-Oriented Modelling approach described here they are used in a dynamic manner, as will be pointed out below briefly.

A conceptual representation of temporal-causal network model can be transformed into a numerical representation of the model as follows ([12], Chap. 2):

- at each time point t each state Y has a real number value $Y(t)$ in [0, 1]
- at each time point t each state X connected to state Y has an impact on Y defined as $\mathbf{impact}_{X,Y}(t) = \boldsymbol{\omega}_{X,Y} X(t)$ where $\boldsymbol{\omega}_{X,Y}$ is the connection weight
- The *aggregated impact* of multiple states X_i on Y at t is determined by:

$$\begin{aligned}\mathbf{aggimpact}_Y(t) &= \mathbf{c}_Y(\mathbf{impact}_{X_1,Y}(t), \ldots, \mathbf{impact}_{X_k,Y}(t)) \\ &= \mathbf{c}_Y(\boldsymbol{\omega}_{X_1,Y} X_1(t), \ldots, \boldsymbol{\omega}_{X_k,Y} X_k(t))\end{aligned}$$

  where X_i are the states with connections to state Y
- The effect of $\mathbf{aggimpact}_Y(t)$ on Y is exerted *over time gradually*:

$$\begin{aligned} & Y(t+\Delta t) = Y(t) + \boldsymbol{\eta}_Y[\mathbf{aggimpact}_Y(t) - Y(t)]\Delta \mathrm{t} \\ \text{or}\quad & \mathrm{d}Y(t)/\mathrm{d}t = \boldsymbol{\eta}_Y[\mathbf{aggimpact}_Y(t) - Y(t)]\end{aligned}$$

- Thus, the following *difference* and *differential equation* for Y are obtained:

$$\begin{aligned} Y(t+\Delta t) &= Y(t) + \boldsymbol{\eta}_Y[\mathbf{c}_Y(\boldsymbol{\omega}_{X_1,Y} X_1(t), \ldots, \boldsymbol{\omega}_{X_k,Y} X_k(t)) - Y(t)]\Delta t \\ \mathrm{d}Y(t)/\mathrm{d}t &= \boldsymbol{\eta}_Y[\mathbf{c}_Y(\boldsymbol{\omega}_{X_1,Y} X_1(t), \ldots, \boldsymbol{\omega}_{X_k,Y} X_k(t)) - Y(t)]\end{aligned}$$

An example of a combination function $\mathbf{c}_Y(V_1, \ldots, V_k)$ is the *scaled sum function* (with scaling factor $\lambda > 0$):

$$\mathbf{ssum}_\lambda(V_1, \ldots, V_k) = (V_1 + \ldots + V_k)/\lambda$$

Another example is the *advanced logistic sum function* (with σ, $\tau \geq 0$ steepness and threshold values):

$$\mathbf{alogistic}_{\sigma,\tau}(V_1, \ldots, V_k) = [(1/(1+\mathbf{e}^{-\sigma(V_1 + .. + V_k - \tau)}) - (1/(1+\mathbf{e}^{\sigma\tau}))](1+\mathbf{e}^{-\sigma\tau})$$

Based on what has been gathered from the literature discussed above, an agent-based temporal-causal network model has been designed featuring for each agent the following mental states, some are applied both to Clinton (C) and Trump (T):

- Statement made (C/T)
- Predisposition (C/T)
- Emotion level
- Level of education
- Economic status
- Interpretation of the statement (C/T)
- Intention to vote (C/T)
- Vote (C/T)

The conceptual representation of the model is depicted in Fig. 1. Within the agents the different mental states are connected according to some intra-agent network, which models the agent's mental (cognitive and affective) processes; see the connections with each of the boxes in Fig. 1. For example, the interpretation of a statement of a candidate has a causal impact on the intention to vote for that candidate. The agents are assumed to belong to certain ethnic groups.

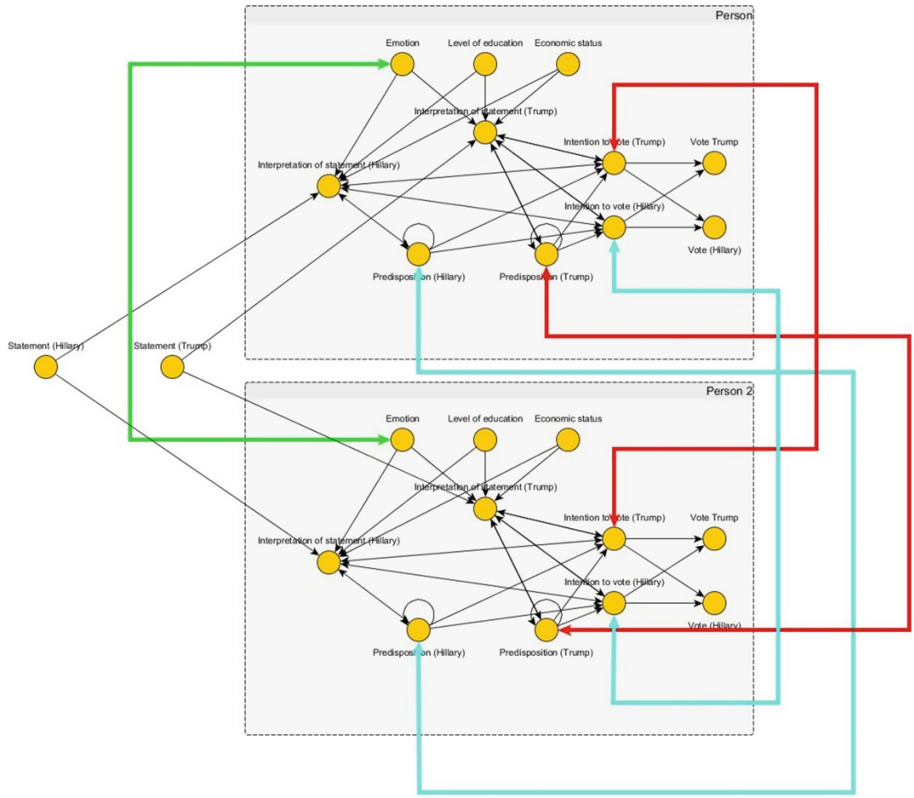


Fig. 1. Overview of the conceptual representation of the model

Within these groups many connections occur, whereas between different ethnic groups there are less connections. These ethnic groups have been selected based on groups that were specified in the McClatchy-Marist poll: White, African American, Latino. Ethnic groups can differ on all states described above. The predisposition of African Americans towards Trump is probably different from the predisposition of whites. There can be contagion between groups when a person of one group has a connection (bridge) with a person from an different ethnic group. Due to Matlab restrictions (that was used for implementing the model) only a divide between whites and non-whites was made. The African Americans and Latinos were considered as one group due to these limitations. As each agent involves 11 mental states, the total amount of variables rapidly increases.

The connections between different agents are a basis for contagion between these agents. This takes place simultaneously for different mental states: emotions, intentions, and predispositions (see the inter-agent connections in Fig. 1). The model features two input states that represent the statements made by the candidates. The language intensity score that is obtained through sentiment analysis will serve as the value for these states. Over time statements will be made and thus the model will see a spike in values for these states as a value is only ascribed to the state on the point in time that the candidate gave a speech. For the other points in time the value of the input states will simply be 0, and so it is assumed there is basically no other information for the voters to base their decision on in terms of statements of the candidates themselves. The value of these states ranges from 0 to 1 and is determined by dividing the language intensity score by 100. These statements can be interpreted by the voters in different ways. This interpretation is based on different factors depending on person-specific characteristics, and forms one of the core concepts of the model of every specific agent. The emotion level, predisposition for a certain candidate, level of education, economic status, and intention to vote for a certain candidate all influence the interpretation. The value of this state ranges from 0 to 1 and the updates for this value uses the advanced logistic combination function. This way, whenever a certain threshold is reached, the value of this state switches between a low value (value below threshold, negative interpretation of the statement) or high value (value above threshold, positive interpretation of the statement). The interpretation of the statement of a certain candidate influences the intention of voters to vote for that candidate. A more negative interpretation of the statement will result in a decreased intention to vote for the corresponding candidate.

The level of education, economic status and emotional level are all properties of the voter that influence the way they interpret statements made by the candidates. Safe for the latter one, the value of these states are constant. The level of education and economic status will influence the interpretation of the statement in a negative way. The higher the value for these states, the lower the value of the interpretation. This comes from the understanding that these kinds of people are less likely to take politicians at face value and seek more argumentation before being convinced by them. The emotion level of a person influences the interpretation of the statement in a positive way based on the belief that a positive emotional state will allow for people to accept what others say more quickly. Predisposition, just like emotion, education and economic status, influences the interpretation of the statement. A high predisposition towards one of the candidates will positively influence the interpretation a voter has of statements that were made by that candidate.

The intention to vote influences the actual voting for a candidate. In this process a voting intention for one candidate can suppress the voting for the other candidate. It also influences the predisposition for a candidate under the assumption that if someone intends to vote for a candidate they also like the candidate more. Therefore there is a two-way interaction between these two states. The intention to vote for one candidate has a inhibiting effect on the intention to vote for the other candidate.

Like the other states in the model the values for the actual vote states range from 0 to 1. There are three possible outcomes for each person in terms of how they vote. Whenever one of the states has a high value this means that the agent voted for the corresponding candidate. Whenever both states have high values this indicates that the agent would like to vote for both candidates. This is obviously not possible and thus interpreted as the agent being unable to decide between them. Low values for both states indicates that the agent does not intend to vote at all. This resembles the options that were presented during the polls of the presidential elections as well.

The notations of the states in the numerical representation of the network model slightly differ from the one used in Fig. 1. Table 1 displays the states in the numerical representation: $State_i$, …, $State_k$ indicate that the state of the current agent is used together with the same state of other agents that have a relation with the current agent.

Table 1. Numerical representation of states

State	Numerical representation
Statement (Clinton, Trump)	StatC, StatT
Predisposition (Clinton, Trump)	PreC, PreT
Interpretation of statement (Clinton, Trump)	InpC, InpT
Emotion	Emotion
Level of education	Education
Economic status	Economic
Intention to vote (Clinton, Trump)	InvC, InvT
Vote (Clinton, Trump)	VoteC, VoteT

Examples of numerical representations, of the interpretation of a statement (Clinton, Trump) and the emotion state within one agent:

$$\begin{aligned}\mathrm{InpC}(t+\Delta t) &= \mathrm{InpC}(t)\\ &\quad + \boldsymbol{\eta}_{\mathrm{InpC}}[\mathbf{alogistic}(\boldsymbol{\omega}_{\mathrm{StatC,InpC}}\mathrm{StatC}(t), \boldsymbol{\omega}_{\mathrm{Emotion,InpC}}\mathrm{Emotion}(t), \boldsymbol{\omega}_{\mathrm{Education,InpC}}\mathrm{Education}(t),\\ &\quad \boldsymbol{\omega}_{\mathrm{Economic,InpC}}\mathrm{Economic}(t), \boldsymbol{\omega}_{\mathrm{PreC,InpC}}\mathrm{PreC}(t)) - \mathrm{InpC}(t)]\Delta t\end{aligned}$$

$$\begin{aligned}\mathrm{Emotion}(t+\Delta t) &= \mathrm{Emotion}(t)\\ &\quad + \boldsymbol{\eta}_{\mathrm{Emotion}}[\mathbf{alogistic}(\boldsymbol{\omega}_{\mathrm{Emotion}_1}\mathrm{Emotion}_1(t), \ldots, \boldsymbol{\omega}_{\mathrm{Emotion}_k}\mathrm{Emotion}_k(t)) - \mathrm{Emotion}(t)]\Delta t\end{aligned}$$

The other numerical representations are similar, given the conceptual representation of the network model.

4 Simulation Experiments

The model was tested by a simulation experiment. A scenario was simulated in which two groups (whites and non-whites), each of 4 numbered agents X_1 to X_4 and X_5 to X_9 reacted to the statements made by Hillary Clinton and Donald Trump. The two groups were only connected to each other through a 'bridge' between agent X_4 and X_5; see Fig. 2. The initial values for the interpretation of statements and the vote states have been set to 0. It is assumed that no statements prior to the simulation are being interpreted and that people have not yet decided on who to vote. The initial values for the other states were randomly chosen since in reality people would differ from each other as well and in this current scenario the connection between agents is already manipulated. Manipulating initial values of other states as well to, for example, have a group of Clinton supporters and a group of Trump supporters would introduce an extra independent variable.

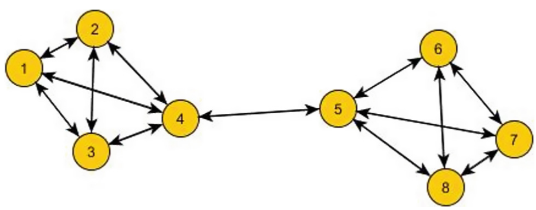


Fig. 2. The two groups of agents in the scenario

The speed factor values were all 0.5 except for the voting states for Trump or Clinton. Actually voting is a slower process so the chosen value was 0.2. For the initial values of all states, see the Appendix. The combination functions were all advanced logistic, except for emotion. This was a scaled sum of all the connections with the other persons in the model (for all persons 4, except for person X_4 and X_5 who also had a connection with each other; they had a scaled sum of 5).

4.1 Results of the Simulation Experiment

Figure 3(a)–(l) shows the simulation results after parameter tuning was performed on the speed factors of the states. In this figure, the Economics and Education states (a) and (b) are constant since it is assumed these do not change in 155 days. Emotion (f), which is a contagion state, seems to converge to a low value. This might be explained by the emotion state being influenced by the emotion of others and the majority of agents starting with low emotional states. The Predisposition Clinton and Trump (c) and (d) converge to 1, Predisposition Trump converges faster than Predisposition Clinton. This indicates that eventually all agents will like both candidates but the likeability for increases more rapidly.

Interpretation of the statements that Trump made are quite different from the interpretation of the statements Clinton made (g) and (h). The interpretation of speeches varies and the predisposition and emotion of a person influences this interpretation together with the two constant states. This fluctuation is likely the result of the varying language intensity of the statements made by both candidates. It is interesting to see that Hillary Clinton only has statements with a negative language intensity score yet still, there are several agents who almost always interpret her statements as positive or negative. Two Agents change their overall opinion of the statements from negative to positive but in two very different ways. This behaviour can be attributed to the different speed factors that the two agents ended up having after parameter tuning. For the interpretation of statements made by Donald Trump we see that one person changed their interpretation of his statements from positive to negative, which is one less person that switched than for Hillary Clinton. This might be due to the fact that predisposition for him is high early on in the simulation.

The intention to vote (i) and (j) for all 8 persons converges over time to 1 for both Clinton and Trump. That means that they would all have the intention to vote for Clinton and Trump. However, looking at the votes in the end, only one person votes for Trump (X3) and no one for Clinton (k) and (l). This means that in this simulation almost every agent decided not to cast a vote at all.

Something that is very remarkable about these results is that there is no noticeable reaction to the second last statement of Donald Trump that has a relatively high language intensity score. It is unclear what causes this lack of reaction.

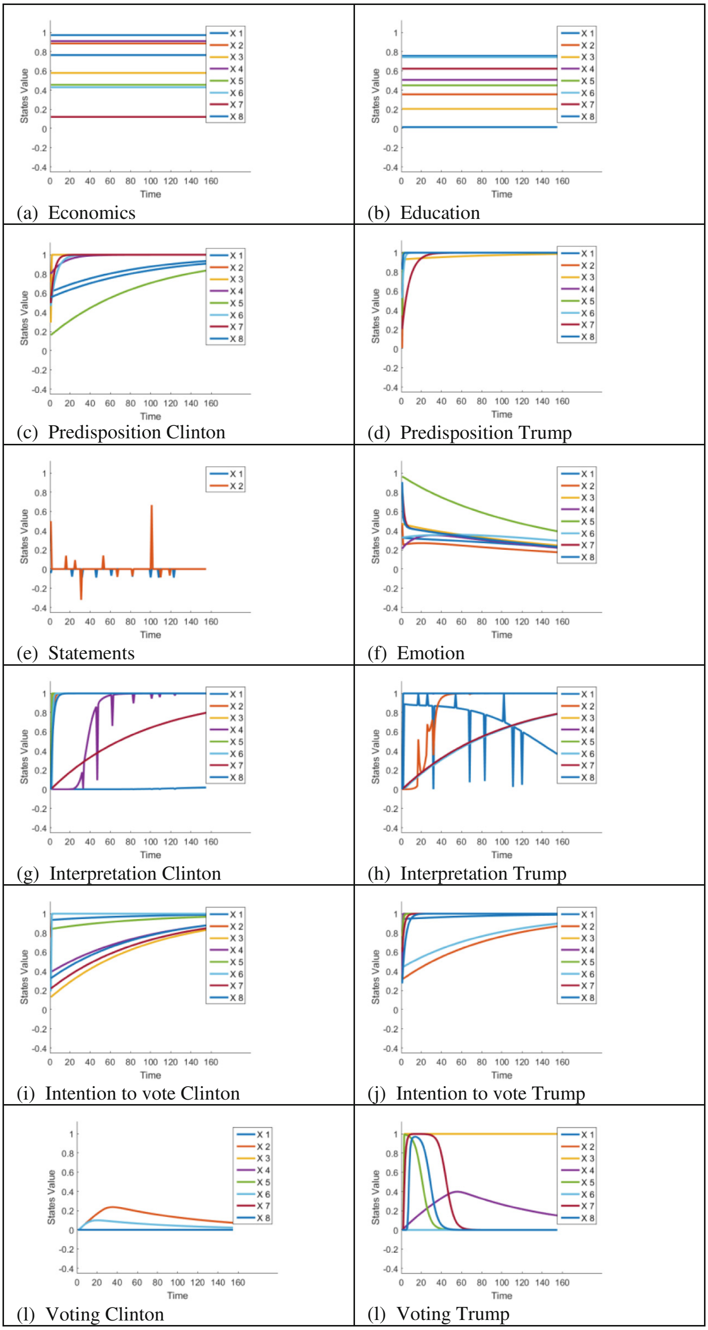
5 Verification of the Network Model by Mathematical Analysis

To verify the model, a mathematical analysis of stationary points of the network model was done. A state Y has a *stationary point* at some point in time t if $\mathbf{d}Y(t)/\mathbf{d}t = 0$; they are the (local) maxima and minima in the graphs. An equilibrium occurs at when there is no change for all states. For the dynamics of any model described by a temporal-cauasal network from the specific the differential or difference equations it can be analysed that state Y has a stationary point at t if and only if (see also [12], Chap. 12):

$$\mathbf{c}_Y(\boldsymbol{\omega}_{X_1,Y}X_1(t), \ldots, \boldsymbol{\omega}_{X_k,Y}X_k(t)) = Y(t)$$

where X_1, …, X_k are the states with connections to state Y. The current model doesn't come into a equilibrium where there is no change for all states. However, there are states that have a stationary point. For example, the state Emotion which is modeled by a scaled sum combination function. The equation expressing that the state Emotion for X_1 is stationary at time t = 155 is:

$$(\boldsymbol{\omega}_{X_1,Y}X_1(155) + \ldots + \boldsymbol{\omega}_{X_k,Y}X_k(155))/4 = Y(155)$$



(a) Economics
(b) Education
(c) Predisposition Clinton
(d) Predisposition Trump
(e) Statements
(f) Emotion
(g) Interpretation Clinton
(h) Interpretation Trump
(i) Intention to vote Clinton
(j) Intention to vote Trump
(l) Voting Clinton
(l) Voting Trump

Fig. 3. Simulation results

The left hand side is:

$$(1 * 0.2290559 + 1 * 0.1751461 + 1 * 0.246681258 + 1 * 0.222314)/4 = 0.21829931$$

The value of Emotion for X_1 at time t = 155 is 0.2290559, so the equation holds with accuracy $<10^{-2}$. The stationary point equations for X_2, X_3, X_6, X_7, X_8 are similar to the equation above. The connection between X_4 and X_5 forms a bridge which means that the scale factor here is 5 instead of 4. From the checks on stationary points explained above that have been performed in this way, it was found that they succeed, which contributes evidence that the model was implemented in a correct manner.

6 Parameter Tuning and Validation

Parameter tuning was performed using the optimizer tool in Matlab.[3] The tool offers parameter tuning through simulated annealing. Using this tool the speed factors of the 90 states that have been used were analysed. In addition to the speed factors the parameters used in the advanced logistic combination function could also have been tuned; however, due to the large amount of parameters, it was decided to only use parameter tuning for the speed factors. In the appendix the optimal values for the speed factors that were found through simulated annealing have been listed. The different speed factors the agents end up having would resemble the ability of one agent to process certain information faster than the other.

For validation, the results of the values retrieved with the model were compared to the values of the three McClatchy-Marist polls. In the first poll (conducted from the first of August to the third) 35% of the whites would support Hillary Clinton if the November's presidential election were held that day. 39% of the whites would support Donald Trump. For African Americans and Latinos together 67% would support Hillary Clinton and 11% would support Donald Trump (calculation was done by adding the two percentages, dividing it by 200 and then times 100 for a percentage). In the second poll conducted from the 15th until the 20th of September, 35% of the whites responded with Hillary Clinton on the question: "2016 presidential election including those who are undecided yet leaning toward a candidate". 49% of the whites answered with Donald Trump. For the African Americans and Latinos together, 76.5% supported Hillary Clinton and 8.5% supported Donald Trump. In the third and last poll conducted from the 1st of November through the 3rd, 39% of the whites responded with Hillary Clinton on the question: "2016 presidential election including those who are undecided yet leaning toward a candidate or already voted". 50% of the whites answered with Donald Trump. For the African Americans and Latinos together, 71.5% supported Hillary Clinton and 19.5% supported Donald Trump. Comparing the absolute values to the simulated values it can be seen that out of the 12 comparisons only 2 match. This indicates that there is room for improvement of the model.

[3] https://nl.mathworks.com/help/optim/ug/optimtool.html.

7 Discussion

After comparing the absolute values to the simulated values it turns out that the current model does not predict the real world in an accurate manner. Future research should focus on a number of issues. First, finding a better way to determine the language intensity score of the statements made by the candidates. For the current model different scenarios could be developed in which agents would, for example, have a connection to all other agents or a division in groups can be based on predisposition for a certain candidate. Most of all, the number of agents that could be used in the simulation is very important. In order to be able to compare the data more easily to the poll data, 100 agents could be used. This way a lot more ethnic groups could be created and the model could resemble reality much more.

Appendix

Polls by McClatchy-Marist

First poll: https://www.scribd.com/document/320225575/McClatchy-Marist-Poll-National-Nature-of-the-Sample-and-Tables-August-2016
Second poll: http://www.mcclatchydc.com/news/politics-government/election/article103597232.ece/BINARY/The\%20full\\%20McClatchy-Marist\%20poll
Third poll: http://www.mcclatchydc.com/news/politics-government/election/article112635043.ece/BINARY/Full\%20poll\\%20results

Transcripts of Donald Trump

June 22nd: http://www.politico.com/story/2016/06/transcript-trump-speech-on-the-stakes-of-the-election-224654
July 21st: http://www.politico.com/story/2016/07/full-transcript-donald-trump-nomination-acceptance-speech-at-rnc-225974
July 27th: https://www.washingtonpost.com/news/the-fix/wp/2016/07/27/donald-trumps-falsehood-laden-press-conference-annotated
August 18th: www.realclearpolitics.com/video/2016/08/18/watch_live_donald_trump_gives_first_campaign_speech_since_hiring_stephen_bannon.html
August 31st: http://www.latimes.com/politics/la-na-pol-donald-trump-immigration-speech-transcript-20160831-snap-htmlstory.html
September 15th: http://time.com/4495507/donald-trump-economy-speech-transcript/
October 2nd: http://thoughtsonthedead.com/transcript-of-donald-j-trumps-speech-in-manheim-pa-10116/
October 13th: http://www.npr.org/2016/10/13/497857068/transcript-donald-trumps-speech-responding-to-assault-accusations
October 22nd: http://www.whatthefolly.com/2016/10/26/transcript-donald-trumps-speech-in-gettysburg-pennsylvania-part-1/

Transcripts of Hillary Clinton

June 7th: http://bluenationreview.com/full-transcript-of-hillary-clintons-june-7-victory-speech/

July 18th: http://fortune.com/2016/07/18/hillary-clinton-speech-naacp-transcript/
July 28th: http://www.nytimes.com/2016/07/29/us/politics/hillary-clinton-dnc-transcript.html?_r=0
August 11th: http://europe.newsweek.com/hillary-clinton-full-transcript-economic-speech-489602?rm=eu
August 25th: http://www.politico.com/story/2016/08/transcript-hillary-clinton-alt-right-reno-227419
September 15th: http://www.whatthefolly.com/2016/09/15/transcript-hillary-clintons-speech-in-greensboro-north-carolina-part-1/
October 3rd: http://www.presidency.ucsb.edu/ws/index.php?pid=119154
October 11th: http://www.dispatch.com/content/stories/local/2016/10/11/hillary-clintons-speech-at-ohio-state.html
October 26th: http://www.presidency.ucsb.edu/ws/index.php?pid=119693

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Understanding Homophily and More-Becomes-More Through Adaptive Temporal-Causal Network Models

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Abstract. This study describes the use of adaptive temporal-causal networks to model and simulate the development of mutually interacting opinion states and connections between individuals in social networks. The focus is on adaptive networks combining the homophily principle with the more becomes more principle. The model has been used to analyse a data set concerning opinions about the use of alcohol and tobacco, and friendship relations. The achieved results provide insights in the potential of the approach.

Keywords: Homophily · More becomes more · Temporal-causal networks · Alcohol · Tobacco

1 Introduction

Social networks model how individuals in a group relate to each other. The analysis of social networks has been studied in various domains, such as marketing, social life, mathematics, computer science and physics [1]. Wasserman and Galaskiewicz explain that in social network analysis the focus lies on social entities or actors (also called agents) in interaction with one another and how these interactions constitute a framework or structure that can be studied and analyzed in its own right [2]. A network can be represented conceptually as a graph in which the social actors are shown as *nodes* and their social links represented as *edges* [3]. The links between these actors are any connections of interest. When mapping these nodes and their connections one can get an overview of the social relations in such a network and how the nodes may influence one another. Adaptive networks can also change their shape over time: persons and their interests change and this in turn can influence the connections they share.

Peer groups are a primary context in which adolescents develop their identities [4]. This includes positive influences and changes, like academic achievements, but also negative influences, such as substance abuse. Studying such influences within a group can lead to insight on how these aspects develop over time. McGloin, Sullivan and Thomas investigated in [4] adolescent substance abuse and the effects of immediate friendships and broader schoolmate influences. They argue that the degree to which friendship groups and other social reference groups in an adolescent's life have similarities or dissimilarities

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should be considered, as it can have a meaningful impact on the social behavior. If the values of schoolmates are different from those of the proximate friendship group, effects on each other would decrease; if schoolmates are similar to one's friends, the values would be reinforced. Findings of the study indeed showed that the influence of the friendship groups on adolescents decreased if the friendship group substance use and the adolescent's substance use are more dissimilar. Similar findings were found in [5–8].

Within social networks the phenomenon that contact between similar persons occurs at a higher rate than among dissimilar persons is called *homophily* [9]. It has a circular character. Persons that share the same behaviors like each other more, and persons that like each other more, influence each other's behavior more by contagion. This has implications on the information people in a network receive, attitudes and beliefs they form and their mutual connections. Another principle by which mutual connections change, which also occurs at the same time, describes that very popular people seem worth connecting to more; this is sometimes called the *more becomes more* principle [10]. It is assumed that someone with many and stronger connections will over time receive even more and stronger connections. Both principles together describe a social network with connections that change over time: such a network is called adaptive.

In this paper, an adaptive temporal-causal network model is presented incorporating the homophily and more-becomes-more principle. The model was used to analyse a data set for longitudinal data on opinions on alcohol and tobacco consumption and friendships for high school students on a school in Glasgow [11]. One of the goals of this study is to test whether opinions on alcohol or tobacco are the most useful indicators of future development of friendships (modeled by adaptive connection weights) as well as opinions (modeled by dynamic state values) in early high-school students. The Glasgow data set provides data on both these aspects for approximately 13 Year-old students in the city of Glasgow. The students were questioned three years in a row, starting February 1995 and ending in January 1997. For creating the friendship network, they were asked to name up to six friends.

In the next section, the two principles that were addressed, homophily and more-becomes-more, respectively, are explained. In the subsequent section an example social network is defined. Using this example network, the effect of the combined principles on both the states and the connections is explored in some detail by designing an adaptive temporal-causal network model. Furthermore, the interaction between the two principles is elaborated on. Finally, the adaptive temporal-causal model is deployed on the Glasgow dataset to verify its validity and, subsequently, its usability for real-world applications.

2 Two Social Network Adaptation Principles

The adaptive temporal-causal network presented in this paper incorporates two adaptive social network principles: homophily and more becomes more. The homophily principle states that the more similar two nodes are, the stronger the connections between the two nodes will become ('birds of a feather, flock together'). The more becomes more principle describes the phenomenon that nodes that have more and stronger connections than others, grow connections faster than nodes that are less connected. In this section the background of these principles is discussed and it is described how they are incorporated in the adaptive temporal-causal network model.

The connection weight from person A to person B is denoted by $\omega_{A,B}$, and the considered states for A and B are denoted by X_A and X_B. In Fig. 1 a conceptual representation of an adaptive temporal-causal network is presented for the *homophily* principle. An assumption made is that the connection weights $\omega_{A,B}$ are affected by the connected states X_A and X_B, as depicted by the arrows from X_A and X_B to $\omega_{A,B}$. To obtain a dynamic equation for the connection $\omega_{A,B}$ it is needed to determine how the activation levels affect this connection exactly.

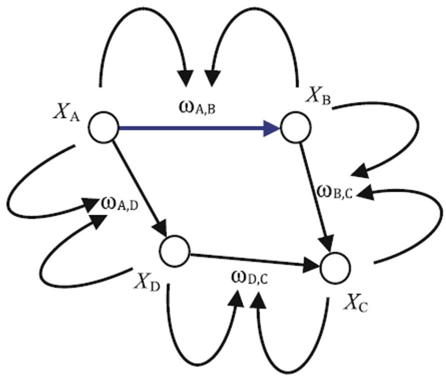

Fig. 1. Conceptual representation of the Homophily principle [10, Chap. 11].

Following the Network-Oriented Modeling approach described in [10], the homophily principle can be formalized numerically by a combination function $c_{A,B}(V_1, V_2, W)$:

$$\omega_{A,B}(t+\Delta t) = \omega_{A,B}(t) + \eta_{A,B}[c_{A,B}(X_A(t), X_B(t), \omega_{A,B}(t)) - \omega_{A,B}(t)]\Delta t$$
$$\mathbf{d}\omega_{A,}/\mathbf{d}t = \eta_{A,B}[c_{A,B}(X_A, X_B, \omega_{A,B}) - \omega_{A,B}]$$

Here the $X_A(t)$ and $X_B(t)$ represent the activation levels of the states X_A and X_B of person A and person B. The parameter $\eta_{A,B}$ is the update speed parameter of connection weight $\omega_{A,B}$. Assumptions are that the values of $\omega_{A,B}$ stay within the interval [0, 1], $c_{A,B}(V_1, V_2, W)$ is higher when $|V_1 - V_2|$ is smaller, $c_{A,B}(V_1, V_2, 0) \geq 0$ and $c_{A,B}(V_1, V_2, 1) \leq 1$. Here V_1 is the argument of the function $c_{A,B}(\ldots)$ used for X_A (t), V_2 for $X_B(t)$, and W for $\omega_{A,B}(t)$. A relatively simple continuous function $c_{A,B}(V_1, V_2, W)$ that satisfies these requirements is obtained when a threshold value $\tau_{A,B}$ is assumed such that for $|V_1 - V_2|$ above this threshold, the connection weight decreases and under the threshold it increases:

$$c_{A,B}(V_1, V_2, W) = W + W(1 - W)(\tau_{A,B} - (V_1 - V_2)^2)$$

Using this combination function, the dynamic relations for $\omega_{A,B}$ are:

$$\mathbf{d}\omega_{A,B}/\mathbf{d}t = \eta_{A,B}\omega_{A,B}(1 - \omega_{A,B})(\tau_{A,B} - (X_A - X_B)^2)$$
$$\omega_{A,B}(t + \Delta t) = \omega_{A,B}(t) + \eta_{A,B}\omega_{A,B}(t)(1 - \omega_{A,B}(t))(\tau_{A,B} - (X_A(t) - X_B(t))^2)\Delta t$$

As discussed above, the more becomes more principle describes the phenomenon that well-connected nodes tend to get new or increased connections faster than nodes with less or weaker connections [10]. For example, when many other C's follow B on Twitter, B seems to be interesting to follow for A as well. This can be modeled taking into account the connection weights $\omega_{Ci,B}$ for $i = 1, \ldots, k$ of all connections from others C_i to B as follows; see also the conceptual representation depicted in Fig. 2. Based on the Network-Oriented Modeling approach from [10], the generic numerical representation is as follows:

$$\mathbf{d}\omega_{A,B}/\mathbf{d}t = \eta_{A,B}[c_{A,B}(\omega_{C_1,B}, \ldots, \omega_{C_k,B}) - \omega_{A,B}]\Delta t$$
$$\omega_{A,B}(t + \Delta t) = \omega_{A,B}(t) + \eta_{A,B}[c_{A,B}(\omega_{C_1,B}(t), \ldots, \omega_{C_k,B}(t)) - \omega_{A,B}(t)]\Delta t$$

Here $c_{A,B}(\ldots)$ is a combination function, for which in the current paper the advanced logistic function is chosen (for more detailed explanation, see [10, Chap. 2]):

$$c(V_1, \ldots, V_k) = \mathbf{alogistic}(V_1, \ldots, V_k) = \left[\frac{1}{1 + \mathbf{e}^{-\sigma(V_1 + .. + V_k - \tau)}} - \frac{1}{1 + \mathbf{e}^{\sigma\tau}}\right](1 + \mathbf{e}^{-\sigma\tau})$$

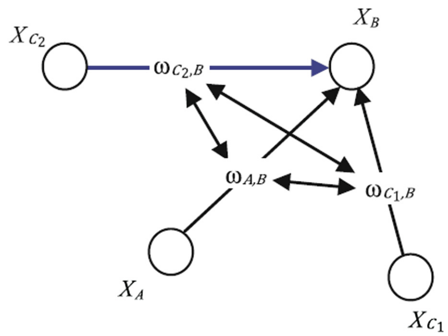

Fig. 2. Conceptual representation of the More Becomes More principle [10]

Both principles influence the connection weights between the nodes in the network over time. As in the real world they occur simultaneously, they have to be combined thus achieving an integrated model. Assume a parameter α between 0 and 1 that indicates the relative influence of the homophily principle, then $1 - \alpha$ indicates the relative influence of more becomes more. The overall combination function is the weighted sum of the above two combination functions with weights α and $1 - \alpha$, respectively:

$$\omega_{A,B}(t+\Delta t) = \omega_{A,B}(t) + [\alpha\eta_{A,B}^{\text{HOM}}\omega_{A,B}(t)(1-\omega_{A,B}(t))(\tau_{A,B}-(X_A(t)-X_B(t))^2) \\ + (1-\alpha)\eta_{A,B}^{\text{MBM}}(\textbf{alogistic}(\omega_{C_1,B}(t),\ldots,\omega_{C_k,B}(t)) - \omega_{A,B}(t))]\Delta t$$

In addition to this connection adaptation model, also a state contagion model was used based on a scaled sum function with the sum of the weights as scaling factor:

$$X_B(t+\Delta t) = X_B(t) + [(\omega_{C_1,B}X_{C_1}(t) + \cdots + \omega_{C_k,B}X_{C_k}(t))/(\omega_{C_1,B} + \cdots + \omega_{C_k,B}) \\ - X_B(t)]\Delta t$$

3 An Example Social Network

The example network model analysed here (shown in Fig. 3) contains two groups of individuals that are connected through two hubs with outgoing connections to the other group (called bridges). Each group consists of 6 nodes. Their drinking opinions are assumed to be represented by values in the range of [0, 1], in which 0 represents someone very much against drinking, and 1 for someone that is addicted to alcohol. Two simulation experiments were conducted to investigate the effect of both principles in a network with strong initial bridge connections (0.8 between nodes 3, 4, 8 and 12). It is expected that due to the strong bridge connections, the more similar the initial values (and thus the more similar their opinions), the faster the two groups converge to the same value, and the stronger the two groups become connected to each other. If the initial values on opinions differ a lot, their opinions are expected to converge much more slowly. Under influence of homophily, the groups will reinforce their opinions within their group, but the bridges will eventually bring the groups together slowly (unless these bridge connections break). The initial connection weights can be found in Table 1. The example social network consists of 12 nodes and 31 edges, as shown in Fig. 3. As can be seen in the figure, the nodes with most connections are 3 and 4. The average number of connections of all nodes is 5.167. The two nodes 3 and 4 also form the main bridge connection between the two groups. A network analysis also reveals two communities, namely nodes 1, 2, 3, 5, 7 and 8 on one side and nodes 4, 6, 9, 10, 11 and 12 on the other, as was expected (for the chosen parameter values, see Table 2).

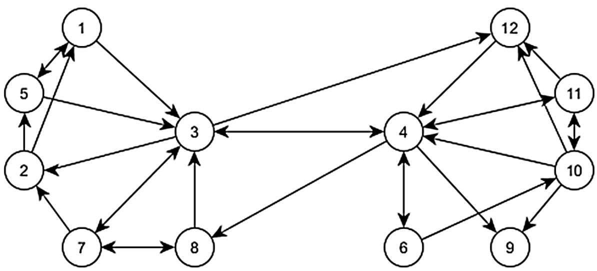

Fig. 3. Example social network

First, the parameter α was set at 0.5, meaning that the influence of the homophily and more becomes more principles are equal. The adaptation rates η are set at 0.4 for the weights and 0.3 for the states. The threshold value τ for homophily was set at 0.04. The value for the maximal time is 100 and the step size Δt is determined at 0.3. In Table 3 the initial values for the opinions for the two experiments are shown.

Table 1. Initial connection weights

	1	2	3	4	5	6	7	3	9	10	11	12
1	0	0	0.3	0	0.6	0	0	0	0	0	0	0
2	0.4	0	0	0	0.4	0	0	0	0	0	0	0
3	0	0.2	0	0.8	0	0	0.5	0	0	0	0	0.8
4	0	0	0.8	0	0	0.3	0	0.8	0.4	0	0.2	0
5	0.4	0	0.5	0	0	0	0	0	0	0	0	0
6	0	0	0	0.4	0	0	0	0	0	0.7	0	0
7	0	0.3	0.6	0	0	0	0	0.4	0	0	0	0
3	0	0	0.2	0	0	0	0.7	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0.3	0	0	0	0	0.7	0	0.5	0.6
11	0	0	0	0.5	0	0	0	0	0	0.6	0	0.7
12	0	0	0	0.4	0	0	0	0	0	0	0	0

Table 2. Network parameter values

Parameter	α	η weights	η states	τ homophily	Max. T	Δt
Value	0.5	0.4	0.3	0.04	150	0.3

Table 3. Initial node values

Node	1	2	3	4	5	6	7	8	9	10	11	12
Experiment I	0.2	0.1	0.2	0.9	0.3	0.7	0.3	0.3	0.8	0.9	0.7	0.8
Experiment II	0.4	0.3	0.5	0.6	0.3	0.7	0.4	0.3	0.7	0.8	0.6	0.7

In the *first example simulation* shown in Fig. 4 of the example social network from Fig. 3, the two groups differ more from each other in their opinions and use of alcohol: their opinions are dissimilar. The first group has higher initial values as they drink more often, these are the nodes 4, 6, 9, 10, 11 and 12. The values of this group range from 0.7 to 0.9. The second group, that is nodes 1, 2, 3, 5, 7 and 8, all have lower initial values as they do not drink that often. These range from 0.1 to 0.3. Within groups the nodes converge to a shared state value quickly due to their similarity. However, due to the bridge connections (of nodes 3, 4, 8 and 12) the groups themselves should still converge very slowly toward each other or break the two groups apart eventually. Figure 5 shows how the opinions of the groups change over time, with values for homophily and more becomes more functions both set at 0.5 so their influence in the model is the same. It can be seen that both groups converge almost equally. The two groups converge together before time point 20, after which they reach a shared value of 0.5 where they remain constant. In the group with lower initial values (0.1 to 0.3) we see that node 8 tends to curve towards the other group at the start. This is explained by the connection that node 4 from the other group has on this node. With equal values for both principles, the influence of homophily is visible in the convergence of the state values of individuals in the subpopulations, and more becomes more in the convergence of the groups towards each other.

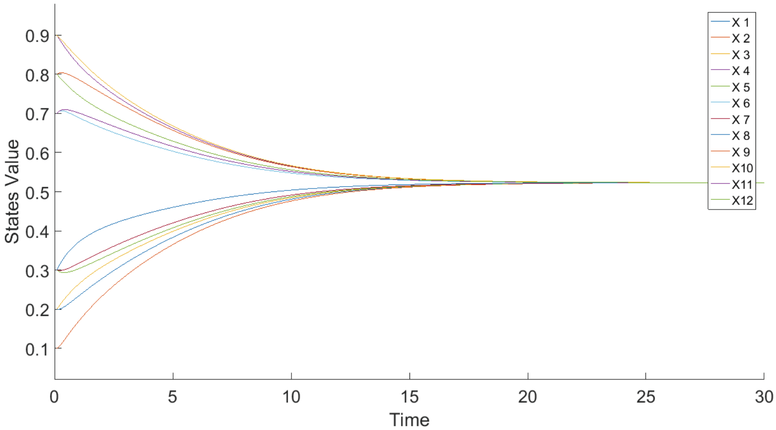

Fig. 4. Example simulation 1: the states (homophily 0.5, more becomes more 0.5)

In Fig. 5 the weights of all connections between the two groups are displayed. What is immediately visible is that all connections weights reach a value 1 after some time. Most connections start to increase from their initial value towards a value of 1. A few connections however first decrease to lower values (between 0.2 and 0.5) after which they curve upwards and eventually also reach 1.

The initial downward trend can be due to the influence of homophily, and the shifting upward trend due to the influence of the more becomes more principle. As nodes with many and strong connections get more and stronger connections over time, the main bridge connections (node 3 and node 4) contribute much to this pattern and it eventually leads to all connection weights reaching the same value.

Since no new connections are created in this example by design, the more becomes more only manifests itself in the strengthened connections. To make it more concrete: if everyone likes node 3 and 4, 10 will like them more as well, increasing the connection weights existing towards these nodes. There exists no connection to node 3 and no connections can be created in this example, but the more becomes more principle still influences the connection from node 10 to 4. Under the homophily principle, the states become more similar and the connections grow stronger even more. This self-enforcing force of more becomes more and homophily explain the fast connection strength growth after the initial poor start.

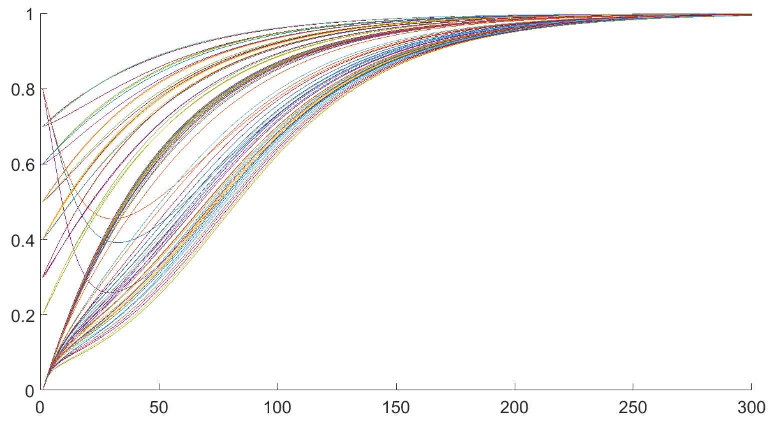

Fig. 5. Example simulation 1: the connection weights (homophily 0.5, more becomes more 0.5)

The contribution of homophily and more becomes more has also been investigated with different values for both principles. In Fig. 6 the homophily was given a value of 0.7 and a corresponding 0.3 value for more becomes more. As seen in the figure, the convergence of the groups among themselves is almost the same as in the previous example. The higher influence of the homophily is mainly seen in that the groups take slightly longer to converge towards each other. The curve at which they converge is also more straight than with equal influences of both the principles. They both join at the same value around 0.5 and remain constant there.

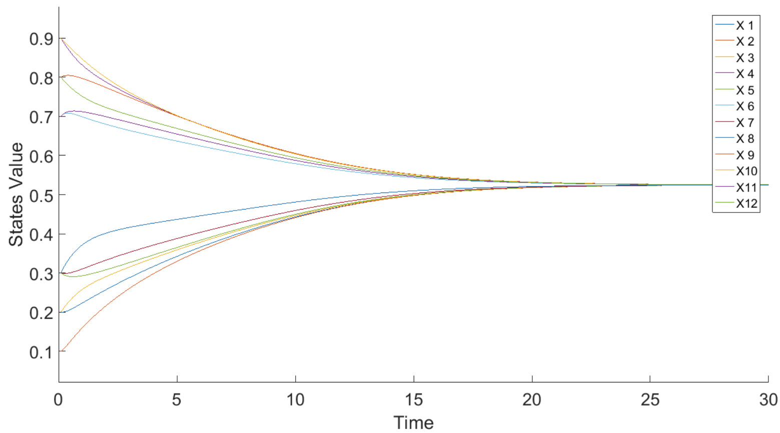

Fig. 6. Example simulation 1: the states (homophily 0.7, more becomes more 0.3)

In the Fig. 7, the homophily value has been set to 0.3 and the more becomes more value to 0.7. What is now visible is that, because the influence of homophily has decreased, the groups seem to converge towards each other sooner than with equal influences of the principles. Although the actual convergence of the two groups is only a little sooner than previously, it is notable that the curve at which they converge towards each other is more steep. This is due to the more becomes more having a higher influence, and thus making the groups converge slightly faster. The nodes with the most connections (node 3 and 4) gather the groups more quickly. Once they meet both groups follow the same constant value of 0.5.

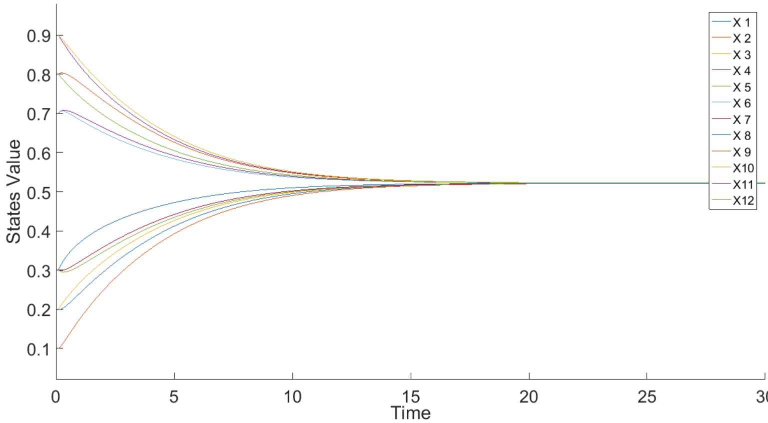

Fig. 7. Example simulation 1: the states (homophily 0.3, more becomes more 0.7)

In the *second simulation experiment* the initial values of the two groups are more similar to each other than in the previous simulation. The first group (node 1, 2, 3, 5, 7 and 8) now have initial values ranging from 0.3 to 0.5, while the initial values of group 2 range from 0.6 to 0.8. The values within the groups are still quite similar, but now the difference in values between the groups has become smaller. The groups now share more similar opinions on the use of alcohol and as a result of homophily and more becomes more, one would expect that the groups among themselves converge together quickly, but also that the two groups converge faster towards each other, as their opinions are more similar. In Fig. 8 the trend in opinions over time of the nodes can be seen with homophily and more becomes more values set a 0.5. The figure shows that the two groups do not converge as much among themselves in the beginning. Only a slight curve is seen in some nodes, that initially move towards their own group and away from the opposite group (the nodes with initial values of 0.4 and 0.5 of the first group, and the nodes with initial value of 0.6 in the other group). The nodes more or less gather all together than in two separate groups. The point where all nodes reach one value is only slightly sooner than compared to the simulation in which the groups were more dissimilar. The most notable difference now is that the nodes are more spread out at the beginning.

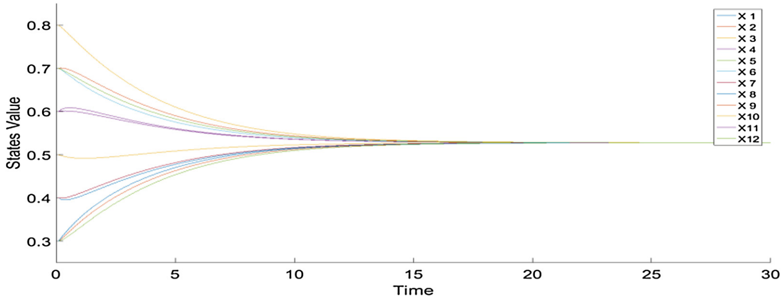

Fig. 8. Example simulation 2: the states (homophily 0.5, more becomes more 0.5)

4 Validation in a Real World Domain

In order to compare the temporal-causal network model with real world data, a longitudinal temporal real world data set was used on the tobacco and alcohol use among subjects aged approximately 13 at time point 0. The data spans three measurement points in a period of two years. For the model ten time steps a year were calculated to achieve a smooth simulation ($\Delta t = 1$, with 21 time points in total). The friendships were originally coded 0 (no friendship), 1 (best friends) or 2 (just friends). Since the simulation requires to allow new connections to be created to successfully simulate the more becomes more-principle, the new values were determined at 0.1 (no friendship), 0.5 (just friends) and 0.9 (best friends). The only connections with a value of 0, are the ones from states to themselves. The alcohol measures ranged from 1–5 (no drinking - more than once a week) and were mapped to a range from 0.1–0.9, in steps of 0.2 ([0.1, 0.3, 0.5, 0.7, 0.9]). Finally, the tobacco use measures were originally coded as [1–3] (no smoking, occasional, regular) and were mapped to [0.1, 0.5, 0.9]. In order to limit computational load, only the data on the first 50 of a total of 160 subjects was taken. Any subject for which the data on either tobacco or alcohol use, or on the relationships (due to the subject being removed from school for whatever reason) was missing, was completely removed from the network. As a result, a subset of 30 subjects remained.

The next step of comparison of the model to real world data is to optimize the model parameters, to see how much the best choice of simulated data deviates from the real-world data. The evaluation of the difference between simulation and real world data was measured by a Sum of Squared Residuals (SSR) error function, which is the sum of the squares of the differences between simulated values and empirical values. The fast Simulated Annealing algorithm in Matlab was applied to optimize the parameters, combining the SSR of states and connections in one error measure. Figures 9 and 10 show for the alcohol use data the SSR value plotted against the number of iterations. The temperature used is 100, re-initiating took place after every 100 iterations. The 50 initial iterations are shown in Fig. 10. Note that in the beginning, the SSR is very high due to the random initialization values that were taken. Also, due to the high temperature, a lot of variation occurs. Table 4 shows the found optimized parameter values and the corresponding performance measure separately for both the alcohol and the tobacco use data. Since it is assumed that no individual is immune to influences from others on both their behavior and their relations, nor do they follow others blindly and immediately, the ranges of the speed factor parameters η for both the states and the relationships were limited to [0.1, 0.9]. The ranges for the parameters α, τ for homophily and τ for more becomes more were set at [0, 1], while the steepness parameter σ for more becomes more was limited to the interval [0, 10]. The latter was desired, as with the alogistic function a relatively low steepness parameter is required to simulate processes in a smooth gradual manner over the period of two years. Note that the speed factors for the states were individually tuned, but were not included in Table 4 for the sake of clarity.

The average deviation of the model for each state and relationship when compared to the real-world data from the Glasgow dataset was calculated by dividing the combined SSR by the number of data points used and then taking its square root. There were 1860 known data points (900 relationships and 30 state values) for time points 10 and 20. The data points from time point 0 are not included in this calculation, as they were used as initial values. This means that by definition there is a SSR of 0 over the first data points. The resulting values for tobacco of 0.12475 must be interpreted such that the model has an average predictive error of 12.475%. The predictive error of the model using alcohol use data is thus 11.231%.

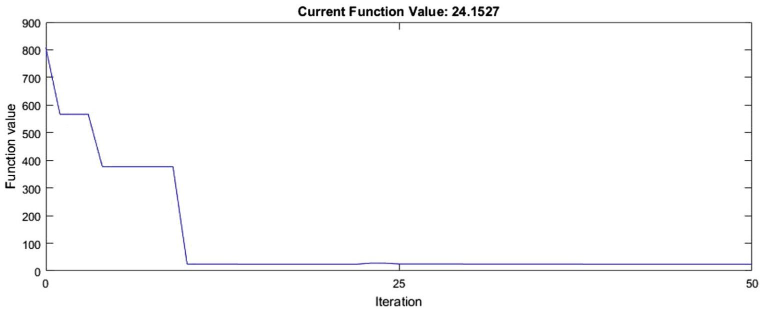

Fig. 9. The variation of the SSR value during the first 50 iterations of Simulated Annealing

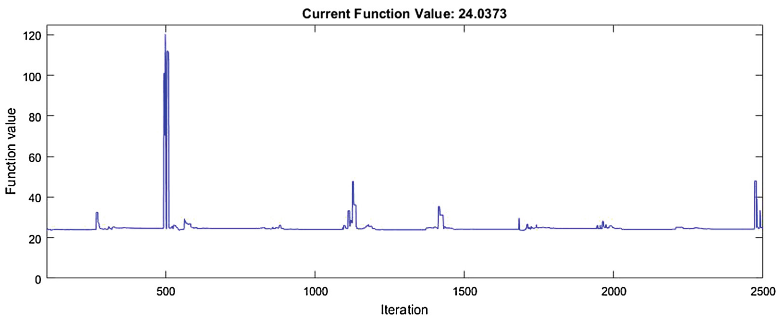

Fig. 10. Simulated annealing parameter tuning: development of the SSR value over 2500 iterations

Given few empirical data points available, the model may be considered to perform not too bad in simulating the development of real-world networks over time. The lack of information on more time points lowers the models predictive accuracy.

Table 4. Tuned parameter values

	η_ω	α	τ_{hom}	τ_{mbm}	σ_{mbm}	SSR	$\sqrt{(SSR/n)}$
Alcohol	0.80894	0.99851	0.01354	0.65446	8.74965	23.46141	0.11231
Tobacco	0.83675	0.99713	0.01396	0.54581	1.06990	28.94731	0.12475

5 Discussion

As shown in Table 4, the approach works better using the data on alcohol use than when using tobacco use data. This difference in accuracy may be explained by the fact that the alcohol states were measured on a 5-point scale, rather than on a 3-point scale like the tobacco data. As a result of this decreased data precision, less changes occur, but every change that occurs is more abrupt. For example, if a subject were to reduce his tobacco use in the real world from ‘0.65’ to ‘0.35’, this difference is not represented in the data points; they show a constant value of 0.5 due to rounding. Given the same scenario values for alcohol use, the data would show three data points with a clear, smooth trend: at data point the subject scores 0.7 on alcohol use, on time point 2 probably 0.5 and on the last data point 0.3. Although numbers are still being rounded, the mere knowledge that the substance use changes, helps better predict the substance use of all his friends as well. Therefore, the alcohol use data in this data set is more useful than the tobacco use data for simulating the development of social networks. The deviation of the simulated values from the real data points averages 11.2% on the alcohol use data and 12.5% on tobacco use data.

These findings could suggest that alcohol use is a more useful indicator for the development of social networks than alcohol use, although the effect of data precision should not be ignored. Another interesting finding are the optimal values for α, which are both higher than 0.99. This means that the more becomes more principle has less effect than 1% in this simulation. This might be the result of the data set, which allowed only a limited number of connections between subjects (6 per subject). This means that the data may limit the more becomes more principle in that it cannot generate as many new connections as one would hope. Finally, although this model appears to perform well on simulating longitudinal changes in substance use, it performed poorly on predicting the development of future relationships. This is caused by the dominance of relationships that did not exist at time point 0 that in the simulation never develop later on. Since there are approximately 750 static non-existent relationships (for which the value remains 0.1 throughout the experiment), the remaining about 150 relationships sharing the same η of the connections cannot be properly tuned. Ignoring the development of these future relationships, as proposed in an earlier study [12], therefore yields better results on the usability of temporal-causal network models for predicting - and potentially steering - behavior of people in social groups.

Further research can be done comparing the two given data on both alcohol and tobacco use on the same measure precision scale. Future research in this field would benefit if one of the biggest issues in the field is tackled: a lack of longitudinal data sets containing fine-grained data points on human behavior. The Glasgow subject-data set used in this study is valuable, but may as well be considered too outdated to develop present-day policies aimed at reduction of smoking among subjects, as it has been created years ago. Although it is useful for measuring the usability of approaches as done in this study, the results have to be replicated using more recent, and if possible, more fine-grained data before the findings of this study are turned into actions.

The adaptive temporal-causal network model presented here has an origin in [10, Chap. 11], just like the work reported in [11]. However, in the current work a different interpretation of the more becomes more principle was used, according to which the available connection weights are added to each other, after which a logistic function is applied. In [11] not a sum but the average was used of the available connections. That interpretation means that the connection is adapted to the average weight over the other connections. For example, more connections may have a decreasing effect when their weight is below the average of the weights of the other connections. In the approach in the current paper every extra connection has an additional positive effect. Another difference is that in the current paper, for the homophily principle a quadratic function in the difference between two states is used, whereas in [11] a linear function was used. Yet another difference is that in the current paper the data both for alcohol and for smoking have been considered, whereas in [11] only the data for alcohol were considered. For further refinements of the model, also more specific models for the contagion effects can be included, for example using inspiration from [13].

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Towards a Framework for Agent-Based Simulation of User Behaviour in E-Commerce Context

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Abstract. In order to increase sales and profits, it is common that e-commerce website owners resort to several marketing and advertising techniques, attempting to influence user actions. Summarizing and analysing user behaviour is a complex task since it is hard to extrapolate patterns that never occurred before and the causality aspects of the system are not usually taken into consideration. There has been studies about characterizing user behaviour and interactions in e-commerce websites that could be used to improve this process. This paper presents an agent-based framework for simulating models of user behaviour created through data mining processes within an e-commerce context. The purpose of framework is to study the reaction of user to stimuli that influence their actions while navigating the website. Furthermore a scalability analysis is performed on a case-study.

Keywords: Agent-based simulation · Behaviour mining · E-Commerce

1 Introduction

Customers interact with e-commerce websites in multiple ways and the companies operating them rely on optimizing key performance indicators (KPIs). In order to increase profits, retailers resort to target-marketing techniques, changing the web content and how it is displayed to the users [8]. Modelling user behaviour on the web is not new in e-commerce; it has been applied, *e.g.*, for the improvement of search engines, for influencing purchase patterns, and for recommending related pages or products [6]. The typical approach consists in predicting which page has an higher probability of being the next one in the user path. This requires extensive use of historical datasets which might not expose all the causality aspects of the system.

In this work we present an agent-based framework that simulates users behaviours in an e-commerce context and assesses their interaction with artefacts that

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influence their navigation experience. The frameworks purpose is to be used as a "plug-and-play" test-bed where the modeller simply integrate a pre-built customer model that implements a set of actions. Particular emphasis is given on the scalability of the framework.

The remaining of the paper is organized as follows: Sect. 2 describes the implementation of the proposed simulation model and Sect. 3 discusses some validation aspects of the simulation. Some related work is presented in Sect. 4, and we finally draw our conclusions in Sect. 5.

2 Architecture and Implementation

In the following paragraphs we discuss in detail the requirements and the implementation aspects of the framework.

2.1 Requirements

Having considered several e-commerce web platforms, we have analysed the features and characteristics common to all of them in order to better assess what the framework should be able to represent and model.

Website Representation: A website consists of a collection of web pages and hyper-links between them. The common entry point is named homepage and pages have tag that describes it purpose. Product pages have, at least, the product name, its description and price [3,4].

A virtual shopping cart is used as a staging area for the products that are going to be bought and the checkout is the act of taking all the products in the shopping cart and effectively buying and paying them.

Navigation Agents: Navigation agents are representations of customers interacting with a website. Some common interactions are: browsing, exiting the website, adding a product to the shopping cart, checking out, rating a product, writing a review or comment, bidding on a product, filling out forms and comparing two products side by side.

Website Agents: Website agents can modify any page before it is *served* to a user/customer. Example use cases are the recommendation of products to the user based on its preferences or observed browsing behaviour, targeted promotions and A/B testing analysis.

Simulation Engine: Given a website, the type of navigation and website agents and pretended simulation time, the simulation can be started, stopped and store its state and calculated metrics in a database. A simulation run can have thousands of navigation agents entering the simulation at each step, and each run can have one or more website agents.

Reporting: Once a simulation run ends, it can be analysed by taking a look at its results, metrics and other previously stored characteristics. At this end, at least two simulation runs can be put side and by side so they can be quickly compared. The comparison can be use it to infer the fitness of the website agent in providing engaging recommendations to the defined navigation agent.

The defined metrics should be relevant to the business context. Some examples are [11]: bounce rate, conversion rate, total/average order value, average order value, items per order, new visitor conversion rate, shopping cart sessions, shopping cart conversion rate, shopping cart abandonment rate, average session length, number of browsing sessions, page views per session and product views per session.

Limitations: In order to keep simplicity without disregarding the validity of the results of the framework, some limitations were assumed. Namely, adding a product to the cart and the checkout are a single step, there is no customer accounts and related interactions (e.g. *login*), visual information about the pages and products is not represented, it's not possible to remove an item from the cart, interactions with the website are limited and not extensible and the metrics gathered during the simulation are limited.

2.2 Architecture

The simulation framework encompasses two different kinds of agents, navigation agents and website agents, as shown in Fig. 1.

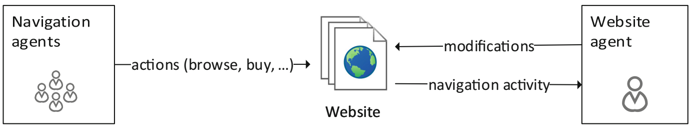

Fig. 1. Agent interaction with the environment

Navigation agents represent users interacting with the website. They have a limited view of the system, namely, access to the website pages and hyperlinks and know the current page they are visiting. Each simulation step, the framework asks each navigation agent which action will they pick next. The action may be to visit another page (`BrowseToAction`), exit the website (`ExitAction`), add aproduct to the cart (`AddToCartAction`), finish the purchase (`CheckoutAction`) or simply do nothing (`IdleAction`). Also related to the navigation agents subsystem, an implementation of `NavigationAgentFactory` is used to decide how many navigation agents are added to the system in each step, number that can be fixed *a priori* or, for example, follow a Poisson distribution model [5].

Website agents are able to modify the pages before they are presented to users. In [4] is presented an approach for behaviour mining of customers in e-commerce context. Here, profiles of regular base users are created using static and dynamic data. Every new user can be classified into one of the pre-built clusters. Considering this mining approach, it is possible to create archetypical user models that the website agent can be based on. Website agents have broader view of the system than navigation agents and are notified of all the actions that navigation agents do. The most common use case of the website agents is to recommend products to the users: before the page is served to a user, a website agent can modify a section of the page to display a custom list of products, based on user profiles.

The framework does not assume how these agents behave however the interactions between them are limited. The agents do not send messages between each other and may only interact indirectly, through the framework. While a simulation run might have hundreds or thousands of navigation agents, to simplify, each run has only one website agent instance.

Simulation Engine: The simulation engine follows a fairly standard and simple discrete event simulation architecture. The domain model we are dealing with allows certain simplifications of the simulation:

- The event list only contains events scheduled for the next step;
- There are no conditional events
- All the events happen instantaneously;
- The events do not depend on other events, they do not require synchronization and may be implemented in a single-threaded engine.

In our approach, in each simulation loop, the engine starts by calling NEWNAVIGATIONAGENTS() which adds new navigation agents to the simulation. The number and type of these agents are decided by the `NavigationAgentFactory`. Afterwards, each navigation agent currently active picks the next action. Depending on the action that was picked, the engine updates its internal state. The simulation state is represented by `WebsiteState` and contains statistics and other performance metrics. Whenever the picked action implies presenting the navigation agent a page from the website, the website agent can modify that page before it is presented, by calling MODIFYPAGE(NAVAGENT, PAGE). The website agent is also notified about all actions that the navigation agents do (NOTIFY(NAVAGENT, ACTION)). The simulation is configured to end after a fixed number of steps, otherwise it could run forever. This process is illustrated in Fig. 2.

Scalability: To assess the scalability and performance of the simulation engine, some benchmarks were made and they are described next. The tests were ran in a Windows 10 laptop with a Intel® Core™ i7-4710HQ CPU @ 2.50 GHz (8 CPUs) processor and the Benchmark.scala[1] library. The focus is not necessarily in the raw speed of the engine but rather in the variation of the simulation time when the number of agents in the system or the number of steps of the simulation are increased. The test performed consists of running the same simulation with an increasing number of navigation agents and number of simulation steps, set up in the following way:

- **Website:** Sample website with 9 pages and 32 total links between pages (1 homepage, 1 cart page, 3 product list pages and 4 product pages);
- **Website agent:** Sample agent, does not modify any page;

[1] https://github.com/balagez/Benchmark.scala.

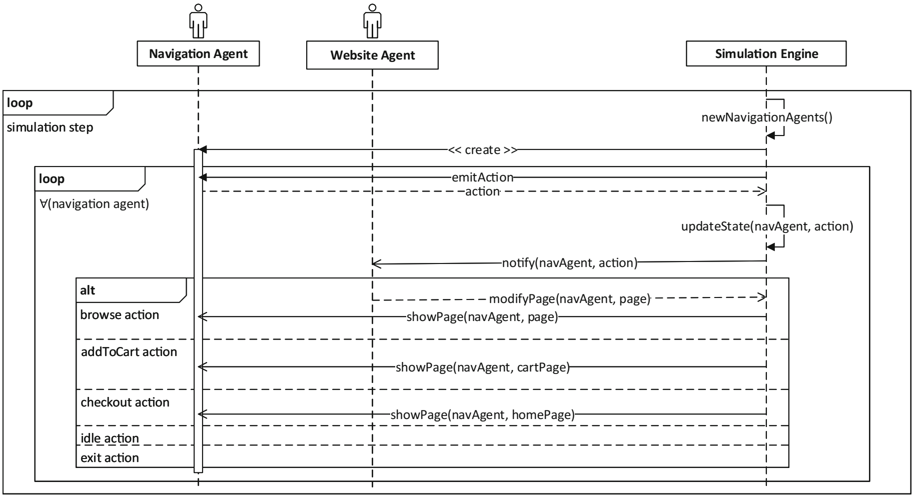

Fig. 2. Sequence diagram for the simulation engine

- **Navigation agent:** Sample agent implementation which picks the next action randomly. Configured with a chance of exiting the website of $\frac{1}{3}$ and a change of adding a product to the cart of $\frac{1}{20}$;
- **Number of navigation agents:** From 1000 to 10000 (increments of 1000);
- **Number of simulation steps:** From 100 to 1000 with increments of 100.

The result of the 10 simulation runs is shown in Fig. 3. A quick analysis shows that the simulation time scales linearly ($\bar{R^2} = 0.99149, \sigma = 0.00648$) with both the number of agents and the number of simulation steps. For instance, a simulation with 1000 steps and 10000 navigation agents (entering the system

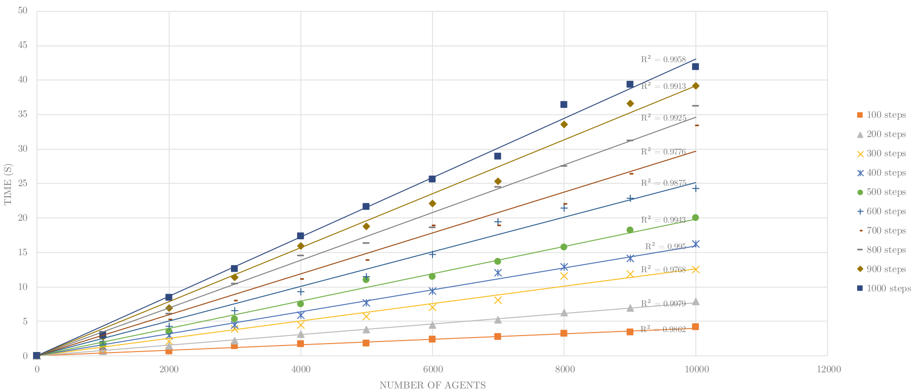

Fig. 3. Simulation running time for different number of navigation agents and simulation steps.

each step) took 41.95 s. These initial results are very satisfactory, however, they should be improved, especially when the number of steps is increased, so that simulations that span a longer period of time can be evaluated.

3 Tests and Validation

To validate the framework two experiments were conducted. The first was a collection of small fabricated test cases, sanity checks, where we compare the output of multiple simulation runs to the expected results to prove the correctness of the simulation engine. The second case deals with a real use of the framework, applied to an on-line store.

This second test case uses data from a real on-line store that sells electronics and computers products. This website presents a fairly standard on-line store, mostly consisting of product listing and product pages. There are three places where it is possible to recommend products: the homepage has two sections, one with product highlights and another with product promotions and each product page has a tab to show related products.

Input data and configuration: The website consists of 2540 pages with 343201 links between pages, spanning 25 base product categories and 103 subcategories. There are 750 product list pages, 1748 product pages, 1 cart page and 41 uncategorised/generic pages.

To simulate users and customers (the `NavigationAgents`) interacting with this particular website, a model based on affinities was built. This model is composed by the *affinities* themselves (a mapping between product categories and the likelihood of the user liking or having interest on products of that category), the probability of buying a product, the probability of exiting the website and the arrival rate.

Table 1. Affinities for a sample user.

Category	PCs	MSI	Pens	Laptops	Intel 2011	Mem. Cards	Brand	Processors
Weight	14.29%	14.29%	7.14%	14.29%	14.29%	7.14%	14.29%	14.29%

Because real usage website data is not available for this website, a sample profile was created with the following properties: the affinities were set up as displayed in Table 1, probability of buying set to 5%, probability of leaving the website of 15% and a rate of arrival to the website following a *Poisson* distribution with $\lambda = 500$.

Simulation: The simulation was configured as described in the subsection above. For validation purposes, in this case, all the navigation agents use the same profile. However, the framework is extensible in order to enable the use of different user profiles for different agents. The "thought" process for each agent is fairly simple: at each step, they try to buy a product and exit the website in

Table 2. Visits per category for a sample simulation run.

Category	Sub-category	Count
Memory cards	Pen Drives	6492
	SD Cards	1203
	Card Readers	1199
	Compact Flash	1158
	-	37
Laptops	MSI	14326
	HP	2623
	Asus	2584
	-	263
Processors	Intel 2011	7097
	Intel 1151	2752
	Intel 1150	2379
	AMD	2234
	-	240
Computers	Brand	19802
	-	188
Motherboards	Intel 2011	4917

Table 3. Metrics/info regarding a sample simulation run.

Field	Value
Unique users	14894
Bounce rate	14.58%
Conversion rate	4.77%
Purchases	676
NavAgentFactory	AffinityFactory
NavAgent	AffinityUser
WebsiteAgent	DummyWebsiteAgent
Start time	00:00:36
End time	00:00:39

accordance to the probabilities defined *a priori* or navigate to a different page based on their categories, with preference as stated by the affinity table. The simulation was run for 30 steps.

Results: The results of a sample simulation run are summarized in the Tables 2 and 3. They are expected: the number of unique users is 14894 and the expected value is 15000 (500×25); the bounce rate is 14.58% and the prior leaving rate is 15%; and the conversion rate is 4.77% and the prior buy rate is 5%.

4 Related Work

Peer-Olaf et al. [10] describes agent-based simulations as a "well suited to modelling systems with heterogeneous, autonomous and pro-active actors, such as human-centred systems".

The Multi-agent systems metaphor has been applied to e-commerce context mostly in two distinct areas, namely, recommendation systems and negotiation. Few relevant works exist in the literature regarding simulation of user behaviour in e-commerce context and even fewer using the agent-based paradigm.

In Petrushin [9] a customer model is created using transaction and click stream data to generate shopping lists. Following the model is simulated under varying set-up conditions with the goal to develop business strategies to capture customer's interest in purchasing product outside of shopping list. Jagannathan et al. [7] have developed an analytical framework for pricing of on demand content in a monopolistic market. The framework models customer behaviour as well as resource constraints. Based on this framework they have coupled an algorithm that suggests prices to the content-provider. Yin et al. [12] work analyses the transaction process between business and customer with its social network, and applies signalling game theory to perceive the signals that affect the utilities of business and customer. An agent-based simulation model of business-customer game is developed for computing the utilities after repeated transactions. In [2] authors, consider user behaviour simulation in using digital services and investigated the impact of online news' attributes on a discrete choice model. Ahn [1] considers agent-based modelling and evolution strategy for evaluating customer aid functions at Internet stores. The method can be used to evaluate customer aid functions under various assumptions at much lower cost compared with previous attempts based on expensive tests or empirical experiments involving human participants with fully or partly-working systems.

As we mentioned previously, few works involving agents are described in e-commerce literature. Respect to existing works we have proposed a "plug-and-play" test-bed to assess user interactions with artefacts that can influence their navigation experience.

5 Conclusions

In this paper, we discuss the implementation of a framework capable of running agent-based simulations of users that interact with an e-commerce website. This approach exploits the agent metaphor, by representing users as navigation agents. On the other hand the e-commerce context is represented by a set of artefacts and a web-page agent that adapts the context and content according to navigation agent's configuration. The framework can be considered to assess recommendation engines performance and optimization algorithms in e-commerce platforms.

There are certain limitations and assumptions in developing the model that should be further considered, such as introducing parallelism in the simulation engine for scaling-up the set-up complexity (e.g. large-scale simulation) and improving the data analytic process by considering more complex metrics on the navigation agents as well as in the website agents. Furthermore, we can consider a more extensive definition of the agents action-state space.

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Low Cost Architecture of Autonomous Subsystems for Internet of Things

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Abstract. The aim of this article is to present home automation system which can be easily integrated into existing buildings without expensive cable installation. A novel solution of a Smart Home control system is proposed and described. The system is based on a number of mutually interconnected nodes, where each node is fully autonomous and can react to user requests directly. Any sensor value or change state of any connected actuator with regards to its position in the system can be measured. Users can interact with the system using web interface situated in one of the nodes. This node then interprets the commands to other devices in the system. The master node owns a list of interconnected devices including their unique identifiers and network addresses. Commands are sent between nodes using IP protocols and using TCP sockets so all responses almost runs in real time.

The node's autonomy is very useful, if there is no Internet connection available. Thanks to their autonomy, nodes can also independently perform specified activities like long term data collection, and react to the current state of monitored environment using internal rules and schedules.

Keywords: Smart home systems · Internet of things · Monitoring · Distributed system · Distributed database · Raspberry Pi 2

1 Introduction

In a Smart home environments there are currently many different electronic or remote controlled devices used in today's houses. They can be categorized into various classes, from shading technology, lighting, heating regulation up to management alarm, photo-voltaic panels, audio or access systems, and objects monitoring. Every device is usually controlled by a spacial control element, like wall switch, specific remote controller, motion sensors, timer or touch screen. In most of currently used architecture no devices can interact with others and has no information about another devices or what user exactly wants. This is not smart and definitely not comfortable too. Smart home systems are currently

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very popular [2,4,6–9,11]. In despite these facts, automation Among main arguments for getting intelligent buildings the most significant is cost savings on its subsequent operation. Further, it may be adapted to user needs, maximal user comfort, or safety of all residents.

The heart of the most of intelligent houses is a central system, which helps with house's operation automation thanks to necessary infrastructure and individual active components. Central control system consists of a highly specialized piece of hardware (often referred as server or central element) with its own firmware and a set of pre-programmed bundle of rules. These rules can certainly be tailored by user to meet her own needs. This server is most often installed directly into electrical power distribution cabinet, close to main house circuit breaker, or to an separate cabinet. In this space have to be also connected all wires from various sensors and actuators, which are deployed in the house. Because of that, a unique sensor or actuator is capable of managing a variety of other systems (e.g. lights, alarm, audio, air conditioning, and many other elements). The server is usually connected to the Internet that opens possibilities for management of smart house systems via Internet, using desktop or mobile applications enabling that appliances can be managed remotely, as well as lights manipulations or temperature regulations.

Nevertheless, these solutions mentioned above include a whole range of various restrictions. The first and the biggest one is the amount of installed cabling. In an average house, the total amount of installed cables can be more than 1000 m [12]. Usually they are became an integral part of the house construction and cabling structure has to be mentioned during projecting phase of the building. When additional integration of smart systems to existing buildings is considered, nowadays technologies are not fully suitable, because their integration requires additional costs for necessary reconstruction of the building for cable installation. Therefore, integration of a complete smart system is better and cheaper in the case of a totally new buildings.

A lot of manufactures counts with integration of smart entities to current buildings and offer also wireless variants that usually based on a MESH network or Bluetooth principles. MESH is a topology, where some nodes are interconnected with more then one different node in network [5,11]. This solution allows communication also in the case of loss of one or a several nodes. These devices have to be able not only sending or receiving their own data, but they must be able to forward them to other nodes.

Usage of wireless technology is also complicated and expensive. Although no wires installation is necessary, but each node has to include also a module for wireless communication, which increases the node size, electricity consumption, and price. Also user is dependent on special devices that are supported by manufacturer, which means impossibility of connecting devices from different manufacturers or a new system interconnection with current system (e.g., building security system).

Our aim is to develop a robust low cost solution based on a single board computer Raspberry PI 2 which can be easily installed to any building and allows to manage all components using single application. System also has to be an network failure proof to keep this system alive and able to operate with local sensors even no internet connection is available.

This paper is organized as follows: Sect. 1 explained main problems of a Smart home systems and provides a new solution. Section 2 provides a brief review of currently used solution in the literature and describe their weakness. Sections 3 and 4 provides a solution of proposed system with a detail implementation of proposed solution. Section 5 deals with all testing methods to ensure all parameters of implemented system with brief description of testing methodology and results. Section 6, concludes this paper.

2 Related Works

However many companies are offering complete solutions, and there are also a lot of various smart home device management or data collection systems for temperature, humidity or others measurement in related literature. There are still many restrictions which are described this section. One of them, described in [12], is a centralized control system built on one Raspberry Pi device. There are individual peripherals connected to this single device, but in this case, large cable installation is necessary, and long distances between control system and sensors seem to be restrictive. For this reason, it is not possible to use digital sensors and analog sensors have to be used instead. However, for Raspberry Pi device digital sensors are preferable and easier to use, because, e.g., analog sensors are based on changes in electrical resistance, which is caused by changes of temperature. When distance between device and supply conductor increases, voltage decreases on output due to the internal resistance of the wire and these losses must be taken into account and the measured value has to be compensated.

Another one, but completely different solution can be found in [3]. This solution proposes for measuring of temperature and humidity, with outcomes stored for statistical purposes. Compared to the previously described solution, here a decentralized structure of control system is used. It means, that expect the central control node (Raspberry Pi), various other control nodes can be connected like Arduino UNO R3 which was used in this solution. The central control node can be extended by another nodes. Each node can autonomously process measured values and send them to the central node or system, where they are stored in a database so data can be efficiently sorted and searched using SQL queries. Communication between nodes is provided by special modules XBee Pro S2B, which are small devices working on Mesh network principles using ZigBee protocol. Here the distance between devices can be up to 1600 m. It means, that it is fully sufficient for home needs, but the main weaknesses is the price, which several times exceeds the cost of node unit. Moreover, this solution does not consider the possibility of requesting the actual temperature or output control in real time, as it was in the previous solution [12].

Another related article is [10], which describes advantages of Raspberry Pi platform as a small single-board computer that has a great popularity among students of computer science, electronics, but also in the fields of artificial intelligence and robotics. In the paper [10], this platform is presented as very universal and suitable for a big palette of applications. In the conclusions, benchmark tests of the proposed solutions are reviewed, with a focus on service availability. All the tests of the proposed device outcomes with surprisingly good results. The price for that is just a fragment of the price of usual web server or web-hosting. The further operation costs are incomparable lower too.

Our new solution combines all advantages of previously mentioned projects, but also reduces or completely eliminates the limitations of previous mentioned solutions and allow active notification of user or forecasting of specific situations based on long term data monitoring.

3 Solution Design

In this section is presented home automation system which can be easily integrated into existing buildings without expensive cable installation. System has to be able to sensing parameters in different parts of the house, and control household appliances including home lighting system. The system needs to be designed to allow automation of selected tasks without user's actions, and it should also be able to operate in reduced mode, if there is no connection available. The system also has to be able to capture values in different parts of the house and control the selected electrical appliances including house lighting. The system should be able to work at least partly during any loss of communication. Some values and data should be downloaded from the Internet from public internet services (e.g., weather forecast or another forecasts).

User have to be able to set some parts or parameters of system or manually switching on various electric circuits using computer, tablet or a mobile application.

One of the ideas that comes around, is decentralizing the control system into several smaller pieces - nodes, which can be strategically placed in different parts of the building. Desired sensors and also, if necessary, relay modules for switching electrical circuits up to 240 Volts, can be connected to these nodes. Mutual coordination between all nodes is ensured using Ethernet computer network. The combination of different connection methods is also possible thanks to standardization of Internet protocols. It is possible to use existing Ethernet cables or wireless home networks to connect nodes in buildings. Other buildings or vehicles can be connected using CDMA/GSM mobile technologies. It is only necessary to ensure access to this device using public IP address or VPN service. With this method it is also possible to monitor moving objects like vehicles, but also monitoring multiple branch offices from one place. Lightweight topology of distributed system can be seen on Fig. 1.

Every node is composed from one Raspberry Pi 2 model B. This device is so small to fit into a standard electrical installation box, while providing sufficient power to run a distributed database, a Web server, and API for providing the data to other applications. At the same time it allows to connect various

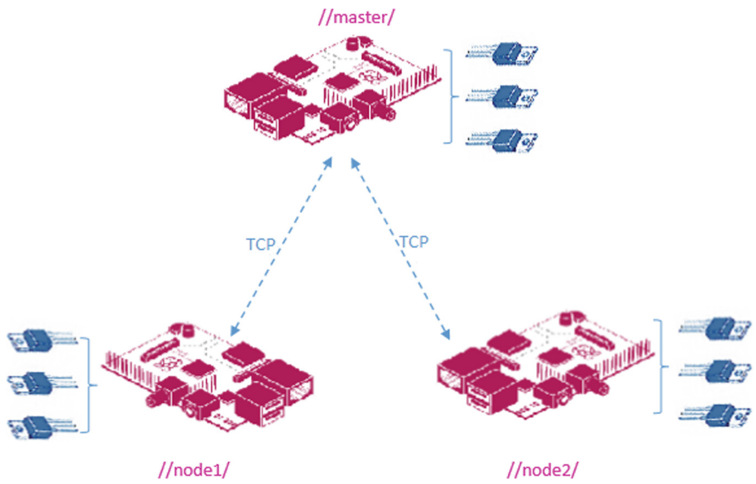

Fig. 1. System topology

kinds of special devices using GPIO bus. Raspberry Pi 2 Model B is a miniature single-board computer, which was developed by the British company Raspberry Pi Foundation. Raspberry PI2 model B is the fifth generation of this computer series. In this project, three units has been used. One of the units will be designated as the master node and all others as secondary nodes - slaves. Master node runs web server which is used to introduce all measured methods and effort overlays about all electrical circuits. For other applications and systems will be possible to connect and read data via opened REST API. Data visualization is provided by HTML5 in combination with JavaScript.

Each single node will periodically measure all physically connected sensors in defined time intervals. All these values are stored in a database and can be obtained from it, if necessary. These values would be lately distributed to other nodes to ensure that all sensors data from whole system can be obtained efficiently. Mainly digital sensors will be used for measurement, as they could be directly connected to GPIO without any additional boards.

In those rooms, where only temperature and humidity will be measured, the temperature sensor DS18b20 and temperature and humidity sensor DHT11 will be used.

A relay board with eight relays, allowing independent switching of up to eight lines with voltage up to 240 V and current up to 10 A, was chosen as an actuator. It can be used for controlling several household appliances in parallel, up to 2500 W of energy output.

The main board is connected to the nodes by GPIO bus and individual circuits are switched by switching the selected pins to logic LOW. This board can be powered by Raspberry power supply pin +5V.

As a data representation, which are obtained from third-party interfaces, weather and wind speed has been chosen. Both values are obtained from openweathermap.org [1] service in JSON format.

As already mentioned in Introduction, the device must be able to respond to user commands with minimal delay. For this purpose Java Sockets communication library has been chosen.

4 Implementation

Main strange of our system is in extremely easy implementation and robust fail safe architecture which is very strange to a network failures which allows each node to operate autonomously for a several time. All implementation details with used technology is described in this section.

The first step of the implementation is a database server installation. For our purposes MySQL server version 5.5.44 has been used.

After installation, it is still necessary to create a new user, database schema, and give the user appropriate privileges. After installing the databases on all the units, it is necessary to install replication tools Symmetric DS, which is offered free in a basic version and offers a many different ways how to replicate data between nodes, supports a wide range of SQL and NoSQL databases. Moreover, this engine enables HTTPS connection for data transfer. In the file `node_name.properties`, which is located in folder/engines, all the necessary parameters have been specified, like used database, credentials for database connection, and the way how data are replicated between nodes.

In this case, MultiMaster data replication was chosen. In the case of an arbitrary record creation, this record is replicated to all the connected nodes. This can be very useful when data are queried because all data can be get from local database. On the other hands it could be a safety risk, because sensitive data are replicated across all devices in the company.

After the first database start, in the database subsidiary records are created, called "SYM_TABLES". They can be identified by the suffix `SYM_` in the names of tables, and in these records it can be specified, which tables will be replicated. Like data visualization tool Spring MVC Framework has been used. It was used because of easy and sustainable code with respect to future scalability of the web application. The Apache Tomcat 8.0 has been used as a web server. Its advantage is ease configuration, good optimization for weaker hardware, and moreover, installation of the package is very simple.

As sensors DS18b20 and DHT11 were used, where the first one is connected directly to GPIO, while the second is connected to power pin +3.3V, digital data IO pin, and ground (GND).

After rebooting the device, sensor is represented as a file in /sys/bus/w1/devices/ like new directory, named by unique serial number which is assigned by the manufacturer. This number has a format "28-" in combination with unique hexadecimal numbers so number can safely be used for identification of a particular sensor within the application. The file w1_slave includes specific information about temperature and other meta information used for verification. It is also possible to collect data from all directly connected sensors in a single cycle using the regular expression "28*". File representation might look like this:

73 01 4b 46 7f ff 0d 10 41 : crc=41 YES
73 01 4b 46 7f ff 0d 10 41 t=23187

Word "YES" in the CRC indicates that all information was transferred without any violation of the information and measured temperature can be considered to be relevant. Item t=23187 then indicates the actual measured temperature in °C but it, it is necessary to divide this number by 1000 before it can be used. In this case, the measured temperature was 23.187 °C. Due to the accuracy of the sensor $\pm 0,125$ °C, it is still recommended to round obtained value appropriately.

For obtaining data from DHT11 second sensor, GPIO data pin is needed to switch to logical LOW state and after re-entry it back into the HIGH state, the sensor should, until 20–40 microseconds, initiate data transmission over the serial data line. The outcome of this call is an array of values with actual temperature and humidity.

Applications for each node are written in Java 1.8. In addition to periodical storage of values into the database, it has also the task of downloading information on weather and wind velocity. Data will be continuously updated every 10 min, and for this purpose the Quartz Scheduler library is used. This option enables restarting of periodically recurring processes in exactly specified times. After each update of the measured values automatically assess whether it is necessary to perform a certain action.

It must also be able to respond requests from users, which will take the form of messages sent via internal library Java.Net.Socket. The application for data mediation for users is a web-based application in Java with the Spring MVC framework. Complete system tooplogy is described by Fig. 2.

5 Testing

In this section will be introduced all testing methods. Main aim of the tests is to check system performance and data availability across all system nodes. In this section will be described three different methods for verifying specified parameters of the implemented solution.

5.1 Data Synchronization

First test is focused on time necessary for syncing all data through databases over all nodes. Including We measured time needed to data synchronization among all nodes in the network. The standard time between individual PUSH/PULL requirements is 60000 milliseconds. Every sixty seconds all new entries are checked and exchanged across all nodes. Push Job service could be also configured to send more parallel PUSH requirements at once, so each new entry

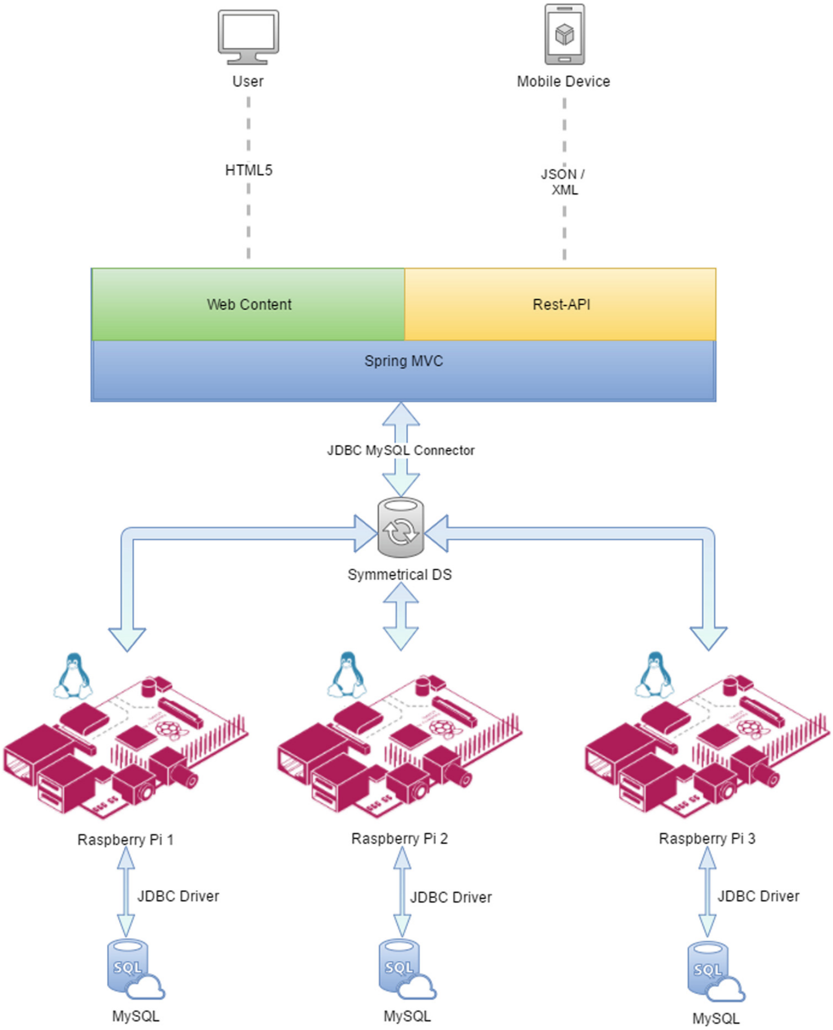

Fig. 2. Detail system overview

could be parallelly distributed among all other nodes. Time required for data distribution between any two nodes is therefore maximally 60 s.

Compared to the MESH network, where the frequency of communication between devices is in the order of minutes, this solution seems to be much more suitable for use in smart home systems.

The interval between PUSH/PULL requirements can be adapted to individual needs of the application, if it is necessary. Longer period between requests can reduce the network bandwidth usage, but with extended time we also extend time needed to synchronize all data. In extreme cases the period between

PUSH/PULL requirements could be higher than the frequency of recording values from the sensors. In this case it must be expected, that sensors, which are not directly connected to this node, are able to process only data from the last synchronization.

5.2 TCP Socket Communication

The TCP socket communication is designed for communication between applications almost in real time. Time between receiving a request and action performed is mainly affected by the network response.

To determine the system response time we will measure time elapsed between calling the action (pressed button) and the response message. To this aim simple java-script code was implemented and we compared system times when the action has been performed and response message has been received from the node. The resulting deviation of times will indicate required time to process the request. In this test, also type of used internet connection is considered. All used connection types and measured times in ms are shown in the following Table 1.

Table 1. Response time measurement

	LAN	WIFI	3G
	42	16	54
	20	17	62
	18	17	58
	24	20	56
	18	24	61
	19	16	59
Mean	23.5	18.34	58.34

All the values are the matter of few milliseconds. Our measurement confirmed, that all system reaction times are mainly affected by used connection type, in all cases an action was performed within few milliseconds without unnecessary system delays.

5.3 Data Visualization

In last test we measured time needed for loading specified number of records, their processing and a results visualization to the user. This part is focused on performance capability of Raspberry Pi 2. As a data providing server. In the test was checked, if web server, which will be installed in one of nodes, will be fast enough to provide data in a feasible time, or some other more powerful device will be needed as web server. Table 2 shows the average time in seconds it takes

Table 2. Loading time measurement in seconds

Testing method	Mean	Variance
Static web page without database readings	0.38	0.127
Web page with reading entries from database	2.38	0.004
Show graph with number of 144 day values	3.80	0.017
JSON output with sensor names and values	2.65	0.024

to load the specified data. The reported value is derived by averaging the sample of 50 measurements.

For any of the tested outputs the waiting time did not exceeded four seconds. This is a really acceptable value for home usage. So the Tomcat Web server was placed directly to one of the nodes of a distributed system. If it is necessary, it could also be possible to perform a web server on a separate workstation, or some kind existing corporate infrastructure could be used as well.

6 Conclusion

In this article has been introduced smart distributed architecture for IoT platform. This project can be used like base platform for sensing various variables in home autonomous systems or for wide area monitoring. It is not an aim to describe how to connect the most of various sensor types in this paper but main purpose of this project is to verify whether it is possible to meet all requirements and stable run continuously. The proposed system is able of monitoring a wide spectrum of magnitudes, depending on the sensors used. Unlike commercial systems the proposed one can connect almost any sensor or control any device. It also allows users to define their own logic for devices controlling. The system is designed in order to be used in home automation system as well as for water level monitoring in rivers, meteorology, transport, and many others corporate areas.

We managed to distribute data in such a way, that not all sensors need to be connected directly to one particular unit, if compared with concurrent solutions. At the same time, it allows almost instant response to user's requests. The API used for integrating this system with other applications has been also proposed.

For further development of the proposed system it would be appropriate to integrate an encrypted connection to the TCP communication or use another protocol, which is more suitable for Machine to Machine communication.

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Special Session on Advances on Demand Response and Renewable Energy Sources in Agent Based Smart Grids (ADRESS)

Long-Term Reliability Analysis of a Microgrid on Isolated Mode Using CPN Formalism

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Abstract. It is well-known that the high penetration of Distributed Energy Resources (DERs) can be troublesome because of their unpredictable behaviors. In this context, renewable energy source (RES) appears as one of the most random component, since, in general, they are weather-dependent. The present paper develops a methodology to evaluate the reliability impacts of RES penetration in microgrid's distribution system. For this evaluation, was used the Colored Petri Nets (CPN) formalism and event-driven analysis, in order to formulate the stochastic behaviors and simulate the system. To avoid the complexity on modeling a microgrid, the agent approach was used, which permits to manage each component as a unique entity, and assemble the whole system using the communication between the agents. Concerning the validation of the proposed methodology, a comparison between the results of CPN modeling and Monte Carlo simulation is done by means of statistical analysis.

Keywords: Agent approach · Coloured Petri Net · Microgrid · Monte Carlo simulation · Power system reliability

1 Introduction

Following the global trends of low emission generation, smart consumption and increase of demand, the government authorities and grid operators are changing the power system scenario investing in decentralized energy resources (DER), renewable energy sources (RES) and communication technologies. Although these technologies permit fast installation and relative low costs, the uncertainties present in these kind of decentralized and weather-dependent system, can be a huge challenge for grid operators.

This new power system concept has been handled in High-Voltage (HV) and Medium-Voltage (MV), as well in Low-Voltage (LV). Referring to LV, the approach of microgrids appears. As defined by the U.S. Department of Energy (DOE), the microgrid is "a group of interconnected loads and distributed energy

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resources with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid and can connect and disconnect from the grid to enable it to operate in both grid-connected or island modes" [1].

The microgrids are a constant theme in Smart Grid context. The main focus over this theme is systems reconfiguration, load forecast, power quality, economics, unpredictable behaviors, management strategies, microgrid elements interactiveness and reliability issues. For instance, the reliability issue of renewable source inserted on Smart Grid is presented in [2], in which a Monte Carlo simulation was used to check the long-term reliability indexes of generation power system with the insertion of wind turbines. Confirming the potential of Monte Carlo method, the paper [3] evaluate the short-term reliability of power systems with high penetration of wind generators. Still considering the reliability, a highlight is given to the uses of Petri Net modeling. About this subject, in [4,5] an hierarchical energy management control is developed aided by Petri Nets. In addition to the same idea, in [6] a new approach based on multi-agent scheme is proposed. A derivation of Petri Net called Fluid Stochastic Petri Net is introduced in [7], where the reliability issue is treated again. Many of this works deal with the microgrid interactiveness, distributed systems, control/management strategies and renewable sources penetration, which shows the potential of Petri Net modeling and Monte Carlo simulation.

Hence, the main goal of this paper is to present a methodology to deal with uncertainties and different management strategies present in microgrids, analysing their impacts on power system reliability. Furthermore, the methodology presented here joins probabilistic assess and agent approach, which permits a wide range of analysis. To develop this methodology, the Colored Petri Net (CPN) [8,9] formalism is used.

The motivation to use the CPN modeling in a microgrid environment is the ability that this formalism has to handle the concurrency, communication, synchronisation and stochastic of a system. Moreover, CPN combines simulation methods with graphical representation, which permits a number of analysis tools concerning system behavior and quantitative indexes. Compared to classical simulation methods, for instance Monte Carlo Simulation, the CPN models permit assessment of logical errors, deadlock constraints and interaction between the agents.

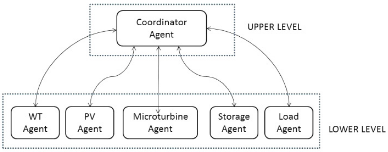
This paper is organized as follows: Sect. 2 presents the proposed methodology. The CPN models are shown in Sect. 3. Section 4 indicates the simulation results. Finally, Sect. 5 presents a brief discussion and conclusions.

2 Methodology

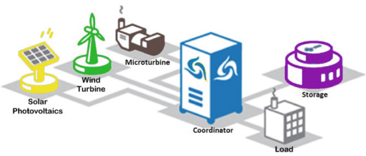
This paper proposes a strategy to assess the reliability of a distributed microgrid composed by RES. For this reason, a microgrid with centralized control is modeled by the CPN formalism using an agent-based architecture. Each agent is simply represented by a local controller, which is responsible to manage the agent, and communicate with the others. Following the centralized control, the system has two distinct agent levels, as shown in Fig. 1a: (1) upper level - coordination; (2) lower level - operation. The upper level has only the coordinator agent, and the lower level is composed by wind turbine (WT), photovoltaics (PV), microturbine, storage and load agents.

To validate the reliability analysis, some indexes are evaluated. According to [10], the indicators are the Loss of Load Expectation (LOLE) that express the expected hours per year during which a system capacity shortage occurs, Loss of Energy Expectation (LOEE) expressing the expected energy not supplied by the generating units per year, and Energy Index of Reliability (EIR) which designates the percentage of planned load energy that was effectively supplied by the generation system.

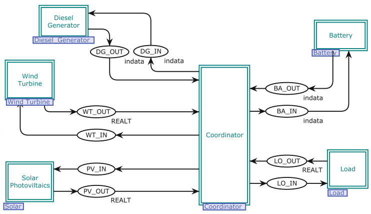
The methodology presented here was first used in [7], that uses the Fluid Stochastic Petri Net (FSPN) formalism to represent a microgrid. But, the authors of the present paper, express the authenticity and originality of the current work bringing new interpretation to the models, adding new elements to the microgrid, for instance storage and coordinator units, and making analysis of microgrid policies, which are new contributions. Besides that, the formalism adopted is different from any other previous work.



(a)



(b)



(c)

Fig. 1. (a) Agent-based microgrid structure; (b) Microgrid architecture on isolated mode; (c) Agent-based CPN model of microgrid on isolated mode

3 Microgrid CPN Models Using Agent Approach

The proposed microgrid is composed by six components and operates on isolated mode, as shown in Fig. 1b. Then, this system is transformed into a CPN model as represented in Fig. 1c. Once the microgrid operation is too complex, the Top-Down modeling strategy was used [11]. The Top model represents just the grid architecture and the main interaction between the agents. As shown in Fig. 1c only the six elements (rectangles), and the communication interface (ellipses) are designed. The details of each agent is depicted on the Down models, which reveals the logic and operation inside them.

Concerning the agents, two types are assumed. One is a non-reactive agent, which is an element that implements a simple function without any perception of the environment. The other is a reactive agent, which can perceive the environment and responds in a timely fashion to change the actual state of the environment.

3.1 Non-reactive Agents

The non-reactive agents do not perform any kind of strategy of control, since they do not react according to the microgrid state, but rather according to stochastic variables (weather and load demand). However, this simple kind of agent has the quality to communicate to other agents. Here, the wind turbine, PV and load are defined as non-reactive agent, just implementing functions of generation and curves of consumption.

Starting with the wind turbine, the power generation states is calculated by Eq. 1 as shown in [2]. It depends on wind speed V, which is calculated by Eq. 2 for each hour i. The wind speed follows the probabilistic Weibull distribution, so, it is necessary determine its two parameters, called shape factor (k_W) and scale factor (c_W), The term c_W is calculated by Eq. 3, where V_{annual} is the mean annual wind speed, and k_W is a constant [12]. Back to Eq. 1, the term P_R is the wind turbine rated power, and V_{in}, V_{out}, and V_R are the cut-in, cut-out and rated wind speed respectively. The terms a, b and c can be calculated using Eq. 4.

$$P_{WT}(V) = \begin{cases} 0, & V < V_{in} \quad (a) \\ a + b.V + c.V^2, & V_{in} \leq V \leq V_R \quad (b) \\ P_R, & V_R \leq V \leq V_{out} \quad (c) \\ 0, & V > V_{out} \quad (d) \end{cases} \tag{1}$$

$$V_i = c_W.(-ln(rnd(0,1)))^{1/k_W} \tag{2}$$

$$c_W = 1.128.\overline{V}_{annual} \tag{3}$$

$$\begin{array}{rl} a + b.V_{in} + c.V_{in}^2 = 0 & (a) \\ a + b.V_R + c.V_R^2 = P_R & (b) \\ a + b.V_c + c.V_c^2 = P_R.\frac{V_c^3}{V_R^3} & (c) \end{array} \tag{4}$$

The photovoltaic agent (PV) uses external real information of temperature, global radiation and incident radiation to calculate the generated power. The annual data were provided by Centro de Estudos e Previsão do Tempo e Clima de Minas Gerais - CEPreMG/UNIFEI. The calculation of how much energy a PV can generate is exposed by Eq. 5, presented in [13].

$$P_{PV} = n_{inv}.f_{PV}.P_{STC}.\frac{G_A}{G_{STC}}.(1 + (T_C - T_{STC}).C_T) \tag{5}$$

$$T_C = T_a + \frac{(NOCT - 20)}{0.8}.G \tag{6}$$

where n_{inv} is the inverter efficiency, f_{PV} is the photovoltaic panel efficiency,P_{STC} is PV rated power on Standard Test Conditions (STC), G_A is the incident radiation, G_{STC} is the incident radiation over test conditions, and T_{STC} is the test condition temperature. The PV cells temperature T_C is given by Eq. 6, which depends on temperature coefficient C_T, ambient temperature T_a, Normal Operational Condition Temperature (NOCT), and global radiation G [7].

The load agent just models the dynamic of consumption curve. To test the system, the dynamic established was IEEE_RST [14]. The load CPN model, have the simple function of import data from a text file, and then encapsulate this data in a CPN corresponding token.

The non-reactive agent CPN models are omitted once they just implements sequential states.

3.2 Reactive Agents

The reactive agents have all the properties necessary for a proper agent. So, it implements autonomy, reactivity and social/pro-activeness. This agents are called as reactive since they have the ability to perceive and change the environment based on certain knowledge. The storage, microturbine and coordinator agents are denominated as this kind, which have synchronous, concurrent and parallel behaviors increasing the system complexity. In this point, the CPN formalism shows as a powerful tool to perform a well-designed microgrid control dynamic.

The storage model is defined as Fig. 2a. It represents the level of energy in the storage system (place **Pbat1)** and its interaction with the coordinator agent (place **IN**). The storage policy is simple. It charges the energy when the microgrid power balance is positive and discharge when it is negative. In order to bring more realism to the model, the storage system has a charging limit, assumed as Maximum State of Charge (SOC$_{max}$).

For the microturbine model, it is divided in three parts. The first one has the function of assess the start-stop process, which means evaluate if it occurs some starting failure. The second verify how much energy the microgrid requires. In this point, it appears a microturbine constraint. This constraint refers to the maximum power that this generator can supply P_{MTmax}. The last one is the communication socket, essential for the interaction with the coordinator. Figure 2b shows part of this model, considering the logic of start-stop failure analysis, which is implemented by transition **Tmt1** and function **fail()**.

For the proposed microgrid, a centralized control was adopted. The coordinator assesses the microgrid global states and does the actions in favor of the power balance. Since the coordinator module is responsible for the power balance, all

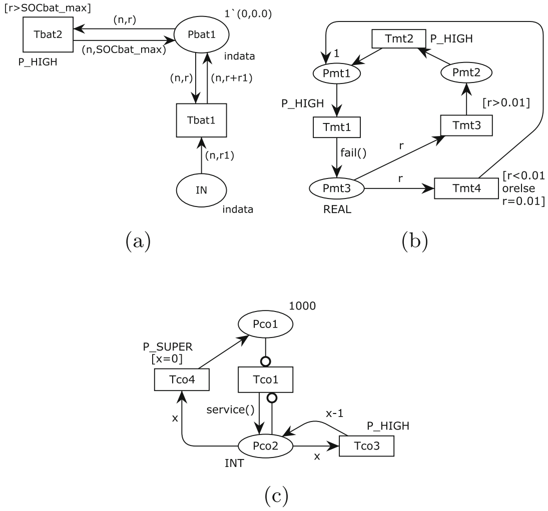


Fig. 2. (a) Storage CPN moodel; (b) Microturbine CPN model; (c) Coordinator microturbine maintenance logic CPN model

the information and data have to pass through it. Hence, its communication socket is linked with all elements in the system. In other words, this model is a decision maker that aims to satisfy the energy balance. This agent has the highest complexity, thus, it was assumed as the upper level. The coordinator CPN model is too large, and because of space limitation in the present paper, just the microturbine failure/maintenance analysis is shown in Fig. 2c. In this model, the transition **Tco3** performs the reliability indexes based on the microturbine behavior and place **Pco2** indicates the repairing status. Table 1 indicates the CPN models description.

4 Simulation and Results

The objective of simulations is to evaluate the reliability indexes (*LOLE*, *LOEE* and *EIR*). Two scenarios are studied, both using the simulation inputs presented in Table 2, but in the first, called scenario 1, the microturbine operates as ON/OFF strategy, that is, when a mismatch in the power balance occurs the microturbine turns on, and after that it turns off. In scenario 2 the microturbine operates constantly. Summarizing, the analysis is made on a microgrid with two different generation policies: (1) ON/OFF microturbine generation, (2) constant microturbine generation. Table 3 indicates the results for both scenarios. A Monte Carlo simulation is made just to validate the CPN proposed methodology. The comparison between them is presented in the result table above.

Figure 3 shows that both scenarios operate with almost the same power balance. Although there is a correlation between them in power balance profile, these two scenarios presents very different reliability indexes. Comparing both,

Table 1. Partial description of Microgrid CPN model

CPN instance	Functionality description
Pbat1	State of charge storage
Pbat2	Command of charge or discharge
Tbat1	Calculation of energy amount to charge or discharge
Tbat2	Storage limitation
Pmt1	Microturbine OFF
Pmt2	Microturbine ON
Pmt3	Flag of failure analysis
Tmt1	Turn microturbine ON
Tmt2	Turn microturbine OFF
Tmt3	Microturbine not fail
Tmt4	Microturbine fail
Pco1	Enables the Microturbine Operation
Pco2	Remaining hours to repair the Microturbine
Tco1	Repair Microturbine
Tco3	Calculates the Loss of Load and decreases the remaining hours to repair
Tco4	Microturbine Repaired
service( )	Uniform distribution function between interval [2,24] to represent the number of hours to repair
fail()	uniform distribution between interval [0,1]
x,n	integer variables
r,r1	real variables
P_SUPER/P_HIGH	event priority: P_SUPER $>$ P_HIGH
$\multimap$ / $\rightarrow$	inhibitor arc/regular arc

Table 2. Inputs of simulation

Description	Symbol	Value
Shape factor Weibull	k_w	2
Annual wind speed	V_{annual}	7 m/s
WT Mean Time to Failure	$MTTF$	1920 h
WT Mean Time to Repair	$MTTR$	80 h
WT rated power	P_R	20 kW
WT cut-in speed	V_{in}	3 m/s
WT rated speed	V_R	11 m/s
WT cut-out speed	V_{out}	22 m/s
Storage maximum charge	SOC_{max}	10 kWh
Incident radiation (STC)	G_{STC}	1 kW/m^2
Temperature (STC)	T_{STC}	25°C
Nominal Operating PV cell temperature	$NOCT$	48°C
Inverter efficiency	n_{inv}	0.9
PV derating factor	f_{PV}	0.9
PV peak power	P_{PV}	20 kW$_{peak}$
Load peak	$Load_{peak}$	25 kW
Microturbine maximum power	P_{MTmax}	18 kW

Table 3. Comparison of CPN and Monte Carlo Methods for scenario 1 and scenario 2

Scenario	Index	CPN	Monte Carlo	Error
Scenario 1	LOLE (h/ano)	469.93	469.1	0.18%
	LOEE(kWh/ano)	2184.4	2134.4	2.29%
	EIR	0.9837	0.9841	0.033%
Scneario 2	LOLE (h/ano)	328.1	348.16	5.76%
	LOEE (kWh/ano)	997.53	1018.1	2.02%
	EIR	0.9926	0.9924	0.016%

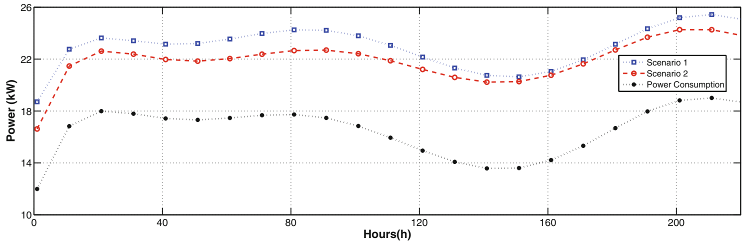


Fig. 3. The power balance evaluation for the case scenarios 1 and 2, and load consumption

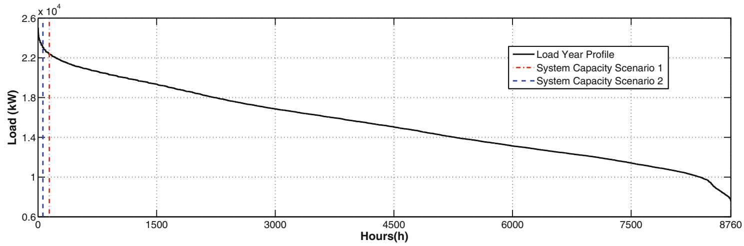


Fig. 4. EIR for the case scenarios 1 and 2, and load consumption

the scenario with constant microturbine operation have improved all the three indexes. That is justified because the demand energy tracking in this scenario is better. Besides that, the power generation is lower than the ON/OFF microturbine policy, which means that the second scenario is more optimized than the first. Confirming the improvement that the constant microturbine policy brings to the system, Fig. 4 indicates the system capacity of both scenarios. And, once more, the scenario 2 shows a slightly better efficiency.

5 Conclusion

The CPN formalism showed that the presented methodology can support a microgrid planner on a easy way of simulation. Different scenarios can be evaluated and checked. Even new control strategies can be easily assessed. In terms of results, it was validated that both Monte Carlo simulation and CPN formalism has, statistically, the same level of confidence. The limitation of Monte Carlo simulation, considering flexibility of new scenarios evaluation and state analysis, is overcame using the CPN formalism. Evaluating the results, this methodology can be a powerful tool helping the grid operators and government authorities on new microgrid installations. Finally, as further works, the authors propose a multi-agent hybrid solution.

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Photovoltaic Inverter Scheduler with the Support of Storage Unit to Minimize Electricity Bill

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Abstract. The increase of distributed generation in several countries has led to new legislation that allows the owners to use the energy obtained from them in three possible ways: use the energy to face own consumption such as on-site generation, sell energy to the grid as a producer, or finally, do both according to context of operation. In this way, these technologies can be more easily introduced to the average public if there is a managing application that can represent the interests of its owners and perform the appropriate measures. This paper proposes a methodology for the management of different available technologies owned by a prosumer, analyzing the possible role it can have and what type of scheduling can be made, operating in the third way mentioned before.

Keywords: Energy management · Photovoltaic · Scheduling · Self-consumption

1 Introduction

In recent years, there has been an exponential increase of renewable generation amongst several countries, mostly due to the necessity of reducing their energy dependency on fossil fuels or pollution [1]. A known example is the European Union that imposed deadlines regarding energy to a more sustainable future [2, 3].

The increase of the number of consumers with generation units achieved a new concept: the prosumer [4]. An entity capable of both consuming and producing at the same time, i.e. a power node within itself [5]. Although the legislation that defines the activities of such an entity didn't accompany their implementation at first, it is now reaching a high development state where the prosumer is a very important part of power systems, and future of smart grids [6]. Moreover, when integrating Demand Response (DR), the modification of load profile in response to monetary or price signals thus providing flexibility [7], the consumer goes from a passive entity in the energy system, to one of the most active by managing both local consumption and generation resources. In this way, the consumer is of the upmost importance to the future of power systems, especially for the full implementation of smart grids.

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Distributed generation (DG) is mainly implemented by prosumers, with the installation of small-size generation units that, near consumption, has several advantages for the power system. Per example, DG can have a relevant role in voltage control and system losses [8]. The development of renewable technologies has caused an increase for their implementation as DG, namely, photovoltaic (PV) and wind. These two types of generation have several aspects that make them the most used, per example, PVs' easy installation, endurance, and variety of application, are the features that make this technology have a huge potential regarding its implementation in several sectors, as residential buildings [9]. Wind is difficult to install near populated areas due to their level of noise and turbulence. In the smart grid context, prosumers offer an adequate solution for the implementation of DG at the same time that can supply flexibility to the power system through demand-side management [10].

The concept of demand-side management implicates several topics, of which DR belongs to, together with energy efficiency, spinning reserve, and time of use [11]. DR is defined as the modification of the typical load profile, is response to monetary or price signals [12]. Monetary signals are incentive-based DR, since the consumer is induced to participate in an event following the interests of a third party. As for price-signals, these are price-based DR where the consumer chooses or not to respond, however, these will have influence in the consumer's electricity costs, since high rates are applied to induce load reduction. The management of demand-side allows the operators and prosumers to adjust load according to generation and insure cost reduction for demand at costly times [13, 14]. When considering that multiple entities need to communicate between each other, and interact at a decision/control level (such as, the implementation of DR programs and load modification), a relevant concept arises to define this mechanism, multi-agent systems. These are defined as distributed and autonomous entities that can be intelligent or not, but moreover, can allow for interaction between several systems. In a smart grid context, energy management systems can be individual agents that act and decide, upon previously defined rules or in an intelligent way, the path to improve operation. Moreover, if participating in DR programs defined by another agent (e.g. grid operator), management systems can automatically apply these considering some restraints.

The present paper addresses this topic by providing a methodology for an agent, that in this case is the consumer. The consumer is provided with an independent management that approaches the several resources capabilities and contributions for the minimization of energy bought from grid. With this methodology, the consumer can interact with upper-level entities (e.g. grid operator), to better manage its operation.

2 Proposed Methodology

The proposed methodology enables the optimal scheduling of the consumer's resources to minimize the costs of operation, therefore, to lower the electricity bill. The resources considered are the Main Network (MN) to which the consumer is connected, PV systems, energy storage battery, and consumption flexibility through load shedding. The consumer is involved in a time-of-use tariff program and it is assumed that energy injection in grid is possible and remunerated. The methodology is modelled to be implemented in different consumer conditions and number of resources. The following Fig. 1 shows the context behind the development of the proposed methodology, considering a household consumer, however, it can be applied to other types of consumers that are also producers (prosumer). The methodology considers that PV generation is free to use by the consumer, since it is underlined that the system belongs to the consumer. In the opposite, costs for the use of PV must be added to the objective function and energy supply priorities must be reviewed.

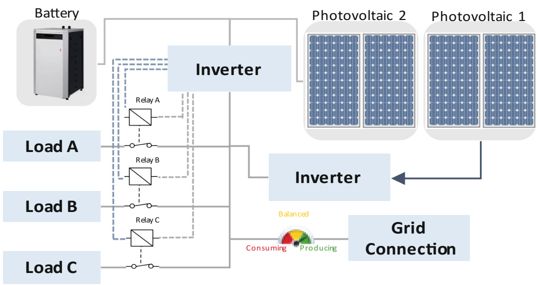

Fig. 1. Implementation context for the proposed methodology.

In the present paper, it is considered that PV has priority above all others, meaning that the PV generation, if available, will always be consumed, either by the load's necessities, battery charge, or injected in the MN. The grid's interaction is assumed as bidirectional, however there may be cases where thus is not allowed due to limitations in the physical network or in the legislation currently applied. In these situations, usually the on-site generation is mainly used for own load without injection in the MN. Also in Fig. 1, it is shown that up to three loads can be connected through relays, adding DR to the consumer's management.

In sum, the consumer can use the PV, energy storage battery, and DR to avoid consuming form the grid in times where energy is costly, and take advantage of reduced tariffs to charge the battery or satisfy consumption. In this way, the objective of the methodology is to minimize the energy bought from the grid to supply its consumption, and undertake the advantage of PV generation and DR to make the most of the flexibility that the battery system provides. The methodology considers an optimization process that runs side-by-side with the remaining resources, acting as a management system for the consumer to improve its energy efficiency and savings.

3 Scheduling Formulation

The mathematical formulation is an important part of the methodology and thus, it is presented in this section. In this paper, one intends to minimize the operation costs of a consumer given its interaction with the MN, which can be performed through a mixed-integer linear programming optimization. The optimization problem was modeled in MATLAB™/TOMSYM™ environment, and solved using CPLEX solver.

The DR curtailment cost in the objective function, is represented through weights $(P^{cut}_{(c,t)} \cdot W^{cut}_{(c,t)})$ showing the interests of the consumer for the load c in period t, and therefore affecting its operation if DR is applied. The objective function of the optimization problem, Eq. (1), shows the costs $(P^{grid\_in}_{(t)} \cdot C^{grid\_in}_{(t)})$ and revenues $(P^{grid\_out}_{(t)} \cdot C^{grid\_out}_{(t)})$ of the consumer's operation, i.e. when being supplied by the MN and when it injects power in the MN in each period t, respectively. The term, Δt, is equal to 4 and is needed to adjust consumption to the tariff at play, since consumption is in a 15-min basis, while the tariff is in an hourly basis.

$$\min EB = \sum_{t=1}^{T} \left[\left(P^{grid\_in}_{(t)} \cdot C^{grid\_in}_{(t)} - P^{grid\_out}_{(t)} \cdot C^{grid\_out}_{(t)} \right) \cdot \frac{1}{\Delta t} + \sum_{c=1}^{C} P^{cut}_{(c,t)} \cdot W^{cut}_{(c,t)} \right]$$
$$\begin{cases} P^{grid\_in}_{(t)} = P^{grid}_{(t)},\ if\ P^{grid}_{(t)} > 0 \\ P^{grid\_out}_{(t)} = P^{grid}_{(t)},\ if\ P^{grid}_{(t)} < 0 \end{cases} \quad \forall t \in \{1, \ldots, T\} \tag{1}$$

Equation (2) insures the balance between load and generation. As for the interaction with grid, one considers that when the energy is bought from the grid in period t, the variable $P^{grid}_{(t)}$ assumes positive values, otherwise, when the energy is sold to the MN, the same variable has negative values - Eq. (3).

$$\sum_{p=1}^{P} P^{PV}_{(p,t)} + P^{grid}_{(t)} + \sum_{c=1}^{C} P^{cut}_{(c,t)} + \sum_{st=1}^{ST} P^{dch}_{(st,t)} = P^{load}_{(t)} + \sum_{st=1}^{ST} P^{chg}_{(st,t)}, \quad \forall t \in \{1, \ldots, T\} \tag{2}$$

$$-P^{grid\max\_out}_{(t)} \leq P^{grid}_{(t)} \leq P^{grid\max\_in}_{(t)}, \quad \forall t \in \{1, \ldots, T\} \tag{3}$$

The flexibility provided by DR is an important part of the integration of DG, since it allows the load profile to be adjusted according to the output of generation. In this case, the proposed methodology considers the use of load shedding through relays incorporated in the PV inverter. Equation (4) represents the limits for the load shedding, $P^{cut}_{(c,t)}$, in the different loads connected to the relays. Equation (5) shows that when the relays are activated, the loads that are connected to them are shed. This is insured by the decision binary variable $X^{cut}_{(c,t)}$, for each of the relays.

$$0 \leq P^{cut}_{(c,t)} \leq P^{cut\max}_{(c,t)}, \quad \forall t \in \{1, \ldots, T\}, c \in \{1, \ldots, C\} \tag{4}$$

$$P^{cut}_{(c,t)} = P^{cut\max}_{(c,t)} \cdot X^{cut}_{(c,t)},\ X^{cut}_{(c,t)} \in \{0, 1\},\ \forall t \in \{1, \ldots, T\},\ c \in \{1, \ldots, C\} \tag{5}$$

Moving on to the battery system, this is very useful in applications where there are time-of-use tariffs, per example, the battery can be charged during the less costly periods and discharged during the costlier periods to avoid a higher amount of energy bought from the MN. Similar to the generation units, the battery has operation capacity

$(E_{(t)}^{stor})$ limits, Eq. (6), charge $(P_{(t)}^{chg})$ and discharge $(P_{(t)}^{dch})$ limits, Eqs. (7) and (8), respectively, in each period t. Equation (9) represents the impossibility of charging $(X_{(t)}^{chg})$ and discharging $(X_{(t)}^{dch})$ during the same period t. The parameter ST, represents the total number of batteries considered, which in this case, is only one. The battery system maintains a power balance within, thus Eq. (10) presents the balance between what comes in and out of the battery, and its state.

$$0 \le E_{(st,t)}^{stor} \le E_{(st,t)}^{stor\,\max}, \quad \forall t \in \{1,\ldots,T\}, st \in \{1,\ldots,ST\} \tag{6}$$

$$0 \le P_{(st,t)}^{chg} \le P_{(st,t)}^{chg\,\max} \cdot X_{(st,t)}^{chg},\ X_{(st,t)}^{chg} \in \{0,1\}, \quad \forall t \in \{1,\ldots,T\}, st \in \{1,\ldots,ST\} \tag{7}$$

$$0 \le P_{(st,t)}^{dch} \le P_{(st,t)}^{dch\,\max} \cdot X_{(st,t)}^{dch},\ X_{(st,t)}^{dch} \in \{0,1\}, \quad \forall t \in \{1,\ldots,T\},\ st \in \{1,\ldots,ST\} \tag{8}$$

$$X_{(st,t)}^{chg} + X_{(st,t)}^{dch} \le 1, \quad \forall t \in \{1,\ldots,T\},\ st \in \{1,\ldots,ST\} \tag{9}$$

$$E_{(st,t)}^{stor} = E_{(st,t-1)}^{stor} + P_{(st,t)}^{chg} - P_{(st,t)}^{dch}, \quad \forall t \in \{1,\ldots,T\},\ st \in \{1,\ldots,ST\} \tag{10}$$

4 Case Study

The present paper addresses a prosumer located in a Portuguese network, and following its current legislation which allows small producers like consumers with local generation, not just use the energy produced to satisfy their own load necessities, but also sell it to the MN. The case study considers a system built of two PV systems and a battery, that belongs to a consumer, as illustrated in Fig. 1. The consumer has a supply power contract of 10.35 kVA with the MN characterized by time-of-use tariffs, namely, three different periods: peak, intermediate, and off-peak. Beyond the dynamic pricing, the consumer can inject energy into the MN until half of its contracted power, approximately, 5.1 kW. The prices applied to the consumer's operation with the grid are showed in Table 1. The prices shown are real values that a major supplier in Portugal offers to its clients.[1] This contributes to a more accurate study and methodology application, since real-life conditions are considered. In what concerns DR, the objective function considers weights defined by the consumer for the periods where is more acceptable and beneficial to use load flexibility, that in this case, is directly related with the dynamic pricing as when the energy is cheaper, less attractive is the DR. The amount obtained from the weights considered in the objective function is removed after the optimization problem since it doesn't represent an actual cost but rather a consumer's preference that influences the scheduling. Regarding the on-site generation and storage units, the PV system is composed by two inverters divided between the PV modules, having a maximum production of 7,5 and 2,5 kW. The battery is connected to

[1] https://energia.edp.pt/particulares/energia/tarifarios.

Table 1. Prices of the different periods and contracted power.

	Energy (€/kWh)			Contracted power (€/day) - *DCP*
	Peak	Intermediate	Off-peak	
Buy from grid	0,3326	0,1681	0,0930	0,5120
Periods	10 h–13 h 19 h–21 h	08 h–10 h 13 h–19 h, 21 h–22 h	22 h–00 h 00 h–08 h	
Sell to grid	0,1659			–
DR weight	0	0,2	0,4	

the same inverter as the second PV (2,5 kW), being able to be charged from it, from the other PV system, and from the MN.

The inverter that holds the PV and battery system can perform the shed of up to three loads with incorporated relays. In case of insufficient PV production and/or energy stored in the battery, the loads connected to these relays can be shed to guarantee the energy balance in the inverter, opening a path for DR to support DG operation. In this case study, it is considered that the load of the dishwasher, air conditioning, and water heater can be shed, while the unknown load cannot (designated by "Others"). Figure 2 shows the discriminated load and PV generation forecast throughout the periods – 15-min intervals. Through Fig. 2, one can see a typical load profile with a peak of 11,5 kW, around 11:45 h.

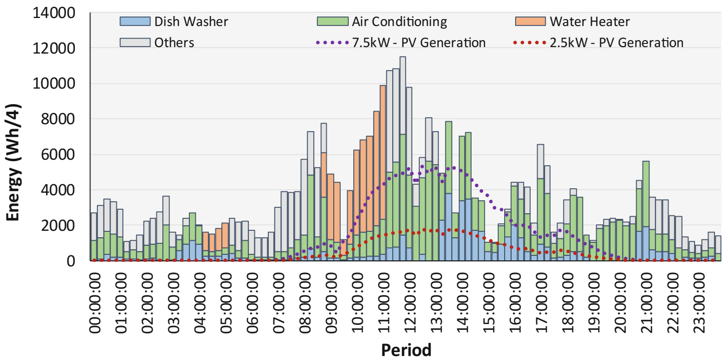

Fig. 2. Discriminated consumption by appliance.

5 Results

In the present section, one analyzes the results obtained from the implementation of the proposed methodology and respective case study. In Fig. 3 it is shown the resource's scheduling obtained by the consumer and its interaction with the grid. As mentioned

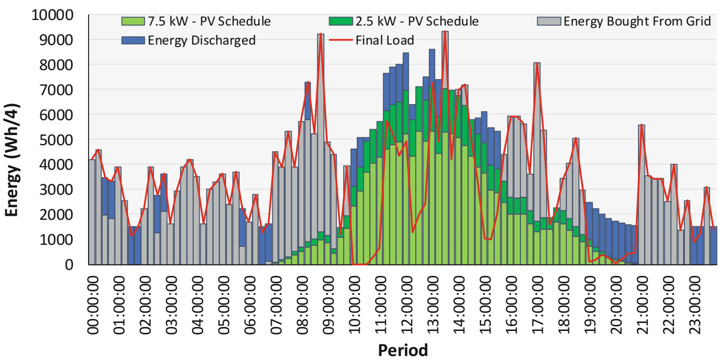

Fig. 3. Resources scheduling for the consumer.

before, the PV generation has the highest priority and thus is always scheduled. By Fig. 3, it is possible to observe that due to this condition the generation exceeds the consumption needs, and in this case, the energy surplus will either be used to charge the battery or sell to the grid. In this way, the consumer avoids buying energy from the grid to charge the battery and to meet consumption necessities. The above figure shows that the battery is mostly charged during the dawn, to be later discharged during the peak hours (10:00 to 13:00, and 19:00 to 21:00).

Also, as shown in Fig. 4, DR is applied during peak hours due to the contract's high tariff. The results obtained for the operation costs, show an improvement in terms of energy savings when the methodology is applied, as shown in Eq. (11), in comparison with the consumer being supplied always by the grid connection (normal operation of consumers).

$$EB_{New}^{Day} = DCP + \sum_{t=1}^{T} \left[\left(P_{(t)}^{grid\_in} \cdot C_{(t)}^{grid\_in} - P_{(t)}^{grid\_out} \cdot C_{(t)}^{grid\_out} \right) \cdot \frac{1}{\Delta t} \right], \quad \forall t \in \{1, \ldots, T\} \tag{11}$$

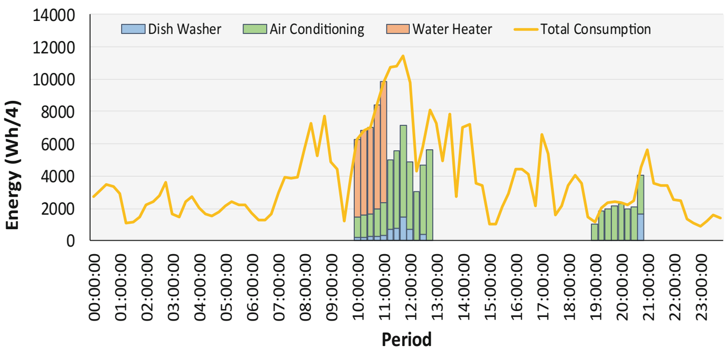

Fig. 4. DR actuation regarding the initial total consumption.

With the proposed methodology, the daily operation cost is 2,48 €, while in normal operation (without PV, battery and DR) it is 18,24 €. This means that, in this case study, energy savings could be achieved up to 86,4%, by implementing PV-battery system and adopting simple DR strategies.

6 Conclusions

The present paper addresses a methodology for the scheduling of hybrid systems composed of demand flexibility, PV and battery units, where the prosumer's electricity bill is minimized with a dynamic pricing contract. The proposed methodology represents a simple optimization problem that can considerably improve the consumer's energy savings, through an efficient use of resources and intelligent consumption strategies. Moreover, the application of this methodology, due to its formulation simplicity, is easily implemented as an executable in a system software, and run on a timely basis, while a monitoring infrastructure provides the needed data.

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Real-Time Emulation and Simulation System of Asynchronous Motor Consumption

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Abstract. Electric power systems have been altered at the operating and planning level in the last years. Evidence of this was the liberalization of the energy market and the implementation of concepts such as smart grids and the active participation of consumers through demand response programs. The main objective of the present paper is to propose an emulation model for asynchronous motors, in the scope of dynamic measurement and control of loads, included in demand response programs. Since this type of electric motor is of upmost importance in the current consumption context, it was necessary to model consumption and evaluate its impact on the power system. The development of this paper aims to evaluate the system's capabilities using the motor as a load, and a wind emulator. Thus, we can represent various applications (e.g. division of a house) and realize the effect of distributed generation in the operation of the electric power system.

Keywords: Load metering · Real-time simulation · Benchmarking · Emulator

1 Introduction

Electric Power Systems (EPS) have been the subject of major changes in the operating paradigm over the last decade. Nowadays, the increasing use of distributed generation instead of traditional large centralized production, is one of the main approaches these days. In addition to difficulties in maintenance, these large plants use primary fossil energy sources, such as coal and oil, which contribute largely to high pollutant emissions [1]. The dependency of fossil fuels to which the EPS was subject has boosted the commitment to renewable energy sources (RES) by several countries. This kind of initiative is very effective, since the use of fossil fuels presents many problems. The strong price volatility associated with the scarcity of resources from the buyer entity, together with the political and financial instability of the seller countries, represents relevant issues to the future implementation of fossil-based generation. As mentioned before, high pollutant emissions coupled with a growing environmental concern have boosted the focus on alternative energy sources [2, 3].

The liberalization of the EPS has given rise to the concept of Smart Grids. This concept includes the activities of all connected users on the same system, such us,

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advanced information, network control and communication technology, making it possible to save energy and reduce consumption costs [4]. This concept is characterized by the integration of several complementary components and the cooperation of several subsystems, that coexist within the electrical grid. In [5], it's demonstrated the various components that are associated with smart grids. The great push of the Smart Grids is associated to the capacity of bidirectional communication between producer and final consumer, regulating the generation through Demand Response (DR), i.e. to design a real-time and cost-effective response, it is necessary that the consumers adjust to the amount of power that is delivered and behaviour. In this context, costly features as energy losses and spinning reserve can be avoided [6]. The use of strategies, which include price fluctuations or even incentive payments, seek to reduce energy consumption at higher prices on the wholesale market or when the reliability of the system is compromised [4, 7, 8]. The DR includes all intentional changes in energy consumption, either by time of use, level of demand at critical times, or patterns of consumption adjusted to market prices [4, 7, 9, 10]. Since RES are not constant, its use does not guarantee a stable operation. New methodologies require a careful evaluation of, the developed software and its applicability. In [11], one can see the relations between the ambient and application conditions that can be applied in system's evaluation [11, 12]. As there is no perfect model solution for DR, computational simulation or emulation arise as the least costly alternatives. In sum, there is the need for a platform that creates a reasonable compromise between simulation and emulation, combining software and real-life applications.

The proposed emulation method intends to provide a model for the simulation of load profiles, with a real-time communication infrastructure of monitoring and control that enables its user a diverse range of operation scenarios. The paper is divided into five sections. Section 2 details the importance of multi-agent systems (MAS) in this approach, while Sect. 3 specifies the components of the emulation method. In Sect. 4, it is presented the case study and its results for the application of emulation method, and as for Sect. 5, it is shown the conclusions of the results obtained.

2 Multi-Agent Systems

The concept of MAS is very useful in the context of smart grids, since it defines autonomous, local, and distributed managers of systems, that are connected to form an agent network of cooperation and interaction that simplifies processes [13]. In this way, MAS (intelligent or not) can be integrated as a solution for monitoring and controlling distributed systems. MAS are often applied in energy markets simulation, namely, in terms of energy bids and the interaction between several entities, as mentioned in [14, 15]. Per example, MASCEM [16, 17], represents a multi-agent tool that can model several electricity markets and their operation, considering agent's interaction, their characteristics, behaviours and interests [15, 17].

In [18], the authors present a solution for the practical implementation of MAS, SOICAM, and how these can be integrated with a scheduling platform, MASGriP. In this way, this kind of approach can enable interactions between several agents in a simulated environment, that can accurately demonstrate the usefulness of these systems in real applications, such as, residential energy managers, sensor hubs, operators, aggregators, amongst others. In the present paper, it is assumed the existence of two agents, namely, the user of the software (computer) and the monitoring equipment (*master* analyser), communicating through TCP/IP protocol. The interaction between these two enables a multi-agent system, related to the implementation of smart grid measures.

3 Developed Solution

This section presents the communications and electrical connections that compose the implemented platform.

3.1 Equipment

- **OPAL.** is a real-time simulator, allowing several simulation and control systems, including hardware-in-the-loop (HIL) testing, rapid prototype control, complex power networks, distributed energy resources and electronic power systems. The simulation can be in real time, i.e. in a time as low as 10 μs [18].
- **PLC.** is a control device, which executes a program that monitors inputs and handles the outputs. From a computer, it is possible to communicate with the PLC and control equipment, in addition to being able to receive data as well. They are also distinguished by their reliability in a harsh environment [19, 20].
- **DIGIWATT.** a digital multimeter with floating inputs for voltage, current and electrical power, that can assimilate different states of all the equipment which it is connected. The DIGIWATT is capable of performing power measurement considering the DC component, a single phase, and the three-phase balance.
- **GRANMECA.** an equipment for exposing three mechanical values: torque, speed and mechanical power. It makes a reading of the speed and torque through the voltage received from the tachymetric dynamo and the torque sensor, respectively. The equipment has an adjustable knob that controls the magnetic brake.
- **VISIREAL.** Enables analogue measurement outputs (GRANMECA and DIGIWATT) to record and display electrical and mechanical quantities on a computer. The LOGIREAL software, which works together with VISIREAL, allows the user to view the variables in real time, through an RS-232 connection that links the measuring device to a computer. During real time acquisition, the several parameters are shown through curves or in numerical displays.
- **ANALYSERS.** Architecture based in only one *master* analyser (Janitza® UMG 604) connected to motor A, being motors B and C considered *slaves* (Janitza® UMG 103), that are more limited but adequate and less costly.

3.2 Communication Scheme

The developed solution is represented in Fig. 1. This is divided into three distinct phases: decision, monitoring and control, and finally, simulation/actuation.

The decision phase allows the user to access the data coming from the installation and define preferences. This access is versatile since it can be done locally through a computer with network access (via wireless or network cable), or through remote access using a VPN connection. The OPAL, PLC and energy analysers are also connected to the network to be accessible to the user.

In the monitoring and control phase, it is important to emphasize the communication with the energy analyser, since it will allow requests to be made, and after answers received. The communication protocol used with the energy analyser is Modbus TCP/IP (Transmission Control Protocol/Internet Protocol), two independent protocols but working together. Modbus is a communication protocol that has the benefits of flexibility and easy implementation. It can be used for communication between computers and microcontrollers, PLCs and other devices. In the present paper, operation was only considered through the PLC, and OPAL is not being used.

In the simulation/actuation, the communication network uses the *master* device controlled by the computer, to establish a connection with the *slaves*. The analyser waits for a connection request from the computer and, when this is established the analyser responds to the requests from the computer until it closes the connection.

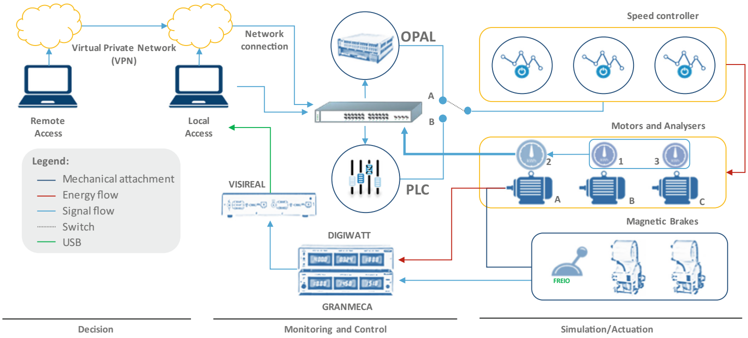


Fig. 1. Communication scheme.

It is important to note that the installation is equipped with three position switches, to make the control option to be used: choice is made between OPAL, PLC or isolated. It is also possible to vary the brake intensity, i.e. the torque. The electrical and mechanical quantities obtained in both equipment are transmitted to a computer where the analysis software is installed. In addition to obtaining information through the energy analyser via MATLAB®, one can also get information and command from the PLC and OPAL. In the third phase, the study considers 3 motors: A (3000 W), B (3000 W), and C (1500 W) with one analyser each, of which the *master* is analyser 2 (motor A). This means that analyser 2, in addition to collecting data from the motor to which is connected, also receives data from the other two analysers, 1 (motor B) and 3 (motor C).

3.3 Wiring Scheme

The wiring diagram used in the installation is presented in Fig. 2. All motors are star-coupled and powered by a three-phase source, however some equipment has single-phase power, namely the metering and brake devices. Motor A is coupled to a magnetic brake, a torque sensor, and a tachymetric dynamo. The magnetic brake serves to regulate the torque that the motor is developing, and it can be adjusted through a potentiometer. The reading obtained from the torque sensor is fundamental for the user to regulate the brake, since in a model environment this is one of the parameters that can be modified in this approach. As for the tachymetric dynamo, it allows the measurement of the motor's speed, through an analogue connection.

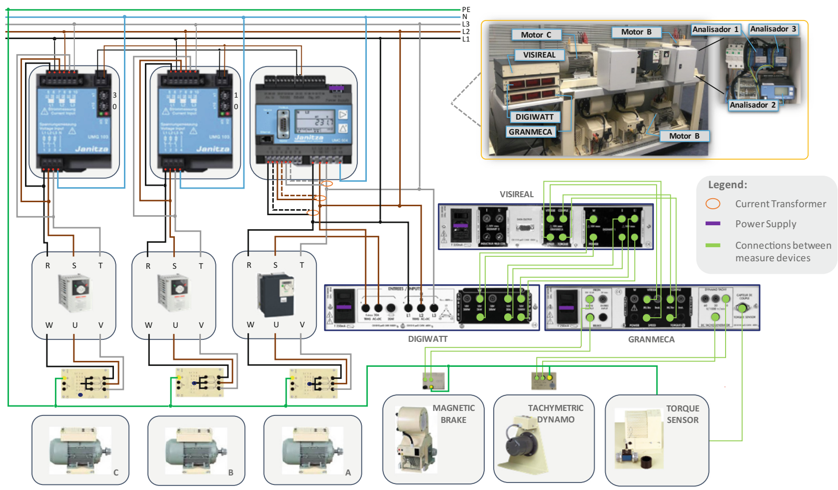


Fig. 2. Wiring scheme.

In short, regarding motor A, it is coupled to a magnetic brake, tachymetric dynamo, and a torque sensor, while motors B and C, are only measured by the analysers. The three-phase source is connected to the variable speed drive, however, firstly, connecting to the energy analyser allowing for voltage and current measurements. In this way, one has a realistic measurement that includes the consumption of the variable speed drive, which otherwise, the measured load would be incorrect since it does not include all load components. Each analyser has an address, which is a necessary information for identification of the analysers in the network, being for motor B the address 1, and for motor C, the address 3. An algorithm is necessary to obtain the electrical quantities with user defined sampling time and desired parameters. Thus, the communication is established through the *master* analyser allowing direct communication with the user, which is connected to the local network. Three versions of the algorithm were developed (Table 1).

- **Version 1** – collects measurements of the *master* analyser and the two *slave* analysers, plotting data after emulation is finalized.
- **Version 2** – collects data only from the master analyser, plotting data after emulation.
- **Version 3** – collects data only from the master analyser, plotting data in real-time.

The user's communication with the analyser was established through a code developed in MATLAB®. Only the master analyser is capable of being connected to the network, thus, it is necessary to use RS-485 communication protocol to obtain the information collected by the other analysers. The *master* device is identified by *unitID* that in this case corresponds to "02", while the analyser for motor 2 and 3, by "01" and "03", respectively. Considering what was mentioned before, this paper aims to simulate operation scenarios of energy systems in a practical environment.

Table 1. Characteristics of the different communication algorithm's versions.

	Version 1	Version 2	Version 3
Number of analysers	3	1	
Total simulation time (t_s)	Defined by user		
Communication time (t_c)	0.9 s	0.2 s	0.05 s
Sampling time	t_c	t_c	T_{iter}
Each iteration time (T_{iter})	t_c	t_c	$t_c + t_t + t_g$
Real-Time Graphing	No	No	Yes
Data processing each iteration	No	No	Yes

Note: the presented times are approximate and may vary on each iteration.

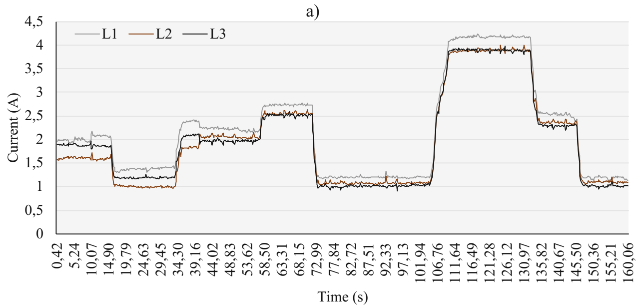
The objectives relate to equipment installation in GECAD laboratory, namely:

- Development of an algorithm in MATLAB® with Ethernet connection to the analyser, through Modbus TCP/IP communication protocol;
- Evaluation of sampling time, i.e. time interval between requests to the analyser;
- Analysis of the processing times required for the extraction and visualization of results, considering the effect of their veracity.
- Evaluation of the potential of the system using the motor as a load, allowing it to represent several applications (e.g. lighting system, among others);
- Integration of a wind emulator, to portray the inclusion of distributed production in an energy system, and its effect on the operation of the same.

4 Case Study & Results

In addition to the measurements of motor A, the active power of the wind emulator is also shown, which is used to simulate energy production from a wind turbine. The load (motor), wind emulator and power grid, are the three resources involved in this study. Three scenarios are considered: in scenario A, it is represented the motor's operation when there is no energy production, and therefore all the load is satisfied by the power grid; in scenario B, wind production is higher than the motor consumption, and thus, can feed the load and inject power in the grid; scenario C considers that the motor's consumption is partially higher than the available wind generation, being needed some contribution from the main network. Figure 3 shows the motor's electrical magnitudes, the production's active power, and the energy flow over time, in the 3 scenarios.

By analysing the energy flows, it is possible to notice that the simulation starts without production and, therefore, the load is fed by the electric grid. Around 5 s we started to have production, but still insufficient to feed the load. At 25 s the output is greater than what is required for consumption and, therefore, the wind turbine feeds the load and injects power into the main network. At 50 s, there are large variations in the production versus consumption balance almost instantly changing the energy flow, stabilizing when wind production is insufficient to meet consumption. After this and at the end of the simulation, the consumption is supported again by the energy produced by the wind turbine. The characteristics of the wind emulator are: Max. current - 5 A; Nominal power - 1.2 kVA; Speed - 1800 rpm.



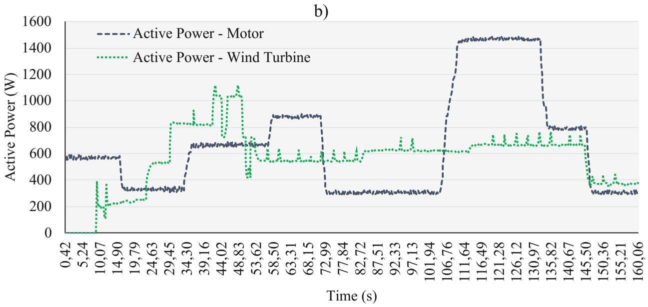


Fig. 3. Graphs of the motor A with wind power production. (a) Efficient currents in Motor A; (b) Active Power in Motor A and in the wind turbine.

5 Conclusions

The smart grids concept was one of the great innovations, since new concepts such as load control and DR emerge has solutions to a better energy management. This work aimed to evaluate the impact of electric loads, namely asynchronous motors in the context of DR programs, to improve decision support and operation awareness. By implementing an emulation framework, it is possible to simulate operation scenarios that imply different analysis and decisions based on the load profile. After analysing all the case studies, it is concluded that each situation requires a different evaluation of what algorithm to be used, and in what context it is applied. From the analysis made, version 1 considers requests for the 3 analysers, and thus is slower than the other versions. In the other versions, 2 compared to 3 presents a great advantage of reduced sampling time, which allows a greater number of measurements, however, version 2 does not allow the visualization of the measurements in real time, capability that version 3 has.

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Economic Evaluation of Predictive Dispatch Model in MAS-Based Smart Home

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Abstract. This paper proposes a Predictive Dispatch System (PDS) as part of a Multi-Agent system that models the Smart Home Electricity System (MASHES). The proposed PDS consists of a Decision-Making System (DMS) and a Prediction Engine (PE). The considered Smart Home Electricity System (SHES) consists of different agents, each with different tasks in the system. A Modified Stochastic Predicted Bands (MSPB) interval optimization method is used to model the uncertainty in the Home Energy Management (HEM) problem. Moreover, the proposed method to solve HEM problem is based on the Moving Window Algorithm (MWA). The performance of the proposed Home Energy Management System (HEMS) is evaluated using a JADE implementation of the MASHES.

Keywords: Home Energy Management System · Multi-agent system · Prediction engine · Interval optimization · Decision-making under uncertainty

Nomenclature

Indices

t Index of time periods.
i Index of Distributed Energy Resources (DERs).
j Index of electrical loads.
k Index of energy storage systems.

Variables

OF Objective function.
P_{i_t} Total power generation for DER i in period t.
P_{net_t} Power generation that is bought from local electricity market in period t.
P_{k_t} Total power generation for energy storage system k in period t.

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C_t^k State of charge for energy storage system k in period t.
L_{j_t} Electrical load j in period t.
$L_{j_t}^{shed}$ Load shedding for load j in period t.
S_{i_t} Spillage amount for DER i in period t.
D_{i_t} Difference between the scheduled day-ahead and predicted power generation for DER i in time period t.

Parameters

$\lambda_{i_t}/\lambda_{net_t}$ Electricity price for DER i/network in period t.
S_{max} Maximum power capacity for the line.
$P_{i_t}^{pred}$ Predicted power generation for DER i in period t.
α_i Optimistic coefficient related to the power generation for DER i.
σ_i Prediction variance related to the power generation for DER i.
U_j^{max} Maximum energy consumption for load j.

1 Introduction

In the recent decade, new visions and approaches have been raised in order to deal with new challenges due to increment of renewable energy sources. One of the most consensual solutions is the so-called Smart Grid (SG) [1]. In this scope, buildings can purchase and sell the generated energy locally [2]. Hence, they are known as *prosumers*- i.e. both consumers and producers. Hence, HEMS is necessary for achieving an economic improvement through automation technologies. In this sense, smart homes can control, monitor and manage the system through network communications [3,4].

Various researches have been presented for optimal scheduling of smart home energy, and different algorithms and methods have been represented based on their goals, strategies, utilized technologies, and software. In [5], the authors have discussed about the necessities of using computational intelligence in the HEMSs. In [6], each smart home has been considered as an autonomous agent that can buy, sell, and store electricity. Furthermore, uncertainty is modeled through generating the random data and functions in [6]. In [7], HEM has been defined as an intelligent Multi-Agent System (MAS). Also, JADE [8] is used to implement the proposed model of [7]. In [9], a MAS has been used in the distribution network scale, while agents consist of home agents and retailer agents. In [9], the purpose of the authors was to minimize the payment cost of electricity. In [10], authors proposed a method to apply the local energy resources optimally through minimizing the loss of energy. The main purpose of [10] is to minimize the purchasing cost of electricity. In [11], HEM problem in connection with transactive energy nodes has been discussed. Authors defined that transactive energy nodes are ones who have two-way communication with market and ca manage energy nodally. Moreover, co-simulation of smart homes and transactive energy market has been studied in [11].

In this paper, MASHES is defined as a class of organization-based multi-agent system where each agent has different tasks in the system. It will deal with the PDS to manage electrical energy as well as the smart home ability to trade electrical energy in the power grid. In addition, information provider is defined as an agent which provides all required information. Hence, JADE is used to implement the proposed organization-based MASHES. Furthermore, the modified stochastic predicted bands method that has been introduced in [12] is used in conjunction with the moving window algorithm to reschedule energy in each time-window.

The rest of this paper is organized as follows. Section 2 introduces the proposed predictive dispatch model of the MASHES. Then, the MAS structure is described in Sect. 3. Section 4 expresses the simulation results. Finally, Sect. 5 provides the conclusions.

2 Proposed Predictive Dispatch Model

PDS is defined as an organization of agents who is in charge of managing electrical energy in the MASHES. In this model, PDS consists of two agents: PE and DMS. The predictive dispatch model is based on the moving window algorithm. According to this approach, the scheduled energy of all agents is updated in each time period. In the following, the tasks of these agents is discussed.

2.1 Prediction Engine (PE)

PE must provide the accurate prediction of all the stochastic variables of the system such as wind speed, solar radiation, weather temperature and electrical non-shiftable loads for DMS. Hence, the outputs of this agent will be the inputs of DMS. As distributed energy resources are non-dispatchable resources, the forecasting of its power output is very important for the DMS. Hence, accurate forecasting of PE can assist DMS to make optimum decisions. To this end, prediction methodology is used to achieve the required forecasted values (e.g., by using the Support Vector Machines [13]).

The Support Vector Machines (SVM). algorithm is implemented by a generalization of the nonlinear algorithm Generalized Portrait created by Vapnik and Lerner in the sequence of [14]. However, the SVM approach in the current form was first introduced at the COLT conference, in 1992 [15]. The information to use in an SVM must follow the format suggested in (1):

$$(y_1, x_1), ..., (y_i, x_i), x_i \epsilon R^n, y_i \epsilon R \tag{1}$$

Where n is the size of training data. For classification: y_i assumes finite values; in binary classifications: $y_i \, \epsilon \, \{+1, -1\}$; in digit recognition: $y_i \, \epsilon \, \{1, 2, 3, 4, 5, 6, 7, 8, 9, 0\}$; and for regression purposes, y_i is in general a real number $y_i \, \epsilon \, R$. The implementation of SVM requires considering some important aspects, namely: Feature Space, Loss Functions, and Kernel Functions. The most applicable kernels for time series forecasting, as in the problem considered in this work, are the Radial Basis Function (RBF) and the exponential Radial Basis Function (eRBF). These two kernels are specifically tailored to regression of time series data.

2.2 Decision-Maker System (DMS)

The task of DMS is to make optimum decisions in the MASHES. In this case, DMS faces a discrete optimization problem. DMS reschedule the optimum decisions in each time-window based on the re-prediction outputs of the PE. Figure 1 shows the scheduling time framework of the proposed HEM problem in the MASHES. As it is shown in Fig. 1, the time step and the interval scheduling are considered to be equal to 1 h, while the scheduling window equals 24 h. The proposed HEM problem includes two stages. These stages consist of Day-Ahead Scheduling (DAS) and Real-Time rescheduling Interval (RTRI) stages. DAS stage obtains the optimum decisions for the system in day d-1 without considering uncertainties of decision-making variables. However, uncertainty is considered in the RTRI stage. This way, RTRI stage is rescheduled in each period to update the optimum decisions of DMS.

Day-Ahead Scheduling Stage has an objective function that is represented in (2):

$$OF^s = \sum_{t=1}^{N_t} (\sum_{i \epsilon DERs} (\lambda_i P^s_{i,out_t}) - \lambda_{net} P^s_{net_t}) \tag{2}$$

In DAS stage, the objective function includes two parts. The first part represents the revenue of selling electrical energy produced by distributed energy resources to the electricity market. The second term expresses the costs due to buying electrical energy from local energy market. In this model, the cost of reactive power as a major element of ancillary service has not been considered. Interested readers are referred to [16]. The constraints of the DAS stage:

$$P^s_{net_t} + \sum_{i \epsilon DERs} P^s_{i,in_t} = \sum_{j \epsilon ELs} L^s_{j_t} \tag{3}$$

$$-S_{max} \leq P^s_{net_t} - \sum_{i \epsilon DERs} P^s_{i,out_t} \leq S_{max} \tag{4}$$

$$P^s_{i_t} = P^s_{i,in_t} + P^s_{i,out_t} \tag{5}$$

$$P^{min}_{i_t} \leq P^s_{i_t} \leq P^{max}_{i_t} \tag{6}$$

$$L^{min}_{j_t} \leq L^s_{j_t} \leq L^{max}_{j_t} \tag{7}$$

(3) establishes the power balance equation due to distributed energy resources, grid power input and electrical loads. Loss of power is not considered in this problem for simplicity. (4) represents the power flow limitation through the distribution line. Besides, the total power generation of each agent of the

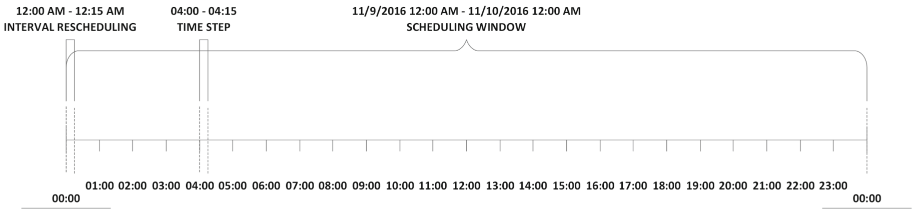

Fig. 1. Scheduling time frame.

distributed energy resources is represented in (5). (6) expresses power output limitations of energy resources. Besides, (7) represents the electrical power consumed of electrical loads.

Real-Time Rescheduling Interval Stage is the second stage of HEM problem. In this stage, the decision-making variables are determined from the outputs of the first stage and the uncertainty in the Real-Time (RT) operation. Moreover, optimum decisions are rescheduled in each period in this stage. The objective function of the RTRI stage, OF^{rt}, is represented as follows:

$$\begin{aligned} OF^{rt} &= \sum_{t=1}^{N_t} of_t = \sum_{i \epsilon DERs} \lambda_i P_{i,out_t} - \lambda_{net} P_{net_t} \\ &+ \sum_{k \epsilon ESSs} \lambda_k P_{k,out_t} - \sum_{j \epsilon ELs} VOLL_j L_{j_t}^{shed} - \sum_{i \epsilon DERs} V_i^s S_{i_t} \end{aligned} \tag{8}$$

$$OF_h^{rt} = \sum_{t=h}^{N_t} of_t \tag{9}$$

(8) expresses objective function in each time-period. OF^{rt} consists of five parts. The first part represents the revenue of selling energy produced by distributed energy resources to the market. The total cost of electrical energy that is bought from market is presented in the second part. The third part represents the profit due to selling the stored electrical energy to the market. The Value Of Loss Load (VOLL) is stated in the fourth part. Finally, spillage cost, V_i^s, of energy resources are introduced in the last part. The objective function of the RTRI stage is updated in each period. Hence, OF_h^{rt} is the updated objective function of the RTRI stage in h^{th} time period. Also, the power balance equation in the RTRI stage is expressed in (10). The power flow limitation through distribution line in the RT is expressed in (11).

$$P_{net_t}^{rt} + \sum_{i \epsilon DERs} P_{i,in_t}^{rt} + \sum_{k \epsilon ESSs} P_{k,in_t}^{rt} = \sum_{j \epsilon ELs} (L_{j_t}^{rt} - L_{j_t}^{shed}) \tag{10}$$

$$-S_{max} \leq P_{net_t}^{rt} - \sum_{i \epsilon DERs} P_{i,out_t}^{rt} - \sum_{k \epsilon ESSs} P_{k,out_t}^{rt} \leq S_{max} \tag{11}$$

DERs generate electricity power in the smart home. The power output of DERs in the RTRI stage, $P_{i_t}^{rt}$, is obtained based on (12). From (12), $P_{i_t}^{rt}$ is the power output of DER in the RTRI, and S_{i_t} is the spillage power of the DER. (13) represents the maximum and minimum power limitations of the DER. (14) represents that total power output of the DER equals its power output consumed in the home and the amount of power generation sold. The spillage amount of DER is the amount of power generation that is generated by DER but it is not used because of technical and economic constraints in period t as presented in (15).

$$P_{i_t}^{rt} = P_{i,p_t}^{rt} - S_{i_t} \tag{12}$$

$$P_{i_t}^{min} \leq P_{i,p_t}^{rt} \leq P_{i_t}^{max} \tag{13}$$

$$P_{i_t}^{rt} = P_{i,in_t}^{rt} + P_{i,out_t}^{rt} \tag{14}$$

$$0 \leq S_{i_t} \leq P_{i,p_t}^{rt} \tag{15}$$

In this model, the MSPB method is used to model the uncertainty of variables in the HEM problem. As highlighted, the proposed interval method to model uncertainty of DERs has been defined for the first time in [12]. This is why the performance of MSPB is explained briefly in this section. Hence, in this approach, the uncertainty of stochastic variables is modeled based on their predicted amounts. Therefore, the prediction amounts of DERs' power generation that come from the PE are used in the formulations of MSPB. Also, σ_i^{up} and σ_i^{down} parameters state the amounts of upper and lower variances of the predicted variables with respect to their actual amounts, respectively. Then, the difference between the day-ahead DERs' power generation, $P_{i_t}^{da}$, and their predicted amount for each time, $P_{i_t}^{pred}$, is determined as (16).

$$D_{i_t} = P_{i_t}^{s} - P_{i_t}^{pred} \tag{16}$$

Moreover, α_i is defined as a slack variable for DMS to handle the stochastic behavior of the DER power generation. Therefore, α_i is labeled an *optimistic coefficient* with values between 0 and 1. In this paper, outdoor temperature and must-run services are considered as deterministic variables for simplicity. However, uncertainty of DERs is considered based on (17).

$$\begin{cases} P_{i_t}^{pred}\alpha_i + (P_{i_t}^{pred} - \sigma_i^{up})(1-\alpha_i) \leq P_{i_t}^{b} \\ \leq (P_{i_t}^{pred} + \sigma_i^{down})\alpha_i + P_{i_t}^{pred}(1-\alpha_i) \quad D_{i_t} \geq 0 \\ (P_{i_t}^{pred} - \sigma_i^{up})\alpha_i + P_{i_t}^{pred}(1-\alpha_i) \leq P_{i_t}^{b} \\ \leq P_{i_t}^{pred}\alpha_i + (P_{i_t}^{pred} + \sigma_i^{down})(1-\alpha_i) \quad D_{i_t} \leq 0 \end{cases} \tag{17}$$

Energy Storage Systems (ESSs) can be utilized economically based on the charge and discharge strategies in the HEM problem. The power generation of ESSs is expressed in (18) and (25). (19) represents the state of charge balance equation in a ESS, and C_i^k is an initial state of charge in the ESS. Maximum and minimum limitations of discharge current of the ESS are represented in (20) and (22). Also, (21) and (23) express constraints of ESS in the charge state.

$$P_{k_t}^{rt} = -P_{k,b_t}^{rt} - \omega_t^c + \omega_t^d + \omega_t^m \tag{18}$$

$$C_t^k = C_{t-1}^k + \omega_t^c \eta_{G2V} - \omega_t^d/\eta_{V2G} - \omega_t^m/\eta_{V2T}, t \geq 2$$

$$C_t^k = C_i^k, t = 1 \tag{19}$$

$$P_{k,d_t}^{min} \eta_k (1 - u_t^k) \leq \omega_t^d \leq P_{k,d_t}^{max} \eta_k (1 - u_t^k) \tag{20}$$

$$P_{k,c_t}^{min} \eta_k u_t^k \leq \omega_t^c \leq P_{k,c_t}^{max} \eta_k u_t^k \tag{21}$$

$$0 \leq \omega_t^d \leq (C_t^k - P_{k,d_t}^{min}) \eta_k \tag{22}$$

$$0 \leq \omega_t^c \leq (P_{k,c_t}^{max} - C_t^k) \eta_k \tag{23}$$

$$P_{k,d_t}^{max} - C_{t-1}^k \leq P_{ev,b_t}^{rt} \leq P_{k,c_t}^{max} - C_{t-1}^k, t \geq 2 \tag{24}$$

$$P_{k_t}^{rt} = P_{k,in_t}^{rt} + P_{k,out_t}^{rt} \tag{25}$$

Electrical Loads (ELs) include electrical consumers that can be controllable and/or shiftable. (26) and (27) represent ELs' power and energy consumed maximum and minimum limitations. Moreover, (28) expresses the load shedding constraint of ELs. (29) and (30) express equal and unequal constraints of ELs.

$$L_{j_t}^{min} \leq L_{j_t}^{rt} \leq L_{j_t}^{max} \tag{26}$$

$$U_{j_t}^{min} \leq \sum_{t=1}^{N_t} L_{j_t}^{rt} \leq U_{j_t}^{max} \tag{27}$$

$$0 \leq L_{j_t}^{shed} \leq L_{j_t}^{rt} \tag{28}$$

$$f_a(M_t^{rt}) = 0; a = 1, ..., N_a.M \in \{L_j, \theta_{out}, \theta_{in}\}. \tag{29}$$

$$g_b(M_t^{rt}) \leq 0; b = 1, ..., N_b. \tag{30}$$

3 Implementation of MASHES

The MAS for HEMS allows to model different devices in a house through autonomous agents. This MAS is implemented in JADE. The architecture of the agent system is depicted in Fig. 2. The organization-based MAS is composed by Local Electricity Market (LEM), PDS, DERs, ESSs and ELs. LEM is a set of external agents that consists in the retailer-the energy supplier- and the Demand Response (DR) aggregator. PDS is a group of agents that is in charge of connecting all the agents in a house. In addition, it analyses and predicts data. Also, the energy management is done by the PDS. DERs is responsible for renewable energy resources, such as wind and PV panels. ESSs is a set of agents, that represent the energy storage units, e.g. battery, and Electrical Vehicles (EVs). ELs is a group of different agents that only consume the electrical energy but whose type is different. This proposed organization-based MAS structure is also capable of interacting with the Multi-Agent Smart Grid Simulation Platform (MASGriP) [17], and the Multi-Agent Simulator of Competitive Electricity Markets (MASCEM) [18].

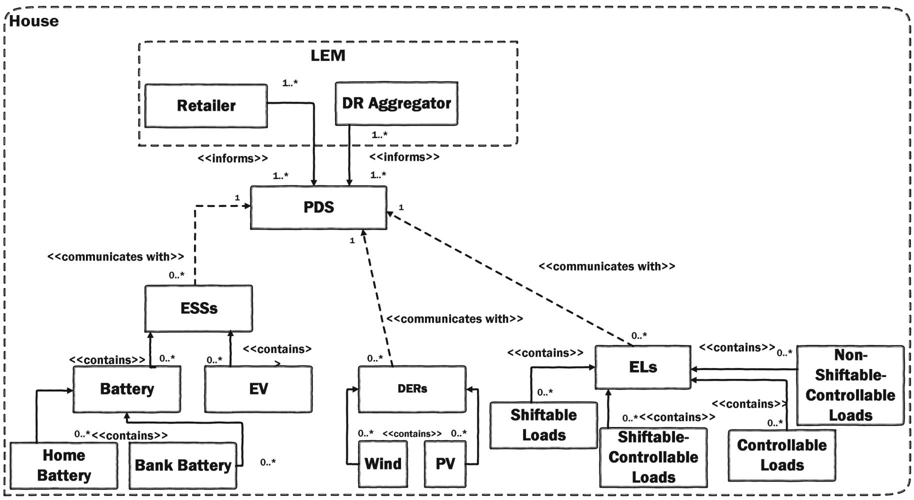

Fig. 2. MAS architecture.

4 Simulation Results

A physical system from [19] is used to evaluate the performance of the proposed HEMS. However, some modifications of the system parameters are made. For instance, the predicted data of PV power generation and the must-run services are used from [20]. The maximum energy produced by the PV system is 2-kWh. The battery can store between 0.48 and 2.4 kWh, and its maximum charging/discharging rates are 400 W. Besides, charging and discharging efficiencies are 90%. Maximum heating power equals 2 kW to maintain the temperature of the house within ±1 of desired temperature (23 °C). The thermal resistance of the building shell is equal to 18 °C/kW, and C equals 0.525 kWh/°C. The energy capacity of the storage water heater is 10.46 kWh (180 L) which has 2 kW heating element. The rated power of the pool pump is 1.1 kW, and it can run for a maximum of 6 h during the day. The performance of the proposed HEM model is assessed in three cases. The program implemented is solved in GAMS 23.7 [21]. In this section, the performance of proposed model predictive dispatch is addressed in three cases.

Case 1: Effect of distributed energy resources and energy storage systems, Case 2: Effect of Demand Response Program (DRP), and Case 3: Effect of the connection state on the objective function of the system are evaluated.

The impact of a battery system on the objective functions is shown in Fig. 3(a). The battery system increases the amount of the objective function. However, the impact of PV system on the objective function is more evident. Figure 3(b) expresses that considering DRP in the HEMS causes to increase the amount of objective function. The impact of DRP is more obvious after 17^{th} time-windows that the objective function is negative without considering DRP

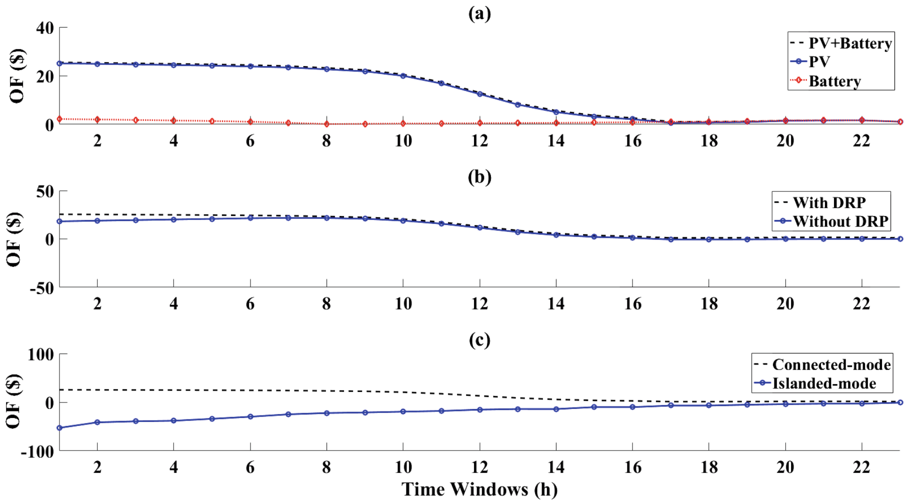

Fig. 3. Impact of (a) DERs and ESSs, (b) DRP and (c) connection state on Objective Function (OF) in HEM problems.

in the problem, while the objective function is alway positive in case (a) even after 17^{th} time-windows that the power generation of PV system equals zero. Additionally, Fig. 3(c) displays the influence of the connection state of the smart home to the power grid. As shown in Fig. 3(c), the objective function is negative in all time-windows because it is impossible for MASHES to sell electricity to the market. Hence, the effects of battery system is less obvious in case (c). Also, MASHES is faced spillage cost due to surplussing electricity generation of PV system, and load shedding cost.

5 Conclusions

The performance of the proposed HEM model has been evaluated based on the impacts of DERs, ESSs, DRP, and the connection state of the smart home to the power grid. From the simulation, considering DRP and the battery system increases the amount of the objective function. However, the influence of DRP in this case is more evident. Besides, the objective function is negative in all time-windows when the smart home is in islanded- mode. In our future work, the control unit will be added to the predictive dispatch system to control noises due to inaccuracy of prediction outputs in real-time operation.

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Smart City: A GECAD-BISITE Energy Management Case Study

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Abstract. This paper presents the demonstration of an energy resources management approach using a physical smart city model environment. Several factors from the industry, governments and society are creating the demand for smart cities. In this scope, smart grids focus on the intelligent management of energy resources in a way that the use of energy from renewable sources can be maximized, and that the final consumers can feel the positive effects of less expensive (and pollutant) energy sources, namely in their energy bills. A large amount of work is being developed in the energy resources management domain, but an effective and realistic experimentation are still missing. This work thus presents an innovative means to enable a realistic, physical, experimentation of the impacts of novel energy resource management models, without affecting consumers. This is done by using a physical smart city model, which includes several consumers, generation units, and electric vehicles.

Keywords: Energy resource management · Optimization · Physical models · Smart cities smart grids

1 Introduction

Smart cities are one of the trending topics in the global research agenda. A smart city concept is the combination of ICT solutions, government policies and society involvement. As defined by the IEEE Smart Cities group a smart city has the following characteristics [1]: a smart economy, smart mobility, a smart environment, smart people, smart living and smart governance. With the increasing population and urbanization, the availability of natural resources will be significant problem. Based on [2], today cities

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are occupied by 51% of population, but consume 80% of the resources. The accelerating growth of cities and their disproportionate consumption of physical and social resources is addressed by the United Nations to be the greatest challenge.

The European Union (EU) is mostly concerned about the eventual fuel based primary source shortage, and hence the impact of electricity use in the environment is presently taken as very serious at scientific, economic and politic levels [3]. These concerns have led to intensive research and to new energy policies envisaging the increased use of renewable energy sources for electricity production and increased energy use efficiency. The EU has, in fact, assumed a pioneer and leading role in energy matters, namely in what concerns the increase of renewable energy sources. EU as a whole has committed to reach its 20% renewable energy target for 2020 [4]. Moreover, in 23 October 2014, EU leaders agreed on setting a revised target for increasing the share of renewable based energy to at least 27% of the EU's energy consumption by 2030 [5]. The EU presents even more ambitious targets for 2050, with the commitment to reduce emissions to 80–95% below 1990 levels [6].

Such ambitions targets demand that energy resources are managed in a completely different way from what was usual so far. In this scope, the Smart Grid (SG) paradigm arises, as the most commonly accepted solution for this problem [3]. The distributed management approach supported by SG boosts the emergence of several innovative energy resource management approaches. The penetration of a large number of electric vehicles is one of the most important topics in this domain, due to the large dimensionality that it brings to the optimization problem. This problem is usually solved using meta-heuristics, namely with simulated annealing in [7] and with a novel multi-dimensional signaling method, in [8], just to name a few. A solid survey on this theme can be consulted in [9]. The impact of different sources of uncertainty is also broadly explored, such as the work presented in [10]. Although a significant amount of work is being done in this domain, the large majority of the performed studies are conducted solely under simulated environmental settings. This is mostly because SG are still an emerging reality, and thus, practical implementations are still not sufficiently widely spread. Even when considering the real implementations that are available, the execution of innovative experimental studies is difficult, because of the implications on the several users that are present in the real environment.

In order to surpass these hurdles, this paper presents an experimental study of an innovative energy resources management approach, in a smart city environment, using a laboratorial physical model of the city. The considered model is located in a BISITE laboratory, and departs from a previous implementation, done in collaboration with IBM as a product for Vodafone. This model has been developed to show how their real services work. So, different requirements about the communication protocol have been set (MQTT messages with a specific frequency and format) in order to be integrated with their IOC software [11]. These models have already allowed the demonstration of different studies, namely: waste trucks routing optimization, home care, public lighting services, and citizens' active participation. The model has been updated to include energy generation systems like solar panels and wind energy generators, so as to allow being used for the demonstration of energy management resources on the scope of the DREAM-GO project [12], specifically, the work presented in this paper.

After this introductory section, Sect. 2 presents the proposed energy resources management optimization model. Section 3 presents the case study using a real model of a Smart City and the results are presented in Sect. 4. Finally, in Sect. 5, the most relevant conclusions are presented.

2 Proposed Method

The prosed method deals with the optimal scheduling of the available resources in a Smart City (SC) context. The optimization model considers the energy sell or buy from the external suppliers or market. The Smart City Operator (SCO) that acts in behalf of its consumers, will sell or buy electrical energy taking into account the available resources. 24 periods of the day-ahead scheduling are used in the proposed method.

$$\textit{Minimize}$$

$$OC = \sum_{t=1}^{T}\sum_{b=1}^{B}\left[\begin{array}{l} \sum\limits_{sp=1}^{SP} P_{(sp,b,t)}^{Main} \times C_{(sp,b,t)}^{Main} \\ + \sum\limits_{g=1}^{G}\left(\begin{array}{c} P_{(g,b,t)}^{Gen2} \times C_{(g,b,t)}^{Gen\_A} + P_{(g,b,t)}^{Gen} \times C_{(g,b,t)}^{Gen\_B} \\ + C_{(g,b,t)}^{Gen\_C} \times X_{(g,b,t)}^{Gen} + P_{(g,b,t)}^{EAP} \times C_{(g,b,t)}^{EAP} \end{array}\right) \\ + \sum\limits_{c=1}^{C}\left(P_{(c,b,t)}^{NSD} \times C_{(c,b,t)}^{NSD}\right) \\ + \sum\limits_{v=1}^{V}\left(P_{(v,b,t)}^{EV\_Dsc} \times C_{(v,b,t)}^{EV\_Dsc}\right) \\ - \sum\limits_{m=1}^{M}\left(P_{(m,b)}^{Market} \times C_{(m,b)}^{Market}\right) \end{array}\right] \tag{1}$$

Below it is presented de constraints of the proposed method. Equations (3), (6) and (7) present the EV technical limits for each period t. The generation units' limits are described by Eqs. (4) and (5).

2.1 Equality Constraints

- Power balance in each period t and in each bus b.

$$\begin{aligned} &\sum_{sp=1}^{SP} P_{(sp,b,t)}^{Main} + \sum_{g=1}^{G}\left(P_{(g,b,t)}^{Gen} - P_{(g,b,t)}^{EAP}\right) \\ &\quad - \sum_{c=1}^{C}\left(P_{(c,b,t)}^{Demand}\right) + \sum_{v=1}^{V}\left(P_{(v,b,t)}^{EV\_Dsc} - P_{(v,b,t)}^{EV\_Ch}\right) - \sum_{m=1}^{M} P_{(m,b)}^{Market} = 0 \\ &\qquad \forall t \in \{1,\ldots,T\}; \\ &\qquad \forall b \in \{1,\ldots,B\}; \\ &\qquad \forall m \in \{1,\ldots,M\}; \end{aligned} \tag{2}$$

- EV battery balance determined by the energy remaining from the previous period, the trip demand and charge/discharge in the current period.

$$\begin{aligned} E^{EV}_{(v,b,t)} &= E^{EV}_{(v,b,t-1)} + P^{EV\_Ch}_{(v,b,t)} \times \Delta t \times \eta_{Ch} \\ &-P^{EV\_Dsc}_{(v,b,t)} \times \Delta t \times \frac{1}{\eta_{Dch}} - E^{EV\_trip}_{(v,t)} \qquad \forall t \in \{1,\ldots,T\}; \\ &\qquad\qquad\qquad\qquad\qquad\qquad\qquad \forall b \in \{1,\ldots,B\}; \\ &\qquad\qquad\qquad\qquad\qquad\qquad\qquad \forall v \in \{1,\ldots,V\} \end{aligned} \tag{3}$$

2.2 Inequality Constraints

- Generation units limits in each period t.

$$P^{MinGen}_{(g,b,t)} \leq P^{Gen}_{(g,b,t)} \leq P^{MaxGen}_{(g,b,t)} \quad \begin{aligned} &\forall t \in \{1,\ldots,T\}; \\ &\forall b \in \{1,\ldots,B\}; \\ &\forall g \in \{1,\ldots,G\} \end{aligned} \tag{4}$$

- Main network supplier maximum limit in each period t.

$$P^{Main}_{(sp,b,t)} \leq P^{MaxMain}_{(sp,b,t)} \quad \begin{aligned} &\forall t \in \{1,\ldots,T\}; \\ &\forall b \in \{1,\ldots,B\}; \\ &\forall sp \in \{1,\ldots,SP\} \end{aligned} \tag{5}$$

- Vehicle charge and discharge are not simultaneous.

$$\begin{aligned} &X^{EV}_{(v,b,t)} + Y^{EV}_{(v,b,t)} \leq 1 &&\forall t \in \{1,\ldots T\}; \\ & &&\forall b \in \{1,\ldots,B\}; \\ & &&\forall v \in \{1,\ldots,V\}; \\ &X^{EV}_{(v,b,t)} \ and\ Y^{EV}_{(v,b,t)} \in \{0,1\} && \end{aligned} \tag{6}$$

- Charge and discharge limit for each storage unit considering the battery charge rate and battery balance.

$$\begin{aligned} &P^{EV\_Ch}_{(\mathrm{v},b,t)} \leq P^{MaxEV\_Ch}_{(\mathrm{v},b,t)} \times Y^{EV}_{(v,b,t)} && \\ &P^{EV\_Dsc}_{(\mathrm{v},b,t)} \leq P^{MaxEV\_Dsc}_{(\mathrm{v},b,t)} \times X^{EV}_{(\mathrm{v},b,t)} &&\forall t \in \{1,\ldots,T\}; \\ &P^{EV\_Dsc}_{(\mathrm{v},b,t)} \times \Delta t \leq E^{EV}_{(\mathrm{v},b,t-1)} &&\forall b \in \{1,\ldots,B\}; \\ &P^{EV\_Ch}_{(\mathrm{v},b,t)} \times \Delta t \leq E^{EV}_{(\mathrm{v},b)} - E^{EV}_{(\mathrm{v},b,t-1)} &&\forall s \in \{1,\ldots,V\} \end{aligned} \tag{7}$$

3 Case Study

The following case study will demonstrate the use of the proposed methodology. The SC have 14 buses as can be seen in the one-line diagram presented in Fig. 1a. Figure 1b shows the real model of the Smart City. The SC distribution power network has 15 kV with one feeder. As can be seen the network is completely meshed but radiality operated.

The SC has: 1 shopping mall – installed power: 1,500 kW; 1 hospital – installed power: 800 kW; 1 fire station – installed power: 600 kW; 15 individual houses – installed power: 190 kW; 7 office buildings: installed power: 555 kW; 3 EVs – 2 cars (25 kW each) and 1 waste truck (250 kW); 1 wind farm (2 wind generators with 1,000 kW each); 1 PV power station (2 PV units with 250 kW each); 1 waste to energy power station (500 kW); 1 power plant (external supplier – 5,000 kW); 5 PV panels for individual houses (3.68 kW each); 7 PV panels for office buildings (11.04 kW each).

For the period 1 the two EV cars are located in bus 4 and the waste truck in the bus 3. Table 1 shows the location of each building type in the Smart City.

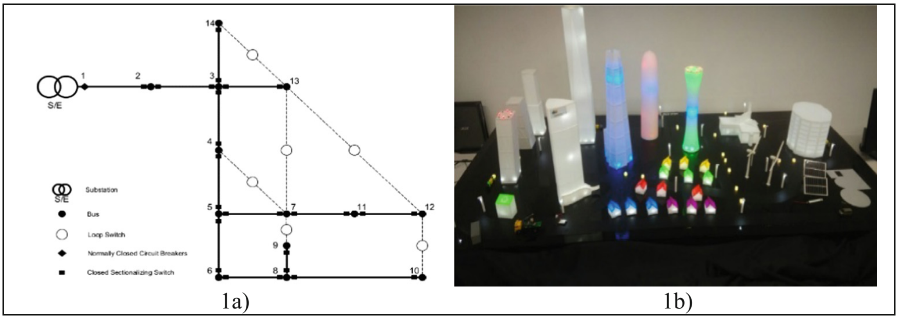


Fig. 1. (a) Smart City one-line diagram. (b) Smart City real model

Table 1. Smart City building type location

Bus	Building type
1	External supplier
3	Wind farm
3	PV power station
4	Individual houses
5	Waste to energy power station
6–12	Offices
13	Shopping mall
14	Hospital
14	Fire station

The considered prices are 0.02 m.u./kW for PV, 0.09 m.u./kW for wind power, 0.04 m.u./kW for waste-to-energy power, 0.10 m.u./kW for the external supplier and 0.15 m.u./kW for V2G discharge. Charge of V2G is considered 0.13 m.u./kW. The initial state for vehicles was considered randomly in the beginning of the day.

All loads with exception of the hospital and fire station are allowed to use incentive-based demand response programs, considering a remuneration for customers to reduce their load at maximum until 20% of the initial load. The incite value is 0.09 m.u./kW.

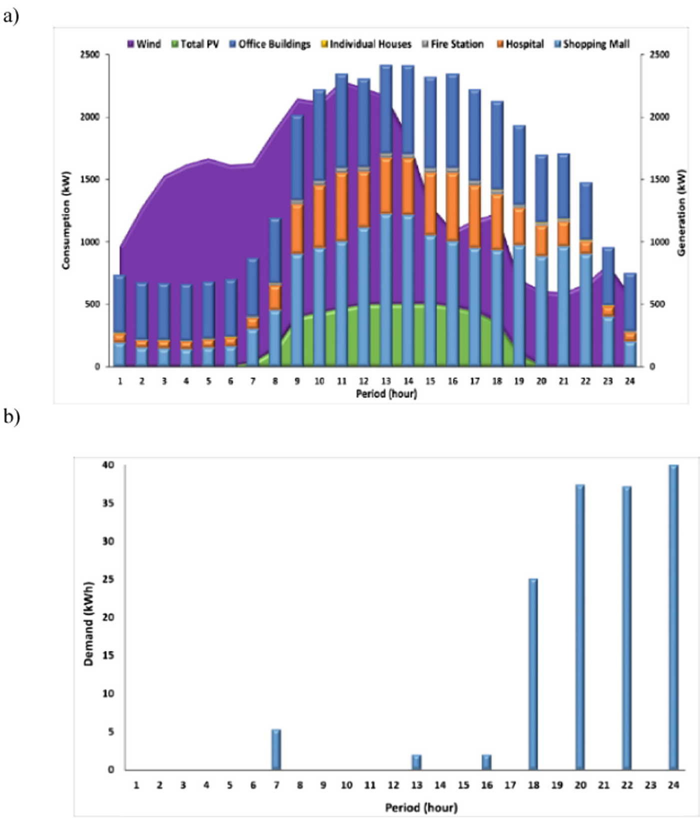


Fig. 2. (a) Forecasted load consumption (by type), PV and wind power profile. (b) Forecast for EVs trip demand

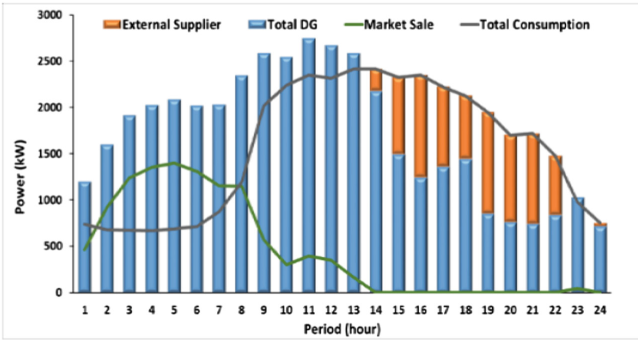
Figure 2a presents the forecasted power demand for each type of building as well as the solar and wind generation profile in the SC, not considering the EVs load. It can be seen that the peak load is expected at afternoon periods due to the great contribution of shopping mall, hospital and office buildings. Figure 2b shows the forecasted EVs' trip demand in kWh. The tool presented in [13] was used to generate the scenarios. Most trips occur at due to a great contribution of the waste truck.

4 Results

The optimization method and simulations were performed in MATLAB 2014a 64-bit using the TOMLAB software [14]. A computer with one processor Intel Xeon E5-2620v2 2.10 GHz with twelve cores, 16 GB of random access memory, and Windows 10 Professional 64-bit operating system was used.

In order to compute the proposed method, the algorithm took around 0.65 s. The result of the objective function, i.e., the final cost is 30.12 m.u.

a)



b)

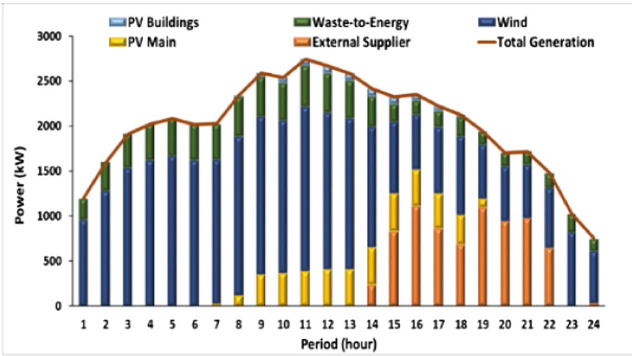


Fig. 3. (a) Power supplied scheduling. (b) Power supplied scheduling by generator type

Figure 3a presents the power supplied by the external supplier and the all distributed generators considered in the case study. It can also be seen the results for the energy sold to the market and the values for the total consumption. It is important to note that the total consumption considers also the EVs charge. These results are for the 24 periods under study. One can see that the external supplier is required at the begging of the afternoon until the night. In these periods the DG power generation decrease and the demand remains higher. Also, it is possible to see that in early morning exists an excess of generation. Due to this, the model considered that exist an advantage to sell the remaining power to the market.

As can be seen in Fig. 3b the generation by wind power has the higher contribution to supply all the demand. The wind power and waste-to-energy power are supplying in all periods. The main reason is related to their cost when compared with external supplier. Additionally, for the wind power, it is considered having dispatchable power.

Figure 4 depicts the scheduling for demand response (in this case study is was considered only the reduction program) and for EVs. The demand response program is verified in periods 20, 21, 22. The power reduced by the demand response program in each of those periods are: 220 kW, 240.19 kW and 13.41 kW respectively. Regarding to EVs scheduling it is only verified the charging and no discharging. It is possible to see in Fig. 4 that the EVs charging occur in periods 5, 6, 10, 12, 19, 21 and 23.

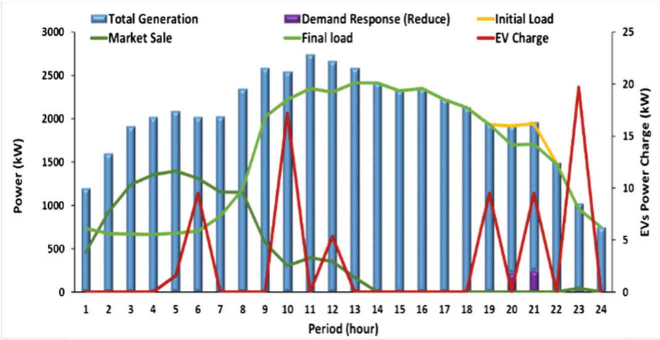


Fig. 4. Demand response and EV scheduling

5 Conclusions

This paper has presented a resource scheduling management approach applied to a physical smart city model environment. The Smart City Operator can use their resources at their optimal operating point while minimizing operation costs and obtaining more profit taking into account the several constraints associated with their resources and energy suppliers. This can be achieved with adequate resource scheduling algorithms as the method proposed in this paper.

The proposed method proved to be adequate to support the Smart City Operator in the operation field which can lead to operation costs reduction.

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Gravitational Search Algorithm Applied for Residential Demand Response Using Real-Time Pricing

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Abstract. This paper has as main objective the performance evaluation of the Gravitational Search Algorithm for Demand Response programs applied to residential consumers. For this purpose, it was considered a model that describes the consumption and energy price, according to the loads present in a residence. This way, it is intended to minimize the cost of electricity for final consumers based on an optimized planning of their loads at different times. In addition, it will be considered a variable cost of electricity over time (hourly price). In this sense, the cost of electricity will be discretized throughout the day. Finally, the performance of the Gravitational Search Algorithm for the considered model will be evaluated.

Keywords: Demand response · Gravitational Search Algorithm · Metaheuristic · Optimization · Smart grids

1 Introduction

One of the main functions of the Demand Response area is to ensure the minimization of the cost of electricity to consumers, encouraging them to plan their consumption in response to price changes over a period of time. In addition, this area emerged as a possibility to economically stimulate consumers, inducing them to use electricity more effectively. Therefore, it is expected that the methodologies focused on the context of Demand Response will enable the reduction of consumption, especially at peak times or when the reliability of the electrical system is compromised [1]. Thus, the Demand Response area plays a crucial role in the context of Smart Grids and in the energy markets [2]. Moreover, compared to the high value that is spent on the power systems infrastructure, the Demand Response can be considered as a low investment [3].

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In accordance with the aforementioned aspects, demand response programs can be divided into, basically, two groups [4]: based on the energy price, which are focused on the electricity market; and, based on consumer incentive, that analyze the loads and sources of energy.

It is noteworthy that demand response programs based on the energy price have the first objective to correlate the energy price to possible changes in the planning and usage profile of consumers' loads [4,5]. However, the benefits obtained by consumers through demand response programs can be optimized. Based on this premise, some researches have been devoted to characterizing the loads of the consumers and to use such information as a reference to integrate the energy consumption and thus to minimize energy price.

In [6], the authors propose an approach for demand response programs that is autonomous and distributed among consumers, taking advantage of a network communication infrastructure. Thus, another objective, besides minimizing the energy price, is to reduce the ratio between peak demand and average demand. It is noticed that this model takes into account a known function. So, this function considers the energy price throughout the planning horizon and the demand divided based on the consumers' loads.

The authors of [7] propose a robust demand response model that considers the uncertainty of energy usage during a 24-hour planning period. Thus, the utility informs the user about the price of the subsequent hour with a few minutes in advance. In this way, historical prices were used in the past hours to define the likely bands for the energy price in subsequent hours.

In the demand response model proposed by [8], the authors consider the consumption of electricity associated with each load used by the consumer and the forecast of the future energy price based on the price history on each day of the week. In addition, in the considered scenarios, the consumer has the option to set priorities for loads.

Following the above context, this paper intends to analyze the performance of Gravitational Search Algorithm using data provided by the Load Profile Generator (LPG) [9] software. Thus, the mathematical model proposed in [6] will be considered. It is worth mentioning that this paper will concentrate its efforts on a model of demand response based on the energy price, since one of the motivations of this choice is the current Brazilian energy scenario, which has operated in the red tariff rate since the beginning of the year 2015. Beyond that, the use of the Gravitational Search Algorithm is analyzed because of the practicality proportioned by this metaheuristic optimization algorithm, which have few parameters to set, does not make use of first and second order partial derivatives and is not dependent on the initial value of the iterative process.

The remaining of this paper is organized as follows. The simulated power consumption residential profiles, used as the basis for the parameterisation of the demand response optimization model, is presented in Sect. 2. The considered demand respond optimization model, proposed by [8], is briefly presented in Sect. 3. The fundamentals of the Gravitational Search Algorithm are presented in Sect. 4. Section 5 presents the results and discussions and, at last, Sect. 6 presents the conclusions and main contributions of this paper.

2 Simulated Residential Profiles

Several factors are capable of directly influencing the consumption profile of a residential consumer, among which it is possible to highlight: weather, time of year, loads used, presence of generators or energy storage (such as photovoltaic panels and batteries), number of residents, as well as the behaviour of these residents in relation to the energy consumption. In addition, the residential consumption profile has a more flexible characteristic compared to the industrial profile, allowing for adjustments and modifications by the consumer (without compromise their comfort).

In order to establish a reliable database consisting of consumption profiles for different scenarios of residential consumers, which are close to the current Brazilian scenario, the software LPG [9] was used. The LPG allows to configure the model of a residence with the desired load and profiles of residents. Thus, these profiles of consumption could be simulated in the desired period of time with a discretization of up to 1 min. It should be noted that the LPG is able to provide a complex modeling, taking into account the geographical location of the residence, time of year and temperature profile in the period of time evaluated.

Through the LPG, for the modeling of a residence with two adults and one child, it was possible to obtain a simulated consumption profile, using the loads described below:

- Bathroom - bulb lamps, hear dryer, and shower;
- Room - bulb lamp, video game console, and TV;
- Kitchen - bulb lamp, electric oven, food mixer, cooktop, microwave, electric clock, air purifier, juicer, food processor, toaster, coffee machine, electric kettle, electric fondue maker, refrigerator, and mixer;
- Living room - bulb lamp, computer, monitor, video game console, TV, printer, scanner, router, stereo, and notebook;
- Laundry - vacuum cleaner, washing machine, and electric iron.

3 Optimization Model

The optimization model to be considered in this paper is the one proposed by [6], where it is considered an autonomous and distributed demand response program. This program considers a certain group of nearby consumers, taking advantage of a bidirectional communication infrastructure that is a strong tendency of the Smart Grids.

Each consumer belonging to the group has an Energy Consumption Scheduler (ECS), responsible for making intelligent measurements, managing the flow of information between consumers and executing the algorithm to minimize the final cost of energy. It is noteworthy to mention that, in this model, the energy prices are communicated to the consumers with antecedence corresponding to the entire scheduling horizon. Therefore the optimization process does not require any price prediction method. Another objective of the proposed model is to reduce the Peak-to-Average Ratio (PAR), since the latter objective indicates the quantity of demand in the peak period. This, is a very important factor that contributes to increase or decrease the energy price.

By calling η the group of consumers fed by the same source, the number of consumers is $N \doteq |\eta|$. The discretization considered in this case is one hour. For each consumer $n \in \eta$, l_n^h denote the total energy consumption at the hour $h \in [1, 2, ..., H]$, where $H = 24$. Thus, the daily load profile for the user n is denoted as $l_n \doteq [l_n^1, ln^2, ..., ln^H]$. Based on these definitions, the total hourly consumption considering all the users can be computed as follows:

$$L_h \doteq \sum_{n \in \eta} l_n^h \tag{1}$$

The peak consumption and the mean daily consumption can be respectively computed as follows:

$$L_{peak} = max(L_h), h \in [1, 2, ..., H] \tag{2}$$

$$L_{mean} = \frac{1}{H} \sum_{h \in [1,2,...,H]} L_h \tag{3}$$

Thus, the peak to average ratio can be computed as:

$$PAR = \frac{L_{peak}}{L_{mean}} = H \frac{max(L_h)}{\sum_h (L_h)}, h \in [1, 2, ..., H] \tag{4}$$

For each consumer, A_n denotes the set of appliances present in the residence. Thus, for each load $a \in A_n$, the power consumption planning vector is given by $x_{n,a} \doteq [x_{n,a}^1, ..., x_{n,a}^H]$, where $x_{n,a}^h$ denotes the consumer's planned energy consumption n for the load a in hour h. In this way, the total hourly consumption of each consumer can be obtained as follows:

$$l_n^h \doteq \sum_{a \in A_n} x_{n,a}^h, h \in [1, 2, ..., H] \tag{5}$$

It is worth noting that in this model, daily energy consumption planning does not aim to change the total amount of energy consumed, but rather to manage and allocate it in order to reduce the PAR or minimize the total cost paid by the consumer. In this case, the consumer must select the start $\alpha_{n,a} \in [1, 2, ..., H]$ and the end $\beta_{n,a} \in [1, 2, ..., H]$ of a time interval in which each appliance can be triggered. The definition of these time intervals impose a set of constrictions to the power consumption planning vector, so the total daily consumption must occur within the set interval. Thus, the total daily consumption is defined as follows:

$$\sum_{h \in [\alpha_{n,a}, \beta_{n,a}]} x_{n,a}^h = E_{n,a} \tag{6}$$

$$x_{n,a}^h = 0, \forall h \in [1, 2, ..., H] \backslash [\alpha_{n,a}, \beta_{n,a}] \tag{7}$$

For each appliance, the use time defined by the consumer must be greater than the time interval required for the appliance to properly perform its function. It is possible to notice by (6) and (7) that, in order to maintain the energy balance, the consumption of all loads powered on must be equal to the sum of the total pre-set consumption of each load. Aditionally, the standby power consumption $\gamma_{n,a}^{min}$ and the maximum operating power consumption $\gamma_{n,a}^{max}$ are defined the for each appliance of each consumer. Thus:

$$\gamma_{n,a}^{min} \leqslant x_{n,a}^{h} \leqslant \gamma_{n,a}^{max}, \forall h \in [\alpha_{n,a}, \beta_{n,a}] \tag{8}$$

Finally, the minimization problem of energy costs can be represented as follows:

$$min(\sum_{h\in[1,2,...,H]} (p^h \sum_{n\in N} \sum_{\alpha\in A_n} x_{n,a}^h) + \lambda_{PAR} \max_{h\in[1,2,...,H]} (\sum_{\eta\in N} \sum_{\alpha\in A} x_{n,a}^h)), \tag{9}$$

where H denotes the set of hours belonging to the planning horizon; N denotes the set of residences belonging to the considered group; A_n denotes the set of loads belonging to the residence n; P^h is the energy cost in hour h; $X_{n,a}^h$ is the planned energy consumption for the residence n during hour h; and λ_{PAR} is a parameter used to weight the impact of PAR minimization on the fitness function. It is worth mentioning that in this paper, the value assigned to the parameter λ_{PAR} is equal to 1.

4 Foundations of Gravitational Search Algorithm

The Gravitational Search Algorithm (GSA) was introduced in 2009 by [10], which is based on the law of universal gravitation. In GSA, the search agents constitute a set of objects that interact with each other through Newton's gravitational force and the laws of motion.

In this way, all particles in the universe attract each other. In addition, the intensity of this attraction is a direct effect of the mass of the particles and the proximity between them. It is worth mentioning that the gravitational constant has a decreasing behaviour over time.

The GSA can be seen as an artificial universe of agents that obey the laws of universal gravitation and Newtonian mechanics. Therefore, agents with larger masses represent better solutions. In this sense, each agent of the GSA has two variables (position and mass). The position of each agent corresponds to a feasible solution of the problem, while the value of its mass is determined by means of the fitness function used. In this context, the better the agent's aptitude, the greater his mass, and consequently the greater the attraction he will exert on the other agents and the slower he will move through the search space. The mass of each agent is calculated according to the following equations:

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best_i(t) - worst(t)} \tag{10}$$

$$M_i(t) = \frac{m_i(t)}{\sum_{j=1}^{N} m_j(t)} \tag{11}$$

where $fit_i(t)$ denotes the fitness of agent i at iteration t; $worst(t)$ and $best(t)$ are the values of the worst and best fitness, respectively, obtained among all agents at iteration t.

At the iteration t, for each coordinate, the force that acts over the agent i because of the mass of the agent j is computed as follows:

$$F_{ij}^d(t) = G(t)\frac{M_i(t)M_j(t)}{R_{ij}(t)+\epsilon}[X_j^d(t) - X_i^d] \tag{12}$$

where $M_i(t)$ and $M_j(t)$ are the masses of agents i and j, respectively, at iteration t; G(t) is the value of the gravitational constant at iteration t; ϵ is a constant very close to zero; and $R_{ij}(t)$ is the Euclidean distance between agents i and j at iteration t.

With the intention of guaranteeing a stochastic characteristic to the algorithm, the component on the coordinate d of the acceleration force acting over the agent i is defined as a randomly weighted sum of all the components on the coordinate d of the forces exerted by the other agents:

$$F_i^d(t) = \sum_{j=1, j\neq i} rand \times F_{ij}(t) \tag{13}$$

where $rand$ is a random number within the interval [0, 1].

Consequently, the acceleration component of the agent i on the coordinate d at iteration t is computed as follows:

$$a_i^d(t) = \frac{F_i^d(t)}{M_i(t)} \tag{14}$$

This way, the velocity of agent i at iteration $t+1$ is equal to the sum of its current acceleration with a random portion of its velocity at the previous iteration (t):

$$v_i^d(t+1) = rand \times v_i^d(t) + a_i^d(t) \tag{15}$$

From the current velocity calculated by (15) and the position occupied by the agent in the previous iteration, its new position is then computed as follows:

$$X_i^d(t+1) = X_i^d(t) + v_i^d(t+1) \tag{16}$$

Thus, the optimization process performed by the GSA consists in adjusting the masses of the objects so that they move through the search space and, at the end of the iterations, occupy the position corresponding to the best solution. The GSA should follow a sequence of procedures presented on Fig. 1.

5 Results

In the analyzed test case, due to the fact that the optimization model considers all the appliances independently, the use time constraints $\alpha_{n,a} \in [1, 2, ..., H]$ and

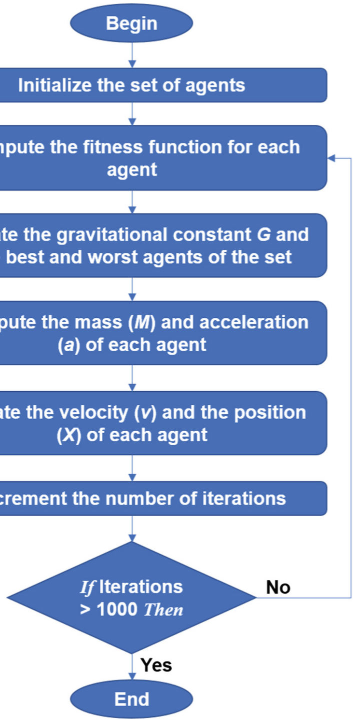

Fig. 1. Flowchart of the Gravitational Search Algorithm.

$\beta_{n,a} \in [1, 2, ..., H]$ for each one of the appliances $a \in A_n$ were defined based on the simulations conducted using the LPG. Beyond that, the test case has consisted on a group of three household, each one with 40 identical appliances. The considered energy prices was the hourly prices informed by the Iberian Energy Market Operator [11] in January 15^{th}. According to the number of residences, the number of loads, the power constraints and the use time constraints defined by Eqs. (6)–(8) based on the LPG simulated consumption profile presented in Fig. 2, it was possible to determine the size and limits of the search space used by the GSA agents. Each dimension of the search space represents the consumption of one of the 40 loads of one of the three residences in one of the 24 h of the planning horizon. In this way, the number of dimensions is equal to 2880. Thus, the GSA was empirically parameterized to have 50 agents and the stopping criterion is adjusted to 1000 iterations. The fitness function used in the GSA was the one that represents the minimization problem of energy costs (9). At the end of the iterations, the GSA returns the energy consumption planning matrix with the minimum price to be paid at the end of one day.

At this point, it is important to state that the novelty of this paper, compared with the work in [6], is the use of a metaheuristic optimization algorithm to minimize the energy cost and serve as a decision support tool for the end consumer.

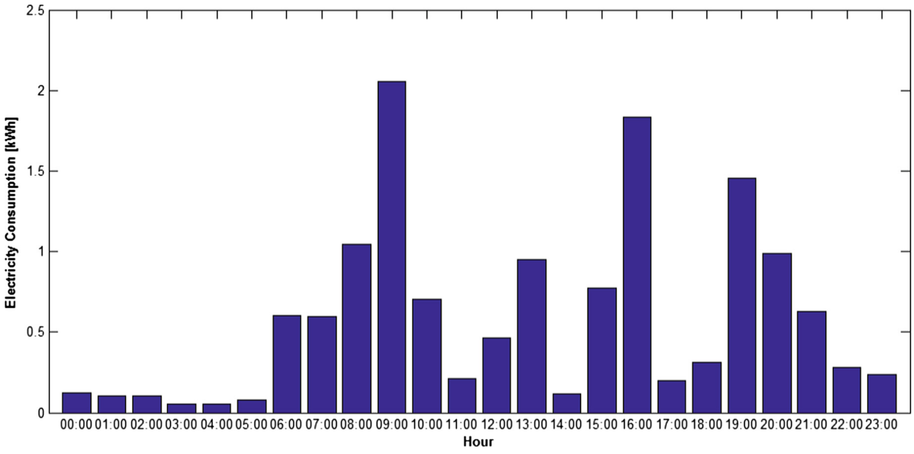

Fig. 2. LPG simulated consumption profile.

The optimized individual consumption planning of each residence of the group in question, obtained for the one-day planning horizon, can be observed in Fig. 3.

As can be seen from Fig. 3, the three residences belonging to the group have individual optimized schedules totally different from each other, with demand peaks at times other than the planning horizon. This characteristic is associated

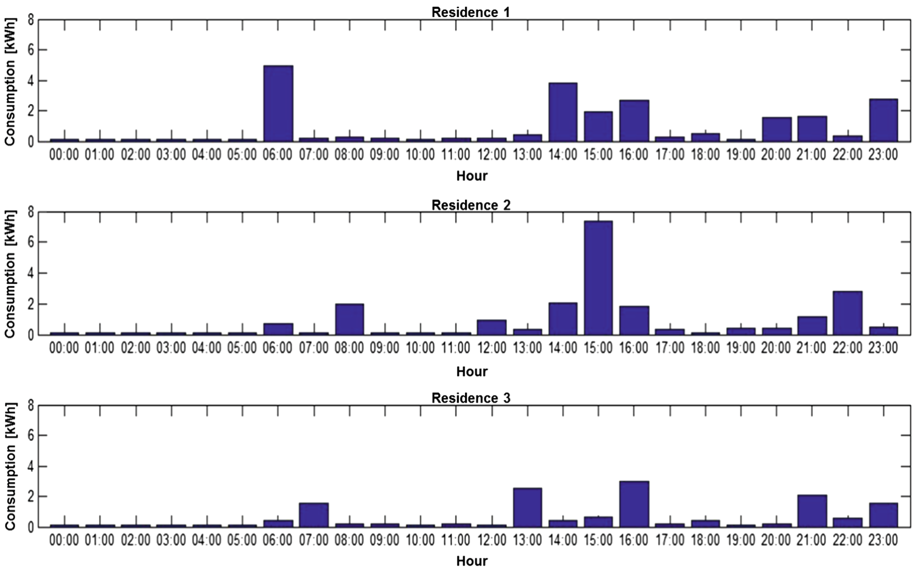

Fig. 3. Optimized planning of consumption for each residence.

with the fact that the model in question has as one of its objectives the minimization of PAR and, therefore, the concentration of consumption of the residences in a single peak time should be avoided. It should also be noted that the periods that comprise considerable consumption values comply with the range of use constraints imposed by the consumer, so that planning is performed considering not only the tariff values, but also the routine and preferences of the residents.

In turn, the optimized consumption planning for the whole group, obtained for the same planning horizon, can be observed in Fig. 4. In this figure, the upper bar graph indicates the total power consumption at each of the planning horizon hours. The lower graph of lines shows the hourly rates that were notified to the consumer.

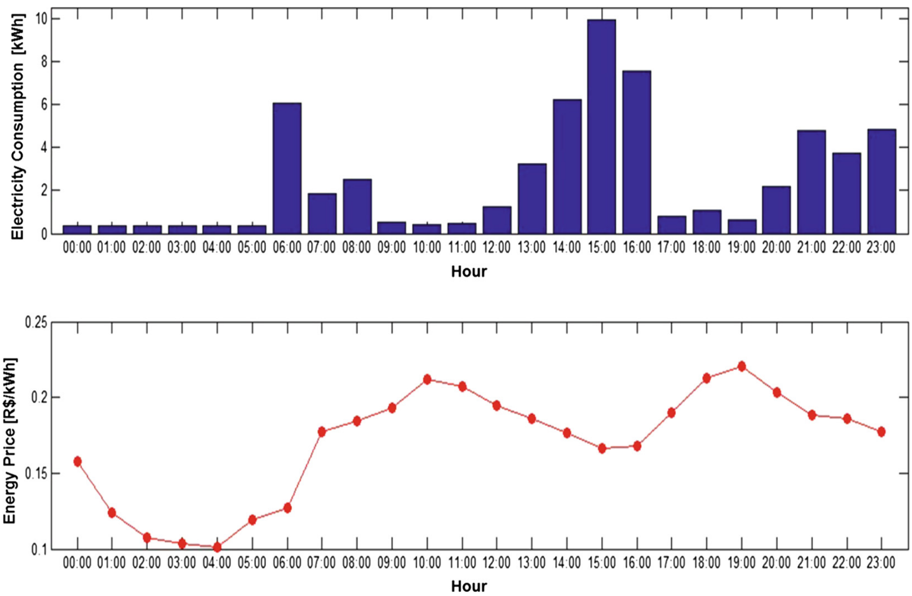

Fig. 4. Optimized planning of consumption for the group of consumers.

As shown in Fig. 4, the optimized planning of consumption for the group of consumers has a more uniform distribution than the individual plans analyzed in Fig. 3. This characteristic is consonant with the goal of minimizing PAR, since the uniformity of the distribution of consumption over the planning horizon results in a decrease in consumption at peak times. It is noted that the consumption trend observed in the optimized planning has a strong relation to the hourly values of the tariff. In this way, the schedules with the highest consumption concentration are precisely the feasible schedules (which respect the constraints imposed by the consumer) in which the value of the tariff presents a decrease. According to this trend, the peak consumption hour is at 3:00 p.m., coinciding exactly with the time at which the tariff presents its minimum value among the feasible schedules.

Based on the results analyzed, it is possible to affirm that the result obtained by applying the GSA to the demand response optimization model proposed in [6] was shown to be duly consistent with the variation of the tariffs paid for the energy consumption and with the reduction of consumption peaks through the minimization of PAR.

6 Conclusions

This paper presents an application of GSA to solve the demand response problem for residential consumers that use Real-Time Pricing. In this tariff structure, the energy price varies in short intervals of time and the consumer is usually notified about the prices on a daily or hourly basis. Due to the greater discretization of prices, Real-Time Pricing tariffs are the ones that best reproduce the volatility of energy prices. For this reason, this kind of tariff structure is generally considered to be very complex.

From the results obtained it was possible to note that the GSA proved to be a meta-heuristic with great potential for the proposed application. Optimized consumption schedules obtained through the application of the GSA in the optimization model proposed by [6] were able to minimize the energy price for a group of residential consumers. Moreover, the model still respects the comfort of the residents and minimizes peak demands. Finally, the main contribution of this paper is the formulation of the optimized consumption scheduling problem and then the specific study of the obtained results, aiming the demand response.

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Single Appliance Automatic Recognition: Comparison of Classifiers

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Abstract. Measuring and recording systems for the consumption of electrical energy which are connected to households, are essential in the optimization of energy use. Non-Intrusive Load Monitoring (NILM) is one of the most used techniques in the study of electrical consumption; these systems are based on the analysis of the load curve (the aggregated electrical consumption of the whole household). Thanks to a significant reduction in the price of sensors and sensor systems in recent years, it is possible to individually monitor each one of the devices connected to the grid. In this paper we compare different classifiers in order to find out which is the most appropriate for the identification of individual appliances attending to their consumption. In this way, we will know which electrical appliance is connected to a smart plug, helping to obtain more accurate and efficient load monitoring systems.

1 Introduction

In recent years, there has been a significant increase in the price of electricity, both for households and industry around the world. In some countries of the European Union, such as France or Germany, the price of electricity has increased by more than 40% in 2015 (in comparison to previous years). In the case of Spain, according to official data from Eurostat (the statistical office of the European Union) [1] between the second half of 2008 and the second half of 2014, the cost of electricity increased by 0.081 euros/kWh, which is the almost the double of the average increase recorded in the EU (0.042 euros/kWh). Controlling the electrical usage in both households and industry is a necessity if we want to manage energy costs efficiently. Monitoring the amount of electricity that is consumed by the elements connected to the grid, lets us establish which of them is the most energy demanding. Knowing this is essential for the reduction and optimization of energy consumption.

Current electrical installations do not provide a simple way to collect the consumption data from the different devices that are connected to the grid. Therefore, the most widespread monitoring techniques are based on the analysis of the whole household

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consumption, that is, the sum of all the individual consumptions that are produced by the connected devices. In order to obtain an estimated value for the different elements, data disaggregation techniques are used. For this reason, creating a system that allows for the automatic detection and classification of household appliances is important for analyzing energy consumption.

Most electrical consumption disaggregation methods are designed to detect switch on/off events of a single appliance. But the reality is that multiple devices can be activated or deactivated simultaneously. Therefore, disaggregation of consumption can be complicated by the simultaneous switch on/off of multiple devices. This technique is known as Non-Intrusive Appliance Load Monitoring (NIALM). One of the first approaches regarding NIALM systems was introduced in the late 1980s by George Hart at MIT [2]. Since then, the NIALM systems have evolved, improving the capacity of disaggregation and reducing their dependency to activation and deactivation events of the devices [3, 4].

In recent years, the cost of technology production has fallen significantly. This has led to new phenomena such as Internet of Things (IOT) [5]. The devices and objects around us are more connected and accessible through the grid each day. There are already devices that are able to monitor the individual consumption of different appliances in real time, sending this data wirelessly. These devices are called Smart Power Plugs. Thanks to these new devices, it is easier to monitor the electrical consumption of certain devices without turning to NIALM systems. The individual consumption profile of the connected appliances can serve to improve the accuracy of NIALM systems.

In this work we show an evaluation and comparison of different classifiers in order to obtain the highest precision when identifying which electrical appliance is connected to a Smart Power Plug. Classifiers based on different algorithms such as fuzzy logic, probabilistic models or neural networks have been used. To perform the tests, real consumption data has been used by installing smart plugs, which are connected to a central node through ZigBee-This central node retrieves the consumption data of all the devices. In this study, we gathered consumption data for seven months, from three different appliances in the same household.

The rest of the paper is organized as follows: Sect. 2 reviews the state of the art on appliance classification; Sect. 3 describes the dataset used in this work; Sect. 4 shows the used algorithms and a comparison of their performance and Sect. 5 shows up the conclusions and future lines of work.

2 Background

Several studies have dealt with the classification of household appliances through their load curve. For example, authors in [6] present a system that provides real-time appliance recognition, based on a single energy monitor –using Zigbee technology-which is connected to the main electrical unit. The system generates consumption profiles for each device, recognizes the different profiles in real time using neuronal networks and is fed with additional information which is provided by the users. In [7] authors propose a new method for the classification and identification of residential appliances. This appliances classification method uses the main power consumption and the performance style as the characteristics of each device. Subsequently, an appliance identification platform is designed and implemented with these characteristics.

Authors in [8] have developed a system which is able to automatically recognize home appliances according to their electrical consumption profile, that is measured in low frequency with low end sensors. This system is based on the traditional machine learning approach. The system uses the consumption profiles from a set of appliances as training data. Authors achieved a classification success rate of 85%.

In the case of [9], authors propose a time-based classifier which first identifies the appliances, and then predicts the future use of those appliances which use a big amount of energy within the household. To that extent, authors propose a new set of meta-characteristics to be included. Their results have been validated with a dataset containing data from 100 houses that have been monitored during one whole year.

In [10], it is stated that the best approach in order to model the appliances classification problem is the use of bottom-up methodologies. These methodologies build the load curve from an elementary entity such as a domestic appliance, the end-use or even the household and aggregate it at the desired modelling level. Through the study of three appliances, authors discuss their main particularities, which are the most influential properties in the individual energy demand. Once these particularities are defined, authors apply the proposed methodology in order to identify similar curves in the consumption.

Authors of [11] use Hidden Markov models to identify different devices at the same time. The independent changes in the active power of each device are described by each Markov chain. With the active power measurements of a single Smart meter, it is required to calculate the hidden variables that define the possible states of the different appliances. In conclusion, the authors conclude that the probabilistic model allows for the identification of appliances that work simultaneously.

The mentioned works have been conceptualized as NILM systems; therefore, they are based on data obtained from the general consumption of the household, registered by a smart meter. This paper proposes the identification of appliances attending to their power demand profile. In this case, instead of using a single smart meter for the whole grid, single smart plugs are used individually for each appliance. The use of this kind of devices allows to create the consumption fingerprint of the appliances, so it can later be used to automatically recognize them with no user interaction. Similar topics are dealt with in previous works such as [12] or [13].

3 Used Dataset

3.1 Data Acquisition

The dataset which has been used when carrying out this research was provided by the Portuguese company Virtual Power Solutions (VPS). This company offers various products that are designed to monitor the electrical consumption of both households and industrial clients.

In the scope of this study, the used devices belong to three different groups: Cloogy® Plug Power (Fig. 1a) which were connected through wireless Zigbee technology to a Cloogy® Smart Hub (Fig. 1b), which, in turn, was connected to a central server. This central server was responsible for storing the received data. The data was collected from 05/05/2016 to 30/11/2016 in a single household, obtaining data from three different Cloogy® Plug Power, that were connected to three appliances: a fridge, a washing machine and an electric heater.

(a) (b)

Fig. 1. Devices from VPS company. (a) Smart plug. (b) Smart Hub

3.2 Dataset

The Smart Plug sends the accumulated consumption data to the central hub every 15 min, providing a total of 96 records per day and appliance. Each row of the generated dataset file corresponds to the electrical consumption of one of the appliances during one day. Each row has 97 columns; the first 96 gather the electrical consumption of the appliance for each measure, while the last one establishes to which appliance does the file correspond. Since we record three different appliance consumptions, the periodicity with which consumptions are recorded in the dataset is different. In the case of the fridge, there is a quasiperiodic consumption and magnitude throughout the day. For this appliance, user interaction does not significantly modify the consumption curve; while in the case of the other appliances -electric heater and washing machine-, user interaction does directly modify the consumption curve. The electric heater is only activated when the user activates it, and consumption frequency cannot be known, the same goes for the washing-machine. The user decides when to switch it on and, does it without a predictable frequency. In addition, the washing machine can be used in different modes (more or less powerful washing modes, using hot or cold water, etc.), it also goes through different cycles while being used.

During data collection, in the case of the fridge, consumption measurements were made every day. In contrast to the rest of appliances, since their activation directly depends on the user, there were no consumption measurements for those days when the user did not use these appliances. In order to evaluate the effect of including empty values -for those days where no activity was recorded-, two different datasets were generated. The first dataset contained raw data, including those days with no consumption measurements from any of the appliances, and the second dataset which eliminated empty values, including only the days where activity was registered.

3.3 Appliances Comparison

As mentioned in the previous section, the three analyzed appliances present different usage patterns. Therefore, it was decided to perform the comparison between them since they operate differently and users use them in different ways.

The fridge is one of those appliances which are essential in every home. The consumption type of this device is characterized as being continuous along the day. As can be seen in Fig. 2, the fridge has an average of 12 daily activations independently of the external factors. Weather (a higher temperature implies a higher consumption in order to keep food cold) or human intervention (opening the door or placing new food) can vary the consumption, but under normal conditions, the consumption cycle barely varies.

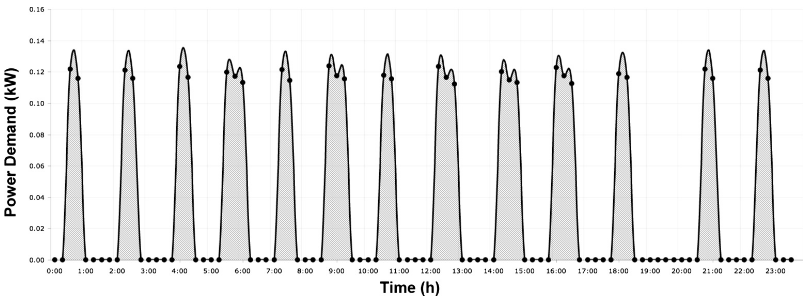

Fig. 2. Daily consumption of a fridge

In contrast, the consumption of a washing machine is not continuous and exclusively depends on the user actions that generate consumption. In some households, the switching on of an appliance happens more or less at the same times, however, this will always depend on the family's habits. In any case, it is not a predictable or periodic consumption. In addition, current washing machines can be programmed with different functions, such as an intensive wash or a high temperature wash (which means an increase in energy consumption). Figure 3 shows a consumption chart of the energy consumption of a washing machine during 24 h. As it can be observed, the appliance has been connected at three different times, and for each of this periods, the load curves are somewhat different.

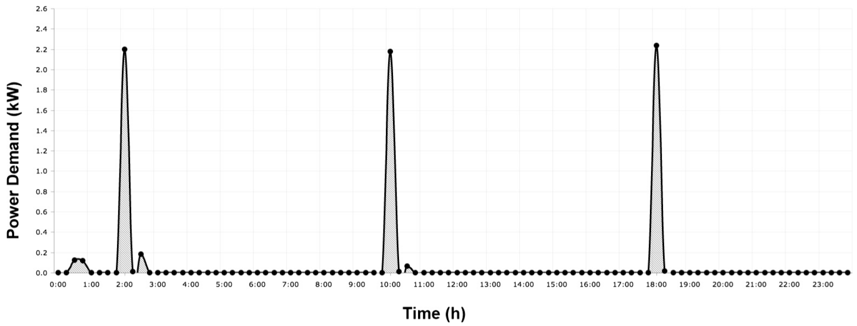

Fig. 3. Daily consumption of a washing machine

We finally analyze the electric heater, which as well as the washing machine is user-dependent. It is a difficult appliance to be temporally classified. Its use varies depending on the outside temperature, the season of the year and the intensity with which it is used. In Fig. 4 we can see the consumption produced by this appliance during a 24-hour period. In this figure, we can observe how the electric heater has been connected five times. Four of these connections present a similar consumption pattern, while one of them shows a substantially higher demand of energy.

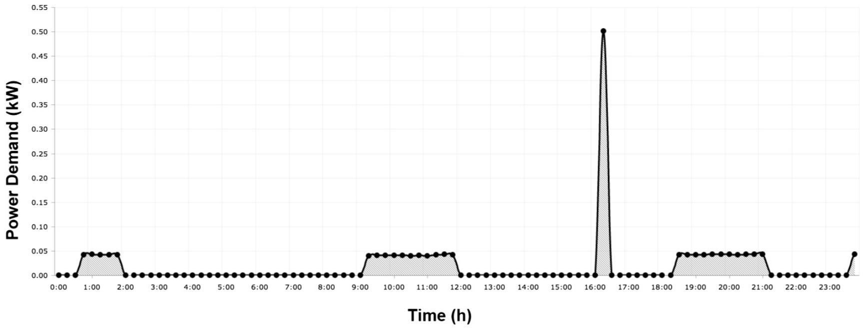

Fig. 4. Daily consumption of an electric heater

4 Experiments, Comparisons and Results

In this section we analyze the results of the used algorithms. We have followed several steps: firstly, we have applied the classification methods with each pair of appliances (fridge and washing machine, fridge and electric heater and washing machine and electric heater), and we have then applied those methods classifying the three appliances at the same time. The used algorithms were: bayesian network, naivebayes, random forest, random tree, REPtree, decision stump, hoeffding tree, J48, logistic model tree and gradient boost.

In order to validate the performance of the classifiers, we analyze different **Cohen's kappa coefficient**, which is a statistic that measures inter-rater agreement for qualitative (categorical) items. It is usually thought to be a more robust measure than simple percent agreement calculation, since κ considers the possibility of the agreement occurring by chance. Table 1 shows evaluation the of Kappa coefficient:

Table 1. Evaluation of Kappa coefficient

Evaluation of Kappa coefficient	
K value	Level of agreement
<0.20	None
0.21–0.39	Minimal
0.40–0.59	Weak
0.60–0.79	Moderate
0.80–0.90	Strong
Above 0.90	Almost perfect

During the validation of results, on the one hand a 10 fold-cross validation iteration was performed and, on the other hand, a division of data with 66% of data for training and 33% of data for testing.

In summary, we present the kappa statistic for each algorithm and dataset. This is a representative statistic, since it represents the level of agreement of the classifier (Tables 2 and 3).

Table 2. Algorithms performance with 10 fold cross-validation

	All data	All data (no empty data)	Washing machine and electric heater	Fridge and electric heater	Fridge and washing machine
Bayes Net	0.4924	0.7703	0	1	1
Naive Bayes	0.5744	0.5479	0.2949	0.9404	0.6623
Random forest	0.6903	0.7867	0.4828	1	1
Random tree	0.5384	0.6807	0.3802	0.9097	0.8063
REPtree	0.4292	0.6807	0	0.8339	0.7253
Decision stump	0.2909	0.3973	0	0.5594	0.559
Hoeffding tree	0.4313	0	0	0.9399	0.5134
J48	0.5078	0.6077	0	0.9549	0.8802
Lmt	0.4241	0.5799	0	0.9399	0.7253
Gradient boost	0.46744	0.78263	0.11372	0.96988	0.88862

Table 3. Algorithms performance with percentage split (66%)

	All data	All data (no empty data)	Washing machine and electric heater	Fridge and electric heater	Fridge and washing machine
Bayes net	0.2971	0.7573	0	1	1
Naive Bayes	0.6058	0.5747	0.3296	0.9539	0.6057
Random forest	0.6208	0.7812	0.4696	1	1
Random tree	0.4495	0.6023	0.3581	1	0.6964
REPtree	0.4417	0.6393	0	0.9091	0.7829
Decision stump	0.3187	0.2996	0	0.5594	0.5036
Hoeffding tree	0.4127	0.2996	0	0.9109	0.4068
J48	0.4417	0.6004	0	0.8643	0.6395
Lmt	0.3459	0.5609	0	0.9552	0.7829
Gradient boost	0.4045	0.7637	0.323170	1	0.93499

5 Conclusions and Future Lines of Work

In the view of the results, we can conclude that all the classifiers have been more accurate when classifying the fridge than any other appliance, as expected a priori, since the load curve of the fridge is more representative than the other appliances in the dataset, since it is continuously working and it has a more or less periodical consumption, while the other appliances are turned on by the householder, and the consumption fingerprint is not as representative as the fridge one. When classifying the fridge individually against the electric heater and the washing machine, we can say that all the algorithms have shown a better performance in the case of the electric heater, since the kappa statistic values denote a strong level of agreement. In the case of the washing machine, the classifiers performance has been slightly worse, but still reaching a moderate level of agreement.

Whereas, the worst results have been obtained when classifying the washing machine against the electric heater, as the kappa statistic points out the minimal or poor level of agreement of the majority of algorithms.

When we have faced the classification of all the appliances together, the results were not as good as we could expect, and the different performances oscillate in the different algorithms, obtaining a range of the kappa statistic results that vary from minimal to moderate levels of agreement.

Based on these results, we realized that it would be impossible to classify the appliances which may have periods of no electrical consumption along the day, because it is not possible to classify them, this no-value data is just noise for the classifiers, making their performance significantly lower. We proceeded to omit the data of the washing machine and the electric heater, for those days where there was no electrical consumption. After removing this data, we applied the classifiers once again (to all the three appliances together), and the results improved significantly.

In order to improve the obtained results, we plan to follow this research line, making additional investigation: although some of the algorithms have shown a good performance when classifying the appliances, the input data is still very time-dependent, that is to say that the specific moment of the day when an appliance is used, establishes to a large extent the proper classification of the appliance. So, in order to improve the performance of the algorithms, the extraction of new variables from the dataset is necessary, including: (i) from consumption data: maximum value, total consumption, mean, variance, standard deviation, interquartile range, number of activation periods (number of times when an appliance has been working along the day), average duration of the activation periods, total duration of the activation periods, (ii) others: maximum and minimum temperatures, day of the month, day of the week, month.

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Non Intrusive Load Monitoring (NILM): A State of the Art

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Abstract. The recent increase in smart meters installations in households and small bussiness by electric companies has led to interest in monitoring load techniques in order to provide better quality service and get useful information about appliance usage and user consumption behavior. This works summarizes the current state of the art in Non Intrusive Load Monitoring from its beginning, describes the main process followed in the literature to perform this technique and shows current methods and techniques followed nowadays. The possible application of this techniques in the context of ambient intelligence, energy efficiency, occupancy detection are described. This work also points the current challenges in the field and the future lines of research in this broad topic.

Keywords: NILM · ILM · Dissagregation · Ambient intelligence · Load monitoring · HMM · LSTM

1 Introduction

The operating condition of appliances used in such different scopes such as home, industry and commerce cannot be truly determined without the proper monitoring system. The main purpose of load monitoring techniques is to ease the conservation of energy consumption through different approaches like appropriate timing of appliance usage, optimization in their usages and getting rid of unwanted activities producing unnecessary energy consumption. These purposes can be achieved showing to the inhabitants of a house the consumption of each appliance in the sum of the total billing for detect malfunction or excesses in some of them [5]. In addition, it could be possible notify to users of possible savings in their billing deferring their main loads when the price of electricity is low. Contrary to this, Kelly et al. [19] argue in a study that it is not proven yet that these additional feedback lead to savings. Recently there is an evident increase

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in micro grids and continuous growth of renewable energy facility installation, so to add quality to these saving efforts, more energy measures need to be collected in order to monitor, automate and manage the power system.

In general terms, the load monitoring is the process of identifying and acquiring the load measurement in a power system [1]. This load monitoring will determine the consumption and appliances' status, in order to comprehend the behavior of individual loads in the whole system.

Depending on the approach used to monitor the appliance monitoring it can be *Intrusive Load Monitoring (ILM)* or *Non-Intrusive Load Monitoring (NILM)*:

– **Intrusive Load Monitoring**: This term covers all those approaches that propose to deploy a measurement device for each appliance or load under interest. The need of several measurement devices in the ILM ecosystem makes it expensive and hard to maintain, install and expand. The term intrusive means that the metering device is located in the habitation, close to the appliance being monitored. As mentioned in [37] there are subclassifications depending on the level of intrusion:

  1. *ILM 1* relies on sub-meters that typically measure the consumption, of a zone of the house, placing it at the circuit breaker level.
  2. *ILM 2* uses metering devices placed at plug level, so one device can monitor one or more appliances at the same time.
  3. *ILM 3* uses metering devices placed at appliance level.

  The above explained reasons, led the introduction of a non-intrusive variant of the method with much lower cost.

– **Non-intrusive Load Monitoring**: These approaches consist of processes in which given data coming from the whole house consumption, typically by installing a metering device at panel level which infers what appliances are being used and how much they consume at a given time. The preference of using NILM techniques over ILM ones are mainly due to its cheaper and easier installation, since it only uses one metering device for each energy entrance to the house instead of at least one metering device per room.

Another synonym for NILM is the term energy disaggregation, which is a computational technique for estimating the power demand of individual appliances from a single meter which measures the overall demand across several appliances. The main motivations to study NILM in the review proposed in this work are: (1) detailed identification of appliance usage, (2) appliance management, (3) energy theft detection, (4) occupancy detection and (5) lower price level and intrusion compared to intrusive load monitoring. In this work we propose a review over the latest techniques used for NILM and energy disaggregation itself, following the next structure: First of all Sect. 2 summarize the related work about NILM from the beginning of the term to nowadays. Section 3 provides an examination of the process that is followed generally in the literature to achieve load disaggregation in NILM. Section 4 offer a recap of the most common machine learning algorithms used to achieve NILM. Finally Sect. 5 present applications, challenges and future lines of research in the topic.

2 Related Work

Hart first introduced the *Non-intrusive Appliance Load Monitor (NALM)* as a paradigm for a software system capable of analyzing single-point electrical data to obtain information about the energy used by individual appliances [12]. Since then, a number of studies have extended its simple linear model to use other directly sampled quantities to augment and increase the resolving power of the ΔP-ΔQ space [38,43]. This approaches couldn't distinguish appliances that draw similar power and similar operational principles, such as an iron and a hair dryer.

The research of disaggregation techniques based on Fourier harmonics aim to be able to separate more fine grained appliances such as low-load complex devices present in homes, offices and industry [26]. Steady-state monitoring techniques are successfully applied in low event rate generation environments, such as homes and small business [25]. On the other hand, large industrial facilities and companies need more complex approaches due to the high amount of event generation, load balancing and power factor correction [40]. Higher harmonics in the aggregated signal adds another dimension to the classification problem, making possible to distinguish loads with similar ΔP-ΔQ space representation.

The advanced load monitor proposed by Laughtman et al. [25] is capable of recognize individual appliance load based on their transient shapes. This behavior is closely related to the task which the appliance performs. For example, a computer and a light bulb produce turn-on transients different enough that makes possible to perform near real-time classification. For continuously variable loads, Laughtman et al. [25] proposes the analysis of the spectral envelopes. This allows the NILM system to disaggregate loads like VSDs, which draws distorted and pulsatile waveforms leaving characteristic traces not only in real power but in the fifth and seventh harmonic.

In the work proposed by Patel et al. [34] a combination of hardware and software performs the task of household-level current sampling at 1MHz, obtaining features from the electric noise due to appliance usage (above all, turning on and off). Then, a SVM model is supervisedly trained to obtain up to 90% accuracy.

The analysis through this set of techniques require high sampling rate (in the order of kHz sampling rate or more) which makes it hard to apply in real-world environments due to metering limitations. Another drawback is the need of calibrate the prediction models for those houses different enough from the training ones.

The need of new techniques capable of perform appropriately in a wide variety of household and the usage of low-cost devices to retrieve the energy consumption make the methods explained above not valid enough to be introduced into services for end-users. Is for these reasons that lately, new techniques have been proposed with low rate data retrieval from 1 Hz to lower sample rate as 15 min per sample (Makonin supports this approach in its thesis [28]) which tries to apply the latest machine learning and deep learning knowledge to make the best high energy disaggregation process, as explained in the later sections. In the next section we will describe the general pipeline followed in the literature in other to perform Non Intrusive Load Monitoring.

3 NILM Process

NILM is presented as a time series classification problem where we have to detect which appliances are active at a time t and how much each one contributes to the total percentage of consumption. Figure 1 shows a general flowchart that describes the NILM process [49]. Each part of this process is described below.

3.1 Data Acquisition

As highlighted previously, most of NILM approaches pretend to use the data provided by the main smart meter of the household exclusively, but in practice, training with data from single point smart energy meters – in varying degrees – is required in most of the approaches. This will be explained in the following sections.

Regarding to the kind of data collected [28,31], the smart meters measure the alternating current (AC), and therefore the most basics measurements are: voltage (ΔV, measured in Volts: V), current (I, measured in Amperes: A), and apparent power (S, measured in Volt-Amperes: VA) which is the product of current by voltage. There are other measurements derived from the previous ones: real power (P, measured in watts: W) is the transference of energy in the net, regardless of the direction. It is also called power or average power. Note that this is different that the gross transference called apparent power (this is due to power losses in reactive components of a circuit). Another interesting measure is the ratio between the previous ones: power factor (PF), (P/S) or $\cos(\Theta)$ where Θ is the angle between voltage and current, as well as reactive power (Q, measured in volt-ampere-reactive or VAR), which is an usual measure related to the rate at which power is stored and released back by components such as capacitors and inductors. Additionally, there are other advanced measures such as electric characteristic, harmonic distortion [27,46], electromagnetic interference (EMI) and transients. Finally energy consumption is the amount of power consumed

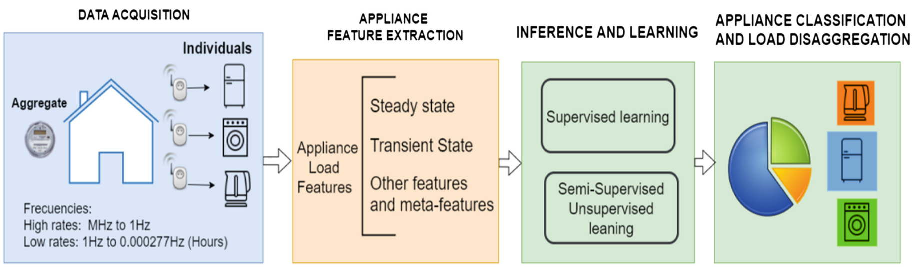

Fig. 1. General pipeline of NILM in literature

over the time (kWh kilowatt-hour). This measure appears in the bill and it is one – actually, the first one – of the main objectives of NILM: disaggregate this total amount to each appliance.

Next to this, it is necessary to emphasize the sampling rate of the data collected, as it determines the type of information that could be extracted from the electrical signals [49]. There are two main groups of data collected based on this criteria [4]:

– **High sampling rate:** The data is collected at a sampling frequency of 1 Hz or more. This kind of data allows to extract some features in the consumption which are only present at these sampling rates. In some cases these very high sampling rates only can be achieved with special hardware.
– **Low sampling rate:** This group includes frequencies of sampling lower than 1 Hz down minutes or even hours. This kind of sampling rate is the most common in the smart meters which can be bought nowadays.

Collected data is stored in remote databases for further feature extraction and processing. In the literature there are several databases of reference in this domain in order to test different algorithms. Some of them are REDD [23], UK-DALE [20], AMPds [29] and others which can be found in this WIKI [47].

3.2 Event Detection and Feature Extraction

After collecting data, the next step is extracting more information about the electrical temporal series in order to obtain features that allow to detect events such as appliance state transitions. Depending on where these features can be extracted, they can be classified as follows [49]:

– **Steady state features:** This features are derived from the steady-sate operation of an appliance. Variations in Real Power (P) and Reactive Power (Q) are commonly used [12] in the steady state to detect the change state events operation of appliances. The number and kind of features that could be extracted will depend on the data sample rating. Features only related to real power can be extracted at a low rate sampling and used to detect appliances with very different power draw characteristics. Features such as current harmonics work better than previous, but they require a high rate sampling to be obtained.
– **Transient state features:** This features are derived from the transient state operation of an appliance. These features are less overlapping between appliances compared to steady state features. However, the major drawback is the high rate sampling required to obtain these features [8]. There are several features such as current spikes, transient response time, repeatable transient power profiles, spectral envelopes, etc.
– **Non traditional features:** These features refer to other new characteristics which are result of the other two kinds of characteristics or other such as time of the day, on/off distribution, use frequency of an appliance and the correlation of usage of multiple appliances [21,48].

3.3 Inference and Learning

Once the features are extracted, it will be necessary to apply methods which determine the appliances that are running at a given time. This techniques can be classified as supervised techniques and semi-supervised or unsupervised methods. The supervised disaggregation methods require individual appliance data to be trained so they can classify the appliances which are working at each moment. Semi-supervised methods need to train a little amount of data at the beginning of the process to perform the classification, and the unsupervised methods can learn from the data collected without previous training data.

Supervised Methods. This kind of methods can be splitted into:

- **Optimization approaches:** They deal with NILM problem as an optimization problem. The extracted features are compared to discover load features stored in a database and to find the closest possible match. These algorithms find the most accurate combination of appliances included in database, which could have caused the output measure. Integer programming [2] and genetic algorithms [3] have been used in this kind of approaches [6].
- **Pattern Recognition approaches:** These approaches are commonly used by researchers in this topic. They can include simple based clustering approach like Hart *et al.* [12], Bayesian approaches [42] – which detect the most likely states of the potential appliances states –, SVMs classifying harmonic features [17], and other approaches like Hidden Markov Models and Artificial Neural Networks [41] – that have demonstrated a great performance due to their ability to introduce temporal and state change information –. Some of this approaches will be explained later. Since the performance of the previous algorithms is dependent of the features extracted, a reference dataset is required in order to evaluate their performance correctly [23].

Semi-supervised and Unsupervised Methods. These methods are highly explored nowadays because they require minimal or no previous information. A lot of companies are interested in these approaches because of their low setup cost, their non intrusiveness and short training phase for load identification algorithms. There are several studies in the literature which use this kind of method to detect loads: In this work [11], authors use steady state features P and Q to cluster the appliances and a matching pursuit to source reconstruction. Other studies – like [39]– focuses on the use a Motif mining approach. This approach uses on/off events and try to identify appliance episode. This method only works for appliances with static episodes of events. In the work [21], the authors have built a probabilistic model using a variation of HMM called Factorial Markov Models (FHMM) and features related to time. Additionally, power consumption of each appliance have been used to model individual models to each appliance. Recently, authors like [15] have developed a method to achieve a fully unsupervised disaggregation. The accuracy obtained from these methods is generally lower than the accuracy obtained with supervised methods in disaggregation, but their easy deployment is highly appealing to the current companies in the sector.

3.4 Appliance Classification and Load Disaggregation

This is the last phase in the NILM process: after completing the load identification, dividing the total consumption among the identified loads is required. Detailed information about the amount of consumption provided by each appliance to the total household consumption will be shown to the user. In addition, information related to the energy price can be provided to inform user about how much every appliance consumption costs.

4 Disaggregation Techniques

This section collects the very latest techniques applied into the energy disaggregation field.

4.1 Autoencoders

NILM and energy disaggregation can be treated as a *denoising* problem. This kind of tasks include removal of grin from an old photo, removal of reverb from an audio or in-filling a part of an image. Energy disaggregation can be treated in the same way, retrieving the clean signal, without the noise produced by other appliances, of the target appliance.

An autoencoder (also named AE) is a neural network which task is reconstruct (rebuild) the input. The key part is that the autoencoder encodes the input to a reduced vector representation and then decodes it for the output. The easiest way to force the network to compress the data representation is having a code layer with a smaller dimension than the input. The behavior of a linear AE with just one hidden layer is equivalent to PCA, thus AEs can be deep and non-linear.

Denoising Autoencoders (dAE) were firstly introduced by Vincent *et al.* [44] tries to recover a clean signal from a noisy one. These are typically trained by artificially corrupting a signal and using it as a the input for the net while the original signal is used as the output of the network.

In NILM, dAEs are used with the aggregated power demand signal as the 'noisy' one to reconstruct and the output is the clean signal of the individual consumption of the target appliance. In the study proposed by Kelly [18] in the use of denoising autoencoders barely reaches an average F1 score of 55%.

4.2 HMM

Hidden Markov Models (HMM) is an approach selected by a broad number of researchers to face NILM [21,28]. This is because they can model time series and represent the unobservable states of that time series. In a HMM the state of the model is hidden (the state is not directly visible to the observer), however, the output is visible and it depends on that hidden state. In NILM the hidden state is the state of all the appliances (each possible combination of theirs possible load states) and the output observed is the aggregate consumption of the household. Each hidden state has a probability distribution related to the all possible outputs and thus, the sequence of outputs provides information about the sequence of the hidden states. Markov property affirm that the conditional probability distribution of hidden states depends only on the value of the immediately previous hidden state and all others previous states have no influence. HMM starts on the premise of that Markov property is holden for a given HMM model. A common HMM can be defined as [28]:

$$\lambda = \{S, O, P_0, A, B\}, \tag{1}$$

where S is the set of possible states, O observations, P_0 initial probabilities, A the transition matrix and B the emission matrix. The total number of states and observations are $K = |S|$ and $N = |O|$ respectively. A defines the probability for state transition from a state to the next state with $K \times K$ matrix where $\sum_i A[i,j] = 1.0$ and B defines the probability for detect a particular observation at the next state with $K \times N$ matrix where $\sum_j B[j,n] = 1.0$. Formally:

$$A[i,j] = p(S_t = j|S_{t-1} = i) \tag{2}$$

$$B[j,n] = p(O_t = n|S_t = j) \tag{3}$$

Algorithms like Viterbi algorithm [45] among others are used to decode the most probable states of the appliances in each moment. This kind of algorithms have a main drawback related to the high complexity in space and time that they present. Given M loads with K internal states (all the loads with the same states for simplicity) the total number of hidden states is k^M so it is a high number of states for a common household monitoring only 10 loads.

There are several approaches using HMM and its variants for disaggregation such us Kolter [22], Parsons [33], Johnson [16] and Makonin [30] which deal with the previous problem and they propose different ways to solve it.

4.3 Deep Learning

Deep learning is a term used to refer to a set of machine learning techniques. In the artificial neural networks field it describes networks with many layers. The objective of using this kind of architectures is learning about a hierarchy of features. Studies points that layerwise stacking of feature extraction often yielded better representations (e.g. classification error, quality of samples generated or invariance properties) [7,24].

Each layer processes some kind of input, processes and learns from it, to give a better representation of the data to the next layer's input, exponentially increasing the number of possible state representations [32]. This computational concept is borrowed from the human brain's ability to observe, analyze, learn and make decisions, especially for extremely complex problems. A major advantage of these representations is that they can be invariant to local changes occurred in the input data. Learning from invariant features is a major goal in pattern recognition tasks like those needed in the NILM field.

This kind of deep architectures have succeeded in recent years due to the recent overcome of many problems that prevented the advance of the techniques. Some of major ones are the creation of optimization techniques and architectures and the huge amount of data available in many fields, which are mandatory to successfully train deep networks. Also, the exponential growth of processing power in GPUs with its lowering price tag per processing power make this devices more affordable and usable to train this kind of architectures in shorter periods of time.

The disaggregation process is made through the use of a sliding time window along the input sequence. As such, the first input sequence for the network will be zeros. Then the input window is shifted K samples (where $K >= 0$). If K is less than the length of the network's input layer size, then it will see overlapping input sequences. This behavior allows the net to process same values in several attempts and detect in a better way appliance activation. Onwards, we explain the most recent deep learning architectures applied to energy disaggregation in three major categories named by the neuron and architecture used in each case.

Convolutional Neural Network *CNN.* There are biologically-inspired variants of MLPs. From Hubel and Wiesel's [14] work on cat's visual cortex we know it has a complex arrangement of cells. These are sensitive to subregions of the visual field, called receptive field. The subregions are tiled to cover all the visual field. These cells act as local filters over the input space and are well-suited to exploit the string spatially local correlation present in images.

A feature map is obtained by repeatedly applying a function across subregions of the entire image and by the convolution of the input image with a linear filter, adding a bias term and then applying a nonlinear function.

Convolutional neural nets build a small number of filters, each with a small receptive field, and these filters are duplicated (with shared weights) across the entire input.

There are several kind of convolution neurons depending on the dimension. For the NILM use case, Convolution 1-Dimensional Neurons are applied due to the unidimensional nature of the input time-series dependant data.

Similarly to computer vision tasks, in time series problems we often want to extract a small number of low-level features with a small receptive fields across the entire input.

As proposed in the work of [35] the typical architecture using convolutional layers with increasingly number of filters. Max Pooling layers are also applied in order to give some translation invariance while reducing the number of parameters of the network. The accuracy result is around 84% for all the houses where individual training and testing were applied. This kind of neural network shows better average accuracy results against LSTM Sect. 4.3 architectures.

Long Short Term Memory *LSTM.* This type of neuron was first published by Hochreiter and Schmidhuber in 1997 [13] and have been applied in a broad range of problems with a great success such as handwriting recognition, speech recognition and time-series related classification.

The kind of architecture in which this neurons are applied was designed to solve the vanishing gradient problem, common in typical recurrent neural network architectures. It makes use of gates to have a better control against gradient flow. However, in presence of backpropagation the error loops in the memory and causes an error known as "carousel error". This issue was fixed with the introduction of peephole connectors, increasing the precision of the network [10]. Also, Gers et al. [9] introduced the called "forget gates" that made possible to the LSTM to learn local self-resets of their memory content that isn't relevant, reducing possible errors due to memory remembrance.

In the NILM field, LSTM based architectures have been successfully applied in energy disaggregation like the work presented by [18,35] reaching up to 80% precision score in different houses and appliances as their work show, a little worse performant than convolutional networks.

5 Applications and Challenges

Finally we will show some of the most interesting application of NILM and their related challenges:

– **Detailed bill information:** The most widespread application, which tries to provide more information to the user in order to obtain energy savings and reductions in its bill. The main objective is achieving the best accuracy. Researchers are searching a way to compare the disaggregation present in the market.
– **Demand response application:** Other interesting use case is the detection of potential consumers of demand response programs by utility electricity companies. The detection of deferrable loads or inactivity periods in the energy consumption of their consumers can target them for a possible demand response program.
– **Ambient intelligence:** The load monitoring enables other sensing approaches without the need of include new sensors in the household.
– **Occupancy detection:** Linked with the previous point, it would be possible infer the presence or absence in household by the power consumption. This is an interesting point for companies to offer extra services without deploy any sensor platform, in the same way this may involve an intrusion into the privacy of thousands of users of the electric network.
– **New companies services:** Thanks to this, load monitoring companies are offering new services like show the current billing amount from the beginning of the billing period to the current time. Also other services like [36] offer real time information about appliances switched on and provide reminders, for example, to switch off certain appliances before leave home.
– **Illegal load detections:** Other useful application of NILM its the detection of anomalous loads in household which can be used to report possible energy thefts in public and private buildings.

NILM is and will be a intense subject of study in the following years as the use of smart grids, demand response programs and other energy-consumption and metering approaches are more and more spread into end user applications. The arrival of new techniques as explained in this work accelerate this spreading process.

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Learning Frequent Behaviors Patterns in Intelligent Environments for Attentiveness Level

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Abstract. Nowadays, when it comes to achieving goals in business environments or educational environments, the performance successfully has an important role in performing a task. However, this performance can be affected by several factors. One of the most common is the lack of attention. The individual's attention in performing a task can be determinant for the final quality or even at the task's conclusion. In this paper is intended to design a solution that can reduce or even eliminate the lack of attention on performing a task. The idea consist on develop an architecture that capture the user behavior through the mouse and keyboard usage. Furthermore, the system will analyze how the devices are used.

Keywords: Attention · User behavior · Ambient intelligent system

1 Introduction

Currently, one of the major problems related to work is the quantity of attention that people spend on performing a propose task. The level of attention of each person is increasingly affected by the evolution of Internet usage and introduction of social networks. These two factors had an high impact in attention because offers many information of general interest.

Research on attention involves nowadays many fields, including education, psychology, neuroscience, cognitive neuroscience and neuropsychology. For this reason, many different views and theories on attention can be found. One of the most frequent ones is the so-called "Attention Economics", which treats human attention as a scarce commodity or resource, which we must use wisely in order to attain our goals [1].

Attention is a very complex process through which one individual is able to continuously analyze a spectrum of stimuli and, in a sufficiently short amount of time, chose one to focus on [2]. In most of us, which can only focus on a very reduced group of stimuli at a time, this implies ignoring other perceivable stimuli and information.

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The main goal of this paper is to propose an architecture to classify the level of attention of each user. This will provide the necessary information to the leadership, which help the user to improve his level of attention.

2 Theoretical Foundations

Nowadays the world is getting increasingly competitive and quality and quantity of the work presented is one of the decision factors in choosing a collaborator. It is no longer necessary to only perform, but, from that performance should result a product with quality, in time, at the lowest possible cost and with the minimum resources. It is essential that the factors that influence performance match the ideal values.

Attention is one of the factors that influence the performance of a human being when performing a task. If the attention of an individual is not at its best when performing the proposed task, its performance will be negatively affected, causing several problems.

In enterprise environments, if an employee has lack of attention in his work, that behavior can cause production delays. Consequently delays in delivery to costumers in extreme situations cause monetary losses. In some situations, such as, flight controllers or bus drivers, if the person is not 100% focused, an error can cause a tragic accident.

In educational environments, attention is considered a fundamental factor in the evolution and success of the student. If the student is not concentrating and paying attention to what is being taught, he will not capture information that is being provided and consequently the academic course will be compromised.

Attention is a resource that allows the human being to be focused on a situation and to be able to ignore non-priority information. As happens with performance, several factors can influence attention, like, stress, mental fatigue, anxiety, emotion, new environments, and human health. Besides these factors, the advancement of technology has been a real problem which has increased the lack of attention. With the emergence of the smartphone that provides new and varied information in real time and new ways of communication, people's attention is easily captured and the task that was meant to be done is left out [3, 4].

2.1 Attention in Computer Science

After being studied by psychology, cognitive psychology, and many other areas, attention is being studied by the field of computer science, because the number of people using new technologies to perform tasks is increasing and it is necessary to study how to increase the attention of people on their task while not being distracted by the amount of information that is provided by these same technologies [5].

Koch and Ullman are two authors who have studied attention in the computing world. They propose the "saliency map" [6]. "Saliency map" is a combination between different visual features that contribute to the selection of stimuli and a single type of topographic map. This proposal can offer the probability that each area of the visual field has to be captured. Later on, the proposal was developed by Laurent Itti. The first system had as input an image and the result was an initial image "saliency map". This was the starting point for many developed models not only for image but also for videos and more recently 3D. This is presented in Fig. 1.

Another author who was interested in this branch is Mancas [5–7]. According to Mancas, attention may have two approaches: the first approach is based on the two theories described above, saliency; the second approach is the visibility. In this model, it is assumed that an individual, when needing help to perform a task, looks for places where the information has good visibility. In this approach, the eye's movement gives an automatic output of the focus area. The Fig. 1 presented an example of this second approach.

Fig. 1. Visibility output example [5].

In the Fig. 1, it is possible to visualize the same picture with the attention's focus targeted to two different areas. In the left, the observer's visual attention is directed to the flower, but in the right, the butterfly is the focus. These are two examples of image's outputs obtained with this approach.

2.2 User Behavior

In the last years, task resolution using new technologies is increasing. Therefore, one of the biggest concerns is to find ways to make this use as efficient and effective as possible. The task resolution is not done similarly by all the users. Each person has its own behavior. This behavior can be derived from several factors, such as: biological characteristics of the user; task's characteristics; and environmental factors.

The recognition of these behaviors is already used in new technologies. For example, the recognition of users as a form of authentication on a device or software. This recognition is made by tracking of behavioral biometrics, such as, fingerprints, face recognition or iris recognition [8, 9].

According to Yampolskiy and Govindaraju [10], this behavioral biometrics can be classified in five categories based on information type:

- Behavioral Biometric based on the analysis of text extracts or drawings made by the user;
  – Device usage, such as, mouse and keyboard. Devices that can capture the muscles' actions;
  – Software interaction: strategy, and knowledge.
- Behavioral Biometric based in monitoring data coming from low level action in software, such as, access log, storage activity, and calls systems.
- Behavioral Biometric based on data from motor skills.

Behavioral Biometric based on strategy, skills in performing mentally demanding tasks. These monitored behaviors can be used to measure several variables that can influence the task development. There are already some studies that focus on recognition of some of these variables in the user behavior.

One of the variables is attention. To recognize the lack of attention on user behavior, different ways of capture and classify attention were discovered. One of the first ways to try to quantify the attention level was a questionnaire. This questionnaire is presented to the user. After the user answers the questionnaire, the study's author analyzes the answers and presents the conclusions. However, this approach is more qualitative and depends on the author's interpretation [11].

The approach more quantitative is the one that use biometrics behavioral. It is an approach more focused on the perception stimuli. Eye-tracking is one of the most used techniques. Using this technology when performing a task on a computer, it is possible to know the screen area where the eyes are directed and, consequently, where is the focus of attention. So it is possible to conclude if the user was with the visual attention directed to the screen area where the task is positioned [11, 12].

Finally, the mouse-tracking and keyboard-tracking are techniques used to measure and classify attention. These techniques have already been used to measure others variables, like, stress [13] and mental fatigue [14].

In the first phase, it was used statistic methods and the first conclusions were obtained. This data was analyzed in two ways:

- To find common behavior in groups of students;
- Individual data was analyzed for each student.

In the second phase, it was used a machine learning method to model the student's response to a stress event. There were used two classifiers. One to classify the all students' data, and other to classify data from an individual student.

This study concluded that stress affected the student's performance on an exam but raised some doubts about the reason for which some students can improve their performance even with stress.

3 Proposed Design

In Fig. 2, it is presented the first version of the system's architecture, which is divided in three major parts. The lower-level is composed by the devices that generate the raw data (e.g. computers, smartphones). These devices store the raw data locally in SQLite

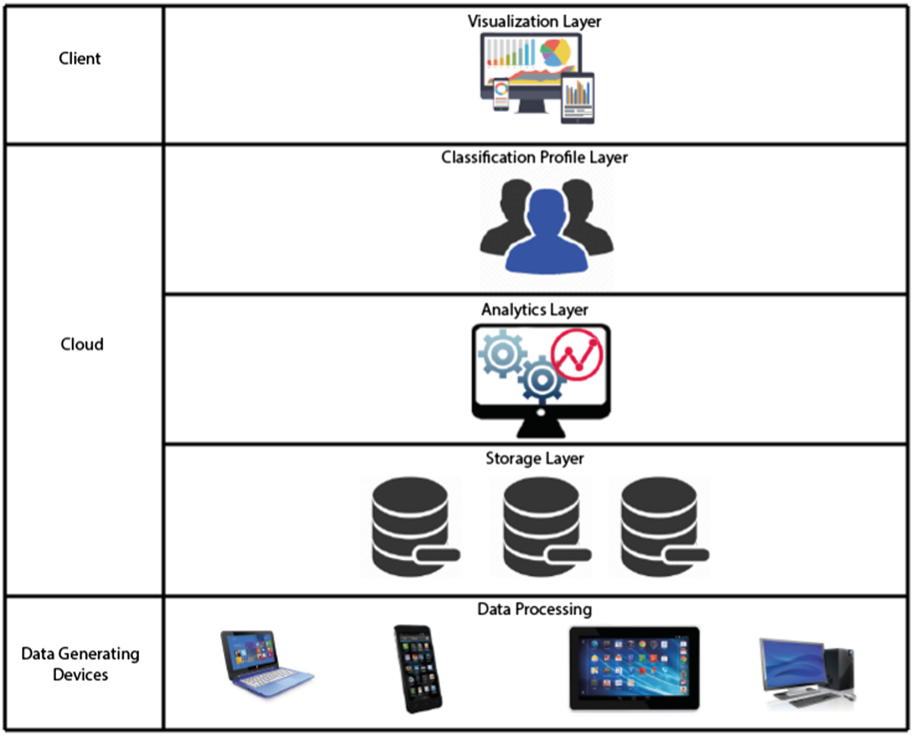

Fig. 2. Architecture of the system.

databases, until it is synchronized with the web servers in the cloud, which happens at regular intervals (normally 5 min).

The cloud is composed of three layers: storage, analytics, and profile classification. In the storage layer the raw data received from the data generating devices is stored in a data store engine. The analytic layer provides powerful tools for performing analytics and statically analysis in real-time. The system calculates, at regular intervals, an estimation of the general level of performance and attention of each user.

The profile classification layer (Classifier) is where the indicators are interpreted. For example, interpreting data from the attentiveness indicators and build the meta-data, that will support decision-making. When the system has a sufficiently large dataset that allows making classifications with precision, it will classify the inputs received into different attention levels in real-time. This layer has access to the current and historical state of the group from a global perspective, but it can also refer to each user individually, creating each person learning profile [15]. The data is processed in Classifier (Classification Profile Layer). In Classifier, the analyzed data use the new information and compare with data from the profile saved.

Profile classification is also a very important aspect to have control of since it allows carrying out analyses within longer time frames. This information will be used by another sub-module, the affective adaptive agent, to provide relevant information to the platform and to the mentioned personalization module.

Finally, the Client layer is developed as a web app with intuitive and visual representation (diagrams and other graphical tools) of the attentiveness states of the group and each user, abstracting from the complexity of the data level where they are positioned. At this point, the system can start to be used by the people involved, especially the administrator, who can better adapt and personalize strategies. With a focus on individual and group performance and using real time analytics, the intuitive visual tools suggest and facilitate decision-making and student management.

3.1 Classifier

The system begins in the HTTP Service with the reception of a post request with three parameters, two dates and a set of task rules. Using the two dates, the Db Module collects the monitored data from a Mongo database.

The main goal of Classifier is to be able to classify the level of attention of each user. This will provide the necessary information to the leadership, which help the user to improve his level of attention.

The classifier is the software that classifies the level of attention. In the Fig. 3, the classifier's architecture is presented. Three parts of equal value compose it: HTTP Service, DB Module and the Classifier.

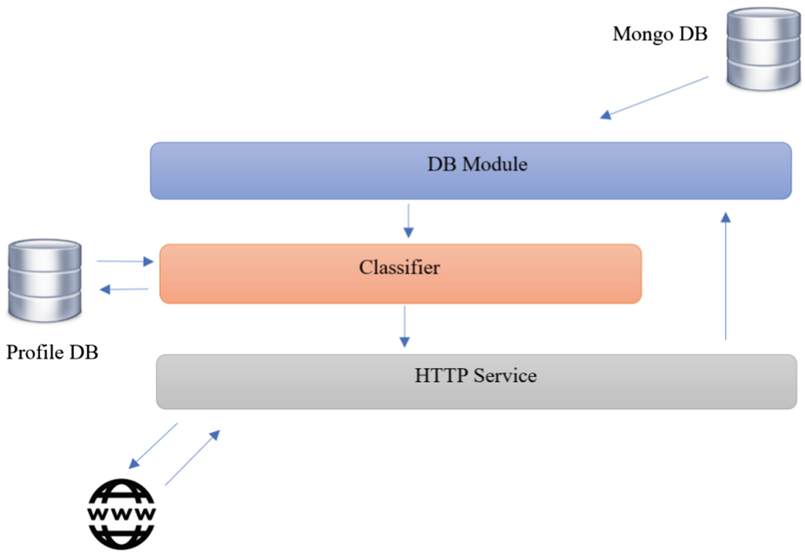

Fig. 3. Architecture of classifier module

The system begins in the HTTP Service with the reception of a post request with three parameters, two dates and a set of task rules. The two dates represent time interval for data collection. Using the two dates, the Db Module collects the monitored data from a Mongo database. The major goal of Db Module is to facilitate the collection of monitoring data. The module is composed by a MongoDB Drive, which makes the connection between a MongoDB, where the user information is stored, and the software system possible. The data of a specific date is collected from the MongoDB. The data collected is divided into three types: related to the task, interaction with the mouse and interaction with the keyboard.

The data is processed in Classifier. In Classifier, the analyzed data uses the new information and compares it with data from the saved profile. The data's analysis is done in two parts: user's attention classification and user's learning style definition. To classify it, it will be necessary to group the data per student. The task data from the new information is the most crucial information because from it derives most part of the attention level. To obtain the task results, the task rules received in the request are used to have a perception of how much time the user has spent on the applications related with the task rules.

As far as the mouse and keyboard results are concerned, their role is present on how the user interaction is occurring and help the coordinator/teacher understand if any student, who has the application active, is really working on it or not. To do that many values, such as mouse acceleration, mouse velocity, distance between clicks, duration of clicks, time between keys, key down time velocity are taken into account.

The data from the saved profile is stored in a MySQL database. This database store all the attention information previous collected and analyzed from the users.

To define the user's learning style, a mathematical method will be used. After the Classifier process is finished, the results of the user's attention level and the user's learning style will be sent back to the request's origin, with a response type JSON.

4 Discussion and Future Directions

Relatively to attention, it is an important theme because it is one of the factors that most influence a person's performance while performing a task. Therefore, it is a very studied theme by several areas, like, psychology, neuroscience and computer science. Understanding how attention varies and which situation the attention varies for each person, it is possible to act at the right moment and right time, to bring the user's attention level to the ideal value.

One way to quantify and classify the attention is the monitoring the user's behaviors when performing a task. Some approach, like, eye-tracking, neural activity caption or mouse-tracking/keyboard-tracking, can be used to monitor the behaviors. The project's approach will be the mouse-tracking/keyboard-tracking because it is a non-invasive and non-intrusive approach.

In previous work [15] the collected data were analyzed in two different ways. First, a general analysis was carried out with the aim of searching for group trends, i.e., behaviors common to a significantly large slice of user's. Secondly, an individual analysis is made, in order to compare the different moments.

One of the first results obtained were counts the number of interactions with the keyboard and the mouse in order to determine each data length user. In this step it was possible to verify the mouse and keyboard activity of each user which depends on the subjects that are applied [15].

The second results obtained were determine which applications are and are not work-related. In this sense it was necessary to measure the amount of time in each interval, that the user spent interacting with task-related applications. By default, applications that are not considered task-related are marked as “others” and count negatively towards the quantification of attention [15].

In the next step, it will start the system application’s development to classify attention and define user’s learning styles. At the end, it is expected to have all the proposed features presented in the first chapter developed on the most efficient way.

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Indoor Children Location System Using BLE Technology

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Abstract. The geolocation of people is a field of research that is in continuous development. Currently, the vast majority of systems that can locate people, are used in open spaces that can directly be viewed from the outside using GPS technology. This technology is based on very weak satellite signals and is not suitable for all types of scenarios. When a child gets lost inside a building, the parents inform the guards responsible for building security; an alarm is announced and different actions are undertaken in order to find the child. The steps taken during the search are based on manual procedures; all rooms in the building are searched and security cameras are reviewed. This is why it is crucial to research new solutions which will allow for the localization of individuals in enclosed spaces such as sports stadiums, museums, shopping malls etc. In the last decade, indoor location systems (IPS) have experienced increased growth due to reduced production costs of hardware and miniaturization of device size. This work focuses on the design of an architecture that allows for the monitoring, localization and identification of individuals (especially children or dependent persons) indoors through the use of low cost hardware.

Keywords: Indoor location system · Bluetooth 4.0 low energy · MQTT

1 Introduction

In recent years, the breakthrough that electronics have undergone has contributed to the reduction of the size of sensors and devices. This contributed to lower manufacturing costs, offering end user services at a very reasonable price. Despite significant advances in RTLS (Real Time Location System) systems [1], research on algorithms and platforms that could accurately determine the user's location is still in its process. The ability to locate individuals in public spaces is important for security, especially places with a high concentration of people, such as sports stadiums, shopping centers, subway stations, where children and other dependent persons can be disoriented easily. In the literature, [2, 3] provide statistics according to which at least 70% of parents with children between the ages of 2 and 9 have experienced the horrible situation of losing their child, with 58% occurring in a shopping center or a similar enclosed space. These

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statistics prove the importance of researching technologies that allow to locate children or elderly people who can be susceptible to getting lost in their daily life.

This article presents a new architecture for locating children in indoor spaces through the use of BLE technology and low cost hardware. The system will send alerts to the child's guardian if the child is away from them at a particular distance or if they are close to a restricted area. The security guards at the center will be able to view the position of each user in real time.

The paper is organized as follows, Sect. 2 reviews existing commercial technologies and compares them briefly, Sect. 3 describes the proposal and finally Sect. 4 describes the results and conclusions.

2 Background

First, we carried out a study of the current state of the art in indoor location systems. In work [4] the authors describe the SpotON system, a localization system based on the triangulation from the strength of the radio signals emitted by a system of low frequency radio beacons. According to the authors, this system has an accuracy of 1 m^2 indoors.

The second system described is the Ekahau RTLS in [5]. This system can be deployed in hardware location devices through a small service that enables communication with the localization engine deployed on the server. This system is based on 802.11 WiFi communication standards [6], making it easily deployable on any device that has this technology, such as the users' smartphones. The communication between the client and the positioning engine uses a minimum bandwidth due to the fact that the only information sent is the strength of the received signal (RSSI).

Another outstanding system is Skyhook RTLS [7, 8], an indoor location system based on the fingerprinting method, it is not necessary however, to perform a pre-calibration of the indoor space since Skyhook has a broad base of calibration data in the USA. In fact, the company employs a fleet of drivers to perform data collection work. The Skyhook architecture is designed in a way that all location calculations are performed on your servers with a calculation time of less than 2 s.

Other commercial systems that should be mentioned are the BLIP System [9], Microsoft RADAR [10] and CISCO's AeroScout Industrial [11].

The BLIP System [9] solution, groups a set of indoor and outdoor localization systems, capable of locating hundreds of thousands of users simultaneously. The multinational Microsoft has the RADAR system [10], based on the radiofrequency (RF) technology for the location and tracking of users inside buildings. Finally, CISCO's AeroScout Industrial [11] localization system which has a series of indoor localization solutions based on WiFi 802.11 and radio frequency (RF).

Table 1 shows compares the different indoor location systems examined in the state of the art.

Table 1. Comparison between different indoor positioning systems (IPS)

System	Location Technology	Positioning Algorythm	Accuracy	Complexity	Scalability	Cost
SpotON	Active RFID, RSSI	Ad-Hoc Lateration	⊛⊛	✪✪	⊛	✪
Ekahau RTLS	WLAN, RSSI IEEE 802.11 a/b/g/n	Probabilistic	⊛	⊛⊛⊛	⊛⊛	⊛⊛
Skyhook WPS	WLAN, GPS cell towers	Hybrid location algorithm	⊛	⊛⊛⊛	⊛⊛	⊛
BLIP System	Bluetooth, RSSI	*Not available*	⊛⊛	⊛⊛⊛	⊛⊛	⊛
Microsoft RADAR	WLAN, RSSI	Knn, Viterbi-like algorithm	⊛	⊛⊛⊛	✪✪✪	⊛⊛
AeroScout	TOA triangulation, TDOA, RSSI in IEEE 802.11	AeroScout	✪✪	✪✪	⊛⊛	⊛

3 Proposal

To carry out the location of users in the system, it is necessary to take into account that the system has to be easily adaptable to the environment, so alternatives such as fingerprint [12] are not suitable when rapid deployment is necessary, since this would require previous calibration of the environment. This calibration must be reset every time there is a change of location in the position of the beacons. Due to this reason, only alternatives that do not require previous calibration of the environment such as signpost, triangulation or trilateration [13] were analyzed. Alternatives such as triangulation or trilateration analyze signal changes to determine the location of users more accurately [14], but signal changes due to obstacles and moving objects make it difficult to have a stable result, so we have chosen to use the method of signpost which determines the location from the highest signal level. Therefore, the location of the user carrying the BLE tag is determined by the strongest signal and cannot determine intermediate positions between two reference beacons.

The system works in a passive way, that is, the tags that the users carry are not connected to any device. The beacons scan the tags within their radius of action. According to the signal levels, each tag is detected and positioned to the nearest beacon in the building. In Fig. 1 we can observe the general scheme of the location platform in interior environments developed in this work.

A location infrastructure based on BLE routers is deployed in the surroundings of a commercial center or other inland location (cinemas, museums, stations, schools, etc….), which are responsible for scanning the levels of RSSI signal of each of the tags. In the case of the implemented system, these tags are BLE bracelets that users will carry at all times. Once the bluetooth signal levels are detected by the different routers, they are sent to the central server in JSON format, where the signpost algorithm will be applied. After the position is calculated, it will be possible to view it through a web portal created for this purpose.

For the system to work, it is necessary to have a data connection for sending the RSSI frames to the central server. A data connection with a high bandwidth is not necessary since the transmitted frames are light and their data consumption is low. This facilitates the implementation of such systems in places where a wired internet connection is not available. A simple 3G router will be enough to provide a stable connection to the system.

The beacons used in this proposal are based on the use of WiFi routers NEXX-WT1520f with an OpenWRT Firmware, each with a BLE type USB adapter based on the CC2540 chipset.

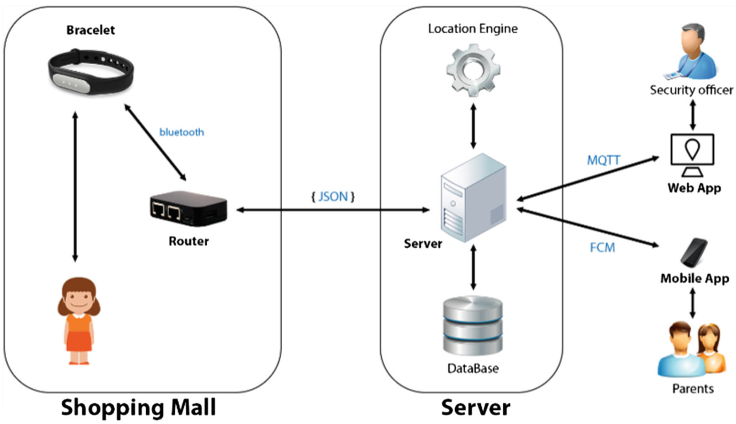

Fig. 1. Diagram of the general operation of the system

4 Results and Conclusions

The case study proposed in this paper has been evaluated in the R&D&I building at the University of Salamanca, with 3 floors and 5600 m^2 total. The layout of the beacons has been made in a linear manner with a 4 m gap between each one.

An Android-based mobile application has been developed, notifying tutors when children are at a distance of 5 linear meters of a certain area that was previously set as an alert. The total number of beacons used is 100 units. The proposed solution has obtained a reliability of 100% in the tests carried out. The battery life of the beacons carried by users is approximately 3 months, sending a low energy Bluetooth signal every 300 ms. Figure 2 shows the distribution of the beacons deployed in the case study for the present research. The plan shows a part of the third floor of the building of about 1800 m^2, where a total of 7 rooms has been outlined in order to check the accuracy of the system.

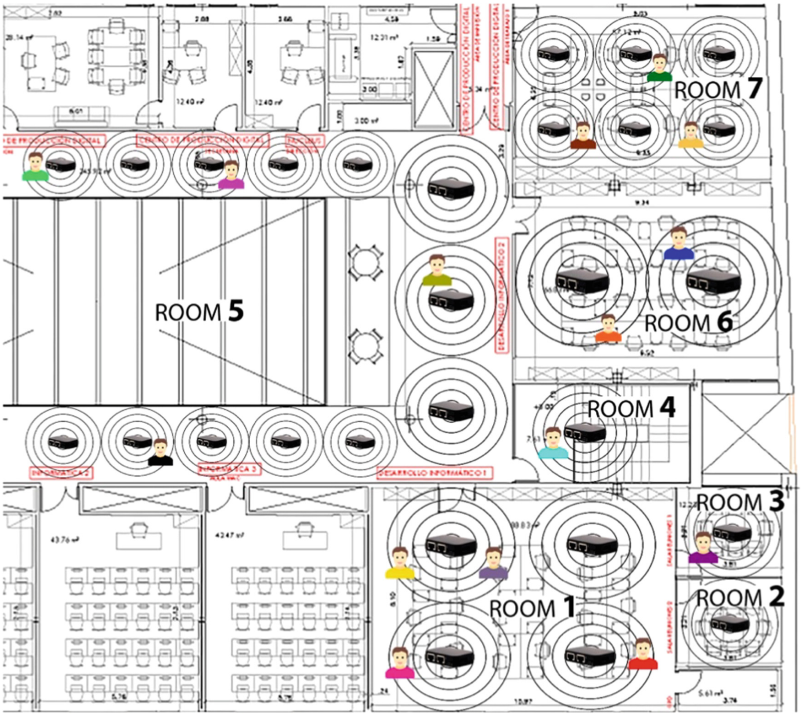

Fig. 2. Distribution of the beacons in the case study carried out in the R&D&I building at the University of Salamanca.

Each beacon is located in a certain position and has been previously registered on the map as shown in Fig. 2. To further increase accuracy, several beacons have been deployed in the same room in order to describe the location not only by room, also by the specific area of the room.

Figure 3 shows the application interface developed for mobile devices. This application fulfills the function of informing the user (usually the parent or guardian of the child) that the child has left the area marked as a safe zone by the tutor in the web application. Similarly, it is possible to issue an alert when the individual enters a zone marked as exclusion zone. This application also allows to view the last point in which the child had been located by the system in order to make it easier to find the child.

This system, besides having the capacity to determine the positions of the individuals, can show statistics on the percentage of people using the system and their geolocation inside the building. As seen in Fig. 4, the distribution of users in the different areas of the building can be viewed on the website.

It is possible to determine the location of users without having to perform calibration previously, so the deployment of the system is simple and only the routers have to be located on the map. If one of the zones happens to be detected with low precision, it is only necessary to include new router and it is not necessary to modify or restart the calibration process. In this way, system maintenance is greatly simplified. The use of a

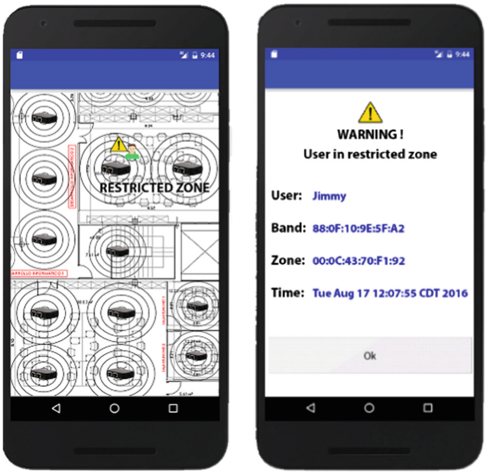

Fig. 3. Application for mobile devices developed for monitoring alerts.

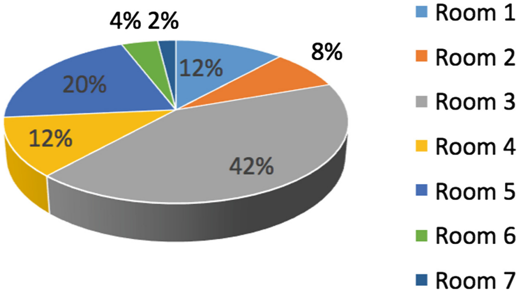

Fig. 4. Statistics provided by the website

passive system for localization reduces costs and lengthens the functioning of the batteries in the bracelets, since it is not necessary to establish a connection with the routers nor to transmit any type of information from the bracelets. The average battery life of a bracelet is 87 days, making the system practical and valid. In addition, passive localization allows for the integration of different types of tags without configuration, allowing the system to handle different bracelets or tags.

In conclusion, it should be noted that the system described in this paper provides a solution to a real problem such as the location of minors or vulnerable people indoors. Families spend most of their leisure time in shopping malls or large indoor areas where it is easy for children to get lost and even be kidnapped. The integration of the Indoor Positioning Systems (IPS) in these large areas will provide an improvement in the safety of children and will encourage parents and guardians to visit these places. The low cost and easy implementation of the system is an advantage for large-scale security companies.

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RGBN Multispectral Images: A Novel Color Restoration Approach

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Abstract. This paper describes a color restoration technique used to remove NIR information from single sensor cameras where color and near-infrared images are simultaneously acquired—referred to in the literature as RGBN images. The proposed approach is based on a neural network architecture that learns the NIR information contained in the RGBN images. The proposed approach is evaluated on real images obtained by using a pair of RGBN cameras. Additionally, qualitative comparisons with a naïve color correction technique based on mean square error minimization are provided.

Keywords: Multispectral imaging · Free sensor model · Neural network

1 Introduction

The computer vision field has been growing considerably during the last decades. It is now ubiquitous in our every day life for a number of applications. Some of these applications rely for instance on image processing techniques such as image segmentation or object classification. These image processing techniques are based on photometric information obtained from the scene, such as color or relative difference between the color of the different regions. However, there is almost no difference between two different materials with the same color under a given light source; in other words, it is not possible to discriminate objects' material if they have exactly the same color. A possible solution for such a challenging problem can be found if we consider information from the electromagnetic spectrum beyond the range that the human visual system is sensitive to (400–700 nm), were visually similar samples may exhibit very different characteristics (e.g., [1–4]).

Such a property has been largely exploited in remote sensing applications where different spectral bands are used to characterize elements, such as materials, vegetation, water pollution, etc. (e.g., [5,6]). Among all the different spectral

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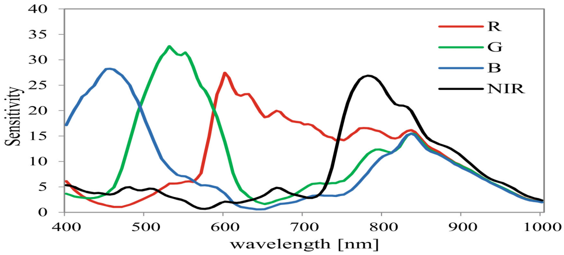

Fig. 1. (*top − left*) RGB image (obtained in the spectral band 400–1100 nm) with NIR information overlapped; (*top − middle*) NIR image (400–1100 nm) with RGB information overlapped. (*top − right*) RGB image (400–700 nm) used as ground truth; (*bottom*) Sensor's spectral sensitivity.

bands used in the computer vision beyond the visible spectrum, the near-infrared (NIR) is the most widely explored, since on the one hand it exhibits peculiar properties related with material energy absorption and reflectance; on the other hand sensors based on silicon (SiO_2) are sensitive to NIR up to 1100 nm, hence NIR camera are relative cheap in comparison with cameras working, with other technology, at other spectral bands. Since the NIR band is the closest in wavelength to the radiation detectable by the human eye, NIR images share several properties with visible images (see illustrations in Fig. 1). However, as mentioned above, surface reflection in the NIR band is material dependent. For instance, most dyes and pigments used for material colorization are somewhat transparent to NIR. This means that the difference in the NIR intensities is not only due to the particular color of the material, but also to the absorption and reflectance of dyes [1].

The absorption/reflectance properties mentioned above are used for instance in remote sensing applications for crop stress (water and nutrient stress being the most common) and weed/pest infestations. These applications are based on the fact that NIR is not absorbed by any pigments within a plant, it travels through most of the leaf and interacts with the spongy mesophyll cells. This interaction causes about half of the energy to be reflected and the other half to be transmitted through the leaf. In plants with turged and healthy mesophyll cell walls and in dense canopies, more NIR energy will be reflected and less transmitted. This cell wall/air space interaction within these cells causes healthy vegetation to look very bright in the NIR spectral band. In fact, much more NIR is reflected than visible. By monitoring the amount of NIR and visible energy reflected from the plant, it is possible to determine the health of the plant.

Trying to exploit such attractive properties (absorption/reflectance at NIR band and low cost technology) new cameras have been developed being able to work from the visible spectrum (400–700 nm) up to the NIR spectral band (700–1100 nm), providing the information in four independent channels—through this paper this technology will be referred to as RGBN cameras. Although interesting, the main problem with this technology lyes on the overlap between bands, as can be appreciated in Fig. 1, NIR sensor is sensible to RGB spectral bands, and part of NIR information goes also below 700 nm generating RGB images visually distorted (in general biased toward the red channel, see illustration in Fig. 1($top - left$)). The current work is focused on this problem (spectral band overlap) trying to restore color by removing NIR information. There are recent approaches in the literature, which are based on the sensor models (they will be reviewed in Sect. 2). In the current work a novel neural network based approach is proposed. It is trained by using RGBN and RGB images. The RGB images have been obtained using a IR cut-off-filter (IRCF), hence they are not affected by the NIR information. Promising results have been obtained independently of the lighting of the scene, which is a parameter needed in most of the sensor-based-model approaches.

The rest of the paper is organized as follows. In Sect. 2, both RGBN camera technology as well as previous work on RGBN color restoration from multispectral cameras are presented. Then, the proposed approach, which is based on the usage of a simple neural network, is introduced in Sect. 3. Experimental results are provided in Sect. 4. Finally, conclusions are given in Sect. 5.

2 Related Work

In the last years a new type of single sensor camera for simultaneous acquisitions of color and near-infrared images in the CMOS system has been proposed. Although it is an appealing technology, new problems have to be tackled in order to solve the band overlap problems discussed in the previous section. Additionally, the overlapping between the RGB and NIR channels could vary according to illumination, sensor characteristic and surface properties [7]. Hence, due to the complexity of the problem, some authors have proposed different solutions valid for controlled environments. For instance, [8] proposes a solution that works for controlled indoor scenarios, where the RGBN camera response is less influenced by NIR information. Other recent works have been proposed to solve this band overlapping problem (e.g., [9,10]), which is referred to in the literature to as color correction.

A color correction process is intended to obtain accurate color information. In [9] the authors propose the combined use of RGBN information for shadow removal and feature detection, although interesting results are presented

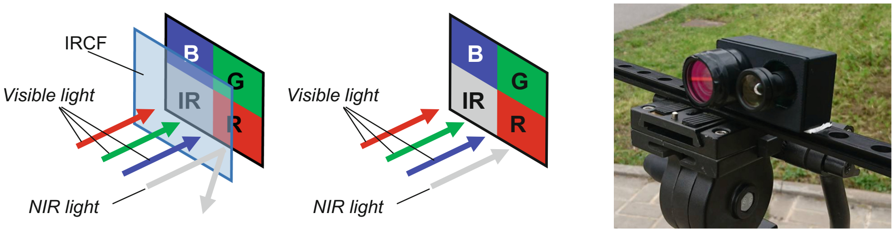

Fig. 2. Illustration of: (*left*) infrared filtered imaging system (IRCF: infrared cut-off filter); (*middle*) RGBN imaging system; (*right*) See3CAM-CU4 RGBN cameras used in the experiments. The infrared cut-off filter can be appreciated in the left side of the figure; it is used to generate the ground truth RGB images).

it should be noted that the proposed approach has been tested in a particular set of RGBN images obtained in a lab with fluorescent lamp. The obtained color corrected images were evaluated using a X-rite color checker chart, therefore in the visible spectrum there is not a considerable influence of sunlight; the tested scenario does not contains vegetation where the NIR influence plays an unknown and considerable role. This color correction in constrained scenario has been also considered in [11,12], although the authors mention sunlight presence in the indoor scenes tested. In these works the authors tackle the complex problem of restoring the three channels (R_{vis}, G_{vis} and B_{vis}), which are contaminated with an unknown quantity of NIR information. The proposed method is based on a spectral decomposition, it implies that the spectral response of each channel will correspond to the RGBN values. Each one of the channels contains a NIR and a visible spectrum part, which initially is formulated as follows: $NIR = NIR_{vis} + NIR_{nir}$, $R = R_{vis} + R_{nir}$ and so on, where the result is obtained as follows:

$$(\hat{R}_{vis}, \hat{G}_{vis}, \hat{B}_{vis})^T = \mathbf{M} \quad (R, G, B, N)^T, \tag{1}$$

where $\mathbf{M}$ is the decomposition matrix obtained by modeling the sensor sensitivity and band correlation; it is a scaling factor coefficient that relates the visible spectrum and NIR bands. Authors describe that the additional NIR information infected in the RGB channels maybe an unknown value. In other words, the spectral sensitivity curves presented in Fig. 1 depend on the sensor and are needed to solve Eq. 1. Note that the amount of NIR information will depend on both, the light in the scene and the type of material present on it. For instance, in outdoor scenarios, NIR information may change depending on the amount of vegetation, or materials with different absorption/reflectance properties (see Sect. 1).

Another image restoration technique has been recently proposed in [10]. In this case the visible image is obtained by subtracting at each visible channel a different amount of NIR information, according to coefficients previously computed. These coefficients are obtained from the sensor sensitivity curves (see Fig. 1). This particular formulation is only valid for a NIR wavelength range of

{650–819 nm}, since the camera used in that work is only sensible to the aforementioned range values. Although the results are quite good and the algorithm is efficient and fast to compute, its main drawback lies in the short wavelength validity. In [13], the authors propose a demosaicking[1] and color correction approach for improving the quality of acquired RGB and NIR images. The performance of this approach has been only evaluated using indoor images, when it is used in outdoor scenarios, the color correction does not work properly so that the obtained results are not like the natural colors.

3 Proposed Approach

We formulate the removal of the NIR information from the R_{RGBN}, G_{RGBN}, and B_{RGBN} channels of a RGBN camera as a regression problem. This regression problem is solved by using a neural network defined by two hidden layers with ten neurons each. The network is trained to learn a mapping function $\Omega : \mathbb{R}^4 \rightarrow \mathbb{R}^3$ that maps a pixel color from an RGBN camera (see Fig. 2(*middle*)) to a RGB pixel value of the same scene, but obtained without NIR information (see Fig. 2(*left*)).

The network model's input consists of a tuple $I = \{\mathtt{R}_{RGBN}, \mathtt{G}_{RGBN}, \mathtt{B}_{RGBN}, \mathtt{N}_{RGBN}\}$ that represent a color pixel value in a RGBN camera. The model has two hidden layers of ten neurons each and produces an output tuple $O = \{\mathtt{R}, \mathtt{G}, \mathtt{B}\}$ that contains the R,G,B values of the RGBN camera where the NIR information has been filtered.

We use a Smooth L1 loss function, defined as:

$$loss(x, y) = \frac{1}{n} \sum \begin{cases} 0.5 * (x_i - y_i)^2 & \text{if } |x_i - y_i| < 1 \\ |x_i - y_i| - 0.5 & \text{otherwise} \end{cases} \tag{2}$$

where, x is the set of all RGBN pixels values in the training set, and y the set of the corresponding pixels from the groundtruth.

The network has been trained using Stochastic Gradient Descent with the following parameters: learning rate 1e-5, momentum 0.17, weight decay 1e-5, and batchsize of 128. Figure 3 presents just an illustration of the proposed architecture.

4 Experimental Results

The proposed approach has been evaluated using two 4 megapixels single sensor RGBN cameras[2] rigidly attached in a common platform (see Fig. 2(*right*)). In one of the cameras an infrared cut-off filter is used; the obtained RGB images

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[1] Demosaicking refers to obtaining the {R,G,B,NIR} components from a given pixel, where all the information is attached together is a single square array {B,G} in top and {IR,R} from the bottom, see an illustration of this pixel composition in Fig. 2.

[2] https://www.e-consystems.com/.

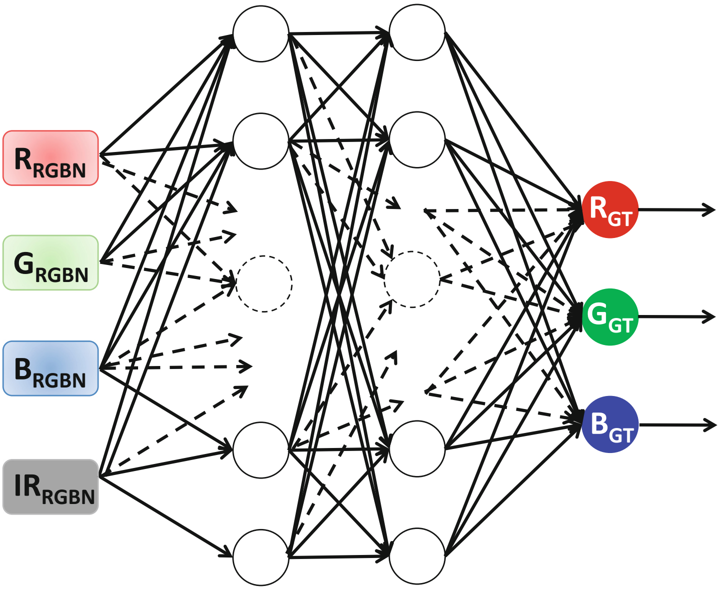

Fig. 3. Illustration of the network architecture used to learn the mapping function Ω.

are considered as ground truth. In order to qualitatively evaluate the obtained result a naïve approach based on minimizing the square error between the RGB and the corresponding RGBN images is provided; with this naïve approach a color correction matrix $\mathbf{M}_{CC}$ is obtained as follows:

$$E = \sum_{i=1}^{i=N} (RGB_{GT} - \mathbf{M}_{CC} \times RGB_{RGBN})^2, \qquad (3)$$

where subindex GT corresponds to the ground truth values (elements from the camera with infrared cut-off-filter), subindex RGBN corresponds to the pixel values obtained with the RGBN camera, $\mathbf{M}_{CC}$ is the color correction matrix (a square matrix of 3×3 elements), and N represents all the pixels from all the images used to estimate (E). In order to do a fair comparison the same set of images (83 pairs of images of 256×256 pixels) used to train the network have been considered; in other words (E) is computed by considering $N = 83 \times 256 \times 256 = 5,439,488$ elements.

With the setup presented in Fig. 2(*right*) a set of 89 pairs of images has been obtained[3]. Note that although the cameras have been rigidly attached, trying to place their optical axis as parallel as possible, the obtained images need to be registered. This registration process is needed in order to guarantee a pixel-to-pixel correspondence. Differences due to camera disparity are neglected since cameras' optical axis are quite near in comparison to the depth of the

[3] http://www.cvc.uab.es/~asappa/Color_Correction_Dataset.rar.

(a) (b) (c) (d)

Fig. 4. Illustrations of: (a) Original RGBN image; (b) Result obtained from the MSE color correction; (c) Result from the network trained with RGB and NIR images; (d) RGB ground truth image obtained by using the infrared cut-off-filter.

objects in the scene (actually, the data set has been created having in mind this assumption, so that scenes containing objects far away from the camera have been considered). RGB and RGBN images have been registered using the Matlab Image Alignment Toolbox (IAT)[4] (in the RGBN images just the RGB channels are considered for the registration process). After images have been registered, they were cropped into images of 256×256 pixels to avoid problems with border pixels. This cropping area is centered in every registered image. From the 89 pairs data set 71 pairs have been used for both the network training and for computing the $\mathbf{M}_{CC}$; the remainder 18 pairs were used for validating the results. A qualitative validation (just 18 pairs) has been performed comparing the results from the neural network and those obtained by using the naïve color correction approach.

Figure 4 presents just three illustrations of the results obtained with the neural network proposed approach Fig. 4(c), which can be compared with the corresponding ground truth Fig. 4(d), as it can be appreciated, although the network architecture is quite simple, the results obtained with the proposed

[4] http://iatool.net/.

approach looks quite similar to those form the ground truth. On the contrary, the result obtained from the color correction matrix (see Fig. 4(b)) are not so similar to those from the ground truth. As a conclusion from these results we have identified two ways to improve them. The first one is related with the data set. A larger data set, with more color variability, obtained at different daylight time is required to learn a more accurate Ω mapping function by the network. The second improvement is related with the used architecture, other configurations should be evaluated (more hidden layers and more neurons per layer). In Fig. 4 just three results from the 17 pairs used for validation are presented, the whole set of images used for validation can be downloaded from: http://www.cvc.uab.es/~asappa/Results_for_Validation.rar.

5 Conclusions

This paper presents a novel approach to tackle the challenging problem of NIR information removal (referred to as color restoration) in single sensor RGBN cameras. On the contrary to previous approaches, which are based on a sensor model that work under constrained scenarios, the proposed approach is based on a neural network architecture that is able to learn a mapping function Ω that transform the 4D coupled information into a 3D representation. Experimental results with different outdoor scenarios have been tested showing the validity of the proposed approach. Additionally, comparisons with a naïve color correction based on minimizing the square error are provided.

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Learning to Colorize Infrared Images

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Abstract. This paper focuses on near infrared (NIR) image colorization by using a Generative Adversarial Network (GAN) architecture model. The proposed architecture consists of two stages. Firstly, it learns to colorize the given input, resulting in a RGB image. Then, in the second stage, a discriminative model is used to estimate the probability that the generated image came from the training dataset, rather than the image automatically generated. The proposed model starts the learning process from scratch, because our set of images is very different from the dataset used in existing pre-trained models, so transfer learning strategies cannot be used. Infrared image colorization is an important problem when human perception need to be considered, e.g., in remote sensing applications. Experimental results with a large set of real images are provided showing the validity of the proposed approach.

Keywords: CNN in multispectral imaging · Image colorization

1 Introduction

Image acquisition devices have largely expanded in recent years, mainly due to the decrease in price of electronics together with the increase in computational power. This increase in sensor technology has resulted in a large family of images, able to capture different information (from different spectral bands) or complementary information (2D, 3D, 4D); hence, we can have: HD 2D images; video sequences at a high frame rate; panoramic 3D images; multispectral images; just to mention a few. In spite of the large amount of possibilities, when the information needs to be provided to a final user, the classical RGB representation is preferred. This preference is supported by the fact that human visual perception system is sensitive to (400–700 nm); hence, representing the information in that range help user understanding. In this context, the current paper tackles the near infrared (NIR) image colorization, trying to generate realistic RGB representations. Different applications could take advantage of this contribution—infrared sensors can be incorporated for instance in driving assistance applications by

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providing realistic colored representation to the driver, while the image processing can be automatically performed by the system in the infrared domain (e.g., semantic segmentation at the material level avoiding classical problems related with the color of the object surface).

The NIR spectral band is the closest in wavelength to the radiation detectable by the human eye; hence, NIR images share several properties with visible images. The interest of using NIR images is related with their capability to segment images according to the object's material. Surface reflection in the NIR spectral band is material dependent, for instance, most pigments used for material colorization are somewhat transparent to NIR. This means that the difference in the NIR intensities is not only due to the particular color of the material, but also to the absorption and reflectance of dyes.

The absorption/reflectance properties mentioned above are used for instance in remote sensing applications for crop stress and weed/pest infestations. NIR images are also widely used in video surveillance applications since it is easier to detect different objects from a given scene. In these two contexts (i.e., remote sensing and video surveillance), it is quite difficult for users to orientate when NIR images are provided, since the lack of color discrimination or wrong color deploy. In this work a neural network based approach for NIR image colorization is proposed. Although the problem shares some particularities with image colorization (e.g., [1–3]) and color correction/transfer (e.g., [4,5]) there are some notable differences. First, in the image colorization domain—gray scale image to RGB—there are some clues, such as the fact that luminance is given by grayscale input, so only the chrominance need to be estimated. Secondly, in the case of color correction/transfer techniques, in general three channels are given as input to obtain the new representation in the new three dimensional space. In the particular problem tackled in this work (NIR to visible spectrum representation) a single channel is mapped into a three dimensional space, making it a difficult and challenging problem. The manuscript is organized as follows. Related works are presented in Sect. 2. Then, the proposed approach is detailed in Sect. 3. Experimental results with a large set of images are presented in Sect. 4. Finally, conclusions are given in Sect. 5.

2 Related Work

The problem addressed in this paper is related with infrared image colorization, as mentioned before somehow it shares some common problems with monocromatic image colorization that has been largely studied during last decades. Colorization techniques algorithms mostly differ in the ways they obtain and treat the data for modeling the correspondences between grayscale and color. Non-parametric methods, given an input grayscale image, firstly they define one or more color reference images (provided by a user or automatically retrieved) to be used as source data. Then, following the image analogy framework, color is transferred onto the input image from analogous regions of the reference image(s). Parametric methods, on the other hand, learn prediction functions from large datasets of color images at training time, posing the problem as either regression onto continuous color space or classification of quantized color values.

Welsh et al. [6] describe a semi-automatic technique for colorizing a grayscale image by transferring color from a reference color image. They examine the luminance values in the neighborhood of each pixel in the target image and transfer the color from pixels with matching neighborhoods in the reference image. This technique works well on images where differently colored regions give rise to distinct luminance clusters, or possess distinct textures. In other cases, the user must direct the search for matching pixels by specifying swatches indicating corresponding regions in the two images. It is also difficult to fine-tune the outcome selectively in problematic areas.

The approaches presented above have been implemented using classical image processing techniques. However, recently Convolutional Neural Network (CNN) based approaches are becoming the dominant paradigm in almost every computer vision task. CNNs have shown outstanding results in various and diverse computer vision tasks such as stereo vision [7], image classification [8] or even difficult problems related with cross-spectral domains [9] outperforming conventional hand-made approaches. Hence, we can find some recent image colorization approaches based on deep learning, exploiting to the maximum the capacities of this type of convolutional neural networks. As an example, we can mention the approach presented on [3]. It proposes a fully automatic approach that produces brilliant and sharpen image color. They model the unknown uncertainty of the desaturated colorization levels designing it as a classification task and use class-rebalancing at training time to augment the diversity of colors in the result. On the contrary, [10] presents a technique that combines both global priors and local image features. Based on a CNN a fusion layer merges local information, dependent on small image patches, with global priors, computed using the entire image. The model is trained in an end-to-end fashion, so this architecture can process images of any resolution. They leverage an existing large-scale scene classification database to train the model, exploiting the class labels of the dataset to more efficiently and discriminatively learn the global priors. In [11], a recent research on colorization, addressing images from the infrared spectrum, has been presented. It uses convolutional neural networks to perform an automatic integrated colorization from a single channel NIR image to RGB images. The approach is based on a deep multi-scale convolutional neural network to perform a direct estimation of the low RGB frequency values. Additionally, it requires a final step that filters the raw output of the CNN and transfers the details of the input image to the final output image.

Generative Adversarial Networks (GANs) are a class of neural networks which have gained popularity in recent years. They allow a network to learn to generate data with the same internal structure as other data. GANs are powerful and flexible tools, one of its more common applications is image generation. It is a framework presented on [12] for estimating generative models via an adversarial process, in which simultaneously two models are trained: a generative model G that captures the data distribution, and a discriminative model D that estimates the probability that a sample came from the training data rather than G. The training procedure for G is to maximize the probability of D making a mistake. This framework corresponds to a minimax two-player game. In the space of arbitrary functions G and D, a unique solution exists, with G recovering the training data distribution and D equal to 1/2 everywhere. In addition on [13] is explained Some techniques to improve the efficiency of the generative adversarial networks, one of them called, the virtual batch normalization, which allows to significantly improve the network optimization using the statistics of each set of training batches. The disadvantage is that this process is computationally expensive. Our proposal is based on designing a generative adversarial deep learning architecture that allows the colorization of images of the near infrared spectrum, so that they can be represented in the visible spectrum. The following section will explain in detail the network model used.

3 Proposed Approach

This section presents the approach proposed for NIR image colorization. A GAN network based architecture is selected due to its fast convergence capability. The network is intended to learn to generate new samples from an unknown probability distribution. In our case, in order to obtain a true color, the GAN framework is reformulated for a conditional generative image modeling tuple. In other words, the generative model $G(z; \theta_g)$ is trained from a near infrared image in order to produce a colored RGB image; additionally, a discriminative model $D(z; \theta_d)$ is trained to assign the correct label to the generated colored image, according to the provided real color image, which is used as a ground truth. Variables (θ_g) and (θ_d) represents the weighting values for the generative and discriminative networks.

The GAN network has been trained using Stochastic AdamOptimazer since it prevents overfitting and leads to convergence faster. Furthermore, it is computationally efficient, has little memory requirements, is invariant to diagonal rescaling of the gradients, and is well suited for problems that are large in terms of data and/or parameters. Besides, GANs provide a powerful technique for generating plausible-looking natural images with high perceptual quality. The model was trained with the following hyper-parameters: learning rate 0.0001 and 0.0002 for the generator and the discriminator networks respectively; epsilon = 1e-08; exponential decay rate for the 1st moment momentum 0.5 for discriminator and 0.4 for the generator; weight initializer with a standard deviation 0.0081; weight decay 1e-5; leak relu 0.2 and patch's size of 64×64. The convolutional architecture of the baseline model is conformed by convolutional, de-convolutional, relu, leak-relu, fully connected and activation function tanh and sigmoid for generator and discriminator networks respectively. Additionally, every layer of the model uses batch normalizaton for training any type of mapping that consists of multiple composition of affine transformation with element-wise nonlinearity and do not stuck on saturation mode. Figure 1 presents an illustration of the proposed GAN architecture.

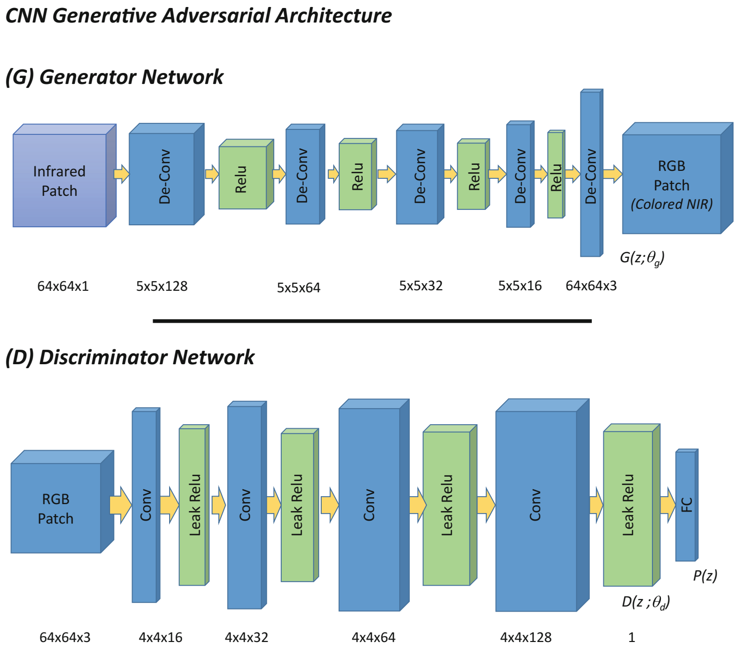

Fig. 1. Illustration of the network architecture used for NIR image colorization.

The generator (G) and discriminator (D) are both feedforward neural networks that play a min-max game between one another. The generator takes as an input a near infrared image patch of 64×64 pixels, and transforms it into the form of the data we are interested in imitating, in our case a RGB image. The discriminator takes as an input a set of data, either real image (z) or generated image (G(z)), and produces a probability of that data being real (P(z)). The discriminator is optimized in order to increase the likelihood of giving a high probability to the real data (the ground truth given image) and a low probability to the fake generated data (wrongly colored NIR image), as introduced in [12]; thus, it is formulated as follow:

$$\bigtriangledown_{\theta_g} \frac{1}{m}[\log D(x^{(i)}) + \log(1 - D(G(z^{(i)})))], \quad (1)$$

where m is the number of patches in each batch, x is the ground truth image and z is the colored NIR image generated by the network. The weights of the discriminator network (D) are updated by ascending its stochastic gradient. On the other hand, the generator is then optimized in order to increase the probability of the generated data being highly rated:

$$\bigtriangledown_{\theta_g} \frac{1}{m} \sum_{i=1}^{m} \log(1 - D(G(z^{(i)}))). \quad (2)$$

where m is the number of samples in each batch and z is the colored NIR image generated by the network. Like in the previous case, the weights of the generator network (G) are updated by descending its stochastic gradient.

4 Experimental Results

The proposed approach has been evaluated using NIR images and their corresponding RGB obtained from [14]. The *urban* category has been considered; it contains 116 images of (1024×680 pixels). From these images 64,200 pairs of patches of (64×64 pixels) have been cropped both, in the NIR images as well as in the corresponding RGB images. Additionally, 12,800 pairs of patches of (64×64 pixels) have been also generated from the given *urban* dataset for validation. It should be noted that images are correctly registered, so that a pixel-to-pixel correspondence is guaranteed (Fig. 2).

Fig. 2. Pair of images (1024×680 pixels) from [14], *urban* category: (*top*) NIR images to colorize; (*bottom*) RGB images used as ground truth.

The GAN network proposed in the current work for NIR image colorization has been trained using a 3.2 eight core processor with 16 Gb of memory with a NVIDIA GeForce GTX970 GPU. On average every training process took about 8 h. The obtained results (RGB_{NIR}) where qualitatively and quantitatively evaluated with respect to the corresponding RGB images provided in the given data set, which are used as ground truth (RGB_{GT}). The quantitative evaluation consists of measuring at every pixel the angular error between the obtained result (colorized NIR image) and the corresponding RGB image provided in the given data set as ground truth values:

$$AngularError = \cos^{-1}\left(\frac{\mathrm{dot}(RGB_{NIR}, RGB_{GT})}{\mathrm{norm}(RGB_{NIR}) * \mathrm{norm}(RGB_{GT})}\right) \quad (3)$$

Fig. 3. Set of **good results** obtained from the proposed approach (**average color angular error: 5.7°**): (*top*) Original NIR patches to be colorized (64×64 pixels); (*middle*) Results from the proposed approach; (*bottom*) Ground truth images.

This angular error is computed over every single pixel of the whole set of images used for validation, obtaining the following results: mean angular error = 9.86°; standard deviation = 5.31°. As aforementioned, these are mean values, so in order to visually appreciate these results, two sets of image patches colored with the proposed approach have been generated—due to space limitation just three images per set are presented[1]. In the first family, patches with small angular error are presented (in this case average angular error is below to 6°), see Fig. 3. In the second family, patches with larger angular errors are depicted (in this case average angular error is higher than 15°), see Fig. 4. In this second case, although the angular error is larger than before, the global color is some how obtained; the main problem with these patches lies on the texture present in the scene.

[1] The whole set of image patches used for training and validation, as well as the obtained results, are available by contacting the authors.

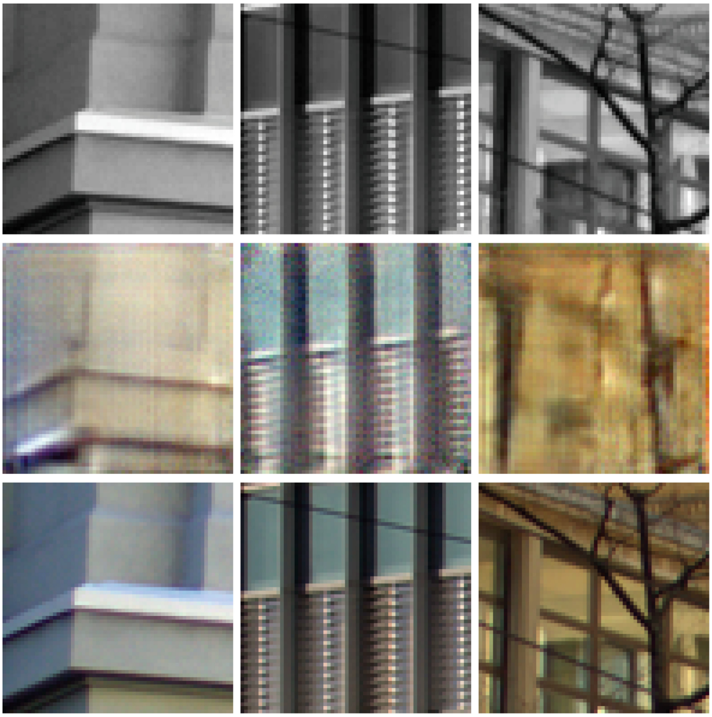

Fig. 4. Set of **bad results** obtained from the proposed approach (**average color angular error: 15.28°**): (*top*) Original NIR patches to be colorized (64 × 64 pixels); (*middle*) Results from the proposed approach; (*bottom*) Ground truth images.

5 Conclusions

This paper tackles the challenging problem of NIR image colorization by using a novel Generative Adversarial Network architecture model. Results have shown that in most of the cases the network is able to obtain a reliable RGB representation of the given NIR image. Future work will be focused on evaluating others network architectures, like autoencoders, which have shown appealing results in recent works. Additionally, increasing the number of images to train, in particular the color variability, will be considered. Finally, the proposed approach will be tested in other image categories.

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Special Sessions on Web and Social Media Mining (WASMM)

Automatic Construction of Domain-Specific Sentiment Lexicons for Polarity Classification

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Abstract. The article describes a strategy to build sentiment lexicons (positive and negative words) from corpora. Special attention will paid to the construction of a domain-specific lexicon from a corpus of movie reviews. Polarity words of the lexicon are assigned weights standing for different degrees of positiveness and negativeness. This lexicon is integrated into a sentiment analysis system in order to evaluate its performance in the task of sentiment classification. The experiments performed shows that the lexicon we generated automatically outperforms other manual lexicons when they are used as features of a supervised sentiment classifier.

Keywords: Sentiment analysis · Opinion mining · Sentiment lexicon · Polarity classification

1 Introduction

There exist two main approaches to finding the sentiment polarity at a document or sentence level. First, machine learning techniques based on training corpora annotated with polarity information and, second, strategies based on polarity lexicons. Lexicon-based approaches are very popular in sentiment analysis and opinion mining, and they play a key role in all applications in this field. The main concern of lexicon-based approaches is that most polarity words are domain-dependent since the subjectivity status of most words is very ambiguous. The same word may be provided with a subjective burden in a specific domain while it can refer to an objective information in another domain. It follows that domain-dependent lexicons should outperform general-purpose dictionaries in the task of sentiment analysis. However, the construction of domain-dependent polarity lexicons is a strenuous and boring task if it is made manually for each target domain. With the increasing of many sentiment corpora in diverse domains, the automatic generation of this kind of resources for many domains is becoming a fundamental task in opinion mining and sentiment analysis [4]. The objective of this article is to propose a method for automatically building polarity lexicons from corpora. More precisely, we focus on the construction of a domain-specific

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lexicon from a corpus of movie reviews and its use in the task of sentiment analysis. The experiments reported in this article shows that our automatic resource outperforms other manual general-purpose lexicons when they are used as features of a supervised sentiment classifier.

The rest of the paper is organized as follows. In Sect. 2 we describe the related work. Then, Sect. 3 describes the method to create our proposed lexicon and how to use it in the classification task. The Experiments are introduced in Sect. 4, where we also describe the evaluation and discuss the results. We draw conclusions in Sect. 5.

2 Related Work

There are, at least, two ways of building sentiment lexicons: hand-craft elaboration [5,13], and automatic construction on the basis of an external resource [9]. We are interested in the automatic strategy, which builds the sentiment lexicons using diverse resources. Two different automatic strategies may be identified according to the nature of these resources: thesaurus or corpora.

2.1 Thesaurus-Based

This strategy requires seed sentiment words to bootstrap new polarity entries. They are based on the synonyms and antonyms structure of thesaurus. [6] report a thesaurus-based method that makes use of synonymy relation between adjectives in WordNet to generate a graph. More precisely, the authors measure the shortest path between the adjective and two basic sentiment seeds, "good" and "bad", to determine the polarity of a word. This is a semi-supervised learning method which starts with a lexical resource, WordNet, and a small list of seeds in order to expand the lexical resource in an iterative process. In a similar way, [7] propose a method that starts with three seed lists containing positive, negative and neutral words, which are also expanded with their synonyms in WordNet. Unlike these strategies, our method does not require any thesaurus to expand the lexicon with synonyms or antonyms.

2.2 Corpus-Based

The work described in [14] is one of the pioneer studies focused on learning polarities from corpus by classifying reviews into two categories "recommend or not recommend" depending on the average number of positive and negative phrases appear in the review. Their algorithm consists of the following steps: first, it searches for phrases in the review by using a Part-Of-Speech (POS) tagger and then determines the polarity of the extracted phrases by computing Pointwise Mutual Information and Information Retrieval (PMI-IR). Then, the algorithm identifies those associative words returned by the search engine using the NEAR operator. Finally, the polarity of each phrase is determined by computing all the polarities returned by the search engine.

[8] present an automated approach for constructing a context-dependent lexicon from an unlabeled opinionated text collection based on existing lexicons and tagged consumer reviews. Each entry of this lexicon is a pair containing a sentiment term and different "aspect" terms associated with the former. The same sentiment term may diverge in polarity when co-occurring with a particular aspect term. This strategy is semi-supervised since it needs to start with a seed list of words or with an existing lexicon. By contrast, our method generates the lexicon of positive and negative adjectives and adverbs directly from any labeled corpus for any language without needs to start with the small set of words as a seed or any existing lexicon.

3 The Method

Our strategy consists of two tasks: first, we create a corpus-based polarity lexicon with two labels, negative and positive, and a polarity weight assigned to each word. Second, sentiment classification is performed by making use of this lexical resource.

3.1 Sentiment Lexicon Generation

We detail how to construct a lexicon that ranks words from the negative values to positive ones. The lexicon can be generated using any corpus of reviews labeled with star rating: one star (most negative) to N stars (most positive). The category set is the number of stars that can be assigned to the reviews. For instance, we are provided with 10 categories only if each review can be rated from 1 to 10. The first step to create our proposed lexicon is to measure the relative frequency (RF) for every word w in each category c according to Eq. 1:

$$RF_c(w) = \frac{freq(w,c)}{Total_c} \tag{1}$$

where c is any category of the star rating, from 1 to N; $freq(w,c)$ is the number of tokens of the target word in c; and $Total_c$ is the total number of word tokens in c. As in our experiments, the corpus was PoS tagged; words are actually represented as (Word, Tag) pairs. Besides, we only work with adjectives and adverbs as they are the most relevant part of speech tags in sentiment analysis for any language, according to [2].

The second step is to calculate the average of the RF values for two ranges of categories: negative and positive. For this purpose, it is necessary to define two values: first, a borderline value for negative and positive opinions, which might vary according to the specific star rating of the reviews. Second, the number of neutral categories. For example, if the star rating goes from 1 to 10 categories and we set the borderline in 4 with two neutral categories, the negative reviews would be those rated from 1 to 4, while the positive reviews would be from

7 to 10. So the neutral reviews would be those rated from 5 to 6. Given a borderline value, B, the average of the negative scores, Avn, for a word is computed as follows:

$$Avn(w) = \frac{\sum_{c=1}^{B} RF_c(w)}{B} \tag{2}$$

On the other hand, given Nt and N where N is the total number of categories, and Nt is the number of neutral categories, the average of positive scores, Avp, for each word is computed in Eq. 3:

$$Avp(w) = \frac{\sum_{c=B+Nt}^{N} RF_c(w)}{B} \tag{3}$$

In the following step, the negative and positive words are selected by comparing the values of Avn with Avp. Given a word w, we compute the difference D in Eq. 4 and assign this value to w, which stands for the final *weight* of the word:

$$D(w) = Avp(w) - Avn(w) \tag{4}$$

If the value of $D(w)$ is negative, w will be in the class of negative words. If the value of $D(w)$ is positive, w will be in the positive class.

3.2 Sentiment Classification

As our aim is to evaluate the efficiency of our proposed lexicon, we train a sentiment classifier by making use of simple lexicon-based features, namely: the number of positive and negative terms in the document, and the proportion of positive and negative terms. We use just lexicon-based features because the purpose of the evaluation is to measure the quality of the given lexicon. Those features were used to train a Linear Support Vector Classifier (sklearn.svm.LinearSVC)[1] with the scikit-learn free software machine learning library for the Python programming language. Each dataset was randomly split into a training set and a test set (75% and 25% of the documents, respectively). The classifiers were optimised by applying 5-fold cross-validation against the training data.

4 Experiments

In our experiments, we automatically built a polarity lexicon using the strategy defined above in Sect. 3.1. Our lexicon was evaluated and compared with other two existing handcraft lexicons in the task of classifying reviews as positive or negative. For the purpose of evaluation, we used movie reviews.

Movie reviews have been examined for sentiment analysis and opinion mining in many studies [1,11]. We have chosen to deal with movie reviews in all experiments since many datasets are freely available in this domain. In addition to

[1] http://scikit-learn.org/stable/modules/generated/sklearn.svm.LinearSVC.htmll.

that, [14] found movie reviews is one of the most sensitive domains for sentiment classification. The reason is that the negative opinions about a bad movie may contain positive words for describing the events or characters in the same movie. The contrary is also true. So, movie reviews are very challenging for sentiment analysis compared to other domains.

4.1 Lexicons

In the following, three lexicons will be compared: the lexicon we built using our strategy, called SPLM, a manual resource reported in [13], called SO-CAL, and SentiWords [3].

4.1.1 SPLM

Our proposed lexicon was built from the corpus introduced in [12]. The corpus[2] consists of data gathered from the user-supplied reviews at the IMDB. Each of the reviews in this collection has an associated star rating: one star (most negative) to ten stars (most positive). The reviews were tagged using the Stanford Log-Linear Part-Of-Speech Tagger. Then, tags were broken down into the WordNet Tags: *a* (adjective), *n* (noun), *v* (verb), *r* (adverb). Words whose tags were not part of those syntactic categories were filtered out. The list of selected words was then stemmed.

Table 1. A sample of the IMDB collection format for the word "bad" as adjective ("a") in each Category (from 1 to 10)

Word	Tag	Category	Count	Total
bad	a	1	122232	25395214
bad	a	2	40491	11755132
bad	a	3	37787	13995838
bad	a	4	33070	14963866
bad	a	5	39205	20390515
bad	a	6	43101	27420036
bad	a	7	46696	40192077
bad	a	8	42228	48723444
bad	a	9	29588	40277743
bad	a	10	51778	73948447

Table 1 shows a sample for the adjective "bad", where *Freq* is the total number of tokens of a (Word, Tag) pair in each Category (from rate 1 to 10), while *Total* is the total number of word tokens in each Category. Notice that Total

[2] http://compprag.christopherpotts.net/code-data/imdb-words.csv.zip.

values are constant for all words but they repeated for each one in order to make processing easier.

The next step is to compute *Avn* and *Avp* for each word. By making use of the equations defined above (3, 2 and 4), we obtain the weights assigned to each word-tag pair. It results in a ranked opinion lexicon, which is freely available[3].

4.1.2 SO-CAL

[13] constructed their lexicon manually as they believe that the overall accuracy of dictionary-based sentiment analysis mainly relies on the quality of those resources. They built lexicons with content words, namely adjectives, adverbs, nouns and verbs, adding sentiment scores between -5 and $+5$ (where semantically neutral words are assigned zero score).

4.1.3 SentiWords

SentiWords is a sentiment lexicon derived from SentiWordNet using the method described in [3]. It contains more than 155.000 words associated with a sentiment score between -1 (very negative) and $+1$ (very positive). The words in this lexicon are arranged with WordNet lists, which include adjectives, nouns, verbs and adverbs.

4.2 The Datasets

In order to evaluate the performance of the proposed lexicons in a sentiment classification task, we used the following two datasets:

4.2.1 Sentiment Polarity Datasets

This collection[4] consist of 1000 positive and 1000 negative processed reviews. All reviews in this dataset have been extracted from IMDB and Introduced in [11].

4.2.2 Large Movie Review Dataset

This collection of documents[5] reported in [10] consists of 50,000 reviews from IMDB, allowing less than 30 reviews per movie. The dataset consists of two balanced training and test sets, with 25,000 reviews each. The rating scale is larger than in the previous dataset: it goes from 1 to 10. The borderline variable is set to 4, so the negative reviews are assigned values between 1–4, while the positive ones are in the range 7–10.

[3] https://github.com/almatarneh/SPLM-Lexicon.
[4] https://www.cs.cornell.edu/people/pabo/movie-review-data/.
[5] http://ai.stanford.edu/~amaas/data/sentiment/.

4.3 Evaluation

The three lexicons are evaluated on the two datasets of scaled reviews by using the sentiment classifier introduced above in Sect. 3.2.

Equation 5 is used to compute the f-score F_1, which is the weighted average of the precision, P, and recall, R.

$$F_1 = 2 * \frac{P * R}{P + R} \tag{5}$$

The experimental results are shown in Table 2. By comparing the f-score obtained by the three lexicons, we may conclude that the lexicon we automatically generated, SPLM, consistently outperforms the other manual lexicons on the two datasets.

It is worth noticing that SO-CAL and SentiWords are general-purpose polarity lexicons, while SPLM is a domain-specific resource. This might explain why our lexicon performs better. However, we should point out that SPLM is the result of an automatic method while the other resources were made manually.

Table 2. Results in terms of precision (P), recall (R), and F_1 scores for Positive and Negative classification. The best F_1 in each datset is highlighted (in bold)

Lexicon	Dataset	Negative			Positive		
		Precision	*Recall*	$F1$	*Precision*	*Recall*	$F1$
SPLM	SPD	0.84	0.81	**0.83**	0.81	0.84	**0.83**
	LMRD	0.77	0.75	**0.76**	0.75	0.77	**0.76**
SO-CAL	SPD	0.69	0.69	0.69	0.67	0.67	0.67
	LMRD	0.72	0.68	0.70	0.69	0.73	0.71
SentiWords	SPD	0.72	0.69	0.70	0.69	0.72	0.71
	LMRD	0.69	0.65	0.67	0.67	0.67	0.70

5 Conclusions

Lexicon-based approaches are very popular in sentiment analysis and opinion mining, and they play a key role in all applications in this field. We described in this article a method for automatically building domain-specific polarity lexicons from annotated corpora. A specific lexicon has been built using movie reviews, and we evaluated its quality in an indirect way. More precisely, the lexicon was used to train a sentiment classifier which was evaluated by means of well-known datasets. The experiments reported in our work shows that the lexicon we generated automatically outperforms other manual lexicons when they are used as features of a supervised sentiment classifier. Our corpus-based strategy is not restricted to a particular domain. It is generic enough to be expanded to whatever domain and language if we are provided with corpora annotated in the appropriate way.

In future work, we will build more domain-specific lexicons for diverse domains in order to compare them again with the general-purpose, and manual lexicons we have used in the present work.

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A Hash Based Image Matching Algorithm for Social Networks

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Abstract. One of the main research trends over the last years has focused on knowledge extraction from social networks users. One of the main difficulties of this analysis is the lack of structure of the information and the multiple formats in which it can appear. The present article focuses on the analysis of the information provided by different users in image form. The problem that is intended to be solved is the detection of equal images (although they may have minimal transformations, such as a watermark), which allows establishing links between users who publish the same images. The solution proposed in the article is based on the comparison of hashes, which allows certain transformations that can be made to an image from a computational point of view.

Keywords: Visual analysis · Image matching · Social networks

1 Introduction

This article focuses on the analysis of images published in social networks, more specifically a social network focused on work environments and job searches. In this case, the intention of the social network is to contact users with the same interests based on their publications. The users provide images as data (which may or may not be accompanied by a descriptive text, so that text will not be taken into account).

Therefore, the problem to be solved is to identify which images are the same from a human point of view, but not from a computational point of view for one or more reasons: (i) the quality has been reduced or the image format has been changed; (ii) a watermark has been included; (iii) some changes in tonality have been applied; (iv) a border has been added or removed; (v) the image has been rotated.

The solution presented in this article tries to solve this problem with an algorithm based on obtaining hashes from the images, so that the system is able to quickly compare the existing images and the new image at the moment it is sent by the user.

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The remainder of the article describes existing methodologies used in image matching and the mechanisms involved in processing large amounts of information in real time. Next, the proposed algorithm for image processing and matching is described, as well as the platform that supports real-time processing. This system is evaluated in the results section with a set of images. Finally, the article present the conclusions drawn and the lines of future work.

2 Background

As stated, the main focus of this article is to identify images that are the same from a human point of view but differ computationally, in order to put people who publish similar images in contact, as they may share common interests.

When identifying whether two images are the same, it is necessary to perform a series of checks because two apparently identical images may be computationally different due to problems of compression, different quality of the Image, number of colors, size, slight modification of the image with filters or watermarks, changes in the tonality, insertion of borders, or rotations.

In the computer vision and the image processing fields, different methodologies have been presented to extract relevant information with an image as input. These techniques are catalogued under the concept of feature detection.

There are different types of image features including edges, corners or interest points, and blobs or region of interest. In this regard, there are multiple algorithms used to process images in search of features, the most common of which are:

- **Edges**: Canny, Sobel, Harris and Stephens, SUSAN [9].
- **Corners**: Harris and Stephens, SUSAN, Shi and Tomasi, Level curve curvature, FAST, Laplacian of Gaussian, Difference of Gaussians, Determinant of Hessian.
- **Blobs**: FAST, Laplacian of Gaussian, Difference of Gaussians, Determinant of Hessian, Maximally stable extremal regions (MSER) [5], Principal curvature-based region detector (PCBR) [2], Gray-level blobs.

The concept of perceptual hashing is similar to that of the classical paradigm of cryptographic hashes, where the tiniest changes quickly evolve into an entirely different hash. In perceptual hashing the image content is used to try to fingerprint the image, so that even if hashes are not identical they can be used to determine how "close" the images are to one and other.

Another important concept that has been applied when comparing different images is the Hamming distance [6]. It can be used on most of the resulting hashes to determine the perceived difference between two images, so that a perceptually similar image would have a short hamming distance, 0, for the same image. A quick definition for hamming distance, $d(x, y)$, is the number of ways in which x and y differ. In other words, the hamming distance is simply the number of positions in which they are different.

There are different proposed algorithms based on the hash value generation technique: pHash (also called “Perceptive Hash”, with different variations) [3], aHash (also called Average Hash or Mean Hash) and dHash Also called Difference Hash) [4]. The typical hash-based algorithms flow diagram is shown in Fig. 1.

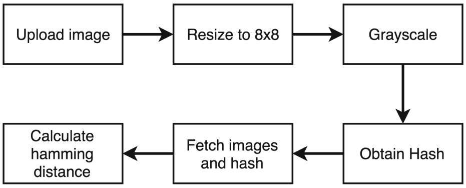

Fig. 1. Typical hash-based algorithms flow diagram.

However, all variations of this methodology present different problems when dealing with an image to which a border has been added, or one which has been rotated.

For the latter problem, a modification of these steps is proposed in [1] by introducing a rotational system whereby it is possible to differentiate images rotated 22.5°; however, this implies a loss of precision in the corners when the original images are rectangular or square, the most common situations with images uploaded to social networks, so its solution is not applicable to the present problem.

There are online platforms dedicated to the search of images that exist on the Internet and are similar to those provided by a user, without taking into account the meta-data or associated text. Their applicability is oriented to the search of image plagiarism. This is the case of TinEye [10], whose algorithm is not public, but is based on the analysis of hashes.

3 Proposed System

The proposed methodology is based on the application of techniques of image matching based on hash value generation, with certain transformations and pre-processing that are able to discriminate the possible transformations that a social network user may have applied to the image prior to uploading it.

One of the main characteristics of the proposed system, which makes it possible to improve the result of similar systems, is the preprocessing stage. This stage is focused on applying a series of transformations to the images that are received as input by the user. This is followed by a scheme similar to hash-based algorithms.

3.1 Preprocessing

The strategy followed in this first stage ensures that images which have been slightly transformed are stored in the system in the same way. This allows the system to start comparing the same or most similar image.

The present study considered the following possible transformations that a user could perform on an image, after which the image would still be considered the same: (i) insertion of an outer uniform border; (ii) rotation of the image; and (iii) insertion of a watermark. It should be noted that all hash-based algorithms are really robust if a uniform change is applied to the tonality. Therefore, such modifications were not considered for the comparison.

When a watermark is inserted, a hash-based algorithm application can be sufficient to determine if it is the same image or not despite the modification. Therefore, in this first stage of preprocessing, the proposed system focuses only on any modifications based on the insertion of an outer uniform border, and the rotation of the image.

– **Solid border addition**: The proposed system applies the Algorithm 1, allowing the following steps of the methodology to be performed without considering the uniform outer border. The first step is to transform the original image provided by the social network user I to a grayscale image gI, which will also be used in the following steps.

Algorithm 1. Solid border removal algorithm

function BORDERREMOVAL(I)
 gI = grayscale(I)
 if hasBorder(gI) **then** ▷ Check border
  $value$ = getBorderTonality(gI) ▷ Get border tonality value
  bI = toBinary(gI, $value$) ▷ Border tonality as threshold
  cnt = findContour(bI) ▷ Get contour
  ⟨ x,y,width,height ⟩ = boundingRect(cnt) ▷ Find bounding rectangle
  $gI = gI[x : x + width, y : y + height]$ ▷ Crop grayscale image
 end if
 return gI
end function

– **Image rotation**: The most common rotations that a user applies to an image are based on 90° modifications. This part of the preprocessing is centered on precisely this type of rotation. The objective is for the images to follow a rotation pattern so that they always have the same orientation in the system. Different solutions are possible, depending on whether the shape of the image is rectangular or square.
If the image is rectangular, the system will always work with the image in landscape mode (the two longest sides are in the x-axis) The system must then determine which side is placed on the top and which is placed on the bottom. If the image is square, the previous logic cannot be applied, since the four sides are the same length. In both cases, the key of the final orientation will be the tonality of the image, as described by the Algorithm 2. Although this step appears in the preprocessing section, it is applied in an intermediate step of the Algorithm 3, which will be detailed below, to avoid possible changes in the tonality resulting from the insertion of a watermark.

Algorithm 2. Image rotation algorithm

```
function imageRotation(gI,sI)
    width = getWidth(gI)
    height = getHeight(gI)
    if width == height then                                   ▷ Square image
        nsI = sI[0 : width, 0 : height/2]                     ▷ Get North middle
        ssI = sI[0 : width, height/2 : height]                ▷ Get South middle
        wsI = sI[0 : width/2, 0 : height]                     ▷ Get West middle
        esI = sI[width/2 : width, height/2 : height]          ▷ Get East middle
        highestMean = getHighestValue(\overline{nsI}, \overline{ssI}, \overline{wsI}, \overline{esI})
        if highestMean == \overline{nsI} then                 ▷ Highest tonality on top
            rI = rotate(sI,180)
        else if highestMean == \overline{wgI} then
            rI = rotate(sI,270)
        else if highestMean == \overline{egI} then
            rI = rotate(sI,90)
        else
            rI = sI
        end if
    else                                                      ▷ Rectangular image
        if width < height then
            gI = rotate(sI,90)          ▷ Longest image side over x-axis (landscape)
        end if
        nsI = sI[0 : width, 0 : height/2]                     ▷ Get North middle
        ssI = sI[0 : width, height/2 : height]                ▷ Get South middle
        if \overline{ngI} < \overline{sgI} then               ▷ Highest tonality on top
            rI = rotate(sI,180)
        else
            rI = sI
        end if
    end if
    return rI
end function
```

3.2 Hash-Based Transformations

Hash-based algorithms are the most suited for the problem of image matching because they are very fast. The pHash algorithm extends the aHash approach by using discrete cosine transform (DCT) [8] to reduce the frequencies. We have followed a similar schema; we defined the Algorithm as 3 and used it to obtain the hash associated with the image I, which is provided by a user of a social network. The input of this algorithm is the grayscale image gI, obtained in the preprocessing step.

Top-left 12×12 values are obtained because they represent the lowest frequency range. In contrast, the bottom right is the highest frequency range. The human eye is not very sensitive to high frequencies.

Algorithm 3. pHash-based algorithm

```
function GETIMAGEHASH(gI)
    sI = reduceSize(gI, 32, 32)                ▷ Reduce size to 32 × 32 pixels
    rI = imageRotation(gI,sI)                  ▷ Rotate as defined in Algorithm 2
    DCT = computeDCT(rI, 32, 32)               ▷ Get a collection of frequencies and scalars
    sDCT = reduceDCT(DCT, 12, 12)              ▷ Get the lowest freq. (top-left 12 × 12)
    for each px ∈ sDCT do
        if px > mean(sDCT) then                ▷ Compare every pixel with sDCT mean
            hash = hash + 1
        else
            hash = hash + 0
        end if
    end for
    return hash
end function
```

As a result, we have the value of the hash composed of 144 values (12×12) 1 or 0 in order to evaluate the distance by using the Hamming distance algorithm, which simply compares each bit position and counts the number of differences.

4 Results

To perform the tests of the proposed system, a set of 200,000 images available in the public repository of Pixbay [7] was used as image dataset.

Figure 2 presents an example of the processing of two images obtained from the original. On the left side, there is an image with a yellowish hue, rotated 90°, with an outer border, and a watermark in the lower left corner. On the right, the processing of an image obtained directly from the original is shown. The result in both cases is a 144-digit value composed of 1 and 0, as detailed in the Algorithm 3. After calculating the Hamming distance, the system determines that both images are 99.3% equal.

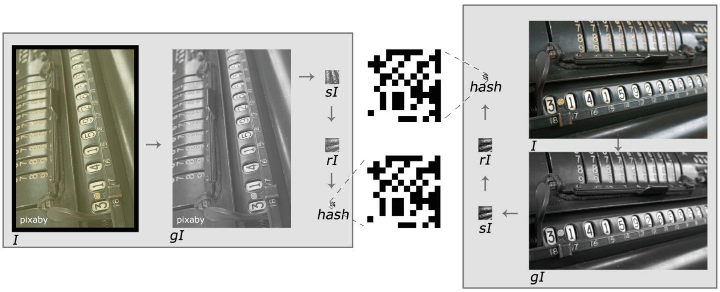

Fig. 2. Example of the system process.

To evaluate the performance of the algorithm, it was compared with the different implementations of hash-based algorithms. 1,000 images were obtained from the total set of the images to which different transformations were applied. The success rate was evaluated by considering the result a success for those cases in which the system associates the modified image with the original image of the dataset as the most similar, having a similarity value greater than 99%. The applied transformations and the images used are shown in Table 1.

Table 1. Test dataset

	n	b	w	r	b + w	b + r	w + r	b + w + r	Total
Images	**125**	125	125	125	125	125	125	125	1000

Legend: n = none; b = border; w = watermark; r = rotation

All of these images were provided as input using the implementations of the pHash, aHas, and dHash algorithms, the proposed algorithm. Regarding to Tineye, whose algorithm is not public (although it has been published that it is based on hash), images have been processed by using its public API [10].

Following these indications, the results obtained are reflected in Table 2, where all images that have been catalogued as equal, and indeed were, are considered a success.

Table 2. Hit rate for hash based algorithms

	n	b	w	r	b + w	b + r	w + r	b + w + r	avg
pHash	**100%**	0%	75%	0%	0%	0%	0%	0%	22%
aHash	**100%**	0%	74%	0%	0%	0%	0%	0%	21%
dHash	**100%**	0%	75%	0%	0%	0%	0%	0%	22%
Tineye	**100%**	0%	**80%**	0%	0%	0%	0%	0%	22%
Proposed	**100%**	**90%**	75%	**100%**	**74%**	**90%**	**74%**	**74%**	**84%**

Legend: n = none; b = border; w = watermark; r = rotation; avg = average

It can be observed that the proposed system shows a better result in all transformations except when a watermark is included. In that case, Tineye and pHash show a higher success rate. In the case of Tineye, the details of its algorithm are not known. With respect to pHash, the improvement in the success rate is mainly due to the number of frequencies obtained when the DST is reduced (8×8), lower than for the proposed system (12×12).

5 Conclusion and Future Work

The proposed system improves current state of the art of image matching, by including images which have been slightly modified by the inclusion of a watermark, outer borders, or rotations of $90°, 180°$, and $270°$.

The results are robust in terms of the insertion of edges and rotations. However, with the insertion of watermarks which have considerably altered the image, none of the algorithms was able to associate the images with precision. In fact, in order not to introduce false positives (identify images as equal images when they are in fact not), it is necessary to compromise the detail with which one wants to perform the analysis.

As a future line of work, this solution will be incorporated into an existing job search social network in order to suggest contacts to users who have published or shared equal images. Regarding the image matching system, different solutions capable of associating images whose proportions have been modified by the user, either by trimming and removing part of the exterior of the image or by having deformed the image, are being evaluated. This evolution could make it possible to check rotations in each of the possible 360°.

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Using Twitter Data to Monitor Political Campaigns and Predict Election Results

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Abstract. In recent years social networks have increasingly been used to study political opinion formation, monitor electoral campaigns and predict electoral outcomes as they are able to generate huge amount of data, usually in textual and non structured form. In this paper we aim at collecting and analysing data from Twitter posts identifying emerging patterns of topics related to a constitutional referendum that recently took place in Italy to better understand and nowcast its outcome. Using the Twitter API we collect tweets expressing voting intentions in the four weeks before the elections obtaining a database of approximately one million tweets. We restrict the data collection to tweets that contain hashtags referring to the referendum, therefore we are sure to include in the analysis only relevant text. On this huge volume of data, we perform a topic modelling analysis using a Latent Dirichelet Allocation model (LDA) to extract frequent topics and keywords. Analysing the behaviour of frequent words we find that connected to voting in favour of the constitutional reform there are positive words such as future and change while connected to voting against it there are words such ad fear and risk.

Keywords: Twitter · Data mining · Topic modelling analysis · Election forecast

1 Introduction

Twitter is a social network for microblogging where users can exchange short messages of 140 characters called "tweets". It has approximately 1.3 billion users worldwide and 320 million active users per month. One of the most significant benefits of social media like Twitter is the capacity to generate a huge amount of data, enabling better predictive modelling. Through social interaction tracking and analysis, the data can be used to find out patterns and trends leading to some conclusions with prediction purposes related to several different areas like consumer behaviours, business decisions, or election results. Two of the main advantages that social networks offer are that data is freely available on the web

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and they allow to monitor users' opinion and preferences almost real-time. As a consequence, the use of Twitter to monitor political opinion formation and predict electoral outcomes has increasingly gained attention in the last decade. A large number of studies analyse the use of social media as devices to assess the popularity of politicians (Gloor et al. 2009), track political alignment and produce forecasts of election results (Ribeiro Soriano et al. 2012). Some of these works rely on very simple techniques, focusing on the volume of data related to parties or candidates. Others have tried to improve this stream of research by means of sentiment analysis, as understanding the opinion of potential voter trough social media can allow to target political campaigns and improve election forecasts. In this respect, the analysis of online sentiment has for example been used for event-monitoring, where the aim is to monitor reactionary content in social media during a specific event such as a political speech or debate of an influential politician. An example is the work of Diakopoulos and Shamma (2010), who characterised the 2008 US presidential debate in terms of Twitter sentiment. Tumasjan et al. (2010) is another example where the authors use sentiment analysis from social networks to monitor German federal election that took place in 2009. They found that the share of volume on Twitter accurately reflected the distribution of votes in the election between the six main parties. Our work is also related to the one of Bermingham and Smeaton (2011), where the authors use a recent Irish General Election as a case study for investigating the potential to model political sentiment through mining of social media. Their approach combines sentiment analysis, using supervised learning, and volume-based measures. They evaluate their results against the conventional election polls and find that social analytics using both volume-based measures and sentiment analysis are good predictors of election outcomes. For a recent review of state-of-the-art related literature see Ceron et al. (2015). Our contribution consists in collecting and analysing Twitter data related to a referendum that recently took place in Italy, where voters were asked whether to approve a constitutional reform that would change the distribution of powers between the state and the regions. In particular we monitored Twitter posts related to the referendum and classified them as either in favour or against the reform. We use a topic modelling analysis, and in particular we estimate a Latent Dirichelet Allocation model (LDA) to identify main topics and keywords used to discuss the referendum in the four weeks before the vote took place. Moreover, we monitor voting intentions of users and use the total volumes of tweets to predict the outcome of the referendum.

The paper is organized as follows: Sect. 2 describes the data collection process and the dataset, Sect. 3 present results on the topic modelling and frequent term analysis and Sect. 4 presents some concluding remarks.

2 The Dataset

Our research concerns the constitutional referendum took place in Italy on December 4th 2016. We recorded tweets between November 9th and December 12th, approximately four weeks before and one after the vote, building a new database containing a total of 1.020.844 tweets[1] As it is commonly done in the literature, we decided to collect and analyse only posts containing specific hashtags. These are a sort of labels used in social networks that allow users to find information on a specific topic or content. To decide which hashtags to include in our analysis we monitored Twitter posts talking about the referendum, but also other media such as newspapers, television programs and the national news. We collected all tweets containing the following five hashtags: #referendumcostituzionale, #iovotono, #bastaunno, #iovotosi, #bastaunsi.

Figure 1 reports the volume of collected tweets. Dates are on the x-axis and the number of tweets is on the y-axis; the analysed period is from November 9th to December 12th and the dashed vertical line corresponds to December 4th, the day of the elections. The black time series gives an idea of the total number of tweets related to the referendum, as each data-point is the daily sum of the five hashtags: #referendumcostituzionale, #iovotosi, #iovotono, #bastaunsi, #bastaunno. On November 9th, when we start monitoring tweets, the total number of tweets is approximately 20.000 while on the election day, tweets talking about the referendum reach 100.000. The blue line corresponds to the sum of the number of tweets containing the hashtags #iovotosi and #bastaunsi while the red line is the daily total number of tweets with the hashtags #iovotono and #bastaunno. As shown in the plot, the red time series is always above the blue one, showing that most of Twitter users are against the constitutional reform.

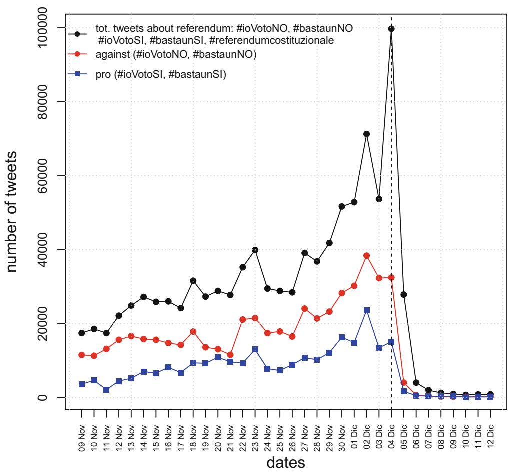

Fig. 1. Total Twitter volumes (black line) and volumes divided by *pro* and *against* the referendum. Total Twitter volumes (black line) and volumes divided by *pro* and *against* the referendum.

[1] We collected this information using the Twitter API trough the `R` package `twitteR`. The `R` package used is available at the following link: https://cran.r-project.org/web/packages/twitteR/index.html.

On December 2nd the total number of tweets *pro* constitutional reform is 23.670 while the total number of tweets *against* it is 38.402, which corresponds to 62%.

3 Topic Modelling Analysis and Frequent Terms

To analyse the text and terms contained in the tweets, we apply a topic modelling analysis allowing the probabilistic modelling of term frequency occurrences in documents. These models extend classical methods in natural language processing such the unigram model and the mixture of unigram models (Nigam et al. 2000) or the Latent Semantic Analysis (Deerwester et al. 1990). An introduction to topic models is given in Steyvers and Griffiths (2007) and Blei and Lafferty (2009). In particular, in our analysis we use the Latent Dirichlet Allocation model, henceforth LDA, that is a Bayesian mixture model for discrete data where topics are assumed to be uncorrelated. We fit this model using the `R` package `topicmodels`, that provides codes to fit an LDA model using a variational expectation-maximization (VEM) algorithm as implemented by Blei et al. (2003); for all the details see Hornik and Grün (2011). Figure 2 shows the result of the estimation of an LDA model obtained using the document-term matrix in the time period from November 9th to December 12th.

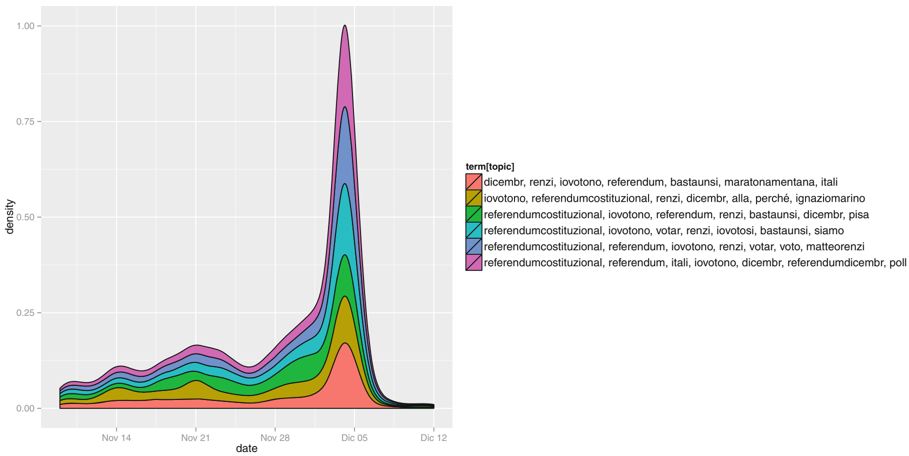

Fig. 2. Topic modelling analysis using a Latent Dirichelet Allocation model (LDA).

We run several different configurations models and we choose to present the results using 6 topics, and the 7 most likely terms for each of them. As we can see from the plot, there are two peaks on November 14th and 21st, and a major one in all topics in the days immediately before the election; this simply reflects the fact that there is a "last minute" boom of users discussing about the elections. Note that many words are present in more than one topic, while the hastag "iovotono" is in all the topics, confirming that most tweets are against the constitutional reform. Then we focus on tweets containing the hashtags #bastaunsi, #iovotosi, #bastaunno and #iovotono and we build two distinct term-document matrices, one for positive and one for negative tweets, allowing us to register the frequency of words in the tweets; terms with less than three characters are discarded. Figure 3 plots the most frequent words contained in the tweets with the hashtags #bastaunsi and #iovotosi and #bastaunno and #iovotono, respectively on the left and on the right; the frequency of terms is displayed in percentage terms. Analysing the most frequent words an interesting pattern emerges. Most of the words connected to #bastaunsi and #iovotosi, in favour of the constitutional reform, are terms connected to positive and optimistic sentiments. For example, frequent words are change, future and pride, respectively *cambiare*, *futuro* and *orgoglio*, while on the other hand words in the tweets containing the hastags #bastaunno and #iovotono are linked to negative sentiments such as risk, danger and complaint, respectively *rischio*, *pericolo* and *denuncia*. We studied the importance of words contained in the tweets using different visualization methods (as for example tag clouds in which the displayed size of words is proportional to their frequency) but we omit these plots for lack of space as they convey the same message displayed in the previous barplots.

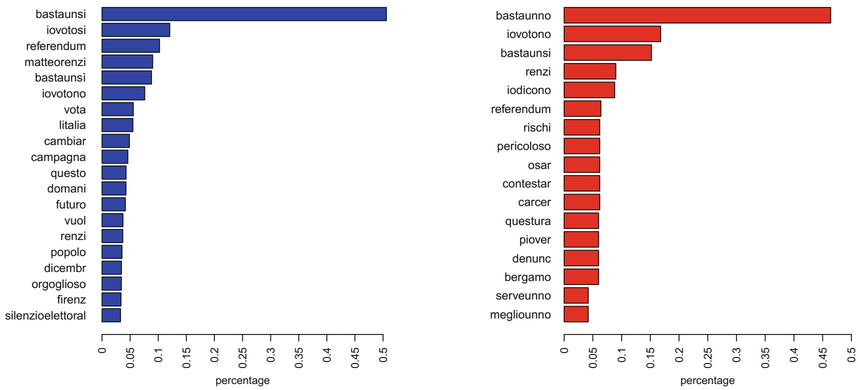

Fig. 3. Most frequent words contained in the tweets containing the hashtags #bastaunsi and #iovotosi (*left*) and #bastaunno and #iovotono (*right*).

Furthermore, we use the percentage of tweets against the constitutional reform as a rough estimate of the outcome of the referendum. The actual outcome of the referendum was 59% against the constitutional reform and 41% in favour of it, therefore the reform was not implemented. We notice that using the volumes of tweets as proxies of votes we are correctly able to predict the election results. In fact, on December 2nd, the day with the highest number of tweets, we calculate that the share of tweets against the reform was 62%, producing a prediction error of only 3%.

4 Concluding Remarks

In this paper we use a newly constructed database to analyse Twitter posts and confirm the ability of social media to nowcast the electoral campaign and to forecast electoral results. Analysing Twitter posts related to a constitutional reform that recently took place in Italy, we perform a topic modelling analysis using a Latent Dirichelet Allocation model to track the main topics and keywords during the electoral campaign. From the analysis we are able to find out words with topics revealing sentiments related either with the positive or the negative results. In particular we can see an interesting pattern emerging from the analysis of the most frequent words, namely the positive and optimist sentiments related with the yes, and the negative sentiments related with the no. As future researches, these patterns can be analysed in comparison with the volume of Twitter posts, which has been used before the referendum to correctly predict the outcome of the elections. Finally, we are aware that these results should be taken as suggestive rather than conclusive and using Twitter volumes as a proxi of votes is a very simple measure; one of the main problems is that we need to rely on a representative sample and the population of Twitter users does not necessarily match the population of voters. Despite the limits of using Twitter to predict electoral outcomes, we believe our results provide reasons to be optimistic about the capability of social networks to become a useful tool to monitor, analyse and predict public opinion formation, as a supplement to traditional off-line tools.

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Applying Data Mining for Sentiment Analysis in Music

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Abstract. Listening to music can affect people emotions. They can experience simultaneous feelings, such as happiness and hope, or sadness and angry, when a song is being played. However, infering emotions that can be caused by a musical fragment is a complex task. To deduce relationships between feelings and music, we propose a sentiment analysis method based on data mining. In particular, different musical features are extracted and classified to analyze the influence of some music parameters on human emotions. In this process, data mining algorithms such as Random k-Labelsets, Multi-Label k-Nearest Neighbors or Apriori have been essential for the success of our proposal.

Keywords: Music · Sentiment analysis · Data mining · Multi-label classification · Music information retrieval

1 Introduction

Music has been considered as a mean of expressing and arousing emotions. Different musical features such as melody, rhythm, harmony or timbre causes mental human reactions, which can be feelings, emotions or moods. To demonstrate the relationships between music and sentiments, some authors have proposed different psychological analysis. [5] address the role of our emotions in the composition of music, the ways that emotions can be communicated via musical structure from different perspectives. [22] investigates if the universal appeal of music lies in the emotional rewards that music offers with four interrelated studies with different listeners. [2] carries out a deep study about the different features of music and how they influence the emotions in individuals or in the society. [8] describes principles underlying the evocation of emotion with music: evaluation, resonance, memory and social functions. [15] investigated the relationship between musical characteristics and the ability of some participants to recognize five basic emotions (happiness, sadness, tenderness, fear, and anger). All of them concludes that music is inherently related to sentiments.

With the rise of opinion mining and sentiment analysis, the fact of finding out what people think and feel has become a necessity [14]. Some techniques such as

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text-categorization [13] or support vector machines [11] have been widely used to solve similar problems of association in other areas. In relation to music, there are many works for predicting the genre a song belongs to [12]. Otherwise, text information (e.g., websites, tags, and lyrics) [4], and a combination of text and audio information [3,6] have been used for music mood classification.

This work aims to classify music by the emotions produced when a person is listening to a musical fragment. Additionally, the relationships between musical features and emotions will be deeper analyzed. To do so, a dataset which contains rhythmic and timbre features for different songs is selected. Each song is described with some rhythmic and timbre features. Our final goal is to label the musical tracks with six different emotions.

The proposal will be resolved as a multi-label problem with data mining, meaning the detection of emotions in music as an approximation to sentiment analysis, which will be modelled as a multi-label task and solved with data mining techniques. As a case study, we make use of the dataset called Emotions from Mulan, which consists of 593 songs with 72 musical features. The music classification will be made using the WEKA framework and its extension MEKA, which provides support for multi-label and multi-target problems. Furthermore, some unsupervised learning techniques will be applied in order to extract some relationship patterns between the considered emotions and the music features.

The next section explains the problem solving process: preprocessing tasks and algorithms used. The results obtained with data mining techniques are shown in Sect. 4. Finally, last section discusses the evaluation of the sentiment analysis and future work proposed.

2 Multi-label Classification

Classification problems are widespread nowadays. Some approaches aim to classify some aspects related to biology and medicine such as tumor types [9] or to perform human recognition [1] and human detection [7] by using convolutional neural networks. All of them classify the different instances with only one class.

However, instances of some problems should be classified with more than one class at the same time; this is known as multi-label classification [17]. In case of films, such classification is easy to understand: for example, "Shrek" movie could be classified as an animated film, but also as comedy, fantastic or adventure.

Multi-label classification has been widely applied in music tasks in order to predict the genre [10] and the feelings a song produces on the listener [21]. In this work, musical features will be used to classify songs into a set of emotions.

3 Problem Description

The present proposal addresses a multi-label classification problem to label instances of a musical dataset. The Tellegen-Watson-Clark model [20] is employed to classify the songs into emotions in Fig. 1 for all the songs [16].

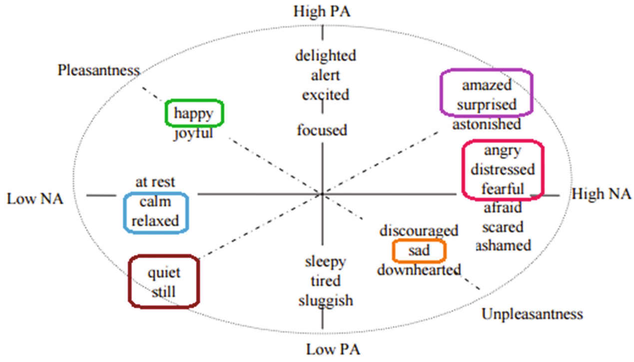

Fig. 1. The Tellegen-Watson-Clark model of mood (figure reproduced from [20])

Initially, the dataset was selected. Among the different options that we have in the Net, we finally select "Emotions from Mulan" because of the large number of instance and its richness in labels and emotions classes. Before applying any algorithm, we preprocess the data selected. To do so, those attributes that does not provide useful information for the classification task were not considered. A statistical analysis was performed to check the possible outliers, missing values and the distribution. With the data retrieved and preprocessed, different algorithms were applied to classify the data according to the classes. Two algorithms are used for the multi-label classification: Random k-Labelsets and Multi-Label k-Nearest Neighbors. Likewise, as a part of the analysis, some association rules are extracted by using the Apriori algorithm.

We will detail the data preprocessing in Sects. 3.1 and 3.2. Section 3.3 will expose the application of the classification algorithms, while Sect. 3.4 will explain the Apriori performance to extract the association rules.

3.1 Emotions Dataset

The dataset used for this work is called Emotions from Mulan [18]. It consists on a collection of 593 songs which belong to 7 different genres: Classical, Reggae, Rock, Pop, Hip-Hop, Techno and Jazz. A period of 30 s after the initial 30 s was considered in each instance in order to extract 72 numerical type musical features. Additionally, 6 classes of emotions are considered as the sentiments that can be felt by the listener.

The musical features can be divided into rhythmic and timbre attributes. For the purposes of this work, only timbre attributes will be considered, based on a musical decision, as we considered that the sound bumps in a song (what is known as rhythm) does not have a strong influence on the emotions that it causes. An example of this could be the rhythm difference between some musical pieces such as Beethoven's Ode to Joy and Radetzky March, even though they both evoke joy and majesty. The full description of rhythmic and timbre features can be found at [16]. Regarding with timbric features, 13 coefficients of the Fast

Fourier Transform are considered. They are known as MFCCs (Mel Frequency Cepstral Coefficients) in the dataset. Furthermore, 3 attributes related to timbre texture such as the spectral centroid, the spectral rolloff and the spectral flux are contemplated. For each of the 16 timbre features the mean, standard deviation (std), mean standard deviation (mean std), and standard deviation of standard deviation (std std) are calculated over all frames. In total, 64 timbre numerical type features are used in the dataset.

3.2 Data Preprocessing

As a first step, a statistical analysis of the attribute values for the instances is needed. This analysis was performed with WEKA tool, and visualized in this framework. According to the results, we can conclude, there is no outliers or missing values in the dataset, and, in general, attributes have a normal distribution; thus, no filter is needed to prepare the attributes for the classification task.

However, before applying any unsupervised learning algorithm, the number of attributes for each of them should be reduced. To do so, a filter of correlation and another filter of information gain are applied on each considered class. The results will be compared to select those features that have a total higher value.

As a consequence, we reduce the list of attributes from 64 to 12 features that will be considered for Apriori algorithm. In particular, the attributes used were: Mean of spectral centroid, Mean of spectral rolloff, Mean of MFCC_0, Mean of MFCC_1, Mean of MFCC_4, Mean standard deviation of Spectral rolloff, Mean standard deviation of MFCC_11, Standard deviation of MFCC_10, Standard deviation of MFCC_11, Standard deviation of MFCC_12, Standard deviation of standard deviation of MFCC_6, Standard deviation of standard deviation of MFCC_7.

Furthermore, specifically for the rules extraction process, a discretization of the attribute values is needed, as it would not make sense looking for rules for specific numerical values of attributes in this concrete problem. Note that the value discretization could be negatively influencing the final results. Additionally, it is important not to create too large intervals to better represent reality. Therefore, we discretize the value to obtain 10 different groups.

3.3 Supervised Algorithms

Once the data are deeply analyzed, we can carry out the classification procedure. Our goal is to classify the songs according to the emotions that they produces while listening. Several emotions can be felt by an individual song; therefore, this problem will be resolved as a multi-labeling classification task. Two algorithms are applied in order to compare the results.

- **Random k-Labelsets (RAkEL):** This algorithm is based on random projections of the label space [19]. The main idea is to create an ensemble, which will be divided in m base classifiers that are trained with a k random subset of the choosen labels. It is widely used in multi-label problems.

– **Multi-label k-Nearest Neighbors (MLkNN):** This algorithm is an adaptation of the k-Nearest Neighbours (kNN) to the multi-label task [23]. It is a classification algorithm that, in order to determine the classification of an instance, combines the classification of the k nearest instances.

In both cases, a cross-validation technique is used. The split percentage is 65%, which means that the analysis is performed on one subset called the training set (65%) and validated on the other subset called the validation set (35%). The parameters and the results are described in Sect. 4.

3.4 Unsupervised Algorithms

In data mining, association rules are a type of association method in which it is sought to find out if there are facts that occur always collectively (or very repeatedly) within a set of data. The algorithm Apriori is selected to observe and to corroborate the relation and influence of the attributes in the classes (emotions). As a consequence, the multi-label feature of the dataset will not be taken into account in this task, considering the emotions as a new feature in the dataset. The final results are detailed in Sect. 4.

4 Results and Discussion

The results can be divided according to the task that we performed. Firstly, we aim to classify the data in six different classes that represent emotions. As we explained above, we apply two different algorithms to make a comparison about the performance and final results.

On the one hand, in the RAkEL algorithm, the number of subsets in which the ensemble or set is divided in m groups and the k number of labels of each subset of the ensemble are variable. The values for this parameters are $m = 12$ and $k = 4$. The base classifier used for RAkEL is SMO (Sequential Minimal Optimization) because of its good performance in this particular case.

On the other hand, the Multi-Label k-Nearest Neighbors implementation that we selected is the Mulan Filter, which is available in MEKA tool. The base classifier will be again SMO so that the comparison between both classifiers will not be biased by the base algorithm.

The final results in both cases are shown in Table 1. The first column corresponds to quality measures obtained by RAkEL algorithm. The second column represents the values for MLkNN. The quality measures considered are the hamming score, hamming loss, one error and ranking loss. The hamming score and hamming loss captures the fraction of labels that are correctly and incorrectly predicted, respectively. One error evaluates the frequency of the top-ranked label that was not in the set of true labels, and ranking loss measures the average fraction of pairs of labels that are ordered incorrectly. The last row represents the total execution time for each algorithm.

As we can see in Table 1, both algorithms produce similar results. Hamming score and hamming loss are practically the same in both cases. The values

Table 1. Comparison between RAkEL and MLkNN performance

	RAkEL	MLkNN
Hamming score	0.788	0.804
Hamming loss	0.212	0.196
One error	0.285	0.251
Ranking loss	0.193	0.154
Running time	2.385	0.138

are near 0.8, thus the accuracy is about 80%. The optima values for one-error and ranking loss is 0. In both algorithms, one error measure is less than 0.3, which means that the top-ranked predicted label is misclassified in less than 30% of cases. Ranking loss values mean that about 20% of label pairs are wrongly ordered for an instance. Finally, the most remarkable aspect is the running time; MLkNN takes close to 0.14 s, and RAkEL, about 2.4; thus, MLkNN is quite quicker than RAkEL.

Additionally, we performed a rules extraction process. In the final results, the minimum confidence accepted for each rule is above 90%, and their support should be greater than 10%. First column of Table 2 shows the most representative rules obtained and the second column reflects confidence values for each one. The third and fourth columns present lift and conviction values respectively.

Table 2. Rules obtained with Apriori algorithm

RULE	CONF.	LIFT	CONV.
std(MFCC_12)$<$ 0.21& ¬Relaxing-calm& ¬Sad-lonely⇒ ¬Quiet-still	0.99	1.33	22.71
std(MFCC_12)$<$ 0.21& ¬Relaxing-calm⇒ ¬Quiet-still	0.99	1.31	12.54
¬Relaxing-calm& ¬Sad-lonely⇒ ¬Quiet-still	0.98	1.3	9.13
¬Amazed-surprised& Relaxing-calm⇒ ¬Angry-aggresive	0.97	1.43	10
std(MFCC_12)$<$ 0.21& ¬Sad-lonely⇒ ¬Quiet-still	0.97	1.3	7.63
Angry-aggresive⇒ ¬Relaxing-calm	0.96	1.74	10.52

As Table 2 shows, the confidence is between 96% and 99% in all the rules obtained, and lift is always greater than 1, so the rules happen with a greater probability than by chance. Finally, conviction values are not too high, thus the rules usually are unknown beforehand.

In rules 1, 2 and 5, the musical feature that appears is the same in all cases: Standard deviation of MFCC_12. It shows that this feature is very relevant and influential in the listeners feelings. The rest of rules show relationship between the emotions, which are considered as a new feature of the dataset. The obtained rules have a very strong logic base, e.g., rule 3: "if the song is not relaxing or sad, it will not be quiet" or rule 6: "if the song is aggresive, it will not be calm".

This kind of associations are obtained due to the existence of opposing emotions in the data set (happy-sad, relaxing-aggresive...).

5 Conclusion

Data mining can be applied to very different problems, such as sentiment analysis in music, providing useful and interesting information that can be used as the starting point for other works. This paper has successfully solved a classification problem of musical songs and emotions. Firstly, a dataset was selected, preprocessed and analyzed using different algorithms of multi-label classification. Additionally, an analysis about unsupervised associations has been performed.

The statistical analysis and filter of the dataset make the classification task easier. Furthermore, data preprocessing is necessary to obtain consistent and optimized results. Timbre features are considered in this work, leaving apart the attributes related to rhythm.

From the application of the algorithms RAkEL and MLkNN very similar results are obtained according to different quality measures. Both of them classifies the songs succesfully according to six emotions. We finally selected the MLkNN as the best algorithm based on its running time.

A unsupervised association algorithm was applied for obtaining different relationships between emotions and musical features. This trial provides an indicator of which attributes are more influential in the emotions the song provokes.

Directions for future research include the empirical analysis of the impact of rhythmic attributes in the feelings produced by music.

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Recommendation of Songs in Music Streaming Services: Dealing with Sparsity and Gray Sheep Problems

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Abstract. The interest for providing users with suitable recommendations of songs and playlists has increased since online services for listening to music have become popular. Many methods for achieving this objective have been proposed, some of them addressed to solve well-known problems of recommender systems. However, music application domain has additional drawbacks such as the difficulty for obtaining content information and explicit ratings required by the most reliable recommender methods. In this work, a proposal for improving collaborative filtering methods is presented, whose main advantage is the use of data obtainable easily and automatically from music platforms. The method is based on a procedure for deriving ratings from user implicit behavior as well as on a new way of managing the gray-sheep problem without using content information.

Keywords: Collaborative filtering · Recommender systems · Sparsity · Gray-sheep problem

1 Introduction

The overload problem, originated in the context of information recovery, has been extended to the music field since a large number of songs can be accessed from web sites and mobile apps. Users have difficulties to find out the music they like in spite of the searching services provided by most of the streaming platforms. Some of these systems are endowed with recommendation mechanisms to provide users with a more efficient support. However, it is still necessary to deal with some usual problems of recommender systems [1].

Most of the current recommender systems use some collaborative filtering (CF) based approach. The aim of CF is to predict the rating that a target user would give to an item taking into account users having similar preferences regarding previously rated items.

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In memory-based (user-based or user-user) CF methods the predictions for a given user, called the active user, are based on his nearest neighbors. They are users who have similar preferences to the active user since they have rated items in common with a similar score. There are different measures for similarity computing; however, the most extended ones are Pearson correlation coefficient and cosine similarity [2].

Model-based (item-based or item-item) CF was proposed in [3] with the aim of avoiding the scalability problems associated with memory-based methods by precomputing the similarities between items. This can be done since it is expected that new ratings given to items in large rating databases do not significantly change the similarity between items, especially for much rated items. However, recommendations provided by item-based methods usually have less quality than those provided by user-based approaches and are thus indicated to be applied in large-scale systems where scalability is a serious problem. They have been used in popular systems like Amazon [4].

Collaborative filtering requires explicit expression of user personal preferences for items in the form of ratings, which are usually difficult to obtain. This fact is the cause of one of the main drawbacks of this approach, the sparsity problem, which arises when the number of ratings needed for prediction is greater than the number of the ratings obtained from the users. This is the main drawback that prevents from the application of CF approach in many systems. Time that users spend examining the items is an alternative way to obtain implicit user preferences but it requires to process log files and this implicit information about user preferences is not as reliable as the explicit ratings.

Currently, hybrid techniques are the ones most extensively implemented in recommender systems, in an attempt to address the limitations of CF and content-based approaches. These methods combine either different categories of CF methods or CF with other recommendation techniques such as content-based schemes [5].

Although there are many proposals in the literature for dealing with the weaknesses of recommender systems, gray-sheep problem has been less studied. Moreover, it is mainly addressed by means of hybrid approaches that involve some content-based technique. Their results are usually good but these methods require information about items and users that often is not available. In the context of music recommender systems, content-based filtering algorithms use musical content for inducing the models; therefore, a complex extraction task of music features is necessary.

In this work, the proposed recommendation methodology addresses the above mentioned drawback when little information is available. The recommendation process could be incorporated into any music platform that stores identifications of users and songs and the time when the users play each song in the platform. The sparsity problem caused by the insufficient number of explicit ratings given by users is also faced by inducing ratings from play counts.

The rest of the paper is organized as follows: Sect. 2 includes a short survey of works about collaborative filtering and their main drawbacks, with special focus on music recommender methods. The proposed methodology is described in Sect. 3 and the empirical study conducted for its validation is reported in Sect. 4. Finally, the conclusions are given in Sect. 5.

2 Related Work

Collaborative filtering (CF) methods are widely used in recommender systems. The GroupLens research system for Usenet news [6] was the first recommender system using CF and Ringo [3] was one of the first and most popular music recommender systems based on CF. In the music recommender area several ways of dealing with the sparsity problem presented by these methods have been proposed. The access history of users is taken as an implicit way of obtaining user interests in a music recommendation system based on music and user grouping [7]. In several works where the Last.fm database is used, the times that the users play the songs (play counts) are converted to ratings by means of different functions [8, 9].

Regarding content-based methods, in the music field, metadata of items, such as title, artist, genre and lyrics, can be exploited as content attributes, but also audio features like timbre, melody, rhythm or harmony. In [10] music similarity was determined from chord structure (spectrum, rhythm and harmony). Melody style is the music feature used in [11] for music recommendation. A content-based method is proposed where a classification of music objects in melody styles is performed and users' music preferences are learned by mining the melody patterns from the music access behavior of the users. Clustering of similar songs according to different features of audio content is performed in [12] in order to provide users with recommendations of music from the appropriate clusters.

The combination of memory-based and model-based CF methods is a common way of building hybrid CF approaches that usually yields better recommendations than the single methods applied separately. Hybrid strategies have been adopted in the development of music recommender systems [13, 14]. However, the described categories of recommender methods have not been particularly formulated to deal with the less addressed but significant drawback that gray sheep users suffer from. This group of users with unusual preferences usually receives poor recommendations since they do not have many neighbors [15]. Furthermore, it is not only gray sheep users that are affected by this problem since it has been proved that the existence of a large number of gray sheep users might have an important impact in the recommendation quality of the entire community [16]. Content-based methods can help to alleviate this limitation but they are not the proper solution.

Most of the ways to face the gray sheep problem proposed in the literature are very complex since most of them are hybrid approaches that involve the joint application of several algorithms. In addition, they require additional information that is not always available. As far as we know, all of the methods proposed for dealing with the gray sheep problem make use of user and/or item attributes.

3 Recommendation Method

The proposed procedure aims at improving the results of CF methods when content and rating information is not available. The method is focused on two important aspects that have a negative impact on the quality of the recommendations, on the one hand the treatment of the gray sheep users and, on the other hand, the induction of ratings from the playing information of the users. In opposition to most of the methods in the literature, gray sheep users are neither treated differently from the rest of the users nor are separated into a different group, nevertheless our strategy involves the determination for every user of a coefficient representing the degree to which they are gray sheep. Likewise, the algorithm designed for recommending songs derives the ratings from the count or frequency of plays without need of collecting explicit ratings from users.

The number of plays, that is, the number of times that each user listens to a specific track is used for computing a listening coefficient in order to characterize the song popularity. The listening coefficient and the user behavior regarding the songs he plays are used to characterize him according to the degree of uncommonness of his preferences. In that way, gray sheep users are identified by considering the songs they listen to, differently from some authors who take into account only the number of ratings provided by that users.

3.1 Deriving Ratings from Plays

Most of the music datasets do not contain any information about user preferences, thus, to estimate the ratings it is necessary to resort to the plays of the tracks, that is the only available information enclosing the implicit feedback from users. There have been proposed few methods for computing ratings from plays and most of them are based on simple frequency functions [8, 9]. Pacula [17] proposed a method that provides better results in the context of artist recommendation where play frequencies have a clear power law distribution since there are few highly played artist and most of them have few plays. It does not occur when ratings are given in an explicit way. The conducted study about the behavior of users regarding listening to songs revealed the same "long tail" distribution than artist playing frecuencies. Therefore, Pacula procedure can be successfully applied when songs are the target of the recommendations.

Extending this procedure to songs, the play frequency for a given song i and a user j is defined as follow:

$$Freq_{i,j} = \frac{p_{i,j}}{\sum_{i'} p_{i',j}} \tag{1}$$

where $p_{i,j}$ is the number of times that a user *j* plays a song *i*.

On the other hand, $Freq_k(j)$ denote the k-th most listened to song for user j. Then, a rating for a song with rank k is computed as a linear function of the frequency percentile:

$$r_{i,j} = 4\left(1 - \sum_{k'=1}^{k-1} Freq_{k'}(j)\right) \tag{2}$$

Once the ratings are calculated, collaborative filtering methods can be applied in the way it is done for dataset containing explicit user preferences.

3.2 User Playing Coefficients

Another key feature of the recommendation algorithm is the characterization of songs depending on their popularity as well as the characterization of users according to the songs they listen to. We consider that gray sheep users, who have unusual preferences, are those who mostly play unpopular songs while standard users have similar preferences to other users since they listen to popular songs.

The aim of the proposed procedure is to compute a coefficient for all users that characterizes them depending on the popularity of the songs they play most. This popularity is based on a listening coefficient that involves the number of users who play them and the number of plays they have. The process can be formalized as follows.

Given a set of songs G and a set of users U where $g_i \epsilon G, i = 1, \ldots, n$ and $u_j \epsilon U$, $j = 1, \ldots, m$ represent a song and a user respectively, the number of times that a user j plays a song i is characterized as $p_{i,j}$.

A listening coefficient (l_{g_i}) for song g_i is computed in order to establish its popularity (Eq. 3).

$$l_{g_i} = \left(TU_{g_i}/\overline{TU}\right) \frac{\sum_j \left(p_{i,j}/\overline{p_j}\right)}{\sum_i \sum_j \left(p_{i,j}/\overline{p_j}\right)/n} \tag{3}$$

where n is the overall number of songs, TU_{g_i} is the number of users who play the song g_i, $\overline{TU}$ is the average number of users per song, and $\overline{p_j}$ the average number of plays per song of user j.

The listening coefficient for a given song takes into account the number of users who listen to it with respect to the average number of users per song as well as the relation between the behavior of the users who listen to the song and the average behaviors for all songs. The behavior of the user is quantified as the number of plays for the given song with respect to the average number of plays of this user.

In order to obtain values between 0 and 1, a normalized listening coefficient L_{a_i} was computed (Eq. 5).

$$L_{g_i} = \frac{l_{g_i} - min\, l_{g_i}}{max\, l_{g_i} - min\, l_{g_i}} \Rightarrow L_{g_i} \in [0, 1] \tag{4}$$

A second coefficient related to users, the User Playing Coefficient (UPC), is proposed aimed at characterizing them according to the popularity of the songs they play mostly (Eq. 5).

$$UPC_{u_j} = \frac{\sum_i L_{g_i}}{TG_{u_j}} \tag{5}$$

TG_{u_j} is the total number of songs played by user j

High values of UPC_{u_j} represent users that like popular songs and low values correspond to gray sheep users. These values provide as with an intuitive and approximate idea about people who have unusual preferences. However, our method does not require to identify this kind of users since the treatment is the same for everyone.

This coefficient is used as a user attribute in collaborative filtering methods in order to improve the quality of the recommendations. In that way, the negative effect that the gray users cause on the entire community of users can be reduced.

4 Validation of the Proposal

An experimental study was conducted in order to validate the method for recommending songs. This study was carried out with a subset of 420209 records of a last.fm dataset collected by Oscar Celma (http://mtg.upf.edu/node/1671) containing information about 86000 tracks played by 53 users during two years.

The results of our proposal were analyzed against those of traditional CF approaches. K-nearest neighbor (K-NN) was the method used in the study since it is usually used in the implementation of CF-based recommender systems. K-NN builds a neighborhood of K users similar to the active user according to a given similarity measure, which can be computed from user ratings as well as from other user attributes. We tested user-based K-NN using both cosine similarity and Pearson measures. User-based K-NN algorithm was also tested making use of a user attribute, the user playing coefficient (UPC), specific to our proposal. In this case, cosine measure was used since Pearson coefficient is not defined to compute similarity between users making use of user attributes. The number of K neighbors was set to 5 since it provided the best results.

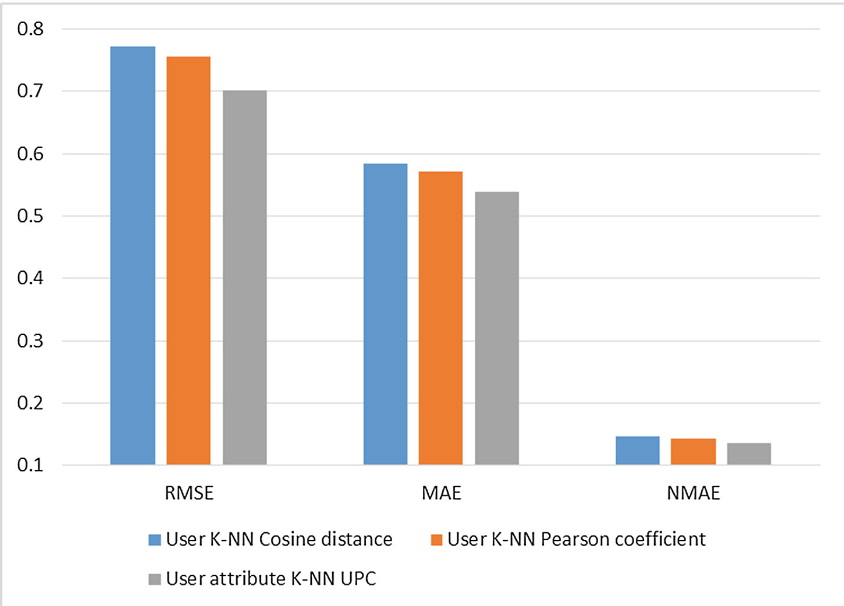

Fig. 1. Errors of the collaborative filtering methods tested in the study.

The methods were used for rating prediction and the validation metrics were RMSE (Root-Mean-Square Error), MAE (Mean Absolute Error) and NMAE (Normalized Mean Absolute Error). Ten-fold cross validation was performed in the evaluation of all the algorithms.

Figure 1 shows the values of the error metrics of the results obtained from K-NN using two different similarity measures, cosine distance and Pearson coefficient, against those yielded by our proposal, KNN UPC.

The first observation from the graph is the better behaviour of the Pearson coefficient versus cosine measure for computing user similarities. This fact confirms the findings obtained in other works in the literature. On the other hand, it can be clearly observed that the lowest values of the error measures are given when the coefficient UPC, proposed in this work, is used in CF recommendations. When user attributes as UPC is involved in the similarity computation, metrics as cosine must be used since Pearson coefficient is only defined for ratings. However, the introduction of the attribute UPC significantly reduces error rates, even versus K-NN with Pearson coefficient.

5 Conclusions

Music recommendation is the target of intensive research in the last years given the great quantity of songs available nowadays from multiple applications and devices. However, this application domain presents some problems such as the difficulty for extracting content information that prevents from implementing reliable recommendations methods.

The objective of this work has been to contribute to improve music recommender system by using information easily collectable from music platforms. The proposed method is focused on the induction of ratings from implicit feedback of users as well as on addressing the gray sheep problem without need of resorting to content-based and other complex techniques.

Song and user playing coefficients are used to determine the popularity of the songs and the degree to which a user is a gray sheep respectively. But, unlike other approaches it is not necessary to separate this kind of users in a different group since all users are treated in the same way.

The validation of the proposal was performed by means of a study where several CF algorithms for rating prediction were tested. The results showed that our method outperforms other CF approaches.

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Recommender System Based on Collaborative Filtering for Spotify's Users

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Abstract. In recent years, with the rise of streaming services like *Netflix* or *Spotify*, recommender systems are becoming more and more necessary. The success of *Spotify's Discover Weekly*, a music recommender system that suggests new songs to users every week, confirms the need to implement these recommender systems. In this paper we propose a methodology based on collaborative filtering to recommend music for *Spotify*'s users from an ordered list of the most played songs over a period of time.

1 Introduction

In the last decade music streaming services have gained great popularity thanks to smartphones. Further, these services let his users share his favorites songs, artists and playlists. Within streaming music services, *Spotify*[1] has more than 75 millions of active users, more than 30 millions of songs plus 20,000 each day, and about 1TB of usage data generate per day.

Even though *Spotify* is the largest streaming service in the world, until July 2015 when *Spotify's Discover Weekly* was introduced, *Spotify* did not officially have any recommendation system (RS). In addition, the amount and quality of the information that *Spotify* provides through its API[2] presents challenges for creating RS.

Regarding RS for *Spotify*, there are various works such as artist recommendations through *Twitter*'s *hashtags* [4], combining *Spotify*'s history and *Facebook* likes to generate recommendations [3], and even artist visualization tools [1].

All cited works use third party information to make the recommendations, creating a dependence on the availability of such information. This article proposes a RS based on collaborative filtering (CF) that is based entirely on the information that Spotify provides through its API.

2 Methodology

The CF provides recommendations or predictions of items based on the opinions of other similar users [5]. In CF methods we can find both model-based

1 https://www.spotify.com.
2 https://developer.spotify.com/web-api/.

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and memory-based algorithms. Memory-based algorithms, known as the nearest-neighbor algorithms, seek similar users at the same time the recommendation is been made by using Neighbors and rely on that neighborhood to make the recommendations [5].

The similarity between users is calculated by means of correlation coefficients such as the cosine similarity coefficient, Pearson's correlation coefficient, Spearman's correlation coefficient, or the Phi coefficient (also called the Matthews correlation coefficient, indicated for binary variables) as it's described below.

In the case of *Spotify*, where music playlists are ordered lists of the most played songs without their number of reproductions, both the Pearson's coefficient as the Phi coefficient are valid to calculate the similarity between *Spotify*'s users.

Once the subset of most similar users to the active user is obtained, the last step is to predict what items the active user might be interested using the weighted average of all the ratings, defined in the following equation:

$$P_{a,i} = \overline{r_a} + \frac{\sum_{u \in K} (r_{u,i} - \overline{r_u}) \times w_{a,u}}{\sum_{u \in K} w_{a,u}}. \tag{1}$$

Where $P_{a,i}$ is the prediction for the active user for the item i, $w_{a,u}$ is the similarity between users a and u, K is the subset with the most similar users, $r_{u,i}$ is the user's rating u for the item i and $\overline{r_u}$ is the average rating of the user u. For the case of Spotify $\overline{r_u}$ takes the value 1 for all users since the reproductions are considered a dichotomous variable and $r_{u,i}$ will be 1 or 0 in function of if the user has listened to the song or not.

2.1 Pearson's Correlation Coefficient

The Pearson's correlation coefficient is a measure of the linear relationship between two random quantitative variables. As in the cosine coefficient, their values range from 1 to -1. Its main virtue is that it is independent of the scale of the measurement of the variables. Pearson's coefficient is defined as it follows

$$r_{X,Y} = \frac{\sum_i (x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_i (x_i - \overline{x})^2 \sum_i (y_i - \overline{y})^2}}. \tag{2}$$

where x_i and y_i are the ratings for the $i \in I$ item of users X and Y respectively, and $\overline{x}$ and $\overline{y}$ are the average ratings of users X and Y respectively.

In the case of *Spotify*, this coefficient allows to calculate the similarity between two users, since each one of them has an ordered list of the most played songs, which can be used to calculated the similarity. To compute the song rating following score is used

$$x_{i_k} = \log(|I_X| - k + 1). \tag{3}$$

where I_X it is a set of items $\{i_1, i_2 \ldots i_n\}$ ordered of user X and k is the position of item $i_k \in I_X$.

2.2 Phi Coefficient

The Phi coefficient is a measure of the association between two binary variables. It is also a variation of the Pearson's correlation coefficient when the two states of each variable are given values of 0 and 1 respectively. The Phi coefficient was devised for the comparison of real dichotomous distributions, that is, distributions that only have two points in their scale and that indicate some immeasurable attribute, like alive or dead.

In the case of music the user's playlist can be reduced whether or not user has heard a song. In this way the valuations become dichotomic, which is a loss in terms of user information and therefore in the quality of the prediction.

Given the users x and y, you have a, b, c, d where a is the number of items in common of both users, b the items that have x but not y, c the items that have y but not x and d are the Items that do not have any of both. Phi is defined as the following relation:

$$\phi = \frac{ad - bc}{\sqrt{(a+b)\,(c+d)\,(a+c)\,(b+d)}}. \tag{4}$$

Although both the Mathews and the Pearson scores have the same results on the same binary variables, their interpretations differ somewhat because for the Pearson's correlation coefficient the coefficients vary between 1 and -1, whereas in the Phi coefficient the maximum value that it can take is given by the distribution of the variables.

In the case of *Spotify*, the songs' playlist of each user can be understood as a list of binary values 1 where each song took the value 1, representing this value that the song has been heard. The similarity can be calculated from this list using the Phi coefficient.

3 Experiments

Two experiments were carried out, a first experiment to compare both coefficients by means of metrics and a second experiment to compare the results of the developed program with a real case.

To conduct of the experiments we used the dataset *Last.fm Dataset - 1K users*[3], property of Oscar Celma Herrada, presented in his book *Music Recommendation and Discovery* [2], which contains the listening habits from nearly 1000 *LastFM*'s users[4].

3.1 Model Comparison

The dataset has been divided into two datasets, a training dataset and a test dataset. The training dataset contains the songs played until April 5, 2009, while

[3] http://ocelma.net/MusicRecommendationDataset/lastfm-1K.html.
[4] http://www.last.fm.

the test dataset contains the songs played from April 5, 2009 through May 5, 2009.

The test dataset has been transformed so that the playback history of the users are similar to the playback history of the Spotify's users. In such a way these have been reduced to an ordered list with the 50 most listened songs. The training data set contains the listened songs that do not belong to the training set.

Two models have been trained, one with the Pearson's coefficient and another with the Phi coefficient. For each model mean average precision (MAP), F1 score and normalized discounted cumulative gain (NDCG) are shown with different cutoff for the recommended songs.

As you can see in Tables 1 and 2 the results are far from good for a recommendation system, but keep in mind that for testing of the models, the temporal feature of playback history has been maintained. It has not been predicted in a random subset, but has been predicted from the last month's playback history of the global data set, using previous playback histories to predict.

Up to the first 10 songs recommended the MAP is around 0.1, that is, one of every 10 songs is recommended correctly. As for the low value of the score F1 is due to the fact that the recall score is to low.

It can also be observed that both models are almost identical. While for Pearson's coefficient the songs order has been used as song's rating, for Phi coefficient the songs order has not been used. But except the F1 score, both MAP and NDCG have the same results in both models. This indicates that for

Table 1. Pearson's coefficient test results

Cutoff	MAP	F1	NDCG
1	0.11716	0.00303	0.11715
3	0.10099	0.00409	0.15560
5	0.09704	0.00516	0.17218
10	0.08663	0.00766	0.19625
20	0.07284	0.01122	0.21419
50	0.05266	0.01588	0.23270

Table 2. Phi coefficient test results

Cutoff	MAP	F1	NDCG
1	0.11006	0.00066	0.11004
3	0.10414	0.00185	0.15417
5	0.09941	0.00293	0.17507
10	0.08982	0.00560	0.20216
20	0.07290	0.01065	0.21801
50	0.05247	0.01560	0.23499

an ordered subset of items with the highest rating, if the dimension of the subset is much smaller than the dimension of the overall set, the order hardly provides information. That's why both models provide same results.

3.2 Real Case Test

The RS has been developed in *Node.js*[5] and the database has been implemented in *MongoDB*[6]. The tests were performed on a computer with an AMD Phenom II x6 1045t processor and 8GB of RAM.

To apply the CF the listening habits of 992 users has been used. These historic have been reduced to three lists ordered with the 50 most listened songs from the last week, from the last three months and from all the time until the 5 of May of 2009 respectively. In addition, user similarity for each coefficient has been calculated in paged way in blocks of 500 users.

Tables 3 and 4 show the calculation time for the Pearson's coefficient and the Phi coefficient. There have been five tests in blocks of 500 users. As can be seen, the calculation of the coefficient Phi is almost three times inferior to the Pearson's coefficient.

In the Table 5, the first ten similar users for each coefficient can be seen. Seven users match *user_000589*, *user_000640*, *user_000658*, *user_000729*, *user_000883*, *user_000891* and *user_000524*. Therefore it is expected that some songs will coincide in both predictions.

Table 3. Pearson's coefficient calculation time

Test	Users 0-499	Users 500-992
1	10329.904 ms	10993.879 ms
2	9773.329 ms	10724.765 ms
3	10089.402 ms	10726.681 ms
4	10173.564 ms	11196.235 ms
5	9952.863 ms	10768.626 ms

Table 4. Phi coefficient calculation time

Test	Users 0-499	Users 500-992
1	3307.691 ms	3581.039 ms
2	3351.736 ms	3595.325 ms
3	3411.963 ms	3413.078 ms
4	3618.291 ms	3664.589 ms
5	3419.936 ms	3694.509 ms

[5] https://nodejs.org.
[6] https://www.mongodb.com.

Table 5. First ten similar users (User - Score)

Pearson's coefficient	Phi coefficient
user_000626 - 0.0394	user_000815 - 0.0570
user_000589 - 0.0383	user_000658 - 0.0457
user_000640 - 0.0379	user_000589 - 0.0418
user_000658 - 0.0365	user_000524 - 0.0403
user_000729 - 0.0347	user_000640 - 0.0399
user_000883 - 0.0346	user_000729 - 0.0384
user_000891 - 0.0342	user_000667 - 0.0352
user_000524 - 0.0341	user_000960 - 0.0350
user_000511 - 0.0326	user_000891 - 0.0345
user_000403 - 0.0326	user_000883 - 0.0329

Table 6. First ten predicted songs (Spotify's IDs)

Pearson's coefficient	Phi coefficient
0X4mNdzsin7NMm72b6ND1I	1uw5F8dd9IST0XxTKqoqPP
3qkdfqjvHbehlvQNTXmzov	0X4mNdzsin7NMm72b6ND1I
1uw5F8dd9IST0XxTKqoqPP	3qkdfqjvHbehlvQNTXmzov
5yxsVESP0VIznzv0YBNmW0	5yxsVESP0VIznzv0YBNmW0
7ys1RkQ4DA2Olul6pHlO91	7ys1RkQ4DA2Olul6pHlO91
43yuI6JECmXMAq26YI4iaX	43yuI6JECmXMAq26YI4iaX
3b1gPWKiAsWXe6bPjE2rm1	3gNGi2iUGHXGpBQHce6Nua
3gNGi2iUGHXGpBQHce6Nua	3b1gPWKiAsWXe6bPjE2rm1
0832Tptls5YicHPGgw7ssP	6ZHc4hKjDdUdzk2DgFyvMQ
1LytkZ67Tquo5A5TyzqVcZ	6Wuv7MrhesuDsuGv8vcrOd

In the Table 6 the first ten predicted songs are presented. As mentioned before, it was to be expected that some songs would coincide (in this case a total of eight), and the songs *5yxsVESP0VIznzv0YBNmW0*, *7ys1RkQ4DA2Olul6pHlO91* and *43yuI6JECmXMAq26YI4iaX* are in the same position. Therefore, although both coefficients are different, they coincide in the prediction of the songs.

4 Conclusions

This article has presented a RS based on CF for *Spotify*'s users that uses only the information provided by the *Spotify*'s API. This system make recommendations from an ordered list with the most played songs over a period of time. *Spotify* only provides a subset of all the songs played, so that the system can recommend songs the user already know.

As seen in the comparison of the models, when an ordered subset of the most listened songs is much smaller than the total set of user's songs, the order does not matter when calculating the similarity between users.

Regarding the computation time of the similarity between users, the Phi coefficient is clearly faster than the Pearson's coefficient. In addition the fact that the historic of listened songs is transformed to binary values and order information is lost, the quality of the prediction has not been reduced.

On future work, the model could be improved to increase the accuracy of the recommendations. Although Phi coefficient improves the computation time, it would also be interesting to explore other methodologies that allow a better scaling in the relation between the number of users and the time of recommendation.

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Hybrid Tourism Recommendation System Based on Functionality/Accessibility Levels

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Abstract. This paper describes a proposal to develop a Tourism Recommendation System based in Users and Points-of-Interest (POI) functionality/accessibility levels. The focus is to evaluate if user's physical and psychological functionality levels can perform an important role in recommendation results accuracy. This work also aims to show the importance of POI classification (accessibility levels are related with each POI ability to receive tourists with certain levels of physical and psychological issues), through the definition of a different model regarding their accessibility and other characteristics.

Keywords: Tourism · Recommendation · User profiles · Points-of-interest · Emotions · Tags

1 Introduction

Touristic activities are nowadays one of the most important areas in global economy because the demand is growing each day (more portions of world population gain financially conditions to travel). This is creating important challenges to traditional destinations that are now searching for new approaches to mark the difference.

Probably the most effective way to evolve and distinguish a specific destination is to know and understand better who visits each place (this knowledge can be used to adapt the offers). To do that is fundamental to seek better knowledge about visitors, designing an individual profile regarding key personal information, like physical and intellectual issues, personal tastes, similarity with others, etc.

User's modelling as a unique and individual entity is normally poor and rudimentary either in the methods or in the scope because a significant part of the available information is not processed and used in order to allow a more correct knowledge of each one.

In addition to this poor and rudimentary traditional user modelling approaches devotes low attention to key issues such as the physical and/or mental limitations of each one has and which often these are inhibiting factors of the activities that each one can carry out.

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Limitations are characterized as a biomedical change in the structure, physical or psychological functions of the human body, compared to a standard pattern. The existence these limitations should not immediately determine a disability because disability is the result of the addition between a deficiency an environment that has characteristics provides the highlighting of individual user's limitations [1].

User modelling is traditionally developed with two different techniques: knowledge-based or behavioural [2]. Knowledge-based adaptation is normally the result of information gathered using forms, queries and other user studies, with the purpose to produce a set of heuristics. This work uses a knowledge-based approach regarding the usage of information collected through forms and other information acquisition tools (like camera image analysis). The main focus is to consider distinct user related information like the relation between a user and a set of stereotypes defined by Tourism of Portugal (business, nature, sun and sea, etc.), user´s emotional responses to different stimulus, user's tags and user´s functionality levels regarding physical and psychological/intellectual issues.

Tourism Recommender Systems are an important tool for user's decision support (a good suggestion will improve user's experiences). A Recommender System can be defined as a collection of different techniques used to filter and organize different items with the objective of selecting either the best ones or the most suitable ones, according to the user [3].

In this proposal the main focus is in create touristic recommendation results according individual user's objectives and preferences (these are considered in stereotype comparison, emotional states analysis, tag evaluation) but also and this is a key difference that the results can according to each user functionality level regarding the considered physical and intellectual limitations.

2 State of Art

In this section is presented a literature review about in the most important research fields in which this work is based, namely user profiling, tourism recommender systems and the importance of accessibility issues to tourism activities.

2.1 User Profiling

User profiling is a research field that is being studied for almost fifty years. One of the first research's present in literature was developed by Allen et al. [2] in the seventies. Rich [4] and more recently Kobsa [5] are two of the most important references in this subject. In the last decades, several different systems were developed to store different kinds of user information (some were analysed reviews done by Morik, Kobsa, Wahlster and McTear in 2001). In those first systems, user modelling was an application part, which caused difficulties to separate users' profile related processes from the other application components. This was a normal problem in software design before software encapsulation and modularization techniques became popular. Despite the technology evolution related with users' profiles modelling (it has become more complex and intelligent, by making use of newly technological evolutions), the basic concepts and ideas and problems that turned possible the appearance of this research area are almost the same: the identification of user needs, desires, personalities and most important, objectives.

2.2 Recommendation Systems

In this section are briefly described a group of tourism recommendation systems selected in between the approaches available. This description is based in each one specific capabilities and approaches. The application field and approach to accomplish the goal is rather different from each one to another but is interesting to understand the variety of technologies and architectures evolved.

TIP and Heracles [6, 7] systems provide recommendation services through mobile devices for tourism. These services implement hybrid algorithms to calculate tourist preferences, using the defined tourist profile and location data (location-aware).

Crumpet [8] provides new information delivery services for a far more heterogeneous tourist population. The services proposed by this system take advantage of integrating four key emerging technology domains and applying them to the tourism domain: location-aware services, personalized user interaction, seamlessly accessible multi-media mobile communication, and smart component-based middleware or "smartware" that uses Multi-Agent Technology.

CATIS [9] is a context-aware tourist information system with a Web service-based architecture. The context elements considered to this project are location, time of day, speed, direction of travel and personal preferences. This system provides to the user relevant information according to his location and time.

In Tousplan project [10, 11] a Tours Planning Support System (TOURS PLAN) is proposed which intends to help tourists in finding a personalized tour plan allowing them to use their time efficiently and promote the culture and national tourism. Hence, this research focuses on tour planning support, aiming to at define and adapt a visit plan combining, in a tour, the most adequate tourism products, namely interesting places to visit, attractions, restaurants and accommodation, according to tourist's specific profile (which includes interests, personal values, wishes, constraints and disabilities) and available transportation modes between the selected products. Functioning schedules are considered as well as transportation schedules. This project tries to efficiently address the core of the tour planning process. Hence, it defines an optimization model that clearly represents the described tour-planning problem and designs a heuristic algorithm that effectively tackles that problem.

POST-VIA 360 [12], is a platform devoted to support the whole life-cycle of tourism loyalty after the first visit that is designed to collect data from the initial visit by means of pervasive approaches. This data is used to produce accurate after visit data and, once returned, is able to offer relevant recommendations based on positioning and bio-inspired recommender systems. The validation is based in a case study comparing recommendations from the application and a group of experts.

2.3 Accessibility and Tourism

Accessibility is a common issue across several different life domains, that should be considered by us all a priority in sustainable society development policies (the must be focused in people and their specific needs).

In Tourism this is also a key factor in future development because tourists aim to obtain positive and enriching experiences from the touristic trips. This only will be possible for tourists with some physical or psychological limitation if the destinations (monuments, hotels, parks, etc.) are prepared to receive them without becoming a problem to them.

> "Accessibility is a central element of any responsible and sustainable tourism policy. It is both a human rights imperative, and an exceptional business opportunity. Above all, we must come to appreciate that accessible tourism does not only benefit persons with disabilities or special needs; it benefits us all."
>
> Taleb Rifai, UNWTO Secretary-General.

Some authors [13] consider that a we are towards a lost opportunity regarding the reduced investment in accessible tourism development. Some of the overall development touristic politics should be reoriented to address this question like a key factor for tourism future success.

3 Proposal

This work approach aims to contribute to improve touristic experiences for persons suffering from some physical or intellectual limitations (most of the times is more than simply improve an experience, is to create in users the confidence that although their limitations they can visit and experience certain places without being afraid) that, in some way, can frustrate their ambition to live a touristic experience. This can be achieved if the recommendation results are conditioned by user's functionality/POI accessibility levels. In addition to functionality/accessibility model a user stereotype profile, an emotional, a tag and a society model, are also designed and considered, to represent user's related knowledge (this can directly related with the individual or with individual relations network like in the society model) which is fundamental to produce an accurate touristic recommendation plan.

This work is based in an architecture described in Fig. 1 that is divided in 3 layers: knowledge, reasoning and the interface. The focus in this paper is in the tourist knowledge module (composed by a set of different knowledge representation modules regarding user's preferences and physical and psychological/intellectual limitations).

The recommendation module can be classified as a hybrid recommendation system because each of the subcomponents presented in Fig. 3 (the order in the figure is directly related with each component relevancy in the overall module). The referred subcomponents are based in different techniques used to obtain the basic knowledge to produce results.

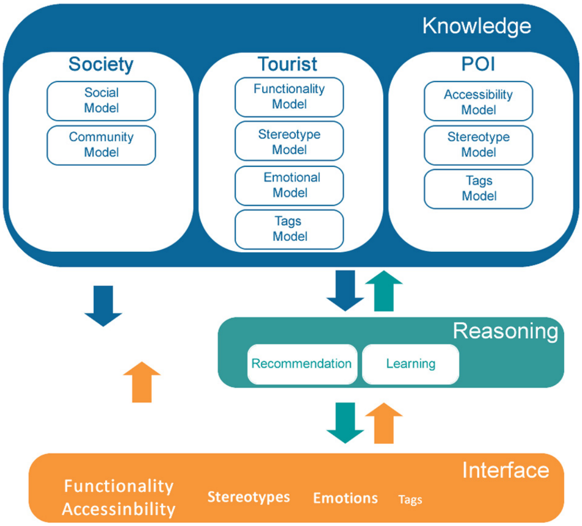

Fig. 1. Proposed overall system architecture

Knowledge layer is composed by several knowledge representation structures and models. These represent acquired knowledge regarding the relation between a user or a POI (Fig. 2) and each considered model (in a zero to one scale).

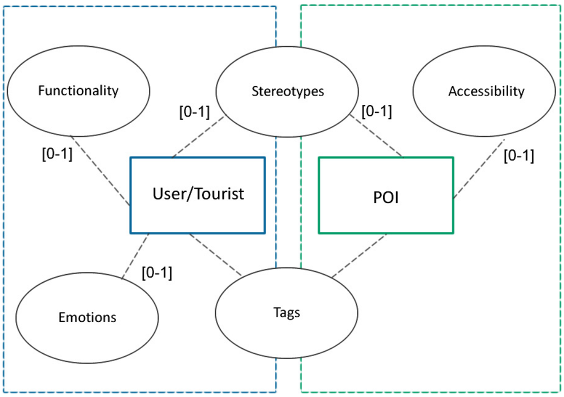

Fig. 2. User/POI knowledge models

3.1 Functionality/Accessibility Levels

The functionality/accessibility model is based in the relation between the user's functionality level regarding a specific physical or psychological deficiency (for instance locomotion, vision, hearing or intellectual pathologies (Fig. 3)) and the accessibility levels obtained by POI characterization and evaluation process accordingly the same referred physical and psychological constraints. This information is relevant to recommendation touristic procedure because it allows to generate touristic recommendation results that can be visited by the tourist.

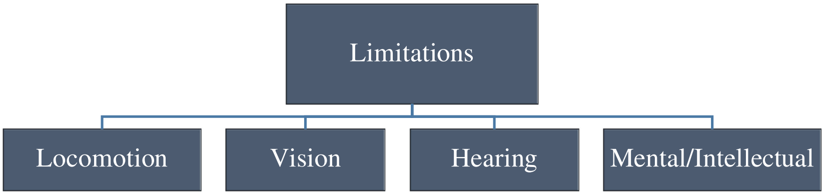

Fig. 3. Physical and psychological limitations taxonomy

3.2 Stereotypes

Stereotype model represents the result of the comparison between user's individual characteristics and a set of stereotypes (Fig. 4) like Nature, Citybreaks, Business or Gastronomy (developed and defined by Tourism of Portugal in [14]). The comparison between a user and a stereotype (the result is a value that defines the relation accuracy) is important to retain user's preferences and tastes.

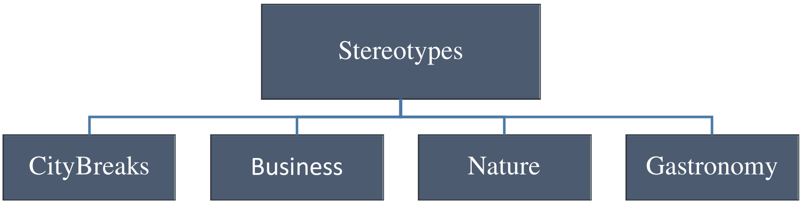

Fig. 4. Stereotype taxonomy

3.3 Emotional Reactions

Emotional aspects are an important approach in user's profiles improvement techniques because it allows to learn about a user without being intrusive.

This is a learning process related with detected (using a video camera) emotions (happiness, surprise, sadness, etc.) from the user's reactions analysis when placed towards a specific stimulus (an image for example).

In [15] this type of technology and approach normally called like Affective Computing is used to obtain student emotions/personality which will be used to model the user and to adapt the learning platforms accordingly to him in order improve learning results,

There are many different approaches and studies regarding Affective Computing [16, 17, 18, 19].

In this work is used a computer program called CLMtrackr (Øygard) to aquire users emotions. This program is based in the *Face Alignment through Subspace Constrained*

Mean-Shifts detection algorism's proposed by Saragih in [20] that maps human face (creating a model) recurring to an analysis of seventy points marked in the acquired face image (Fig. 5). This model is further compared with a set of stereotypes that will allow to identify user emotions. CLMtrackr identifies four different emotional reactions (*angry*, *sad*, *surprised*, *happy*).

The emotional state (2) is obtained when a user interacts with the system (a set of images representing existing POI classes are shown).

$$(2) \quad Emotional\,state(i) = \left(\frac{happy + surprised}{2}\right) - \left(\frac{andry + sad}{2}\right)$$

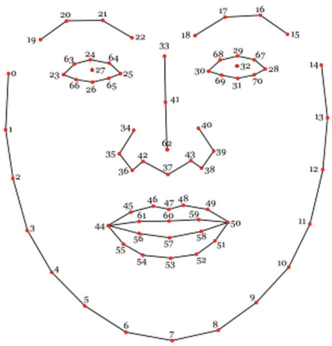

Fig. 5. CLMtrackr (Øygard)

4 Conclusions and Future Work

This research work aims to show that functionality levels can perform an important role in the user profile definition (visiting a specific POI can demand some user's capacities that some could not have). With this approach it is aimed to prove that this can be the next step in user profile creation regarding new information related with user's physical and psychological functionality levels. This works also demonstrates the importance of POI information collection (namely regarding the considered deficiencies) that is fundamental to classify POI (this will define accessibility levels).

Delivering touristic recommendation results to persons with some kind of physical and psychological limitations considered in this work (in future considered limitations should be extended to embrace more population) and at same time respect their own personal preferences and ambitions is a complicated task but if this can be accomplished with success a bigger part of the world population will be feel integrated.

In future developments should be considered the possibility of defining an ontology to represent several domain concepts and relations related that can be used to classify the objects present in this research domain field.

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Doctoral Consortium (DC)

Acceleration of Dissimilarity-Based Classification Algorithms Using Multi-core Computation

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Abstract. The objective of this dissertation proposal will focus on finding the computational structures that allow to adapt costly dissimilarity-based classification algorithms to multi-core architectures for CPU based systems, in order to achieve computational efficiency and improving the accelerations of their corresponding sequential implementations. This paper shows preliminary results of the parallel implementation of the leave-one-out test for the Nearest Feature Line and Rectified Nearest Feature Line Segment classifiers.

Keywords: Parallel/heterogeneous computing · Dissimilarity-based classification algorithms

1 Problem Statement and Hypothesis

A deterministic evaluation of a classification algorithm is a test that offers repeatable results such that other researchers are able to replicate the experiment. However, the complexity and computational cost of deterministic evaluations of dissimilarity-based classification algorithms impose limitations on the analysis of data due to their slowness when performing intensive and repeated experiments. As the amount of data increases, the response time of these algorithms also increases, sometimes in an exponential or combinatorial way, making the characterization and behavior of the data processing expensive when extracting simulations results and delaying, therefore, the drawing of conclusions about the classifier and the influence of the combination of its parameters or the behavior of the dissimilarity measure. In consequence, computational structures that allow to obtain the acceleration of dissimilarity-based classification algorithms are the core of this research proposal. The developed parallel multi-core algorithms will help academic communities and institutes interested in data processing for pattern recognition to perform fast simulations and to deliver results in an efficient way.

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2 Proposal

The use of classifiers with a high level of accuracy allows to guarantee that the models developed with them will have the expected behaviors [2]. Although accuracy is fundamental, the speed at which results are delivered involving a large amount of data is also important. It is at this point that high performance computing (HPC) plays an important role since it could turn the sequential computational algorithms, usually slow, able to operate with greater acceleration [3]. This proposal will focus on finding out the computational structures that allow to adapt costly dissimilarity-based classifiers to multi-core architectures for both GPU and CPU, in order to achieve computational efficiency and speed up their corresponding sequential implementations.

3 Preliminary Results

The leave-one-out test (a deterministic evaluation) was implemented for two algorithms: the nearest feature line classifier (NFL) and the rectified nearest feature line segment classifier (RNFLS) proposed in [1]. Sequential versions of this test were implemented in Python and Matlab and tested on seven data sets taken from the UCI machine learning repository[1]. For the RNFLS algorithm, which is the most expensive one, the Pima data set demanded 14 days of computation in Matlab and eight days in Python. In contrast, the sequential version implemented in ANSI C required two hours of computation while the parallel version on a CPU architecture with 48 cores demanded times of less than five minutes for both algorithms. Table 1 shows the elapsed time obtained for three expensive data sets when comparing the parallel implementation against the sequential one.

4 Reflections

The preliminary results have shown that it is possible to achieve accelerations using parallel architectures for this kind of tests for these classifiers. Future

Table 1. Elapsed times in seconds (parallel vs. sequential), for the leave-one-out evaluation of NFL and RNFLS using ANSI C.

					NFL		RNFLS	
Inst.	Attrib.	Data set	Accuracy	Hits	Seq. Time	48 Cores	Seq. Time	48 Cores
351	34	Ionosphere	0,928	326	17,013	2,436	1367,306	52,451
569	30	WDBC	0,966	550	48,473	4,962	9290,171	325,593
768	8	Pima	0,700	538	44,684	2,142	7145,664	263,191

[1] http://archive.ics.uci.edu/ml.

work will focus on the general formulation of the computational structures used to reduce the computation time of dissimilarity-based classification algorithms as well as on the understanding of their limitations over different multi-core architectures.

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A Study on IoT Technologies in Smart Cities

(An Exploratory Study in India)

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Abstract. "Smart Cities" concept is the most predominated in the research world. Its immense benefits to the whole globe like Quality of Life, economic and sustainable development are phenomenal. In order to bring the operational efficiency in each and every axes of Smart City, massive Internet of Things technologies are deploying. In this line all the business houses, municipalities and citizens are striving to invest in Smart Cities. This article is exploring the Indian Smart Cities like Palava, Lavasa, GIFT, and Kochi. The triangulation method is used for evidence, due to contemporary. Study confirmed that Smart City is a collection of Smart (Economy, Environment, Mobility, Living, Governance, and People).

Keywords: Internet of Things · Quality of life · Sustainability · IoT

1 Problem Statement

Most problems connected to the urban India are fairly well known and are often the topic of casual discussions in all the corners of the country. The existing infrastructure in the Indian cities is crumbling under the pressure of an exponentially raising population. We are all so familiar with our poor public transportation facilities and low quality of roads, congestion, accidents, higher CO_2 emissions and unhealthy journeys. Electrical power and potable water shortages are a part and parcel of every Indian's life, be it due to poor quality equipment, broken pipes, faulty meters, grid failure, or something else. On top of that, we have to put with raising costs for these basic amenities. Security and safety concerns for women and children have been in the lime light for quite some time now. Likewise, there are many issues with education, business, communication, sanitation, cleanliness, tourism, and employment opportunities… the list is endless. That is why there is an urgent need to understand the growth dynamics of fringe areas so as to strategize and design the planning efforts to resolve urban issues for Quality of Life.

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2 Related Work

Though the word "Smart City" is existing since 1992 in the form of "Digital Cities", it was not given much attention in the urbanization until IBM discovered in 2008 in the form of "Smarter Planet Vision". There is no standard operational definition of the word "Smart Cities". There is a big debate among Civil Engineers (Architectural), IT corporates (Technological), Environment (Sustainable) and City Mayors (Urban Management). However, there are some working definitions which were given by city mayors, planners, policymakers, developers, business tycoons, practitioners, researchers, and academicians, based on the city requirement, technologies deployed for different purposes. The author Hall (2000) said that a Smart City is a city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power. Even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens (Dameri and Cocchia 2013; Neirotti et al. 2014). To bring Smart Cities sub systems components operational efficiency, a lot of IoT technologies are to be deployed. The technologies are Smart Cards, RFID, QR Codes, EPC, IPv6, Sensors, Actuators, Wi-Fi, Bluetooth, ZigBee, NFC, GIS, GPS, Social Media, BI, Ambience Intelligence, Cloud Computing, Tele-Medicine, Web 3.0, BDA etc. Much existing content in the Internet of Things has been created through coded RFID tags and Internet Protocol addresses linked into an Electronic Product Code network.

3 Objectives

(1) To better understand deeply into the new phenomena of 'Smart Cities-Six Dimensions' concepts including, Smart Environment, Smart Living, Smart Governance, Smart Economy, Smart People and Smart Mobility in Lavasa, Palava, GIFT and SmartCity Kochi (2) To find out the Internet of Things (IoT) technologies like RFID, EPC, IP, Barcode, Wi-Fi, Bluetooth, NFC, ZigBee, Sensors, Actuators, Ambient Intelligence, GIS, GPS, 3D, Analytics and other technologies in creation of the Indian Smart Cities (3) To study the impact of Smart Cities creation using IoT technologies for the Indian inhabitants to resolve urban problems of utility services like water, electricity, transportation, education, banking, health, safety and jobs etc. offer a Quality of Life.

4 Research Design

See Fig. 1.

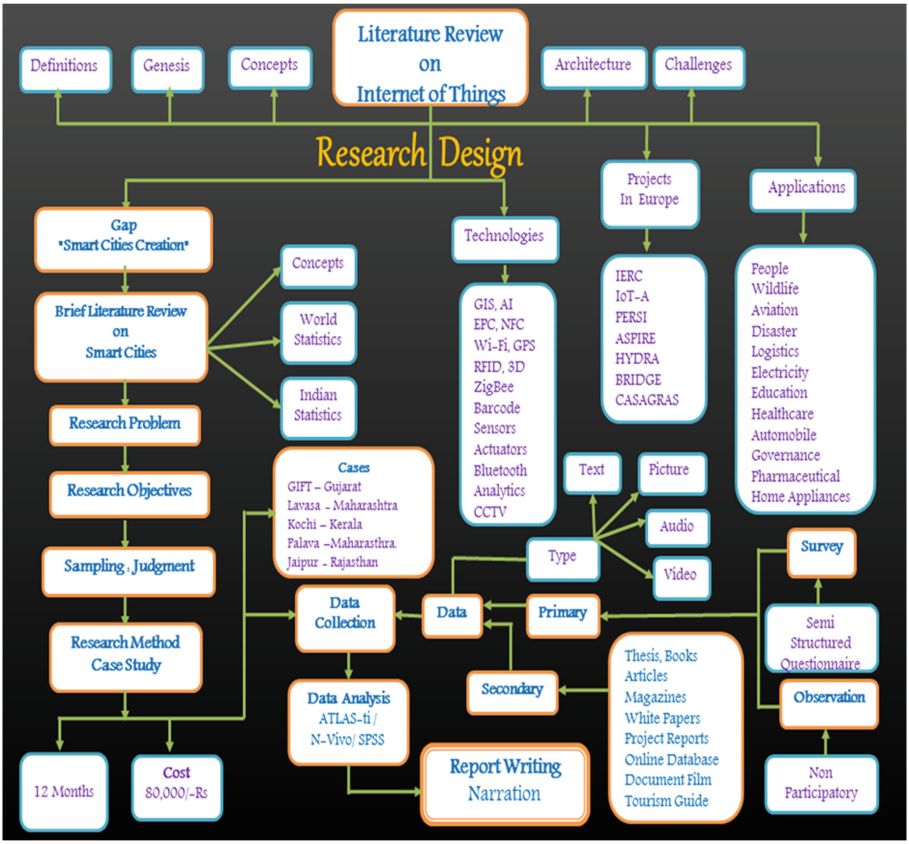

Fig. 1. Research design

5 Preliminary Results

The semi-structured questionnaire consists of the Smart City- Six Dimensions variables (59) in the Smart Economy, Smart Mobility, Smart Living, Smart Environment, Smart People, Smart Governance and IoT technologies. From four cases, authors dide survey data collection with 31 respondents GIFT (9), Palava (7), Lavasa (8) and SmartCity Kochi (7), along with a non-participatory observation from 2013–2015. Respondent's quantitative data was run in IBM SPSS 20.0 and got good reliability (Cronbach's alpha) values and then 0.7. Besides four top management managers done with the in-depth interview because of the study is exploratory and qualitative in nature. The best part is that on-line data analysis was done in thematic using in Atlas-ti version 7.0 software. We know that triangulation is an important part of research design (Doorenbos 2014), used for the data analysis and validation in exploratory studies. The authors found that all the IoT Technologies and six dimensions in all cases to bring the operational efficiency of city sub systems. Based on the Robert (1994) case study methodology too, authors did construct validity, reliability, internal and external validity. So as per urban IoT technologies, in fact, are designed to support the Smart City vision, which aims at exploiting the most advanced communication technologies (IoT) to support the administration of Quality of Services the city and for the citizens. This study indeed, may bring a number of benefits in management and optimization of traditionally public services, such as transport, parking, lighting, surveillance and maintenance of public areas, preservation of cultural heritage, garbage collection, salubrity of hospitals, and school (Zanella et al. 6). This research is going to bring huge impact in the society because of its pioneering work in this realm. It has not only referred in the domain of academic and research work but also at the government policy level including national/central, state and city municipality governments. Because of its interdisciplinary nature, the budding researchers' who are aspiring into IoT technologies, Smart Cities, Quality of Life, economic development models and sustainability connotes, can refer to the conceptual understanding and models framed.

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Malware Propagation Software for Wireless Sensor Networks

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Abstract. Malware infection in a wireless sensor network (WSN) can represent a potential vulnerability due to the low level of security that these networks exhibit. Consequently, it is very important to study the behavior of the propagation of malware in a WSN. This work aims to design a novel agent-based model to simulate malware spreading. It will provide an efficient software of great help for security administrators.

Keywords: Wireless sensor networks · Malware · Mathematical models · Agents-based models · Information security

1 Statement and Problem

A wireless sensor network is a wireless network formed by several sensor nodes where each node is capable of computation, communication and sensing. These networks have been widely applied in critical applications such as military, industrial, environmental studies, healthcare or daily life applications, among others [1]. In general, as these applications are deployed in hostile environments without the human supervision it is not difficult for them to be exposed to malicious actions by a third party. Therefore, WSN are highly vulnerable to environmental noise and malicious acts like cyber-attacks [3]. Our goal is to propose an innovative software tool based in a mathematical model to evaluate control strategies and malicious code's behavior.

Over the last two decades several models have appeared to simulate malware propagation in different stages: computer networks, mobile networks, wireless networks, etc. what has created antecedents for the adaptation of these models to WSN. Similarly, as WSN are usually used in both critical infrastructures and the Internet of Things, where the security requirements are too high, information security is a fundamental issue in WSN; in fact new communication protocols have been implemented with frame ciphers, several studies have been carried out for the detection of false nodes, and the theft or listener data via network.

During this study, we intend to design an agent-based model to simulate malware spreading in WSN. It must include the most important characteristics of a WSN, to design a software tool for simulating malware propagation, creating

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a scenario like the actual WSN. This tool will allow network administrators to implement security policies taking into account the characteristics of the network (since, for example, a network of volcanic studies does not need to implement the same level of security as a military WSN).

Mathematical models are the basis for the study of malware propagation in a WSN. Then, the theoretical model to be used will be developed as a first instance. Several proposed models [2] are being studied and analyzed to correct their errors and drawbacks in order to adapt it to the characteristics of WSNs. Subsequently, several simulation tests of the proposed model will be carried out, in a controlled virtual environment, with existing tools. At the end of these tests, the possible tools, which will be useful for the development of malware propagation simulation software based on the proposed model, will be analyzed.

2 Preliminary Results and Future Work

The documentation related to WSN is very extensive, which has led to an exhaustive bibliographical revision. It has been found that the same device is often called with several terms that can cause confusion. In addition, it was detected that the mathematical models proposed are very theoretical and, therefore, difficult to apply to reality. The great majority of these models are characterized by the use of systems of ordinary differential equations in order to describe the dynamics, and they do not take into account the individual characteristics of the nodes of the WSN and their local interactions.

As a consequence, we propose the use of an individual-based model to simulate malware spreading in WSNs. Specifically, an agent-based model will be defined. The different classes of nodes of the WSN (sensor nodes, cluster-head nodes, sink nodes, and base stations) will stand for the agents. Their particular characteristics will be considered (energy consumption, computation capabilities, etc.) and the local interactions will be defined by the topologies considered in the network: star topology, mesh topology, star-mesh topology, etc. (see Fig. 1).

Each agent will be endowed with a state taking into account their status: susceptible (the agent is not infected by the malware), exposed (the malware has reached the host node but it is in latent status), infected (the malware is active and it is ready to perform its malicious payload), quarantined (the malware has been successfully detected and the infected node is isolated), recovered, etc.

The rules that govern the transition between the states of each agent will be logical rules. These functions update the state of each agent in discrete steps of time, and the variables and parameters involved are the following:

- Variables: the states of the main agent and their neighbor agents at the previous step of time. Note that the neighbor agents are those adjacent agents to the main one taking into account the topology stablished in the network.
- Parameters: infection coefficient, recovery coefficient, latent period, immunity period, vaccination coefficient, etc.

Moreover, these rules must consider the life cycle of each sensor node (see Fig. 2).

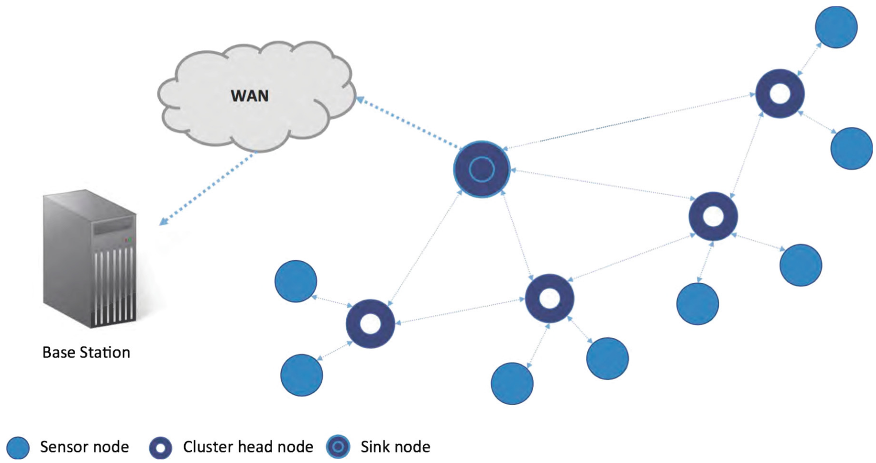

Fig. 1. Scheme with the structure of a wireless sensor network.

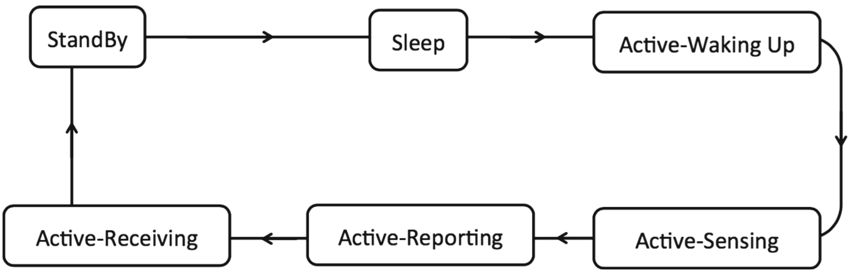

Fig. 2. Life cycle of a node in a wireless sensor node.

This theoretical model will be computationally implemented to obtain a software for the simulation of malware propagation in WSN networks. In this sense, the agent-based model will be designed using Netlogo (or another software with similar options for agent-based modeling). Finally, it is expected to collect real values for the performance of tests.

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New Perspectives in the Study of Advanced Persistent Threats

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Abstract. Advanced persistent threats (APTs) are the new type of cyber attacks that have drastically change the information security landscape. They seek to gather very sensitive information from specific and high-level objectives. The great majority of security tools do not allow handling such an intrusion in a proper way. Consequently, this study aims to analyze its behavior in order to design an agent-based model to simulate the APT cycle of life.

Keywords: Advanced persistent threats · Information security · Cyber attacks · Simulation · Agent-based models

1 Definitions and Main Specifications

An advanced persistent threat is a selective attack that obtains unauthorized access to information and communication systems in order to filter sensitive information or cause certain damage in a predefined company, industry or government organization [1,3].

It should be noted that the basic characteristics of the APT are the following: they have specific targets, they are sophisticated and highly organized attacks endowed with a large amount of resources, they usually remain active for long periods of time focused on using different attack vectors persistently and stealthily, and they implement very complex evasive techniques [5].

There are different models proposed that describe the life cycle of these attacks. In a recent study [7], 22 APT campaigns were analyzed and three main phases was distinguished: (1) initial compromise, (2) lateral movement and (3) command and control, that allow to characterize the relevant attributes that allow to propose approaches of prevention and detection. It is not really known how many groups, that design APT attacks, exist worldwide; in fact there are cyber attacks whose source group is unknown.

The impact of these complex cyber attacks platforms and reported cases like Stuxnet and Duqu 2.0 show us the weakness of the organizations and sectors of the industry to APTs. Nowadays, the efficient detection and prevention of APT

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attacks are the biggest challenges to face in order to guarantee the security of confidential data.

Our main goal is to analyze the concept of APT, focusing on the forms of propagation of malware (usually, zero-days malware), used in these attacks. Also, the differences of an APT with respect to the common malicious code will be also analyzed. Moreover, the analysis of existing known cases will allow us to identity the most common techniques and methods used by APT attackers. This will serve as a basis to propose a new individual-based model to simulate APT behavior. The simulations obtained provide necessary guidelines to prevent such threats.

2 The Work and Future Research

Initially, a bibliographic review on the APT has been carried out. Our scope was based in technical reports published from security providers and other sources such as indexed journals, conference papers, etc. It is important to emphasize that in many cases there is a consequent disinformation about the real danger of these attacks.

Considering this literary revision, it is sought to analyze and propose an APT propagation model [2], using the agent-based model method. In fact there are few published works related to the design of models to simulate the behavior of APTs (see, for example, [4,6,9]). They are based on different tools and do not take into consideration the dynamic properties between the devices that constitute the system.

The methodology based on agents allows us a flexible configuration because of the possibility of generating different simulation scenarios [8]. In this sense, a detailed description of the agents must be provided taking into account the main characteristics of APTs and the cyber environment where the attack is implemented (industry, company, critical infrastructure, etc.) The functional relations that govern the dynamic of the model must be defined taking into account the features of the propagation stage of the APT attack.

We propose the use of complex network analysis techniques in the model. Specifically, some centrality measures such as degree centrality, closeness centrality, betweenness centrality, eigenvector centrality, etc. will be considered in our model.

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Towards Modelling Organisational Dynamics for Large-Scale Multiagent Systems

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Abstract. The research proposed here aims at providing a novel organisational metamodel for Large-Scale Multiagent System (LSMASs), with special emphasis on modelling organisational dynamics. Ontology used for the metamodel will comprise selected concepts of human organisation applicable to LSMAS and a particular application domain thereof, Massively Multi-player Online Role-Playing Game (MMORPGs). Practical results include code-generating feature of the modelled system.

1 Introduction

Presently available models [1] for Multiagent System (MASs) or LSMASs mostly lack specific organisational features which LSMAS can benefit from [8], such as organisational dynamics which is especially useful when considering organisations recursively [6] or as temporary constructs. This research proposes an upgrade of these models following the recently published idea of organisational modelling of LSMAS [6] accompanied by examples applied to MMORPGs.

2 Objectives of the Proposed Research

The main objective is twofold: an ontology comprising selected concepts of human organisation applicable to LSMAS and MMORPG, and an organisational metamodel for LSMAS based on the ontology, both conforming to the approach to organisation modelling in [6], which proposes organisational modelling that follows seven particular perspectives:

– organisational structure,
– organisational culture,
– strategy,
– processes,
– individual agents,

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– organisational dynamics,
– context and inter-organisational aspects.

The following research objectives are defined based on the main objective:

O1 Analyse organisational modelling concepts applicable to LSMAS.
O2 Model organisational concepts applicable to MMORPG.
O3 Explore modelling of organisational dynamics in MMORPG.

3 Preliminary Results and Ongoing Research

Preliminary results of the research originally proposed in [4] include:

(1) ontology for modelling organisation-based LSMAS (merged OOVASIS ontology [7] and MAM5 (MultiAgent Model For Intelligent Virtual Environments (IVEs)) model [2], further enhanced with additional concepts);
(2) developed initial form of the metamodel put to use in several simple examples [5], such as Fig. 1;
(3) early version of code generator for modelled systems that works with SPADE agents [3].

Ongoing and planned research is primarily aimed at developing an ontology of selected concepts for organisational modelling of MMORPGs as a specific application domain of LSMAS. Likewise, concepts of the metamodel will be further modified to be more suitable for the set research objectives. The combination of graph grammars and temporal logic will be explored for modelling organisational dynamics. The metamodel will be tested using several scenarios set in a specific MMORPG, The Mana World (TMW), as part of the ModelMMORPG project[1].

Based on the work-in-progress metamodel, an early version of the modelling tool has been developed and put to use in several simple examples, one of which is derived from the work done by the mentioned ModelMMORPG project. The example shown in Fig. 1 is a model of a quest designed for TMW named *The Quest for the Dragon Egg* [5]. The main idea of the quest was to test cooperation and interaction of human players. The quest demanded of the players to retrieve a Dragon Egg item from one of the three locations in the Mana World, transport it in a group of at least three in-game player avatars (player characters) to a Non-Player Character (NPC). The item will go bad after approximately 24 h, i.e. it will respawn. The quest does not end here though. In order to hatch the egg, players had to supply the mentioned NPC with a Hatching Potion item which can be made using several rare ingredients. Only when both the items are brought to the NPC, the egg can be hatched. The final reward of the quest must be gathered from another NPC. The mentioned tasks can only be successfully completed when players interact and cooperate.

[1] Further information available at: http://ai.foi.hr/modelmmorpg.

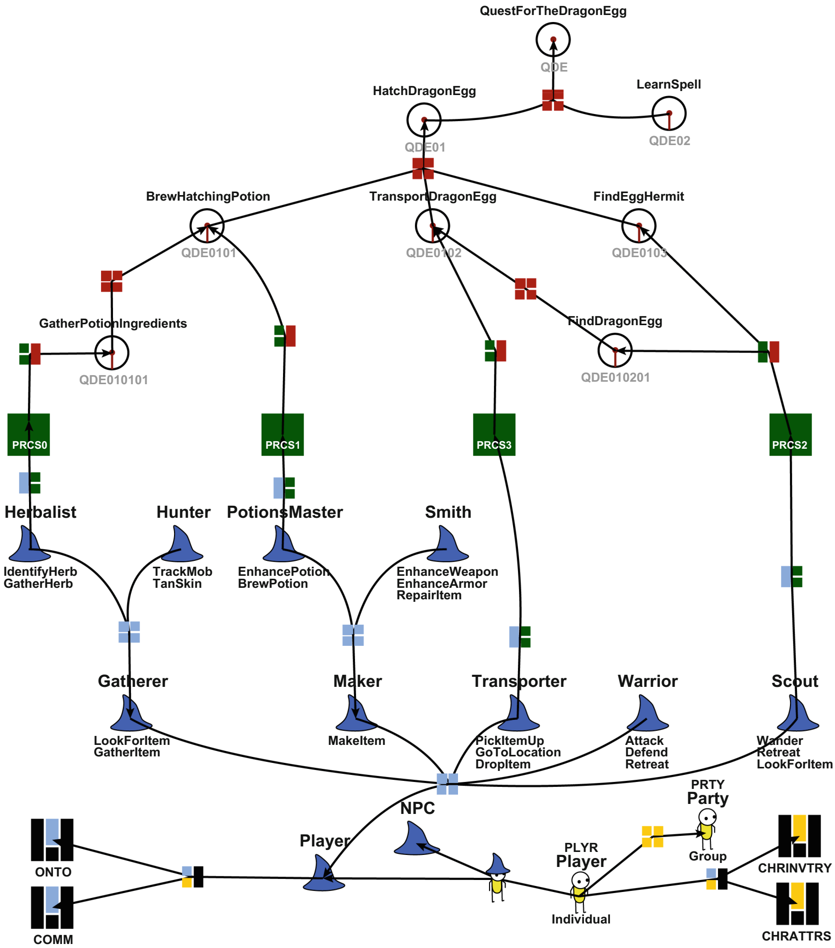

Fig. 1. Example model using the modelling tool being developed

The example in Fig. 1 models agents and parties as organisational units (stickmen), various roles of the example and their respective actions (blue hats), knowledge artefacts accessible by them (bottom left and bottom right elements), processes runnable by the modelled roles (green squares), and decomposition of the described quest (round elements).

4 Reflections

The ontology for modelling organisation-based LSMAS is a first step towards organisational modelling of LSMAS specifically suited for MMORPGs, but significant differences are already detectable compared to previously published research.

The metamodel shows promising results in its current work-in-progress state. This version of the modelling tool introduces visible clutter into the visual part of the model though, as clearly visible in Fig. 1. This problem is being solved by introducing multi-model modelling, i.e. a single system model will be spread over a number of dedicated models (for example one for defining roles, one for processes, and one for objective breakdown).

Process algebra was considered for modelling organisational dynamics, but temporal logic and graph grammars combined are regarded as a more useful approach for this novel organisation driven model for LSMAS and MMORPGs.

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On the Optimal NFVI-PoP Placement for SDN-Enabled 5G Networks

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Abstract. 5G stringent requirements entail numerous challenges to overcome. Optimizing Network Function Virtualization Infrastructure Point of Presence (NFVI-PoP) placement in a Fog Computing/5G environment is one of these challenges. To solve this problem, this paper proposes an approach for the NFVI-PoP placement problem solution considering 5G mobile network requirements in a Fog Computing (FC) and Software Defined Networks (SDN) ecosystem.

Keywords: 5G · NFV · Virtual Network Function (VNF) · NFVI-PoP · Quality of Experience (QoE) · FC · SDN

1 Introduction

5G will revolutionize mobile networking, ubiquitous computing and mobile user experience, merging state-of-the-art technologies such as NFV, SDN and FC. However, in a FC architecture for 5G networks, to ensure latency, performance and scalability requirement satisfaction, overall cost minimization and top-level user QoE, the NFVI-PoP placement optimization **problem** should be tackled.

To the best of our knowledge, no research has been conducted so far to solve the NFVI-PoP placement problem in 5G mobile networks, where NFVI could be placed at the network edge. A significant number of **related works** address the VNF placement problem [1] and NFV has been thoroughly studied [2]. Nevertheless, within the 5G context, current research is still somehow limited in scope. In [3–5] a survey on 5G and its enabling technologies inter-working particularities is presented, while in [6,7] latency and energy efficiency are considered in a FC [8] and 5G environment. In regards to SDN [9], insufficient research has been done regarding their use as 5G enabling technology, specially in a FC context.

Moreover, a deep study of datacenter Information Technology (IT) infrastructure costs and placement strategies was carried out due to its relevance for our research goals. Overall, we found quite a few articles that have addressed the Total Cost of Ownership (TCO) and overall costs for datacenter deployment and operation [10,11]. Finally, in [12] we found a solid foundations for our research. This article proposes several solution approaches for the datacenter placement

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Table 1. NFVI-PoP placement parameters

Name	Meaning	Symbol
$largeAreaSize$	Size of every $a_i \in A$	S_A
$userDensity$	User density in $a_i \in A$	U_A
$smallAreaSize$	Size of every $b_j \in B_{a_i}$	S_B
$serviceUserDensity$	Number of service users in $b_j \in B_{a_i}$	$U_s(b_j)$
$dailyAvgTraffic$	Average traffic per day within $b_j \in B_{a_i}$	$T(b_j)$
$distISPpop$	Distance from a $b_j \in B_{a_i}$ to the nearest ISP backbone connection point	$d(b)$
$linkCapacity$	Link capacity available to connect the NFVI-PoP placed in $b_j \in B_{a_i}$ to a ISP-PoP	$C(b_j)$
$numLinks$	Number of interconnecting links between the NFVI-PoP placed in $b_j \in B_{a_i}$ and the ISP backbone	$l(b_j)$
$minNumNFVIpop$	Minimum number of NFVI-PoP required to serve a $serviceUserDensity$ in a given large area	N_{min}
$nfvipopWRange$	Every RAN node within this range will be served by this NFVI-PoP	W
$maxDist$	Distance between the further $r \in R_{a_i}$ and the NFVI-PoP location ($b_j \in B_{a_i}$)	$d(r, b_j)$
$netEnergyC$	Energy consumption as a result of the number of routing devices involved in a communication between a potential NFVI-PoP location and the further RAN node	$E(b_j)$

cost optimization, while defining a comprehensive set of parameters to evaluate a given territory in search for optimal locations to place a datacenter.

The **hypothesis** of our research is that in 5G scenarios converging NFV, SDN and FC, an effective optimization of NFVI-PoP placement could be achieved by bringing VNF to the fog, managed through an extended SDN control layer.

2 Solution Proposal

The aim of our **proposal** is to formalize the NFVI-PoP placement problem in the above mentioned 5G environment, defining a set of parameters and the following metrics: costs, latency, throughput, energy consumption and reliability.

2.1 Parameters

NFVI-PoP placement parameters definition in this context is a challenge, since there is no current 5G final standard. Therefore, interworking particularities among 5G enabling technologies are mostly still undefined. In fact, there is no warranty that a given technology or feature is going to be in use.

For this reason, in a first approach, our list of parameters is mainly based on the following assumptions: (1) NFVI-PoPs will be very small-sized datacenters (micro-datacenters or fog nodes), (2) the stringent requirements of 5G future use cases, could be satisfied in a fairly accurate way, by placing NFVI-PoPs closer or further to a given set of users, and (3) most performance parameters and placing concerns, could be linked to user data traffic volumes. Table 1 shows the main parameters considered in our algorithm, in which we have defined the following: M territory of interest, A set of areas in which M is divided for analysis, B_{a_i} set of small areas in which every $a_i \in A$ is divided, R_{a_i} set of RAN nodes within every $a_i \in A$.

2.2 Optimization Algorithm

Below there is a pseudo-code summary of how the algorithm works. It is worth to highlight, that due to lack of space we have not included details about the objective function for the optimization process. However, as stated above, several studies have provided us solid foundations about infrastructure costs [10,12], and our objective function is a slightly different approach but the foundations remain the same.

Algorithm 1. NFVI-PoP Cost-aware and requirement-aware optimal placement

```
Step 1:
  Divide M in a_i large rectangular areas of size largeAreaSize
    for a_i ∈ A do
      Classify a_i in urban or rural area according to userDensity
    end for
  #OUTPUT a set of rural areas where the NFVI-PoPs will be located alongside
current base stations; a set L_P of urban areas where the NFVI-PoPs placement will
be optimized

Step 2:
  Analyze L_P and non-technical restrictions to determine non-suitable l_P ∈ L_P
    for a_i ∈ L_P do
      if a_i ≠ nonTechRestrict then
            Declare a_i as a viable location
      end if
    end for
    Save every a_i viable location in the set A_V of viable locations
    for a_i ∈ A_V do
      for b_j ∈ B_{a_i} do
            if b_j ≠ nonTechRestrict then
                  Declare b_j in a_i as a viable location
            end if
      end for
      Save every viable b_j ∈ B_{a_i} small location and a_i ∈ A_V large locations in the
      final set L_V of viable potential locations
    end for
  #OUTPUT the set L_V
```

Step 3:

Check every small area within $a_i \in L_V$ for restriction satisfaction and rank them regarding according to Table 1 parameters

```
for a_i ∈ L_V do
  for b_j ∈ B_{a_i} do
      if b_j ≠ TechRestrict then
          Declare b_j in a_i as a viable location
      end if
  end for
end for
```

#OUTPUT per $a_i \in L_V$ a rank of small viable locations to place a NFVI-PoP

Step 4:

Evaluate all possible combinations of b_j viable locations in search for a cost-optimized NFVI-PoP network. Optimize $TotalCostOwnership = CAPEX + OPEX$

#OUTPUT a ranked list of NFVI-PoP placement solutions

Step 5:

Iterate through Steps 2, 3 and 4 until convergence

Step 6:

Declare as optimal NFVI-PoP locations every b_j according to Step 5 final results

---

3 Reflections

Tackling the NFVI-PoP placement problem is a main challenge for 5G mobile networks, particularly to minimize related capital and operational expenditures. By adopting a FC, NFV and SDN environment within 5G in our research, together with both technical and non-technical parameters and constraints, we believe a comprehensive solution will be obtained.

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Active Ageing Agents

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Abstract. Supporting active and healthy ageing is important both to improve the quality of life of elderly citizens, help them contribute to society as they grow older and to reduce unsustainable pressure on health systems. From social networks to health and fitness, a lot of mobile devices applications (apps) are being developed every day. The variety and availability is such that people start to think that indeed "there's an app for everything". Many of these apps address either problems or characteristics that affect older people and that are related with the ageing process (e.g. memory and visual aids apps). They can effectively help people and are under constant evolution. However, the lack of knowledge about these available technological aids can undermine its dissemination and consequently the help that people really receive, especially those who need it the most: older people. In order to tackle the afore mentioned barriers, particularly those related to the profusion of aid apps and the difficulties it creates to the user to select the appropriate ones, we envisage the development of a multi-agent recommender system. The system will combine the results of different algorithms in order to propose the appropriate apps.

Keywords: Apps · Mobile devices · Multi-agent · Older people

1 Introduction

Demographic ageing is one of the most serious challenges Europe is facing. According to recent projections, the number of Europeans aged 65 and over will almost double over the next 50 years, from 87 million in 2010 to 148 million in 2060. This trend represents a challenge for public authorities, policy makers, businesses and the non-profit sector, especially as it comes at a time of increasing pressure on public budgets, a steady decline in the number of health personnel and growing demands from older people for care products and services. Public spending on health already accounts for 7.8% of GDP in the EU, and by 2060, public expenditure on acute health care and long-term care is expected to increase by 3% of GDP due to ageing. Supporting active and healthy ageing is important both to improve the quality of life of elderly citizens and help them contribute to society as they grow older; and to reduce unsustainable pressure on health systems [1].

The above tendencies are creating an attractive market for most information and communications technology (ICT) products and applications, as well as for smartphones and other personal technological devices [2]. Every day, a great deal of apps is being developed for a variety of purposes. Many address either problems or characteristics that affect older people and may include functionalities known to be commonly

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related to the ageing process, such as: memory, visual and haptic aids; features to minimize error and safety features. Some apps are specially designed to facilitate the use of smartphones by older people. In addition, many apps in this area may help those people even if they were not specifically conceived for them. On the other hand, one should avoid putting labels targeting specific groups of people who might be felt stigmatized. The potential of the technologies for helping older people is far superior to the help that is indeed received [2]. The usual barriers to the use of ICT products and applications by older people are related to the devices' accessibility and support, to age, marital status, education and health. There is also an excess of information and permanent changes of available solutions. If it is not expected that a common smartphone user searches for novelties in apps stores every day, when it comes to an older person this simply won't happen. Particularly when regarding aid apps, we are convinced that another reason is the lack of knowledge about the available aids and their usefulness, i.e., the kind of help provided and how to use it. Perceiving usefulness is a strong motivation for the use of ICT [2].

2 Multi-agent Approach

In order to tackle the above-mentioned barriers, particularly those related to the profusion of aid apps and the difficulties it creates to the user to select the appropriate ones, we envisage the usage of a multi-agent recommender system [3–5]. The system will combine the results of different algorithms in order to propose the appropriate app(s). Those algorithms will take into account the person's health profile, their present condition and their available apps' store.

In addition, the results of recent works [6] regarding the identification of apps based on the ageing-related changes in the human body will be taken on board. Table 1 presents examples of the keywords related to those changes and their consequences.

Table 1. Main capabilities' changes during people ageing

Capabilities changes	Consequences	Keywords
Sensory impairments	Vision impairment: blurred vision; central image distortion; blurred vision; sensitive to brightness; loss of visual field; poor night vision	Vision; view
	Hearing impairment: problems listening to the phone; difficulty following conversations; perception that others murmur	Listen
	Taste and smell impairment: loss of appetite, weight loss, malnutrition (weakened immunity)	Taste. Smell. Odour.
	Touch impairment: increased thermal pain threshold	Touch

(*continued*)

Table 1. (*continued*)

Capabilities changes	Consequences	Keywords
Motor impairment	Overall decrease of energy and vigour; joint degeneration; postural instability	Ankles. Leg.
Cognitive impairments	Loss of memory, concentration and organization	Memory. Mental.
Body changes	Urinary problems; cardiac and respiratory problems; weakened immunity; loss of blood flow	Cholesterol. Breath.
Appearance change	Appearance of wrinkles and blemishes; loss of skin elasticity; hair colour loss; loss of muscle mass	Esteem. Thin.

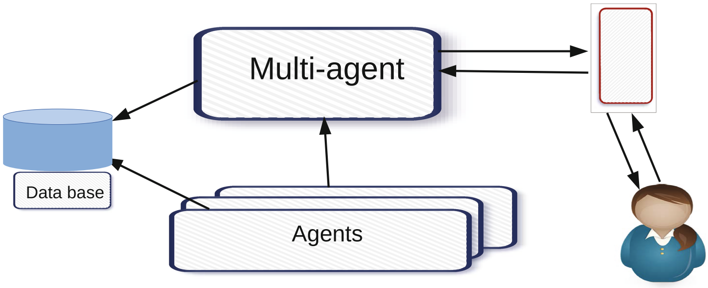

Fig. 1. Multi-agent recommender system

3 Main Innovation

The main innovation presented in this paper is the usage of a multi-agent recommender system (to be developed) which will find, on mobile devices, a personalized solution to alleviate or suppress the difficulties related to health problems. That solution consists in the identification of the appropriate app(s) which are already available but of whose existence or purpose the user is not aware. The system will be particularly valuable for older people who are the most necessitated.

Due to the dynamic and distributed nature of the problem, and the characteristics of the multi-agent systems, such as mobility, proactiveness, reactiveness, we believe this approach will deliver a more suitable and faster response.

4 Expected Results

We are confident that the system, by leveraging the data from people's smartphones and apps' stores, will: (i) mitigate risks related to diseases (including frailty) affecting older people; (ii) improve the quality of life by increasing the use of aids already available on smartphones that otherwise might not be used; (iii) decrease their concerns' relatives about their condition; (iv) reduce the pressure on the health systems; (v) allow them to continue their contributions to society as they grow older.

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Pattern Extraction for the Design of Predictive Models in Industry 4.0

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Abstract. The accelerated proliferation of the Internet of Things (IoT) has laid the foundations for the new paradigm of Industry 4.0 and of digital transformations that now arise in organizations. However, these changes have also created challenges related to the management of the large amounts of data; how to process them, store them and convert them into valuable information enabling for effective and efficient decision making.

Currently, the research is in its initial stage; we have reviewed literature on multisensor data fusion, which will provide a complete overview of the methodologies, techniques and recent developments in this field. Then, we examine the data fusion model proposed by Bedworth and O'Brien (2000) called the Omnibus Model, since we will be able to use it in the recognition and extraction of unstructured data patterns, such as those coming from IoT sensors. After applying this technique of extracting patterns with less uncertainty and imprecision, we could establish a predictive model oriented at Industry 4.0 for a multi-sensor industrial environment.

Keywords: Industry 4.0 · Sensor · Data fusion · Internet of things · Omnibus model · Pattern extraction

1 Problem Statement

Networks generate massive amounts of digital data and thanks to their analysis, doors to new technological trends open, in the search for added value. The technological evolution caused the emergence of new inter-connectable sensors of diverse nature, which are quickly being integrated into our daily life. In this research we address the problem of modelling and integrating the data generated in Industry 4.0, originating fundamentally from sensor solutions, we apply techniques such as integration and data fusion.

2 Related Work

For Mourtzis et al. (2016), the accelerated evolution of information and communication technologies that interconnect objects around us to create intelligent ecosystems, help to adopt of cyber - physical and IoT systems in industries, with the aim of machines and communication facilities being connected by a network [8].

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The concept of Industry 4.0 was first used by the German Government in order to stimulate the technological development of businesses, indeed, many countries took this approach by making use of terms such as the fourth industrial revolution; Smart Manufacturing, Smart Production, Industrial Internet, i4.0, Connected Industry etc. Industry 4.0 touches upon the greatest challenges regarding volume, diversity and speed of access to data, with various questions arising about its implications and linking this paradigm to the technological concept of Big Data [5].

Facing the challenge presented by Industry 4.0 this research will tackle the topic of modelling and integration of the data generated by IoT sensors in an industrial environment, having as its aim the extraction of patterns for the design of models which will be able to make precise predictions on the basis of the data obtained from the installed sensors, documented in this case. Thus, a predictive model is the result of the combination of data and mathematics, where the learning can be translated into the creation of a correlated function between the data input fields and the answer or the variable.

3 Hypothesis

The establishment of a hypothesis in a research, is something that can be done after the key problem of the work is addressed and elaborated. In this sense, "hypotheses are the guides of a research or study and indicate what we try to prove; they are defined as tentative explanations of the phenomenon investigated and are derived from existing theory" [7].

In this research the hypothesis that will guide our study argues that by using data fusion techniques for pattern extraction, a predictive model can be designed and applied in an Industry 4.0 environment.

4 Proposal

Bajo J. et al. (2015) stresses the importance of finding new solutions to deal with the problem of automatic fusion of the information generated by heterogeneously distributed sensors in an effective and efficient manner, outlining various information and data fusion techniques found in the literature [3]. In this context, the literature points out new trends in data fusion, which inspires further research [6]; in this sense, the research project that will be developed will analyze the problem of data generated by a network of sensors installed in an environment of Industry 4.0, extracting patterns through data fusion techniques.

Al Momani B. et al. (2011) states in [1] that data fusion has proved to be valuable for many uses, like the recognition of patterns and classification. In the initial stage of this research, we will examine the literature on multisensory data fusion with the aim of applying a technique which enables us to extract patterns with lesser uncertainty and

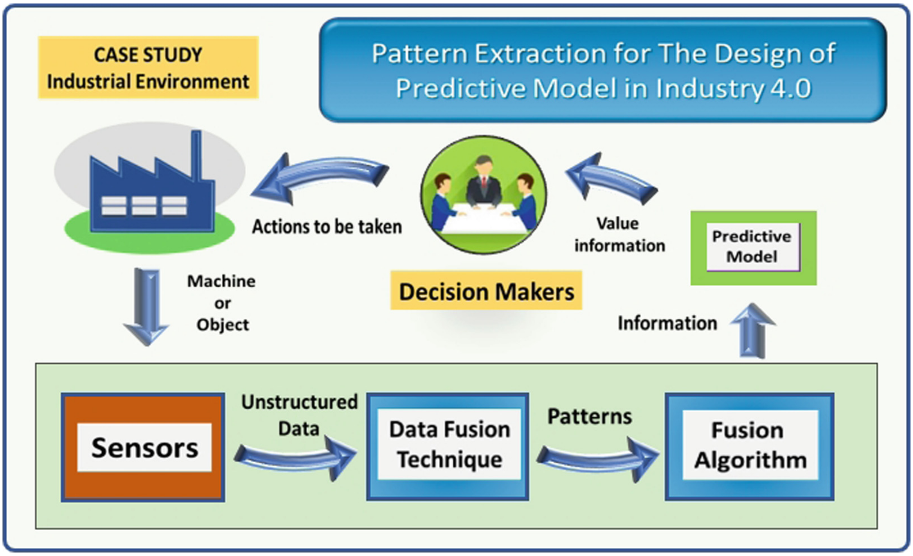

Fig. 1. Design proposal: predictive model in industry 4.0

imprecision. For the design of predictive models in Industry 4.0, we will draw from the multisensor data fusion techniques (Fig. 1).

5 Preliminary Results

This research is in its early stage. The preliminary design in this study consists of examining the multisensor data fusion literature in order to provide a comprehensive overview of the methodologies, techniques and recent developments in this field. We will analyze the data fusion model proposed by Bedworth and O'Brien (2000) called the Omnibus Model, that in opinion of Almasri M. et al., this model: "*has all components needed for an effective data fusion model as it still has the cyclic loop like other models but it considers the importance of having a feedback explicitly in the system*" [2].

The Omnibus Model is based on context activities and its stages follow a cyclic sequence in four steps [4]:

- **Detection and processing of the signal**: the information is collected and pre-processed.
- **Extraction of characteristics**: With the pre - processed information, patterns are extracted and merged to create the necessary contexts.
- **Decision**: the context is processed and the actions that follow are established
- **Act stage**: choosing which is the best plan to follow.

6 Reflections

Before the Industry 4.0 paradigm, data fusion models and architectures have been successfully used in military applications, navigation, robotics, security systems, image analysis and medicine, now with this research we want to apply the omnibus model to measure its effectiveness in the fusion of data in sensors installed in an industrial environment.

The fourth industrial revolution demands data integration and standardized interfaces, which is why more detailed research is required to address the topic of data processing in Industry 4.0 [6] New trends emerge in data fusion prompting extensive research. The main interest of this work is the extension of the application of data fusion algorithms to sensor networks, as well as the need for the evaluation of standard fusion protocols which are suitable for any domain.

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Rethinking Posts Through Emotion Awareness

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Abstract. We address privacy and decision making in social networks, building a temperament model of users, employing sentiment analysis on written posts and creating PAD models of users through facial images and designing a method that combines this information into a model. We also propose a method for advising the user based on this calculated model.

Keywords: Agents · Multi-agent system · Social networks · Privacy · Sentiment analysis · Pleasure · Arousal · Dominance · Advice · Users

1 Problem Statement and Related Work

Several risks, including privacy, are an important and challenging step nowadays at social networks. Vanderhoven et al. [1] cited the risks that teenagers face at social networks, and the characteristics that make them more vulnerable to those risks. Christofides et al. [2] explained the possibilities that lead to a regret on posting, so having into account that we can assume that being in an emotional state in which one feels more insecure or vulnerable can result in making a post that you will regret, we expose our contribution as the proposal of this system that analyzes those sentiment states and performs methods to prevent users and protect their privacy using the information about the sentiment models that the system creates.

2 Hypothesis and Proposal

We propose a multi-agent system (MAS), with user agents and non-user agents, as representations of users and system components, respectively. It is organized by layers (see types). The presentation layer has one type of agent that gets the input, retrieves it to the logic layer and gives feedback to users. The logic layer contains several types of agents that operate together to calculate polarities, PAD (Pleasure, Arousal, Dominance) models, temperament models and give advices. The persistence layer contains one type of agent that is in charge of the persistence of the data needed in the whole process. The set of proposed agents in the logic layer are: *PAD calculator*: Using images from users, extracts facial features for the PAD model calculation. *Sentiment analysis*: Aspect-based

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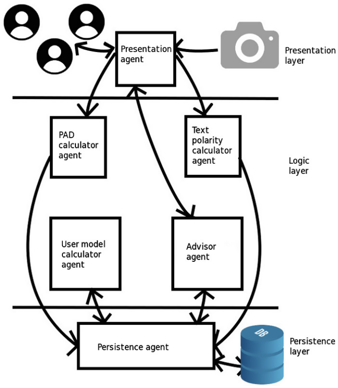

Fig. 1. Architecture of the multi-agent system

sentiment analysis on posts, frequency based method for aspect detection and an artificial neural network for polarity. *User model calculator*: An algorithm designed to calculate the temperament state is employed, based on the information from PAD models and text polarities from posts. We use a set of temperament states derived from the PAD model, proposed by Mehrabian [3]. *Advisor*: Calculate the polarity of a message about to be post, if negative and the user temperament is also negative, we show a warning and also mark the post as private, according to the privacy policy (Fig. 1).

3 Preliminary Results and Reflections

At the moment, we are developing a prototype of the proposed system. We are working to implement it on a real social network used by teenagers, and to create also new characteristics and improving the existing ones for privacy protection and sentiment state detection and modeling. We are planning to test the system with real data from several weeks of usage from the teenagers that use this social network.

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Self-healing Mechanism over the Cloud on Interaction Layer for AALs Using HARMS

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Abstract. In humans, interactions happen as a process taught generation to generation, it is our nature given the implicit need of cooperation within society. When talking about systems, reality is rather different, specifically for systems conformed by heterogeneous agents. In this sense, errors in interactions can occur at any time and for many different reasons. This paper proposes a self-healing mechanism based on model checking, taking advantages of the cloud for ambient assisted living systems.

Keywords: Model checking · Cloud computing · Multi-agent systems · Heterogeneous agents · HARMS

1 Problem Statement

Although the field of robotics is still in early stages, researchers have to insure that interactions between machines, other devices and humans are reliable. In other words, to be trustworthy enough to autonomously interact with humans or other machines and avoid stop working when unexpected situations arise. Much research has been done on the verification and validation of individual systems. Nevertheless, on-line verification during unexpected situations for standalone systems study is still undergoing. Moreover, problems become more complex-intensive, resource-demanding, costly, and error-prone when the number of agents interacting increases. Perhaps, given that the concept of multi-agent systems (MAS) is relatively novel and of high complexity, reasons mentioned above make research efforts in MAS validation and formal verification in an on-line manner less possible up to now. Robots or machines with the ability to correctly react to uncertain situations are needed to let humans feel comfortable to work with and among them. On top of that, given the increase of the elderly population in the world, many efforts have been focused to help this group of persons [2] Ambient assisted living (AAL) systems require special attention due to the complete confidence and trust the user will require from the

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system. The specific scenario addressed in this work is when a person needs to be guided to sleep by a multi-agent system. Problems of reliability become more complicated when different agents work in an autonomous way. HARMS [1] is a multi layer model and architecture to support, through different layers, features between humans, software agents, robots, machines, and sensors. HARMS is based in undistinguishability and agent's capabilities model to accomplish collective goals. The interaction layer between agents is exposed to different type of issues. Problems may be related either to physical devices malfunctioning or lack of specific capabilities of available agents. One of the strategies for this purpose, observed in nature, is self-healing organisms which take corrective actions in advance to assure final completion of goals as a survival ability. However, one challenge for self-healing systems in on-line verification approach is overcoming state explosion problem, since it needs to verify all the paths of possible status.

This paper proposes a self-healing mechanism based in model checking taking advantages of cloud computing techniques. Although, key components of self-healing mechanism, presented in this work, are the ability to create different variations of the original model and parallel execution over the cloud. Models are created to evaluate which solution may present the best benefit.

2 Proposal

The proposed system consists on four non directly connected processes. Nevertheless, the information they exchange empowers the possibility to have a run-time self-healing mechanism. The four processes are:

- **Base model generation** creates a base model in runtime with log data.
- **Current activity verification** verifies the current activity to detect when an error occurs during execution.
- **Solutions generation and evaluation** auto-generates model variations and coordinates models validation through a model checker (e.g. NuSMV).
- **Solutions corroboration** double-checks which solution is more effective and viable to implement according to available resources.

Figure 1 shows the core novelty presented in this work. The solutions generation and evaluation process consists of the following steps:

1. It starts from an original (basic) model that receives as parameter
2. A general process creates several variations of the same model and send it to run in different threads (for that, cloud is one of the options)
3. Gather the results of all the models evaluated by different threads
4. Determine which one would be more efficient to apply to solve the problem

For the last step mentioned in the list above, there are some questions to be addressed. For example, in case of not finding a solution? Or if yes, a solution is found, what is the measure to determine the best one? In terms of resources, which are more possible to be accomplished?

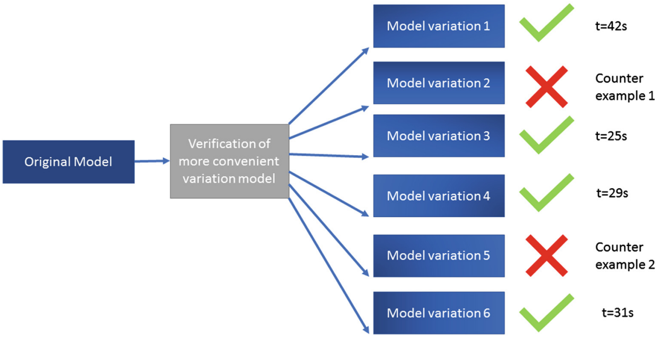

Fig. 1. Solution generation and evaluation mechanism diagram

Solutions must contrast with the different agents that may be involved in the changes proposed in the solution. Hence, solution corroboration process consists on another round of handshaking to reassure requirements of capabilities availability. In case agents lack of capabilities required, our approach will corroborate more than one of the possible solutions. Thus, determining the agent which better achieves subgoals towards accomplishing the original final goal.

Hypothesis: Implementing a hybrid cloud model checking affects in a positive way in self-healing or self-repair mechanisms in survivability scenarios on interaction layer for heterogeneous multi-agent AAL systems using HARMS.

3 Related Work

Self-healing techniques for multi-agent systems or robots are limited in the literature. In the self-healing context, mostly for homogeneous systems, methods are used to monitor and then diagnose based in consequence-oriented detection. Importance is given to efficiency, accuracy, and learning ability of the tool. Self-healing based in the Multivariate Decision Diagram (MDD) and Naive Classifier was developed by Dai and Xiang [3]. RoSHA, a self-healing architecture is presented in [4] was divided in 5 sections: monitoring, diagnostic, recovery plan, repair execution, and knowledge base. Furthermore, authors based a model of skills divided in capabilities, cognition, and cosmetics. In other work, the neural model is applied for stabilizing failures over networked UAVs developed [5]. Another self-healing algorithm for mobile robot formation based in switched topology control and distributed negotiation is presented by Ju and Liu in [6]. In the survivability context, [7] presents a method to make quantitative evaluation of survivability by using model checking. Their approach is based in continuous stochastic logic (CSL) and Petri nets to make the estimation. Efforts in AAL systems have been appearing by regions [2]. Attempts are focused in context-adaptive processes that accommodate their flow depending on specific parameters and observation during execution for elderly and people with some disability [8]. From the formal verification standpoint a survey discussing trends on formal verification on AAL systems and presents a formal system which uses the constructive description logic in upper ontologies enables to specify a semantic model [9].

Unlike solutions mentioned above, our approach focuses in assuring the survivability of the system towards accomplishing the original goal despite some situations not previously programmed to overcome. Nevertheless, our approach uses model checking to validate possible solutions or variants of the model created randomly or exhaustively. Validation is executed in the cloud to fulfill short time constraints. Spectrum of heterogeneous autonomous agents with verification for possible actors available is also addressed in this work.

4 Reflections

This study has led to explore new trends on multi-agent systems interaction self-healing mechanisms. The ultimate goal is to let multi-agents be able to recover from interaction layer problems that occur outside the scope of an autonomous overview, nevertheless, the problem is reflected in the complete system.

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Challenges in Smart Spaces: Aware of Users, Preferences, Behaviours and Habits

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Abstract. There are new opportunities for research in the field of smart environments that should be explored. The concepts of smart homes and home automation, are currently in growing expansion in the scientific and research point of view, as the market demands for better solutions in this field. Users want that those spaces smartly adapt to their preferences in a transparent way. This paper describes the process of planning, reasoning and modeling of a Smart Environment, using emerging wearable devices on the market (smart watches, fitness trackers, etc.) and newer technologies like NFC, BLE and Wi-Fi Direct. Enabling the user to optimize the efficiency, comfort, and safety at the environments.

Keywords: AmI · Smart-environments · Wearables · Wireless · Multi-agent

1 Introduction

The aim of this work is to take advantage of emerging technologies available in the market that support the so-called wearable devices [1], and the non-invasive particularity of these to, in an autonomous way, adapt the environment to the comfort parameters of each user (e.g. thermal, acoustic, air quality, light, sun exposure) [2]. Provide comfort according to the preferences of each individual, is a challenge and an opportunity to create innovative solutions and new paradigms in the context of Intelligent Environments [3].

2 Problem Statement

The problem/challenge, need or, on the economic perspective, opportunity, which aims to overcome, can be defined in general terms as the difficulty in optimizing automatic, transparent and in a non-invasive way for the user, the comfort conditions, both at domestic and professional level or even in the use of public spaces. When it comes to comfort, we can also talk about security, productivity or other.

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This challenge currently has as main difficulty, the mobility of people, the disparity of habits, schedules and every individual comfort preferences [4]. The same is aggravated when depending on physiological conditions, derived from a large number of factors (tiredness, mood, etc.), user preferences often suffer significant changes, that current systems can not measure. Contextualize user preferences, it is a process involving many variables and different dimensions, which makes this a problem of high complexity.

In addition to the physiological conditions mentioned above, there are two critical/essential dimensions, these are the space (user location) and time. In the case of the space can be as an example, the differences between the preferences of a personal, professional, recreational or other environment. Contextualize the user location is essential to optimize the conditions of comfort and contribute to the performance and effectiveness of the solution.

The time dimension is equally critical. Because the comfort preferences will change over the course of the day, as well as the week or even the year. For example, the comfort preferences may be different between daytime and night-time, or between weekday and weekend/holidays. In this dimension, it is also important to assess the changes over the year, that will have the influence of the seasons, which naturally also change quite the user's comfort preferences. In this paradigm, which is intended to be the superlative of the comfort, there are at least these three dimensions: time, space and user comfort preferences.

The time and space dimensions are critical to contextualize the user's personal preferences, and provide the necessary information that will allow assess future preferences in a useful time.

Figure 1, shows the scenario of an environment where it intends to develop this work. Explaining this figure, it can be seen the user who through its different devices (smartphone, wearable, and other compatible) communicates with the system, and for that can be used different technologies (Wi-Fi Direct, Near Field Control, Bluetooth Low Energy). Next, the system performs communication with the Cloud, to validate the information. And then the system will perform the management of the different components in the environment (climatization systems, security systems, other smart systems).

For a better understanding of the overall scenario in the user's daily life, Fig. 2 contextualizes the temporal and space dimensions present in this problem and already mentioned above. We can see that different user locations, combined with time context, naturally results in an environment with different characteristics. This kind of global scenario should also be addressed in this project.

3 Proposed Solution

This section deals with the goals to be achieved, and detail the plan defined to solve the challenge described in Sect. 2.

The aim of this project is to create a solution that takes advantage of emerging technologies on the market that support wearable devices (e.g. smartwatches, smartphones, fitness trackers) and the non-invasive characteristic of these, for

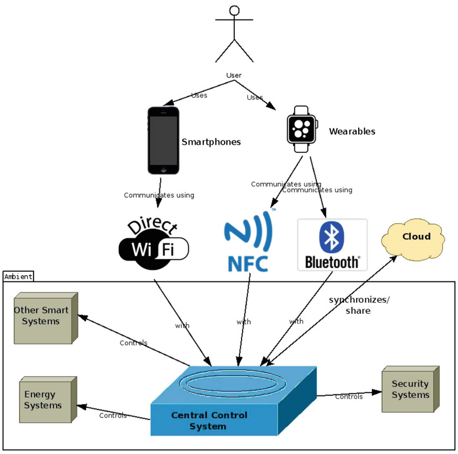

Fig. 1. Problem statement

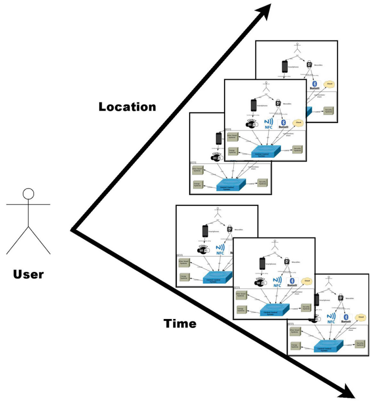

Fig. 2. Contextualization of time/environment dimensions

collecting data in an autonomous and transparent way and without any need of intervention by the user. Specifically this project aims to achieve the following goals:

- Characterize the different types of environments (Ambient Intelligence);
- Characterize the comfort in its different aspects and dimensions;
- Set a base architecture for a non-invasive system that takes advantage of emerging technologies and wearable devices data collection (smartwatches, smartphones, fitness trackers) for the intended purpose;
- Use of intelligent agents [5], to represent the different stakeholders, contexts and dimensions of the problem, who cooperate to achieve the optimal solution;
- Develop solutions that allow ubiquity in the identification of users and their comfort preferences, in an automatic and transparent way, enhancing the integration between space, time and user;
- Define an architecture solution to facilitate the user's interaction with existing systems;
- Use an intelligent multi-agent system, to manage the possible conflicts of interest, namely between users of the same space;
- Apply the proposed prototype at a health facility and/or a higher education institution, taking advantage of the existing company's partnerships;
- Evaluate the prototype using real/simulated problems of conflict management, between different comfort preferences that distinct users that share the same space.

The process and learning model proposed to the system, is intended to be scientifically innovative, taking advantage of the latest research in this field and combining multiple factors and technologies described below:

- **Use dynamically scaled priorities rules**, which must have the information, considered essential for the correct functioning of the system, including the limits for the different parameters, like system reliability or user safety.
- **Use of multi-agent systems** representing the different entities involved in the negotiation process, allowing an efficient outcome in different situations.
- **Use of sensors collected information**, and using machine learning techniques, including Sequence Discovery, Fuzzy Logic, Genetic Programming, Multi-Layer Perceptron, as described in [6], get information about user's habits in the environment.
- **Context awareness**, as described above since the context is entirely relevant in such systems.
- **Use of logical sensors**, there are three types of sensors used to assess the context in such systems: physical, virtual and logical.

That said, the practical applicability of this work, should result in the complete specification of an intelligent environment. To optimize the predictions of the solution proposed, an architecture for a multi-agent system was also defined.

4 Preliminary Results and Future Work

This project combines the use of the latest wireless communication technology with emerging wearable devices, and therefore optimize the everyday people lives and the industrial production environments. Is defined as a truly innovative project and fully applicable to industrial and domestic level. This work resulted in the complete specification of an architecture that supports the proposed solution, to solve the presented problem. It will now be implemented, tested and validated using real case studies, so as to gather statistical information to assess its effectiveness and performance in the context of application.

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Decision Support for Smart Grid Planning and Operation Considering Reliability and All Available Resources

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Abstract. Two of the most important characteristic of a Smart Grid are: (a) working optimally, i.e., using the optimal topology and using optimally all available resources in order to minimize the overall planning costs while improve the reliability indexes; (b) the capability to adapt itself to a contingency, for instance, a load increase/decrease, a fault (automatic repair or removal from service the component in an outage situation, etc.). In these cases the reconfiguration of the distribution system must be performed to reroute supplies of energy to sustain power to all customers. This work will propose a new and innovative methodology with two models using a deterministic optimization technique to support power system planning and operation (reconfiguration) decision making in a smart grid context, in order to minimize the overall costs and the same time improve the reliability indexes.

Keywords: Distribution networks · Operation · Optimization · Planning · Reconfiguration · Reliability · Smart grid

1 Introduction

Distribution networks (DN) reliability in Smart Grid (SG) context is one of the major areas for DN design and operation. In this context new digital and intelligent devices will be incorporated in the DN. These new devices will allow two way communications, providing an opportunity for new control schemes and algorithms. Thus, facing this context and the non-existence of a methodology in DN for planning and operation based on security constrained optimal power flow (SCOPF) by using a deterministic optimization technique to be incorporated in the DN planning and operation, new methods should be developed. These methods must consider in the same model the resources available in the DN (Distributed Generation (DG), demand response, storage, electrical vehicles), the reliability [1, 2] as well as achieve several goals (minimization of costs including total power losses and non-supplied energy). For planning, the model should also consider the optimal DG location, optimal capacitor banks location and size and the possibility of new lines construction. As result, the optimal topology of DN is obtained with the minimum cost for the operator.

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2 Proposal

Two methods are proposed in this work in order to address the identified needs. (1) The method for planning considers in the same model the resources available in the DN (DGs, storage, demand response and electrical vehicles), the reliability, distribution network losses, the possibility to place new DG units, optimal capacitor banks location and size and the possibility to place new lines (multi-objective problem). Factors such as stability, economics and uncertainties related to renewable based generation (wind, solar) will be considered. This method provides the distribution system planner with adequate decision support. Due to the characteristics of the optimization problem the optimal Pareto front and a decomposition technique will be used together with a SCOPF algorithm to determine the optimal network radial topology. The following objectives are considered: Power losses costs; Non-supplied energy cost; Costs for DG placement; Costs for capacitors banks placement and size; Costs for new lines. The obtained solution will include information concerning improvement of reliability indexes, optimal radial topology, power flow, power generation, places for new lines, DGs and capacitors (including the size). (2) The method for operation will also consider in the same model the resources available in the DN (DGs, storage, demand response programs and electrical vehicles), the reliability and distribution network losses. In presence of a contingency (fault, load increase/decrease, etc.) the distribution system operator will have important information concerning the operation, namely the reconfiguration of the DN and corresponding costs. Also, a decomposition technique will be used together with a SCOPF algorithm to determine the optimal network radial topology. The objectives to be consider include: Power losses costs; Non-supplied energy cost; Energy costs.

3 Conclusions

A decomposition technique was chosen to split the hard optimization problem into two problems. The decomposition technique can be used when the optimization problem can be decomposed at least into a master problem and one or more slave problems. In this kind of problems, the master problem will define the topology of the network. Once this solution is obtained, it will be sent to the slave problem for checking all the technical constraints. If there is no violation for any of the technical constraints, then global solution for master and slave is obtained. Contrariwise, a linear cut is produced which means a new technical constraint is added to the master problem to be running as a new optimization problem. The methodologies are in development under the MATLAB and TOMLAB Optimization software applications.

Acknowledgments. This project has received funding from National Funds through FCT under the project UID/EEA/00760/2013. Bruno Canizes is supported by FCT Funds through the SFRH/BD/110678/2015 PhD scholarship.

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An Actor-Based Bottom-Up Simulation Aid for Complex Dynamic Decision Making

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Abstract. Modern organisations are large complex systems operating in an increasingly dynamic environment, and are tasked to meet their competitive goals by adopting suitable courses of action. The decisions to select effective courses of action call for deep understanding of various aspects of organisation such as its goals, structure, business-as-usual operational processes, and overall business dynamics. The current state-of-practice of decision-making that relies heavily on human experts is often reported as inadequate. This research proposes an actor-based simulation platform as an analysis aid to evaluate the efficacy of decision alternatives with increased precision and rigour in the context of complex dynamic decision making.

Keywords: Organisational decision-making · Simulation based decision-making · Socio-technical system

1 Background and Objectives

Decision making within organisation requires precise understanding of various aspects of an organisation such as goals, organisation structure, operational processes, historic data, and the environment where it operates [5]. The socio-technical characteristics of the organisation, inherent uncertainty and non-linear causality in business interactions, and high business dynamics make the decision making difficult in practice.

The current practice of organisational decision making relies heavily on human experts who, in essence, have to depend on primitive tools such as spreadsheets, word processors, and diagrams. A decision based on human intuition and interpretation is often reported as biased, based on short-term implication, and imprecise for dynamic environment [10]. This research aims to improve precision, reduce personal biases, consider short term and long term effects, and reduce the excessive burden on human experts in complex dynamic decision making (CDDM).

It is an external doctoral programme started in November 2014. Guides: Prof. Tony Clark (Sheffield Hallam University, UK), Prof. Balbir Barn (Middlesex University, UK) and Vinay Kulkarni (Tata Consultancy Services Research, India).

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2 Decision Making Approaches and Contributions

For rigour in CDDM, the decision makers typically rely on operational research techniques, system dynamics theory, and sophisticated AI algorithms. The operational research techniques and system dynamic theory use a top-down approach wherein the system under consideration is represented and analysed using global state and aggregated system behaviour [13]. The AI techniques advocate predictive analyses wherein the analysis algorithms rely solely on historical data to reflect on the efficacy of decision alternatives. These approaches are extremely efficient for describing and analysing complex systems whose future behaviour is typically a linear extrapolation of past behaviour. However, they fall short of providing precise understanding of the systems that exhibit emergent behaviour and deal with a large number of socio-technical elements having adaptive and autonomous behaviour [9].

A bottom-up approach, in contrast, considers emergentism [11] as advocated in actor model of computation [7] and agent-based systems [9]. Essentially, the bottom-up approaches define the micro-behaviours of constituent elements of a system (in contrast to the global behaviour of a system), and the global behavior is considered to have emerged out of interactions among constituent elements. This research adopts bottom-up approach [13], actor-based modelling abstraction [7], and actor-based simulation technique for to address a class of CDDM problems that deals with the systems with significant dynamism and emergent behaviour. The key contributions of this research are (a) a language, termed as OrgML, to represent organisation with emergent behaviour and its dynamic environment, and (b) a simulation platform for a-priori evaluation of decision alternatives using *what-if* and *if-what* analyses.

3 Research Overview

A conceptual representation of decision making is depicted in Fig. 1. As shown in the figure, an *Organisation* has a set of *Goals*, it publishes set of key performance indicator or *Measures*. The decision makers analyse, observe or predict Measures, and decide appropriate courses of action or *Levers* in-case they find that stated Goals are not achieved. The key activity of decision-making is to select appropriate Levers so as to meet the stated Goals. It is an iterative exploration and evaluation of the available options to find best possible option that has potential to achieve Goals. The efficacy of such exploration depends on two key factors: (i) the ability to capture relevant information about Organisation and its environment, and

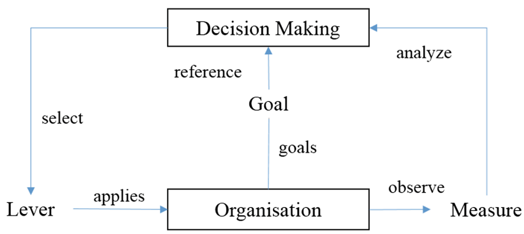

Fig. 1. Decision making process

(ii) the ability to perform *what-if* and *if-what* analyses, *e.g.*, what will happen in terms of Measures and Goals if specific Lever is applied to Organisation or which Levers can leads to specific Measures, *etc.*

This research argues that an Organisation can be understood well by analyzing *what* an organisation is, the motivation of an organisation or *why* aspect, *how* it operates, and *who* are the responsible stakeholders [3]. Decision making further expects the understanding of potential courses of action and their applications, *i.e.*, the *when* and *where* to apply the courses of action. This hypothesis is principally aligned with the Zachman framework [14]. The complexity and dynamism associated with CDDM puts some additional demands on specification in terms of desirable characteristics of organisation that include *reactive*, *adaptive*, *modular*, *autonomous*, *intentional*, *compositional*, *uncertain* and *temporal behaviour* as discussed in [2]. Furthermore, industry practice of decision making that desires precise a-priori assessment to judge efficacy of a decision expects qualitative and/or quantitative analysis in the form of *what-if* and *if-what* scenario playing.

Research proposes *OrgML* to support specification needs and conceptualise a simulation platform to support analysis needs of CDDM. Principally, OrgML builds further upon the concepts of actor model of computation, event-driven systems, declarative rules, goal specification, conventional class model, linear temporal logic and theory of uncertainty. In addition, this research uses a language termed as *enterprise specification language* (ESL)[1] as a basis for developing a simulation platform for CDDM.

4 Summary

This research adopts Design Science Research (DSR) methodology [6] to conduct research activities, and produce research artefacts. Research follows three DSR cycles namely *relevance cycle*, *design cycle* and *rigor cycle*. The literature reviews expected in *relevance cycle* use *systematic mapping study* (SMS) [12] methodology. The meta-modelling technique is adopted to produce *research artefacts* of *design cycle*. The research validation is based on *Artificial* and *Ex-Post* evaluation strategy. The *rigor cycle* that establishes the connection between *research outcomes* and *knowledge-base* is planned using meta-analyses on multiple *Ex-Post* evaluations.

Till date, the problem statement is defined and the relevance of research problem statement is validated through publications [1,4]; the background is established through literature reviews [2] and set of experiments [1,8]; the hypotheses are identified in [3]; and a meta-model describing the core elements of OrgML is defined [4]. The implementation and validation of OrgML are ongoing activities. Validating efficacy of OrgML and OrgML based simulation platform in the context of CDDM is the final step to conclude this research.

This research proposes a synthetic but near real-life case-study to validate research outcomes. Synthetic case study considered for this research focuses on

[1] https://www.gitbook.com/book/tonyclark/esl/details.

a recent Demonetisation initiative in India[2] wherein 87% of cash in circulation in Indian economy was eliminated in a sudden announcement in November 8, 2016. In reality, the initiative resulted into prolonged cash shortage in Indian economy and caused inconveniences to entire population of India. The case study will explore possible means that could have reduced the adverse effects while achieving the overall goals of demonetisation initiative.

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μGIM – Microgrids Intelligent Management System Based on a Multi-agent Approach and the Active Participation on Demand Response

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Abstract. The present paper presents an overview of Luis Gomes PhD proposal, focusing on the problem that will be solved and how it will be solved. In the PhD, μGIM system will be developed for microgrid management and microgrid players' energy management. The proposal also consists in study and analysis of microgrids demand response programs.

Keywords: Demand response · Microgrid management · Multi-agent system · Player representation · Single-board computers

1 Problem Statement

The non-existence of an open source microgrid management system operating in a multi-agent approach that can represent each player inside the microgrid.

One of the biggest problems that microgrids are facing, is the lack of facilities able to participate in them. Old facilities need retrofitting solutions to be integrated in a microgrid. An intelligent, easy to build and open solution is needed to virtually represent facilities in microgrids. This virtual representative agent must talk, negotiate and act in the microgrid while manage the facility's energy consumption and generation.

2 Related Work

Some researches only focus on the multi-agent systems for microgrid management, such as [1, 2]. However, they do not explore the hardware or even the feasibility to be implement in real scenarios. For real implementations new problems arises, such as, the

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computational processing limitation in the facility-side. Other related works are the study of Demand Response (DR) programs for microgrids [3, 4]. However, mostly of these works focus on the microgrid profit and do not make a proper analysis of the end-consumers and how they should participate in DR.

3 Hypothesis and Proposal

The main hypothesis of μGIM proposal are the following: "Multi-agent systems for energy players' representation is a good approach"; "Households' energy management can be efficiently done with single-board computers (SBC)"; and "DR households' intelligent and autonomous participation benefits the microgrid management".

The proposal of μGIM defends the development of a multi-agent system on top of SBC to manage a microgrid and their players. The system will have distributed computational processing, the ability of participate in DR programs using an intelligent and autonomous approach and the ability to negotiate with the microgrid agent and with the other SBC agents (negotiate energy and computational processing). μGIM will also test and validate several DR programs inside microgrids.

4 Preliminary Results and Reflections

μGIM proposal concluded the possibility to manage the energy in households using four types of SBC: Intel Galileo Gen 2; Raspberry Pi Model B; Cubietruck; and Raspberry pi 3 Model B. A multi-agent system is running on these SBC (one agent in each SBC) that monitors energy using Modbus/RTU, Modbus/TCP and/or restful requests, and stores these data in a local database. The communication between SBC are also working (indispensable for negotiations).

μGIM will combine market validated solutions in order to create a system where scientific contributions can be tested and validated. The use of SBC for a multi-agent system will enable the real implementation of the system, to be tested and validated. Also, the use of intelligent and autonomous DR participation in the end-consumer side, compliant to openADR, will enable massive tests with all kind of scenarios.

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Organization-Based Multi-agent System of Local Electricity Market: Bottom-Up Approach

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Abstract. This work proposes a organization-based Multi-Agent System that models Local Electricity Market (MASLEM). A bottom-up approach is implemented to manage energy in this work. In this context, agents are able to connect to each other and the power grid to transact electrical energy, and manage their inside electrical energy independently. A Demand Response Program (DRP) based on Indirect Load Control (ILC) method is also used. The performance of our work is evaluated through an Agent Based Modeling (ABM) implementation.

1 Introduction

In the recent decade, Electricity Markets (EMs) have made competitive environments for complex power systems. Besides, the fast growth of Distributed Energy Resources (DERs) has created new challenges up-keeping system reliability and stability for the system. However, conventional energy management strategies will not be able to resolve these concerns centrally due to DERs generation volatility and lack of dispatch control [1]. Nonetheless, this need is felt on demand-side of the power systems, such as the distribution or retail participants who want to clarify real and fair price in medium- and low-voltage distribution network locations. Furthermore, centralized EMs are not complete enough at present, and cannot provide dynamic reserves that follow consumer behavior due to demand response programs. Also, DERs cannot indicate their potentialities entirely because of the rules of EMs. As a result, centralized EMs transfer to decentralized and Local EMs (LEMs). Several researches have presented energy management of smart distribution networks. In [2], smart homes are connected to transactive energy nodes. Moreover, the co-simulation of smart homes and the transactive energy market has been studied in [2]. In [3], a distributed energy management strategy has been defined by a price-based control method. Also, the authors have decomposed the global optimization problem into independent local optimization problems. While there have been researches

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that discussed local energy and electricity markets and decentralized energy management problems, none have presented a complete solution to how global optimum solutions can be obtained through local decisions. This work proposes a bottom-up energy management approach of an organization-based MASLEM.

2 Proposal

MASLEM is defined as a class of organization-based multi-agent system (MAS), where each agent has different tasks. These agents consist of DERs, electrical consumers, retailers, aggregators, and etc. This structure contains different layers. It is noticeable that the proposed market structure of the smart distribution grid is based on the bottom-up approach. According to this approach, decisions of agents in the bottom layer have priority in comparison to agents' decisions in the upper layer. Moreover, price-based control strategy will be utilized in this model, it requires low-ranged bandwidth communication and control protocols, and JADE is used to implement MASLEM. Although, in this work, we proposed a strategy to manage energy locally, we pursue to optimize global-social decisions. In other words, this strategy provides global-wide, local, nodal, and time scalable decisions. In each layer, different types of electricity commodity- e.g. energy and reserve- can be traded in the LEMs. Hence, agents are enabled to participate in their regional LEM to trade electrical energy at the day-ahead multi-period markets, and reschedule their dispatched energy at the hour-ahead adjustment markets according to the existing uncertainties in the system. Furthermore, the agents of each region can contract bilaterally with other agents in their own region or other regions. These contracts can conclude long-term obligations to the second and real-time scale. If, local and global decisions were not

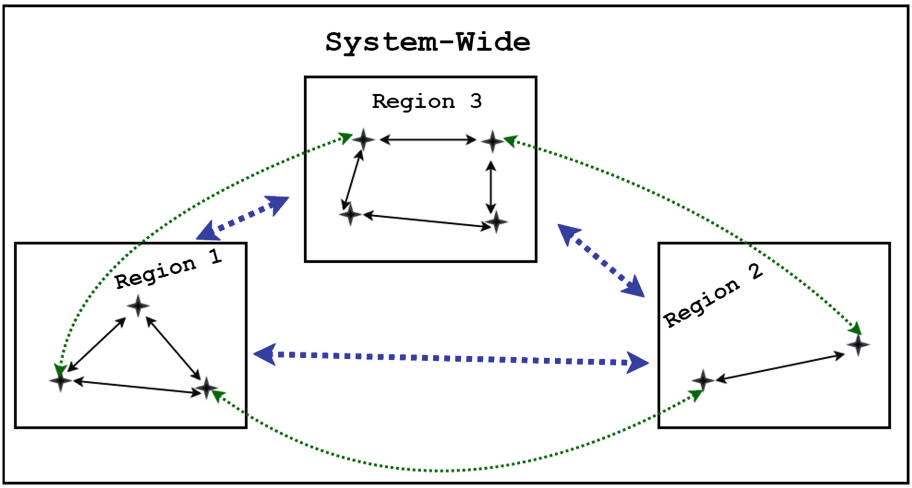

Fig. 1. MASLEM organization.

in the same direction, then flexibility is defined as one type of ancillary services to support global optimization and local-autonomous decisions. Moreover, new structures will be proposed how LEMs can transact energy and ancillary services with the wholesale EM for the first time in this work. The organization of MASLEM's agents is illustrated in Fig. 1. In our future works, different structure of LEMs, aggregation of DRPs, and transaction strategies between demand-side agents will be proposed.

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Remuneration and Tariffs in the Context of Virtual Power Players

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Abstract. Power systems have been through deep changes, with their operation in the scope of competitive electricity markets (EM) and the increasingly intensive use of renewable energy sources and distributed generation. This requires new business models able to cope with the new opportunities. Virtual Power Players (VPPs) are a new player type which allows aggregating a diversity of players (distribution Generation, storage units, electrical vehicles, and consumers) to participate in the markets and to provide a set of new services promoting generation and consumption efficiency and to improving players' benefits. A major task of VPPs is the remuneration of generation and of the services (e.g. market operation costs, and energy reserves) as well as charging energy consumption. This PhD research will contribute by developing fair and strategic remuneration and tariff methodologies, able to allow efficient VPP operation and VPP goals accomplishment in EM.

1 Problem Statement and Related Work

The electricity sector has been completely revolutionized by the emergence of liberalized EM, characterized by many changes in operation rules, increase in competition and profound changes in the participant entities. The restructuring was performed so that the competitiveness could be increased, but it had exponential implications in markets complexity and unpredictability [1]. Much like EM subsystems of the main network are rapidly evolving into a reality, coordinating these entities is a huge challenge that requires the implementation of distributed intelligence, potentiating the concept of Smart Grid (SG) [1, 2]. However, inefficient resource management should be overcome by adequate optimization methods [3]. Player aggregating strategies allows players gaining technical and commercial advantages, individuals can achieve higher profits due to specific advantages of a mix of technologies to overcome disadvantages of some technologies. The aggregation of players gives rise to the concept

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of Virtual Power Player (VPP) [4]. VPPs aggregate different types of resources with individual goals; VPPs should conciliate all players in a common strategy able to enable each player to pursuit its own objectives [5]. Potential benefits will depend on the efficient operation in the market and the remuneration of aggregated players. Important developments concerning EM players modelling and simulation including decision-support capabilities can be widely found in the literature [4–6]. This PhD main goal is to develop remuneration and tariff methodologies in the scope of a VPP. The lack of tariff and remuneration definition methods to enable the compensation of prosumers in a EM environment, fairly and appropriately, is one of the gaps that this study will overcome.

2 Proposed Approach, Preliminary Results and Reflections

This work addresses the identified gaps in the literature by proposing the RemT (Remuneration and Tariffs) methodology. The results of the proposed RemT process are used in a learning algorithm to improve the quality of the remuneration process, with consequential implications to the market bidding process. The establishment of remuneration and tariffs is based on the identification of players' types and on the development of contract models for each player type. The players modelling considers the operation and market context. The terms for new contracts and best strategies for each context are determined by means of machine learning based methods. The first part of the work is related with consumer's classification of player's profiles. Data mining methodology was used, based on the application of a clustering process, which groups the typical load profile of the consumers of a SG according to their similarity. The separation of consumers in different groups allows proposing specific consumption tariffs to each group, so that consumers' load profile is taken into account to meet the objectives of the SG aggregator. This methodology is tested using a real smart grid with 82 consumers, that includes several consumers of different types (residential and commerce). This work proposes a clustering methodology that uses different data normalization methods and a new customized normalization method has been introduced [7]. Preliminary results demonstrated the advantages of data mining methodologies, based on the application of clustering process to group typical load profiles according to their similarity to allow proposing specific consumption tariffs to each group, so that consumers load profile is taken into account to meet the objectives of the SG aggregator. This work allows the development of a tool that provides a decision support for VPP definition of best tariff and remuneration to apply to each aggregated player, RemT.

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Multi-agent Based Uncoordinated Channel Hopping in the IEEE 802.15.4e

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Abstract. An emerging concept in railway management is to reduce the distance between consecutive trains, actively controlling their separation in order to enforce a continued safe distance. This concept is referred to as "Virtual Coupling" and it needs highly reliable and fast, real-time wireless communication systems. In this respect, TSCH was introduced in the IEEE 802.15.4e amendment to improve reliability of communication. Recent studies addressed the fast joining time problem where different traffic schedules must be merged when different communication domains come together. In this paper, we study the hoping strategy involved in TSCH to derive the probability of successful hopping upon merging.

Keywords: Channel hopping · Nash equilibrium · Virtual Coupling · IEEE 802.15.4e · Multi-agent

1 Introduction

Wireless communication, specifically wireless sensor, and actuator networks (WSANs) will play a key role in the future of Internet of Things (IoT), Industrial Internet of Things (IIoT), Industry 4.0. In a WSAN many sensors and actuators are embedded in the same physical environment to measure different parameters and actuate on it according to some feedback control strategy [1]. In the case of vehicular sensor-actuator network-based control in railway systems, physical parameters such as temperature of brake disks, temperature and humidity inside the vehicle, the temperature of heating pipes, speed, direction, and location, are measured by sensor devices and a recent trend is to have them sent to a controller over wireless links.

When using WSANs, train vehicular applications pose additional requirements such as generality, reliability, fault tolerance, predictability, and security. They need to support generality because they will be used in different countries regarding different traffic rules and even different legal frequency bands [2]. Reliability is naturally an extremely important factor. These systems need a reliable and low latency wireless communication

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network, for example to exchange physical parameters like location and speed in a direct communication between vehicles without third party involvement [2]. Fault tolerance is another important aspect that needs to be accounted to increase systems reliability and safety. Predictability is also fundamental to achieve safety and have the vehicles control performing adequately. Concerning the wireless communication, it means avoiding or preventing channel fading, channel interference, channel congestion, channel jamming and channel assignment [3].

In one of the latest reports released by Roll2Rail project [4], many standards such as IEEE 802.15.4 and protocols like, ZigBee, Industrial WLAN, WirelessHART and Ultra Wide Band (UWB) were analyzed to support Vehicle-to-vehicle (V2V) communication. The IEEE 802.15.4 standard, which defines the Physical and Data link layers of several protocols, has several disadvantages such as low reliability, unbounded packet delays, no protection against interference and jamming [1, 5, 6] and thus it is not a good option for a direct V2V wireless communication system. However, recently, IEEE has released the 802.15.4e amendment that extends the original IEEE 802.15.4 standard to better support the emerging needs of embedded real-time applications and improves reliability and latency by Time-Slotted Channel-Hopping (TSCH).

In the concept of TSCH networks, successful-hopping is defined as a hopping strategy that improves communication performance by changing channel every slot according to a predefined sequence. However, it is also possible to disable hopping and remain in the same channel. This can be better if the current channel is in a good state. The work in [7] highlights the effectiveness of channel hopping. But, the authors of [8] observed that random channel hopping communication for unstable zone can be counter-productive. To the best of our knowledge the problem of deciding whether to do hopping or not, has not received enough attention. This is our contribution in this paper, in which we propose a simple multi-agent based way of deciding whether to do hopping or not using a game theoretic approach, namely the Nash equilibrium.

The reminder of this paper is organized as follows. Section 2, is an overview of IEEE 802.15.4 and new amendment. In Sect. 3, we present previous works. Section 4 discusses Virtual Coupling and the reason of using IEEE 802.15.4e standard. In Sect. 5, we present our multi-agent model. In Sect. 6, we define some metrics to evaluate channel performance. Section 7 discusses Nash equilibrium and our game-theoretic description of successful hopping. In Sect. 8, we propose a solution based on Multi-agents and zero-sum game model. Finally, we conclude in Sect. 9.

2 The IEEE 802.15.4 and IEEE 802.15.4e

The IEEE 802.15.4 standard is a standard for low-rate, low-power, and low-cost Personal Area Networks (PANs). This standard, defines the Physical and Data link layers of several protocols but, it has several disadvantages such as low reliability, unbounded packet delays, no protection against interference and jamming [4, 10, 11]. Thus, it is not a good option for a direct V2V wireless communication. Recently, IEEE released the 802.15.4e amendment that extends the original standard to better support the emerging needs of embedded real-time applications and improves reliability and latency. In the IEEE 802.15.4e amendment, there are several Medium Access Layer (MAC) behavior models to support industrial automation application. In this work, our focus will be on Time Slotted Channel Hopping (TSCH) feature. TSCH is introduced to improve packet reliability and increase the probability of the joining time in the wireless communication networks. TSCH combines time slotted access with multi-channel and channel hopping capabilities. In the TSCH network, each node communicates with another node through a link. This link will reserve a time slot and channel for the supposed communication and will translated into the physical channels, by the Eq. 1.

$$Channel = HSL\left[\left(ASN + Channel_{offset}\right) \bmod |HSL|\right] \tag{1}$$

where *ASN* is the Absolute Sequence Number and *HSL* is the Hopping Sequence List.

3 Previous Works

In the work of [9] a Model-based Beacon Scheduling (MBS) algorithm has been proposed to autonomously select the links to use for advertising Enhanced Beacons (EBs) and, minimizes the average Joining Time by provided optimal EB schedule through MBS in TSCH networks. For that, they used a Discrete Time Markov Chain to provide a methodology to calculate the average joining time as it occurs in a different state with a set of discrete transitions which probability of the next transition is dependent on the previous transition. Then, the authors have concluded the MBS algorithm to provide an optimum EB by defining a minimization problem based on Mixed-Integer Non-Liner Programs class over the average joining time.

The authors of [10] proposed a solution that divides TSCH's Slotframe into two parts: the advertisement plane and communication plane. This separation helps to reduces effects of flexible scheduling Enhanced Beacon (EB) broadcast on the overall operation of TSCH network and speed up joining time. In [11] the Authors designed two different EB scheduling algorithms to speed up the joining phase in an IEEE 802.15.4e network: Random Vertical filling (RV) and Random Horizontal filling (RH). In RV the coordinator transmits EBs on a random channel offset and at the first slot of the multi-Superframe structure. In RH, the coordinator transmits EBs at a random slot of the multi-Superframe structure with $Channel_{offset} = 0$. The performance of both solutions is the same. The authors of [12] used fuzzy logic and the idea of dividing slotframe into two parts which were earlier discussed in [10] to speed up joining time and reduce energy consumption. In [6] the authors show how Routing Protocol for Low-Power (RPL) and Medium Access Control (MAC) they affect negatively over network performance by creating inefficient redundant paths. It happens because RPL always creates a routing topology without a priori knowledge about the topology that was created by MAC layer.

The authors of [13] introduced a heuristic blocking solution to exclude poor channels from the hopping list by creating a blacklist of very noisily channels and they called this solution A-TSCH. In [14] works they try to use a Bayesian frequency hopping game model based on Nash equilibrium to improve wireless sensor network's resistant against of attack. In this paper, the authors have considered that there is an intrusion detection procedure which detects the attack and triggers channel hopping request. There are several other works that have been done in this area by using the concept of game theory such as [15–18].

4 Virtual Coupling and IEEE 802.15.4e Standard

A fundamental principle of railway signaling has always been that following trains must be separated by a sufficient margin to ensure each train is capable of braking to a stop before reaching the last known position of the train in front. A wireless communication link between the trains could ensure that if the leading train starts to break, the following train will do the same and maintain separation as the two trains slow together. This concept is referred to as Virtual Coupling or Virtually Coupled Train Sets (VCTS) and can provide maximum use of limit capacity in railway systems [19]. This includes achieving a more competitive and resource-efficient European transport system with a view to addressing major societal and technical issues such as rising traffic demand, congestion, safety, flexibility of timetables, no time-intensive coupling processes, reduction of aerodynamics through coupled wagons and increased capacity, also it provides more flexibility in train operations namely in depot. The concept of VCTS is based on the idea of using modern electronics and data transmission to run several self-propelled units one behind the other without physical contact but at distances as short as mechanically coupled trains. The trains could automatically join or leave when they reach a junction. See Fig. 1.

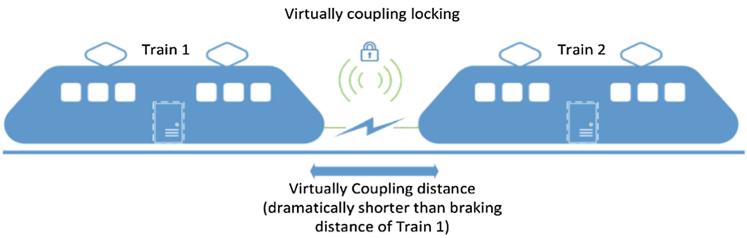

Fig. 1. Virtually coupling distance between 3 trains

New technologies, such as radio systems, satellites, signaling and real-time communications and currently amiable systems like the European Railway Traffic Management System (ERTMS), European Transport Control System (ETCS) enables the application of train coupling and sharing concepts with dynamic joining and splitting of module trains in motion to so-called Virtually Coupled Train-Sets. Having a VCTS needs highly reliable and fast, real-time wireless V2V direct communication. systems. The IEEE 8028.15.4e standard can be a good candidate for this need [4].

5 Multi-agent Model

VCTS by nature needs dynamic and collaborative communication environment. Each train should be able to predict the best time to hop or maximize reliability, safety and, security of communication by not-hopping and using the current channel. By this explanation reliability, safety and, security of communication should be considered as a crucial desire for each train. Multi-Agent Systems (MASs) are well prepared to cope in a dynamic environment with intelligent entities. In our model, each agent must be able to evaluate communication channels performances and decide to use hopping technic or not, which hereafter called “hop” or “not-hop” actions. To have better understand, let denote Alice, Bob, and Trudy as agents with a common environment. This environment is a V2V direct communication through IEEE 802.15.4e based protocols. Physical parameters are speed and location of each train. While Alice and Bob are trying to maximize their communication performance, Trudy is trying to maximize his chance to jam their communication channel. There are different models and different solutions to design a zero-sum game for this scenario. But, what makes our work different than similar works [14, 17, 18] is the way we look at the problem. We will relax Trudy from the targeted model and we will focus on Alice and Bob. By this assumption, our model will have just two agents. Trudy is an agent outside of our system which will have a negative influence on communication performance. Alice and Bob are two trains under VCTS schema. The Fig. 3 shows a sequence diagram of Alice and Bob`s communication. Alice and Bob can exchange some messages in a formal language like the Foundation for Intelligent Physical Agents-Agent Communication Language (FIPA-ACL) to update their latest situation. This communication will help them to change their current behaviors and take future decisions in a cooperative fashion to get into a Nash equilibrium with a high probability. Using MAS and game theory to approach TSCH problem with a high probability of best hop or not-hop decision is discussing for the first time in this work (Fig. 2).

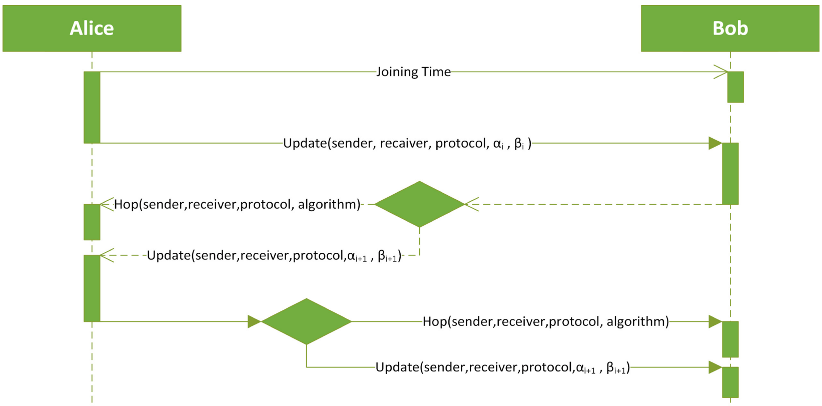

Fig. 2. The sequence of communication between Alice and Bob.

6 Metrics

Based on [6, 8, 20] we will define channel performance ratio by using Expected Transmission Count (*ETX*). The *ETX* is a greedy approach to estimate the number of required transmissions needed before the neighbor (Alice/Bob) correctly receives data. Packet Delivery Ratio (*PDR*) is a ratio between the number of acknowledgments received and packets sent. Note that, λ is an upper-bound for *ETX* and can be tuned in a supervised or unsupervised way.

$$ETX = Min\left(\frac{1}{PDR}, \lambda\right) \mid PDR = N_{ack}/N_{sent} \tag{2}$$

Where N_{ack} and N_{sent} are, respectively, the number of acknowledgments received and the number of packets sent. The studies in literature review approve that this estimation can provide strong evaluation about the performance of channel in wireless sensor networks (Table 1).

Table 1. Symbols used in the game model

Symbol	Meaning
CH	The set of available and not available channels
CU	The set of used channels
α	Probability of hopping with an improved effect
β	Probability of requesting to hop
ε	Variable for probability of network jamming
γ	Probability of finding a free channel to hop
λ	Variable for maximum acceptance ETX

7 Nash Equilibrium

In game theory, a non-cooperative game is a game in which there is no collaboration or communication between players and each player acts independently. In 1950 John Nash proved that a finite non-cooperative game always has at least one equilibrium point [21]. Nash Equilibrium (NE) is a solution concept for predicting how a non-cooperative game should be played. To have a better understand, consider an n-person game with a finite set of strategies, denoted by *S*, for each player (person) and, corresponding to each player, *i*, a payoff function, P_i, which maps S_i into a real number.

$$(A)\,\forall i,\ s_i \in S : p_i\left(s_i^*, s_{-i}^*\right) \geq p_i\left(s_i, s_{-i}^*\right) \qquad (B)\,\forall i,\ s_i \in S : p_i\left(s_i^*, s_{-i}^*\right) > p_i\left(s_i, s_{-i}^*\right) \tag{3}$$

When each player chooses a single or mixed strategy he obtains payoff. Equation (3) shows strict and possible Nash equilibrium. In our proposed game model, we allow two players (Alice and Bob) to have a communication just to build a rapid feedback against of channel unreliability. In fact, Alice and Bob will achieve an NE only when they settled in the most optimum channel, denoted by ch^*. That means they will always do hopping if the probability of successful-hopping is higher than current state. value is higher than staying in the current channel with related ETX value. The Eq. 4 is showing this condition.

$$\exists\, ch \in CH \Big|\, {}_{h}P^{ETX^{\uparrow}} > {}_{nh}P^{ETX^{\downarrow}} \vee_{h} P^{ETX^{\uparrow}} < {}_{nh}P^{ETX^{\downarrow}} \tag{4}$$

Now, let`s assume that the hopping strategy will be based on a randomized method similar to RV or RH as proposed by [11].

$$\left\langle \alpha = {}_{h}P^{ETX}, \quad \beta = {}_{nh}P^{ETX}, \quad \gamma = \frac{1}{|CH| - |UC|} < 1 \right\rangle \tag{5}$$

$${}_{h}P^{ETX} = 1 \Bigg/ \left(\frac{\sum_{i \in CH} ETX_i}{|CH|} \right) = \frac{|CH|}{\sum_{i \in CH} ETX_i} \quad , \quad {}_{nh}P^{ETX} = Max(PDR_i, \varepsilon_i) \tag{6}$$

Based on the above equations we can define a payoff matrix for hopping or not-hopping as shown in Table 2. In another word, α is a ratio between 1 and average of all channel's *ETX*. In each time-slot α is calculated by each player to accounted for future decisions. To have a better understanding about α let's assume the value of *ETX* for each channel is equal to 1. Then, the probability of settling in a better channel or improving the current *PDR* by hopping to another channel is equal to α and, α is equal to 1. While the probability of settling in a better channel by using just a random mechanism will be equal to γ. Note that, α is a raw estimation of channel communication improvement and it does not guarantee the probability of assigning an optimum channel. The Eq. 6 shows that the probability of settling in $ch*$ (optimum channel/channel with better performance) by hopping under α condition is higher than γ or β conditions if and only if α is bigger than β and in the worst-case scenario, α is equal to γ.

Table 2. Payoff matrix for hopping or not hopping

Hop/Not-hop			
Alice	Bob		
		H	NH
	H	α	0
	NH	0	β

8 Our Model

Our proposed solution relies on a MAS environment and creates a zero-sum game to have a good estimation wheatear hop or not-hop. Initially, the IEEE 802.15.4e standard introduce 16 channels for TSCH without any scheduling or hopping strategy. But, to

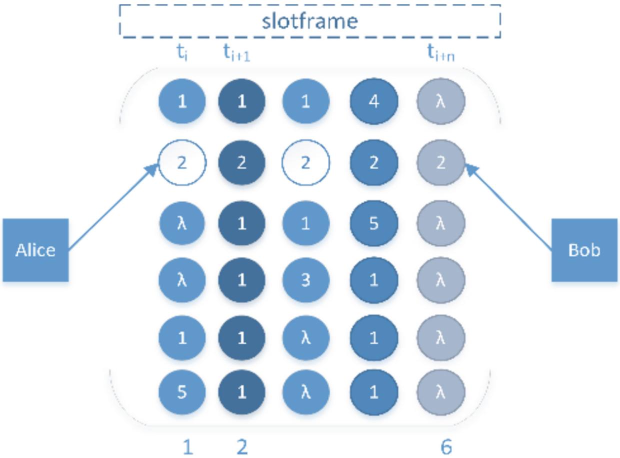

Fig. 3. Alice, Bob, and Trudy are accessing to channels randomly, the value in each channel is presenting the related α

keep our model simple, we assume hopping between 1 and 6 channels. Let denote Alice, Bob and Trudy respectively train A, train B and noisy mode, attacker, jammer, or any other entity that can have a negative influence on communication channel performance. Figure 3 is presenting α for each channel between time-slot t_i and t_{i+n}.

In the immediate section, we are calculating related probabilities for the first two time-slots (t_i and t_{i+1}) by assuming $\varepsilon = 0.50$, $\gamma < 1$ and $\lambda = 10$. Note that, channel number 2 is already occupied by Alice and Bob with $PDR = 2/4 = 0.50$.

$$\gamma = \frac{1}{3} \; and \; \alpha_{t_i} = 1 \Bigg/ \left(\frac{\sum_{i \in CH} ETX_i}{|CH|} \right) = 1 \Big/ \frac{29}{6} = \frac{6}{29} \approx 0.21 \Rightarrow P_{\alpha}^{ch^*} < P_{\beta}^{ch^*} \tag{7}$$

$$\gamma = \frac{1}{5} \; and \; \alpha_{t_{i+1}} = 1 \Bigg/ \left(\frac{\sum_{i \in CH} ETX_i}{|CH|} \right) = 1 \Big/ \frac{7}{6} = \frac{6}{7} \approx 0.86 \Rightarrow P_{\alpha}^{ch^*} > P_{\beta}^{ch^*} \tag{8}$$

Based on the Eqs. 8 and Eq. 9 the following payoff matrices are showing two different strategies for Alice and Bob over different timeslots (Tables 3 and 4).

Table 3. Payoff matrix for timeslot t_i

Hop/Not-hop			
Alice	Bob		
		H	NH
	H	α = 0.21	0
	NH	0	β

Table 4. Payoff matrix for timeslot t_{i+1}

Hop/Not-hop			
Alice	Bob		
		H	NH
	H	$\alpha = 0.86$	0
	NH	0	β

As we conclude from the Eqs. 8 and 9 at the time-slot t_i, the maximum value of β cannot exceed *0.50* so, channel hopping will not be a good strategy for Alice and Bob. But, if we repeat the same calculation for the next time-slot (t_{i+1}) then, channel hopping will be the best strategy for Alice and Bob and will keep them under NE.

Our proposed solution shows that if we keep *ETX* for each channel up to date then we can come up with a nice approximation based on zero-sum game to estimate probability of successful-hopping and settling in a better communication channel while the other works that introduced in the literature review are not capable of providing any decision-making capacity for hopping or not hopping.

9 Conclusion

In this paper, we have investigated strategies that attain cooperation in Time-Slotted Channel-Hopping without coordination or offline scheduling. We have developed an analytical model based on Multi-agents and game theory. Relying on this model, we have formulated a zero-sum game for successful channel hopping. We have showed this game has always a Nash equilibrium.

Finally, we have defined two basic and simple probabilities to estimate probability hopping or not-hopping decision-making process. In particular, we show how Nash equilibrium and agent based system can be used to build a predictable environment to improve random channel hopping communication to not be counter-productive for unstable zone.

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Big Data in Efficient Smart Grids Management

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Abstract. In recent years, we have been witnessing a real explosion of information, due in large part to the development in Information and Knowledge Technologies (ICTs). As in-formation is the raw material for the discovery of knowledge, there has been a rapid growth, both in the scientific community and in ICT itself, in the approach and study of the phenomenon called Big Data (BD) [1]. The concept of Smart Grids (SG) has emerged as a way of rethinking how to produce and consume energy imposed by economic, political and ecological issues [2]. To become a reality, SGs must be sup-ported by intelligent and autonomous IT systems, to make the right decisions in real time. Knowledge needed for real-time decision-making can only be achieved if SGs are equipped with systems capable of efficiently managing all the information sur-rounding their ecosystem. Multi-Agent systems have been increasingly used from this purpose. This work proposes a system for the management of information in the context of agent based SG to enable the monitoring, in real time, of the events that occur in the ecosystem and to predict upcoming events.

1 Introduction

In the literature, there are numerous references that show the diversity of data sources in SG (characterized as unstructured and semi-structured) and its volume is generated at high speed [3]. The data flow in SG drives us to conclude that we are in the presence of BD. Some challenges are yet to be addressed in SG management systems (e.g. better forecast accuracy in energy consumption and generation, real-time processing of optimization algorithms, improvement of relations between all network stakeholders, etc.).

The existence of data has small gains if not transformed into value. This value will be greater proportionally to the increase of the ability to collect other types of data outside the domain, correlate and analyze all these data, not only to decide and predict, but also to discover something even imaginable. One can say that in order to overcome the proposed challenges, the SG requires the ability to handle all the information to be transformed into a successful reality.

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For efficiently respond to one of the major challenges of SGs in a BD context, i.e., real-time processing, the system proposed is based in Apache Spark framework.

2 Proposed Architecture

The system proposed by this PhD work (shown in Fig. 1) is composed of several components, including the streaming and distributed processing provided by the Spark.

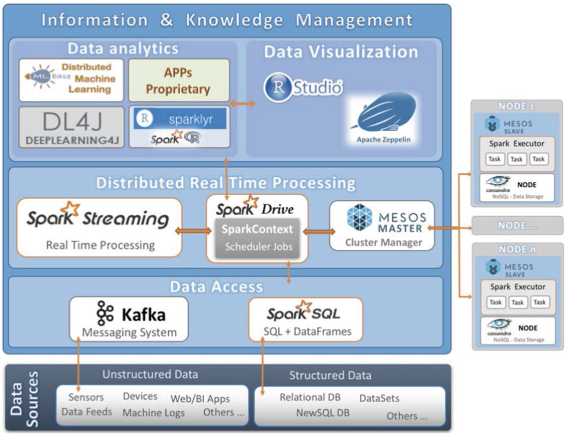

Fig. 1. Knowledge management system in the context of Smart grids.

Apache Hadoop, for many years, was the leading open source BD framework, characterized by Batch Processing, HDFS (Hadoop Distributed File System), MapReduce and YARN (Yet Another Resource Negotiator). Recently, Apache Spark, based in Streaming Processing (i.e. characterized by a continuous flow of data input/output in-memory), has become the most popular framework for Big Data. Spark is faster and more flexible to integrate other applications. It is a set of tools and high level APIs, and in this moment, it is the great unifier for Big Data. Cassandra, a No-SQL data base based on the concept of column, was proposed for the storage of consumption and production data that in real time are being collected by the Kafka component. Cassandra is, according to the literature, one of the best data bases for storage and time series analysis [4]. However, because of the great scalability that characterizes the Spark framework, it is possible to integrate other NewSql or No-Sql databases in a distributed way. The same is verified in relation to applications for data analysis and visualization.

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Ontologies for the Interoperability of Heterogeneous Multi-agent Systems in the Scope of Power and Energy Systems

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Abstract. One of the main challenges in power & energy systems is the development of decision support tools which approach the problem as a whole. In this scope, this work contributes to the increase of the interoperability between heterogeneous agent based systems through the use of ontologies, enabling semantic communications.

1 Introduction

Electricity markets (EM) are complex and dynamic environments with peculiar characteristics [1]. Ambitious targets require major changes in power & energy systems (PES). The increase in the penetration of renewable and distributed production led to the adoption of the Smart Grids (SG) paradigm [1]; and introduction of a competitive approach in wholesale and retail EM [2]. In this context, the use of agent based simulation tools becomes essential [3,4]. Despite the emergence of several tools, there's still a common fault: the lack of interoperability between the various systems. Ontologies ease heterogeneous systems interoperability giving semantic meaning to the information exchanged between the various parties [5]. Several proposals for the use of ontologies in the scope of SG can be found in literature [6,7]. Unfortunately, those are only focused on the needs of the utilities, leaving aside information relevant to consumers.

This work contributes to the increase of interoperability between heterogeneous systems, to study EM, SG operation, and energy management of end users, proposing the use of ontologies in the scope of PES.

2 Proposed Work

It is essential to develop ontologies that allow the representation of different knowledge sources, with the aim of facilitating the interaction between entities of different natures. This eases the interoperability between heterogeneous

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agent-based systems, directed to the study of EM, SG's operation and energy management of end users.

Based on the identified limitations, it is proposed to develop a society of multi-agent systems (MAS) directed to the simulation and study of PES, taking advantage of existing decision-support and simulation tools [4] and complementing with new tools to be developed, ensuring interoperability between them.

The use of real data is considered, for simulations as realistic as possible. These can be acquired from databases or in real time through the infrastructure already installed in GECAD research group.

Ontologies will be developed, reused and/or extended for knowledge representation in a common vocabulary, facilitating interoperability between the various systems. They must be adequate for the various models identified (business, entities and services), both in the EM level as the SG and energy management. Thus allowing, easy integration with systems external to GECAD.

New MAS with the aim of complementing the existing ones will be developed, namely one with the ability to support SG players decisions; and another able to control active loads through a Programmable Logic Controller. This latter, will allow the reading of consumption/production data in real time and to act in loads, particularly in demand response events.

Finally, all of GECAD's MAS will be able to communicate in the main existing Resource Description Framework (RDF) languages, such as RDF/XML, JSON-LD or N3. A tools control center will also be available to ease simulations execution, allowing the simulation of the various systems/algorithms independently, as well as the joint simulation of some or all systems present in the agent society, and an automatic analysis of the results whenever it makes sense.

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Decision Support for Agents' Participation in Electricity Markets

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Abstract. Electricity markets are not only a new reality but also a constantly evolving sector, due to the high frequency of changes in their rules. Simulation tools combined with Artificial Intelligence techniques, particularly multi-agent simulation, can result in a sophisticated and very useful tool in this context.

1 Introduction

Electricity markets (EM) have undergone a severe restructuring process that has led to a considerable increase in competition in this sector, which has consequently created new challenges in the operation of the involved entities [1]. To overcome these challenges, it is essential for the involved players to fully understand the principles of these markets and how to manage their investments in such a competitive environment [2].

The ability to learn and adapt to provide the best possible results for electricity market negotiating players is still not being properly addressed. The intelligent use of multiple electricity market opportunities as they arise is yet a relatively unexplored issue, and should be improved to provide players with the capability of optimizing their participation in several simultaneous electricity market opportunities, including the upcoming possibility of negotiating at a local level. Simulation combined with Artificial Intelligence (AI) techniques, particularly multi-agent simulation, can result in sophisticated and very useful tools in this context, as this type of technology allows analyzing the system as a whole [3].

2 PhD Research Focus

This work proposes to contribute towards surpassing the identified gap in the literature regarding the decision support of negotiating agents in multiple electricity market opportunities. To achieve this, a Decision Support System (DSS) is proposed, which

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includes three phase, as shown in Fig. 1. The initial phase is to formulate the participation model in multiple electricity markets; this model will have to consider the most usual types of negotiations, such as the day-ahead spot market, balancing market sessions, and bilateral contracts negotiations. By defining a targeted time horizon, the model will be able to suggest market agents which should be the best action to perform to maximize its profits or minimize its purchase costs. This model will also include a risk formulation, which will aim at quantifying the risk associated with the performed action. To achieve a good quality of optimization results for this multi-objective problem, it will be necessary to apply adequate resolution methods. There is a wide set of methods capable of presenting good solutions in a short time, considering the multi-objective nature of the problem (return and risk).

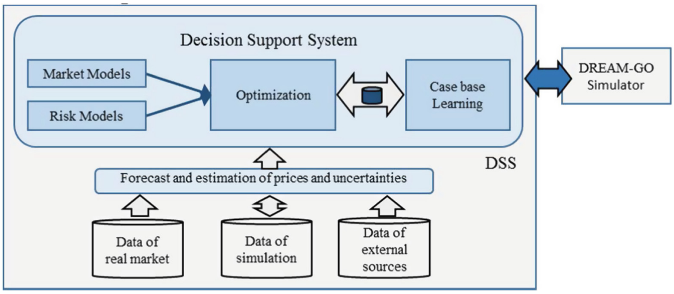

Fig. 1. Proposed DSS overview

Three main steps are required to enable the proposed optimization model: data collection, electricity market prices forecasting and estimation, and the construction of the DSS itself. The latter requires more attention due to the degree of complexity. One of the main issues in this scope is how to enable the system to automatically choose the appropriate optimization approach to use to solve each required problem given the problem characteristics. For this, a Case Based Reasoning (CBR) approach is proposed [4]. The CBR approach is an innovative challenge since the application of this technique to EM is not found in the literature. With the inclusion of this model, the resolution of new cases only depends on the cases stored in the database. CBR is divided into four major steps. The Retrieve is the most important because it is responsible for making the selection of the most similar cases to be used in the task of Reuse to find a solution. The solution should be evaluated in the Review phase, and then if it is according to the requirements, it is applied. Finally, in the Retain phase, it will be decided if the new solved case should or not be inserted into the database to be used as knowledge for future reasoning. The models will be validated using the DREAM-GO simulator, which combines multi-agent simulation of local and wholesale electricity markets.

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

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Abstract. Currently, it is possible to find various tools to deal with the unpredictability of electricity markets. However, they mainly focus on spot markets, disfavouring bilateral negotiations. A multi-agent decision support tool is proposed that addresses the identified gap, supporting players in the pre-negotiation and actual negotiation phases.

1 Introduction

Nowadays, electricity markets (EM) are increasingly competitive and complex, making them increasingly unpredictable [1]. This was due, in large part, to the liberalization of the sector but also to the increasing use of renewable energy. Therefore, there is a need for tools to study and understand the EM's operation and support the participating entities. In order to reach this objective, it is recurring the use of Artificial Intelligence (AI) techniques, namely multi-agent simulation, given its quality of representation of dynamic systems with complex interactions between its stakeholders. Currently, it is possible to find several tools in this domain, such as AMES, EMCAS, GAPEX and MASCEM, among others [2]. However, current tools are mainly focused on spot markets and do not provide adequate decision support for bilateral negotiations between players. This work proposes a multi-agent decision support system that addresses the identified gap.

2 Proposal

The proposed system considers two phases: pre-negotiation and negotiation, identified in [3] as these are the most relevant phases in automated negotiation between agents.

In the pre-negotiation phase, the system determines the opponent(s) which allows the best transaction for the supported player. For this purpose, the player

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indicates the amount of energy to be transacted; the minimum and maximum price; possible opponents (if a filter is intended, otherwise, all known players are considered); and transaction date. Upon receiving this information, the system with transaction context determination. This is very important since the opponents can have very different behaviours, depending on the context in which they are (for example, if it is a weekday or weekend). By knowing the context, the possible scenarios are determined as well as the actions that the player can take (all possible distributions of the energy to be transacted by the opponents under analysis). For each scenario the expected price for each amount of energy, for each possible opponent, is determined . This value will be forecast but, in case there is not enough data, an estimation is performed with available data. The decision process is performed after the process of defining the scenarios and all the possible actions. In this process, the utility value for each possible action is calculated considering both the economic (total price) and the reputation (average reputation of the selected opponents) components. The chosen action depends on the selected decision method that can be one of the following: Pessimistic, the mini-max game theoretic approach in which the action with the highest utility value is selected for the scenario with the lowest global utility; Optimistic, in which the action with the highest value of utility of all the scenarios is selected; And Most Probable, where the selected action is the one with the highest utility of the scenario with the highest probability of occurrence.

After the determination of the best action to take, the player can request the system to support him in the negotiation with each of the selected opponents. To this end, the system recommends the best strategy for negotiating with the opponent in question. For each counter-offer, the system updates the rating of each strategy and recommends a change of strategy when the current one is no longer the best ranked. The classification of each strategy to use with each opponent and in a given context is accomplished by combining information about: the opponent; players similar to the opponent; and all players in general. The contribution of each information type is updated according to the success of the negotiations.

Through the described functionalities, the proposed tool intends to be a viable option to support the decision of EM players in the negotiation of bilateral contracts.

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Tools Control Center to Enable the Joint Simulation of Multi-agent Systems

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Abstract. The penetration of micro-generation brings complex problems to the energy field. In this way, various simulators were designed to give decision support for the stakeholders, however, they intent to solve very specific problems. The proposed tool enables the interoperability between heterogeneous simulators, to simulate more complex problems.

1 Introduction

With the significant increase in the use of renewable energy sources, micro-generation has an important impact in the complexity of the energy markets (EM) [1], due to its intermittent nature. The network, through installed sensors, is capable of collecting information that allows to provide strategic support to EM players, in several applications (e.g. demand response, wasted energy reduction, failure prevention, etc.). Thus, decision support tools become vital to stakeholders to cope with the unpredictability of EM. However, these tools have limitations, because they are designed to act under a particular domain.

2 Proposed Work

To deal with the identified limitations, this work proposes the development of Tools Control Center (TOOCC), which is a multi-agent system that allows the interoperability of heterogeneous simulation energy systems achieved through the use of ontologies, making possible their cooperation for the simulation of more complex scenarios. It has a range of functions that enrich the simulation, such as the automatic distribution of agents and a graphical interface. The implementation of TOOCC goes through three main phases (represented in Fig. 1): setup and definition of scenario models, execution of the scenario and analysis of the data obtained. These scenarios may be more or less complex depending on the number of systems involved.

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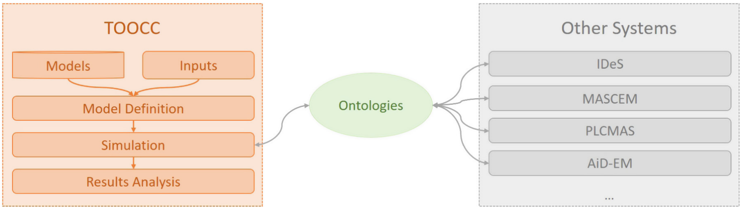

Fig. 1. TOOCC overview

The setup and model definition phase consists of the construction of scenario definitions, indicating which are the tools/algorithms to perform, the insertion of their input data and the definition of models. Some examples of systems whose integration in TOOCC is envisaged are: the Intelligence and Decision Support Multi-agent system (IDeS), Multi-Agent Simulator for Competitive Electricity Markets (MASCEM), Adaptive Decision Support for Electricity Market Negotiation (AiD-EM), Network Manager (NM), Facility Manager (FM), Programmable Logic Controller Multi-Agent System (PLCMAS) [2]. However, other systems can easily be integrated by simply using the ontologies available in [3]. The input data are parameters necessary for the correct operation of each scenario, while the models allow to easily use real information. For the simulation itself, is created an agent, whose function is interact with the systems already mentioned, to achieve the desired result. For better resource management, TOOCC can distribute the agents by computer machines, depending on its processing capacity and installed software. After the execution, data analysis is performed, where the user has access to automatically generated graphs related to the results of the scenarios.

In the future, there are some aspects that must be considered in order to extend the potential of the tool, such as the integration with new systems and algorithms, connection with databases that provide new models and data, and more personalization in the graphical visualization of the results.

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Multi-agent Web Recommender System for Online Educational Environments

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Abstract. In our research work we plan to develop a Multi-agent based Recommender System to help e-learning systems recommend the more appropriate learning resources to students. In our approach we will explore the multi-agent technology potentialities to build a solution where multiple collaborative and content filtering algorithms, working together, leads to a higher performance solution than that obtained with individual algorithms.

Keywords: Recommender systems · Multi-agent systems · Web mining · E-learning · Jade framework

1 Problem Statement and Related Work

Recommender systems are increasingly present on websites, helping them to provide the most appropriate information and resources to visitors. Recommending a set of Web pages, documents stored in web repositories, training material or other kind of resources, based on the users specific interests and preferences or on the student´s learning level, improves the user experience, facilitating the obtaining of information appropriate to their interests.

Recommender systems are classified according to the way recommendations are generated. Accordingly to [3] three types of approach may be identified: content-based approaches, where items with content similar to those that the user has shown preference in the past are recommended; collaborative approaches, in which the recommended items are those that users with preferences similar to those of the active user have liked in the past; hybrid approaches, which combine techniques used in both types of approaches previously mentioned.

Considering the different levels and learning capabilities among e-learning students, personalization of information has been developed as a fundamental functionality in e-learning systems [5]. As a result, the integration of recommender systems has received increasing attention from both researchers and e-learning industry. However, as referred in [5], traditional recommendation algorithms are not directly transferable to the e-learning area, because the student's cognitive state and learning content may change over time, the context may be different and students' preferred learning activities may not be, pedagogically, the more appropriate. Even for students with the same interests

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and preferences, it may be more appropriate from a pedagogical point of view to recommend different learning resources and activities, based on context, goals or level of learning

A multi-agent system can be defined as a system composed of several autonomous agents, capable of working cooperatively to achieve objectives difficult to achieve by an individual agent or by a monolithic system [7]. Multi-agent approaches for developing complex systems, like Web adaptation, were defended in [4]. The use of autonomous agents in a similar context can be found in [1]. Another important usage of multi-agent systems in this context is the automatic collection and update of information in Websites [2]. In their research work, [7] developed a multi-agent recommender system, in which autonomous intelligent agents, implementing different collaborative filtering techniques and algorithms; compete among them to provide the best recommendations to the website's visitors. The results obtained in the offline testing phase, were later confirmed in real-time tests [8].

2 Research Hypothesis and Research Questions

Although the area of recommender systems is an area of wide research and application, its application in e-learning systems only appears at the beginning of the millennium [6]. With the aim of developing a recommender system that will help e-learning systems to recommend the most appropriate educational resources to students, given their interests and their pedagogical path, our hypothesis can be stated as follows: *A Multi-Agent Web Recommender System, in which autonomous agents, implementing different collaborative and content filtering recommendation algorithms, working together, leads to a higher performance solution than the obtained with individual algorithms*.

Based on the above stated hypothesis we may formulate the two following research questions.

- Can a multi-agent web recommender system, with agents based on different recommendation algorithms perform better than a recommendation system based on a single recommendation algorithm?
- Can a multi-agent web recommender system help e-learning systems to recommend the most appropriate educational resources to students?

Thus, in order to test the research hypothesis and answering the stated research questions we plan to build a prototype of a multi-agent web recommender system, to be developed in Java and based on the JADE (*Java Agent DEvelopment Framework*).

In the next section we present the global architecture as well as a brief description of the proposed multi-agent web recommender system.

3 Proposed Solution and Evaluation Plan

As referred above, to test our hypothesis and answer the research questions we plan to develop a prototype whose global architecture is presented in Fig. 1.

In Fig. 1 we define two connection points between the Learning Management System (LMS) and the Multi-Agent Recommender System (MARS). One has the purpose of providing the Recommender System Knowledge Base (RSKB) with user's/student's profile information, as well as with information regarding available learning resources. An HTTP/S connection between the two systems is established through the other connection point. Whenever a user accesses the LMS, a request is generated to the recommender system; in return MARS responds with a set of appropriate recommendations to the user's preferences and interests. On the LMS side, the connection will be implemented using the APIs or plugins provided by the LMS itself.

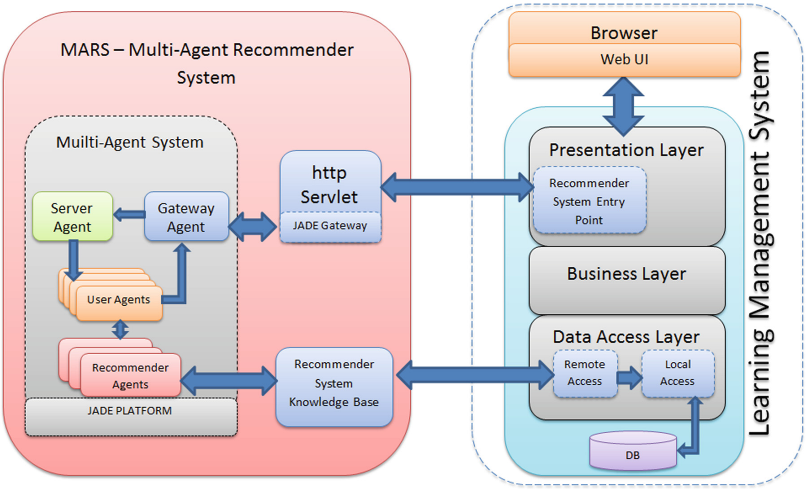

Fig. 1. Multi-agent web recommender system global architecture

On the MARS side, the connection to the LMS is ensured through a JAVA Servlet, which incorporates a gateway to the JADE platform and to the Multi-Agent System (MAS). In the proposed approach the Multi-Agent System is based on four types of agents:

- *Gateway agent* - handles the data flow between MAS and HTTP Servlet;
- *Server Agent* - creates an *User Agent* for each new LMS user that requests for recommendations, ensuring that, at a given time, each user only has one active agent;
- *User Agent* - represents the user on the system, it exists for the duration of the user session and communicates with the *Recommender agents* by sending them recommendation requests. Based on the recommendation sets received from all running *Recommender Agents*, the *User Agent* decides on the best recommendation and forwards it to the user it represents through the HTTP Servlet.
- *Recommender Agents* - based on user's request for recommendation and the data stored in the RSKB, related to the users' profile and available educational resources,

The *Recommender Agents* respond to the User Agent requests, with their bid consisting of a set of recommendations. As referred above we plan to develop multiple *Recommender Agents,* implementing different collaborative and content filtering recommendation algorithms.

Concerning the test and evaluation plan, it is our purpose to test the prototype against appropriate datasets and, if possible, integrate the prototype into an e-learning platform, as is the case of *moodle* (https://moodle.org/), in order to test the solution in real time.

4 Conclusion

In our research work we plan to develop a Multi-agent based Recommender System to help e-learning systems recommend the most appropriate learning resources to students. In our approach we plan to use the multi-agent technology benefits and potentialities, to develop a system able to combine web usage and web content mining algorithms in order to address student´s appropriate learning resources. Our goal is to prove that our approach leads to a higher performance solution than that obtained with individual algorithms.

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Tackling the Interleaving Problem in Activity Discovery

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Activity discovery (AD) is the unsupervised process of discovering *activities* in data produced from streaming sensor networks that are recording the actions of human subjects. One major challenge for AD systems is *interleaving*, the tendency for people to carry out multiple activities at a time a parallel. Following on from our previous work [4], we continue to investigate AD in interleaved datasets, with a view towards progressing the state-of-the-art for AD.

A number of approaches to AD have already been published in the literature. Cook et al. [2] provide an overview of the field as it stood a number of years ago. More recently, [7] proposes a system based on clustering techniques which eliminates the need to store historic sensor data, which could help combat the data-heaviness of AD. Although not strictly a pure AD system, [6] proposes a system to take partially labelled data and automatically annotate the remainder of it. The system uses *Latent Dirichlet Allocation* (LDA), a technique from the NLP community that we also utilised for the system we mentioned above.

We are currently in the process of developing a new AD system from scratch based on deep neural networks [3]. Specifically, we generalise [1]'s concept of a *neural language model* (NLM). Given a set of n contiguous words in a sentence, a traditional NLM predicts the $n+1$th word. By contrast, our system will predict a probability distribution over the next m words. This will be used as the basis of a system that allows us to detect and remove the interleaving from a dataset automatically. This system is presented in Fig. 1.

In Fig. 1(a), we see the initial setup of the system: events **A** and **B** are contained in the sliding window that will constitute our input (so $n = 2$), and events **C** to **F** are in the window of length m that we want to compare to our output layer probabilities. Suppose that our language model predicts that event **D** will appear within the next m events with high probability. We thus add a *link* connecting events **B** and **D** as shown in Fig. 1(b). Note that it is also possible for more links to be added. For example, if event **E** was also predicted with high probability, we would add another link from **B** to **E**. The exact mechanism by which a probability will be decided to be high enough to form a link has yet to be fully determined by the authors, although it will probably involve identifying probabilities more than a certain threshold above the average for the dataset (i.e. significantly more probable than background noise). Once all activities have been found, they can be replaced with new placeholder events, and the system

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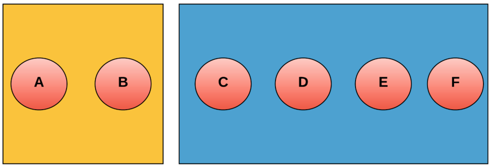
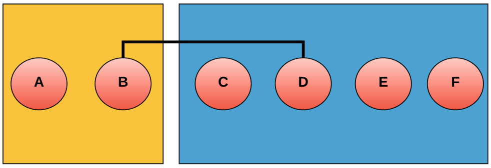
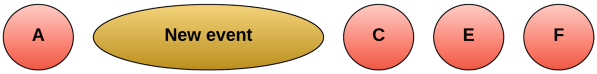


(a) The initial setup.



(b) A link connecting events **B** and **D**.



(c) The discovered activity has been subsumed into a new event.

Fig. 1. An overview of our proposed approach.

can be run again (Fig. 1(c)). This allows us to build a complex hierarchy of aggregate events.

Over the coming months, our intention is to implement this system and report our results back to the wider community.

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Design of an Intelligent Computational System for the Cognitive Training of People with Verbal Fluency Problems Associated to the Mild Cognitive Impairment

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Abstract. Mild Cognitive Impairment is a previous state to the diagnosis of dementia. This condition implies changes over superior cognitive functions. Some associated factors as age, gender, the loneliness in elderly people, the level of schooling and the inversion of population pyramid are important aspects to take into account. Verbal fluency alteration is an outstanding phenomenon in Mild Cognitive Impairment patients. This alteration goes against vital aspects as the communication, reason related with the isolation in elderly people. Traditional cognitive training is limited because it can not be administered without specialized personnel. However, in the next years the amount of specialist will be insufficient. Computational Cognitive Training is a novel porpoise to decrease the effects of low personnel. Nonetheless, these systems are susceptible to be improved by means of the use of friendly Human Machine Interfaces as the speech recognition, the voice synthesis and the incorporation of cognitive characteristics as autonomy an anticipation. In this work, an improved Computational Cognitive Training Systems is proposed. This tool is designed under the Hybrid systems framework of Artificial Cognitive Systems. The principal aspects of the proposed design are shown. The preliminary results are presented.

Keywords: Artificial cognitive systems · Verbal fluency · Mild cognitive impairment · Artificial cognitive architectures

1 Introduction

Mild Cognitive Impairment (MCI) is a previous state to the diagnosis of dementia, in which changes over the superior cognitive functions is higher in comparison with the normal aging process [1]. It corresponds with the alteration in the learning capability, memory problems and concentration [2]. This alterations compromise the people yield in advanced tasks [3]. MCI is a non-communicable disease and affects in higher proportion to people over 65 years old. Although the prevalence of this pathology is not clear and all the work's present different numbers, it is possible to determine that near to the 12.5% of patients diagnosed with MCI will evolve to dementia in the next year. The reduced communication capability is evident in this stage; the skill to produce words is

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restricted in association to problems in memory, processing speed, flexibility, and so on. In summary, the verbal fluency VF in elderly people is seriously affected. The traditional cognitive stimulation processes involve the relation of the patient with a specialized therapist. However, the number of qualified personnel is insufficient to cover the patient demands. In order to compensate the low amount of specialist, some computer strategies have been implemented. It stablishes a novel approach named Computerized Cognitive Training (CCT) and it offers some advantages compared with the traditional therapies as the constant following, practice duration evaluation, times and speed of reaction and adherence to the home training [4]. Nonetheless, the CCT approaches are so far of the ideal level, this, because they are static, they do not learn about the interaction, they cannot anticipate the changes in user behaviors, etcetera. It is important to note that the progress in CCT tools for training people with verbal fluency problems are limited and in the case of systems for VF training is incipient. In this work, a Cognitive Architecture for a VF training system is proposed. This system is based on Artificial Cognitive Systems (ACS) theory, and the Artificial Intelligence (AI) foundations. The idea is to obtain a tool with which MCI patients can interact for training their communicative production skills. This implies the use of friendly Human – Computer Interfaces (HCI) as the speak synthesis, automatic speak recognition, face and emotion detection and visualization techniques as virtual and augmented reality. The ICS should exhibit cognitive features to avoid the problems of existing CCT. The autonomy and anticipation are fundamental features to improve the ISC operation.

2 Problem Statement

Considering the aspects presented in the introduction the problem statement is the following: What is the effect of a computerized cognitive training over the semantic verbal fluency in MCI patients?

3 Related Work

Verbal fluency: is typically defined as the ability to produce words under specific constraints, and within a fixed time interval [5]. In general terms, it is related whit the spoken word production and therefore with communication. A typical VF test consists in ask to the evaluated for producing the biggest amount of words related to a determined category (animals, fruits, objects) in a limited time, usually 60 s. [6] Ina graph-based technique is proposed for evaluating the cognitive state in normal persons, MCI and Alzheimer's patients as an alternative way to test it. **Computerized Cognitive Training**: Cognitive Training is defined as an intervention providing structured practice on tasks relevant to aspects of cognitive functioning, such as memory, attention, language or executive function [7]. A Computerized Cognitive Training correspond with the implementation of these interventions over computational systems. Nonetheless, this CCT software can be enhanced in order to incorporate cognition aspects as autonomy and anticipation to assess the patient behavior and personalize the associate training. **Human Machine Interface**: An HMI is a hardware/software device that permits the translation of human interactions in signals that machines can interpret and *vice versa*, allowing the communication into human and machines. Today, the HMI are limited and in the most cases, it needs experts to be used, or its simple uses is not available for elderly people. In fact, it is uncommon to find this kind of interfaces in the CCT interventions, whereby the interaction is limited to use basics HMI as keyboards, mice and screens. To avoid this, the use and development of more sophisticated HMI is a theme of special interest. The automatic speech recognition [8], automatic face expression recognition [9] and the voice synthesis [10] are examples of improved HMI. **Artificial Cognitive Systems**: An ACS is a system that integrates IA techniques for producing cognitive behaviors and interacts in effective way with the environment. As was presented in [11], these cognitive behaviors correspond with characteristics as perception, action, anticipation, adaptation, motivation, embodiment, among others. ACS can be grouped in relation with its cognition paradigm. Each paradigm defends in different ways every cognitive characteristic. It is possible to determine three ACS paradigms, the cognitivist systems, the emergent systems (subdivided in connectionist systems, dynamic systems and enactive systems) and the hybrid systems. The first one thinks cognition as a symbol manipulation task. The second paradigm determines that the ultimate goal of an emergent cognitive system is to maintain its own autonomy. In third place, the hybrid paradigm combines aspects of cognitivist and emergent systems to take advantage of the best advances of the basic cognitive paradigms.

4 Hypothesis and Proposal

H0: An ACS based on an ACA that implements cognition aspects as perception, action, anticipation, autonomy, can improve/maintain the VF skills in MCI patients.

H1: An ACS based on an ACA that implements cognition aspects as perception, action, anticipation, autonomy, cannot improve/maintain the VF skills in MCI patients.

As was expressed in previous sections, the main objective of this work is to obtain an ACS for training VF in MCI patients. The porpoise is to obtain an ACS that interacts with MCI patients. To enhance this interaction are considered the cognition aspects of perception and action. The perception characteristic allows the system for recognizing the face expression and speech recognition. These automatic recognitions permits to observe the patient engagement with the training intervention. At the same time, the voice synthesis lets to the system to produce speech feedback for driving the patient into the training program. It is a feature of this cognitive element to measure continually the user VF. Other aspects as anticipation and autonomy in connection with the Agent Knowledge base have to be considered because is necessary to previse the user behavior. The modifications in patient behaviors and reactions should generate auto-organization tasks to improve the VF intervention. This entails that the Agent Knowledge Base is necessary to be related to the patient interests. This implies an additional measurement task, to evaluate the difficulty in contrast with the ability of the user to develop the interventions activities and to guarantee an effective training. In addition, the collaborative learning is considered in order to interconnect various SCA to made the Inter-Agent Knowledge Base. This Base will be constituted with the obtained inferences of all of the intervened adults.

5 Preliminary Results and Reflections

As a preliminary result, a web-based development was made. This development include the speech recognition and voice synthesis API's for Google. The intention with this work was evaluate the API's as possible tools to implements a friendly strategy of interaction and measure the acceptability of elderly people. In this moment the web development is able to be proved in the objective population. The few amount of works related with CCT for VF training in MCI patients shows the necessity to propose novel ways of intervention. Also, it is important to note that the CCT interventions in this moment present limited strategies of interaction, for this reason it is important to explore tools for improving the interaction. In this work an ACS is proposed. This system includes speech recognition, voice synthesis and face expression detection as tools to improve the interaction. Some characteristics of cognition as anticipation and autonomy are indicated as appropriate elements in a ACS for training MCI patients.

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Multisensor Indoor Location System

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Abstract. Indoor location facilitates the guidance of user in indoor environment in which it is not possible to use GPS. CPS is available in outdoor but in indoor it is necessary to use other technologies to locate users. Some technologies can be based on radiofrequency or other sensors as compass, camera, barometers etc. I this study, we will include a system to calculate the position of users with Bluetooth and accelerometers, in order to calculate the position at home. The system will incorporate artificial intelligence techniques to calculate the variance of signal with Bluetooth in order to calculate the position of a user.

Keywords: User interaction · Classifiers · Mobile phones

1 Introduction

Location system are commonly used in outdoor environment but in indoor environment it is necessary to create system due to the GPS is not available. Indoor location system can be used to develop context aware system [1, 29] in order to adapt the environment to the need of the user without direct interaction of them. The advances in the artificial intelligent [7, 9, 10, 11] allow to create system to monitor an predict behaviour that can be applied in many fields. There are many technologies that can be used to create prediction system to create indoor location system but the most common is to use radiofrequency and analyse changes in the level of signal to calculate the position of users [22, 32–34], this study is based on neural networks. This system can be improved if we combine several sensors in order to calculate the final position [14]. For this reason in this work, we propose a system to calculate the final position of the users.

In indoor location system, there are many possibilities to calculate the final position of the users. One alternative is to used fingerprint to create map of intensities an use this information with a CBR system [2, 5, 13, 19] and hybrid intelligent systems [3, 4, 25] to calculate the final position of an user. CBR system and hybrid intelligent system can be used in multi-agent system [12, 15, 17, 20, 21, 24] and virtual organization [6, 16, 18, 23, 28, 30, 31] to develop distributed system that can be extended to the need of the users. When we are working with several sensors we have to include the concept of information fusion [8, 26], information fusion system use several sources to improve the results but it is necessary to define methods to combine results in order to provide the solution to the problem.

In this work, an indoor location system based on triangulation is proposed. The system will used Bluetooth and accelerometers to calculate the position. Beside, in

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order to predict the distance to the ibeacon the system will use a CBR system with a neural network. The neural network will be trained with data extracted from several test.

The paper is organized as follows: Sect. 2 describes our proposal, and finally Sect. 3 provides the preliminary results and conclusions obtained.

2 Proposal

The case study will use ibeacon and mobiles phone to locate users. The position of the ibeacon is defined as it is defined in the Fig. 1.

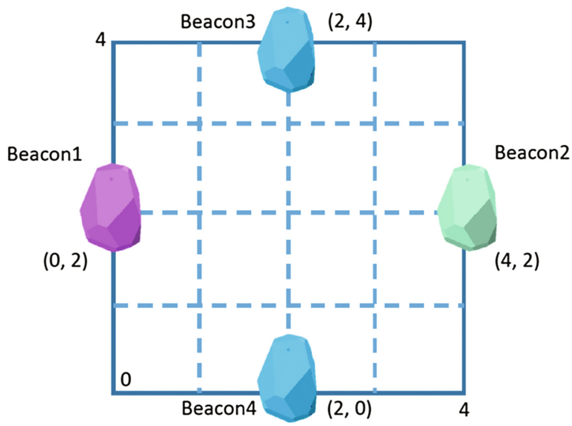

Fig. 1. Position of the ibeacon

In order to determent the distance to the ibeacon we will use a multilayer perceptron to calibrate the variance of signal according the distance. Then we the mobile phone receives the signal from the ibeacon the system will calculate the distance to each ibeacon. The system will calculate the position of the user with triangulation according to the weighted average (1).

$$(x, y) = \sum_{i=1}^{n} w_i(x_i, y_i) \quad (1)$$

The weights are defined as the distance to the ibeacon. The system only considers until three measures to calculate the final position, the weight are calculated as:

$$w_i = \frac{1/d_i}{\sum_{i=1}^{<3} 1/d_i} \quad (2)$$

In order to avoid constant changes in the position of the user the system use the accelerometer to detect steps. The system will stablish thresholds and according to the threshold will detect steps. The process to detect steps is defined in the work [27].

3 Conclusions

The system will be available to detect the position of the users. This position can be improved with the use of other sensors for example compass, besides it would be necessary to analyse other alternatives to calculate the final position of the user for example fingerprint. In order to compare the results with other methods we will include statistical analysis to validate the significance of the differences.

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Automatic Movement Detection Using Mobile Phones

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Abstract. Context aware systems enable interaction between users and their environment in a way that is transparent. Network systems are deployed in these systems in order to collect values from the environment and later retrieve this data which is then used to modify the environment. To improve the interaction between the user and the environment we should create new and simpler interaction mechanisms. In this study we propose interaction through mobile phones, where the system detects and classifies different movements in order to interact with the different elements found in the environment.

Keywords: User interaction · Classifiers · Mobile phones

1 Introduction

Nowadays, context aware systems [1, 29] enable us to interact with our environment in many different ways. Advances in computer vision have permitted us to recognize users and their gestures, this information is also used for interaction with devices [36]. Additionally, advances in computer graphics have contributed to the creation of a new kind of a remote controller, in comparison to a traditional remote controller, this one fuses information with other devices, such as cameras, microphones, accelerometers etc. [35]. This technology has created new interaction models that can be extended to other devices for the management of the environment. For this reason, this work will analyse the possibility of introducing new interaction mechanism through the use of mobile phone with an accelerometer.

Accelerometers can be used to detect user or animal activity, it is possible for example, to find out if the user is walking or running, or the number of steps they have taken [27]. The detection of steps with an accelerometer is easy, the only requirement is to establish an upper and a lower level, the system detects a new step when a change occurs between the two limits. Other movements can be detected using artificial intelligence techniques, such as neural networks [33–35]. In other studies, accelerometers can be used in combination with classifiers and clustering techniques in order to detect activity in cows [32]. In such studies, it is possible to apply hybrid intelligent systems [3, 4, 25, 34] that include the CBR system [2, 5, 13, 19] in order to store cases and incorporate artificial intelligence techniques [7, 9–11] creating systems that evolve over time. Other studies use multi-agent systems [12, 15, 17, 20, 21, 24] and virtual organizations [6, 16, 18, 23, 28, 30, 31] of agents to create distributed systems that analyse

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data from multiple sensors. When we are working with multiple sensors or wireless sensor networks [14, 22, 37–39] it is common to find them in works on information fusion [8, 26].

In this work, we propose a system that will be capable of detecting different movements, this will be done with the use of a three-axis accelerometer found in a mobile phone, in order to retrieve values. These values will be used in combination with classifiers, in order to classify the movements from a number of possibilities. Our system will include CBR to store information and use it for the evolution of the system with time.

This paper is organized as follows: Sect. 2 describes our proposal, and finally Sect. 3 provides the preliminary results and conclusions obtained.

2 Proposal

Initially, the system will be used to detect movements such as hot and cold but later it will expand to include more movements. To classify the movements a time series will be selected and combined with classifiers for detection. The system records maximum and minimum peaks and introduces them into a classifier in order to classify the movements. To identify something as hot the user will shake his mobile horizontally as can be seen in Fig. 1a and to identify cold the user will shake their mobile vertically as can be seen in the Fig. 1b.

Fig. 1. (a) Movement for cold (b) Movement for hot

To carry out the analysis, the system will incorporate a classifier such as SVM, random forest, J48. The system will be tested by several users and we will take several samples for each user. Once we obtain the data, the system will apply the technique leave one out to validate the performance of the system. The performance of the system will be measured with the Kappa index, and the differences among the classifiers will be validated statistically with a t-test.

3 Conclusions

The study will allow the user to interact with their environment using gestures, providing new interaction models which can be used by users with visual disabilities, helping them to manage devices at home. This interaction mechanism can be used in combination with others, for example voice recognition, gesture recognition with a camera in order to make daily life easier [35]. In this study, we also hope to analyse alternative inputs for the classifiers and depending on the results obtained, input patters will be modified.

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Preliminary Study for Improving Accuracy of the Indoor Positioning Method Using Compass and Walking Speed

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Abstract. Indoor positioning systems have already been introduced in commercial facilities. Since, the signals transmitted from GPS satellites do not penetrate inside buildings, Wifi, Zigbee and Bluetooth are used for indoor position estimation. In this work, we only focus on the use of Bluetooth due to its advantages such as low power consumption, wide signal range and inexpensive. However, the accuracy of positioning is not sufficient in current technologies. Therefore, this paper proposes an indoor positioning method for improving accuracy, using compass and walking speed with an extended Kalman filter. Preliminary experimental results improves accuracy up to 21.2%.

Keywords: Indoor positioning · BLE · Fingerprint · Extended Kalman filter

1 Introduction

GPS is widely used as a method of determining location. Location information is often needed in smartphones where many applications require GPS to function [1, 15, 18]. However, the signals transmitted from GPS satellites do not penetrate inside the buildings [2, 11, 14], tunnels and underground subway stations [17]. Hence, we propose an indoor positioning system using Bluetooth and Wifi. Many researches use RSSI (Received Signal Strength Indicator) level of Wifi access points or BLE tags for estimating indoor position [19, 20, 23, 37–39]. Wifi is commonly used for indoor positioning technology but the signal has to be strong and cover a relatively wide area. However, Wifi equipment requires an external power source, more setup costs and expenditure. Bluetooth Low Energy (BLE) [4, 13, 16] is one of the latest technologies. Called BLE beacons (or iBeacons), they are inexpensive, small, have a long battery life and do not require an external energy source [26]. In this work, Bluetooth technology is used for indoor position estimation [29, 30] due to its low cost and low power. Moreover, there are many researches on indoor localization using inertial sensors and geomagnetic sensors using smartphones. This method can estimate position [12, 21, 22] and detect the direction in which the person is walking. Nevertheless, the positioning accuracy is not sufficient in this method [3, 6, 7]. In this paper, we report a preliminary study of position estimation methods using RSSI [5, 8–10] combined with smartphone sensors (inertia and geomagnetic), which can provide location information and walking

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data of people or objects inside a building with possibly better accuracy and better cost performance. In this article, Sect. 2 describes our proposed method, Sect. 3 explains the experiment in detail, Sect. 4 summarizes the experimental results, we discuss future steps in Sect. 5 and finally, we conclude our report in Sect. 6.

2 Proposed Method

There are various indoor positioning methods. In a study written by Shiu [1], Wifi RSSI data was used with a Multi-Layer Perceptron (MLP) [33, 34] based classifier to estimate the position. Moreover, research on location estimation using a smartphone was conducted by Rui [2]. He proposed a method that used Kalman filter [25, 28, 32] for sensor fusion in a smartphone. Therefore, the method proposed in this work is composed of both, position estimation using MLP [24, 27] and extended Kalman filter that improves accuracy. The proposed system is shown in Fig. 1.

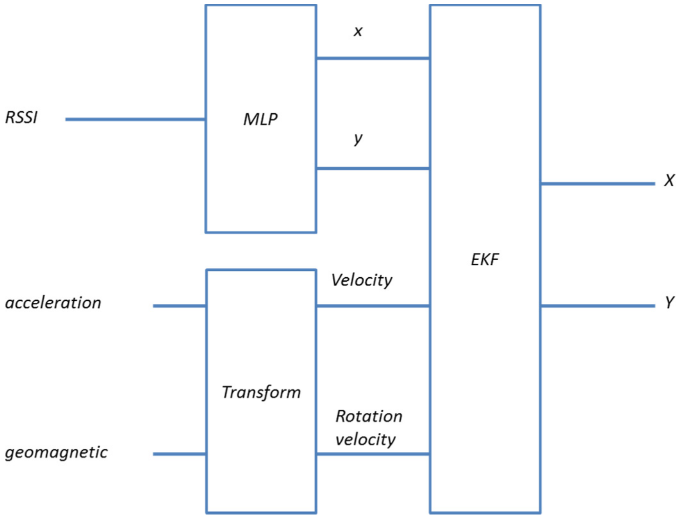

Fig. 1. Block diagram of the proposed system

3 Methods

First, we made experiments of acquiring training data for using finger-prints. This experiment was carried out using a smartphone. Figure 2 shows the environment of the experiment, which was a space of 4 × 4 m. Four BLE beacons have been placed in this space.

We measured RSSI value of 16 points and obtained 20 data at each point. After that, we estimated the position using the MLP algorithm. We then calculated variance of MLP output data, acceleration sensor and geometric sensor. Below, the extended

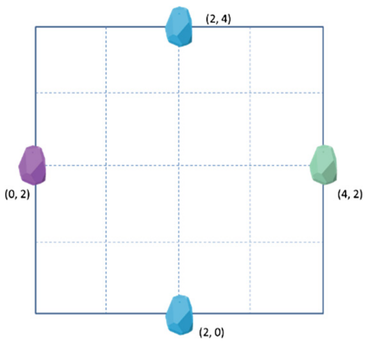

Fig. 2. Experiment environment

Kalman [26, 31] filter algorithm can be seen. Extended Kalman filter expressed in Eq. (1) as the observation update and Eq. (2) as the temporal update.

Step1

$$\begin{gathered} \hat{x}^{-}(k) = f(\hat{x}(k-1)) \\ P^{-}(k) = A(k)P(k-1)A^{T}(k) + \sigma_{v}^{2}(k)bb^{T} \\ g(k) = \frac{P^{-}(k)c(k)}{c^{T}(k)P^{-}(k)c(k) + \sigma_{w}^{2}} \end{gathered} \tag{1}$$

Step2

$$\begin{gathered} \hat{x}(k) = \hat{x}^{-}(k) + g(k)\{y(k) - h(\hat{x}^{-}(k))\} \\ P(k) = \{I - g(k)c^{T}(k)\}P^{-}(k) \end{gathered} \tag{2}$$

4 Results

The experimental results are shown in Table 1. Method number 1 is only the fingerprint method. Method number 2 is the proposed method. The average error shows that error decreases with method 2 by 21.2% in comparison to method 1.

Table 1. Estimation errors [m]

Method	MAX error	Min error	Average error
1	3.61	1.00	2.21
2	2.92	0.51	1.75

5 Discussion

These results show that the proposed method is more effective at reducing the error. However, the accuracy obtained in the proposed method is not sufficient And further work is required to improve accuracy. This study did not test the other estimate method, therefore more research is needed.

6 Conclusions

In this paper, we conducted a preliminary study for improving the accuracy of an indoor positioning method using compass and walking detect. We tested the combination of MLP, velocity and rotational velocity using extended Kalman filter. We evaluated the overall fingerprint matching performance between the proposed method and conventional methods.

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Facial Analysis for the Prediction of Beauty Preferences

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Abstract. Beauty is a factor which is really difficult to measure or evaluate objectively, since every person can have their own preferences. However, it is common for beauty patterns to tend to be similar in communities, mainly because of different cultural factors. The present study proposes the creation of a prediction system capable of determining the level of beauty from face images in different communities.

Keywords: Visual analysis · Prediction · Multi-agent systems

1 Problem Statement and Hypothesis

The different facial features of the human race and the differences among personal likes, make possible the evaluation of that preferences to predict [26,28] how the world communities thinks about the beauty on a picture. By this way, the present work pretends to gather whether or not the personal preferences are similar in a European range population against other ethnic origins like Asians can be.

To do that, the initial approach is based on a gender division as probably there will be differences in the preferences. Furthermore, the main beauty aspects to evaluate on faces can be summarized in five sections depending on the face features: eyes, nose, mouth, ears and chin.

There are many methods for extracting facial patterns. Most of them requires starting from suitable conditions of the image to be processed in order to achieve the best result. The image must be clean, without glasses, or other complements that prevent the correct processing Of the image, as well as, adequate luminosity indexes. Some of these features can be achieved after a preprocessing step.

Then, the first step in the analysis of facial expressions is the detection of the face within the image. Once found, different filters are often applied to reduce the computational load. Subsequently, a series of algorithms are applied to process the easy traits, such as fisherfaces, eigenfaces or Local Binary Pattern (LBP). Finally, the system has to make a decision depending on the gender that has been detected.

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2 Proposal

A multi-agent system [1,3,8,17,32] based on PANGEA [6,18,30] has been designed. Its functionality is divided between the roles that every agent implements and then grouped into three layers. One of them composed of a sub-layer, depending on the affinity of the roles they play [15,31]. Its structure is shown Fig. 2.

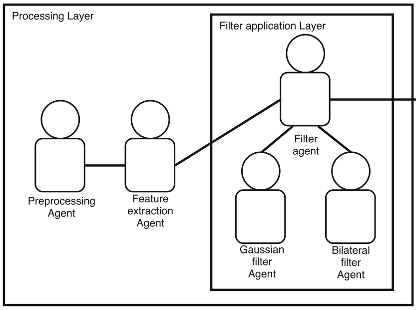

Fig. 1. Example of the system process.

- Preprocessing agent [29]: from the input image, the system obtains the face and detects its position and inclination [21].
- Feature extraction agent: after that, the following features are extracted: eyes, nose, mouth, ears and chin, each of them is processed separately.
- Filter agent: it decides the filters two apply, deciding between Gaussian agent [20] y el Bilateral agent.
- Classifier agent: it decides the classifier to use [12,14], then Fisherfaces agent, Eigenfaces agent or the LBP agent is used for the classification.
- Decision making agent: it compares the results provided by the classifier with the previous results of the database to make a decision.
- Database agent: initially, the database has been created by using the FERET [23] faces database which has been processed and classified manually by humans from different communities.

In the processing layer, the system research about the arrangement and shape of the face parts. An example is shown below in which the sysmte made 9 images following to the image map (Fig. 1).

In the system, the hairstyle matching for each face using the field of visual perception. Recently, the face that outlines of face and parts are curved and to be childish is said to be cute and easy to be likable. We call this “cute face”. The system considers that impression intensity of cute face is higher and complexity

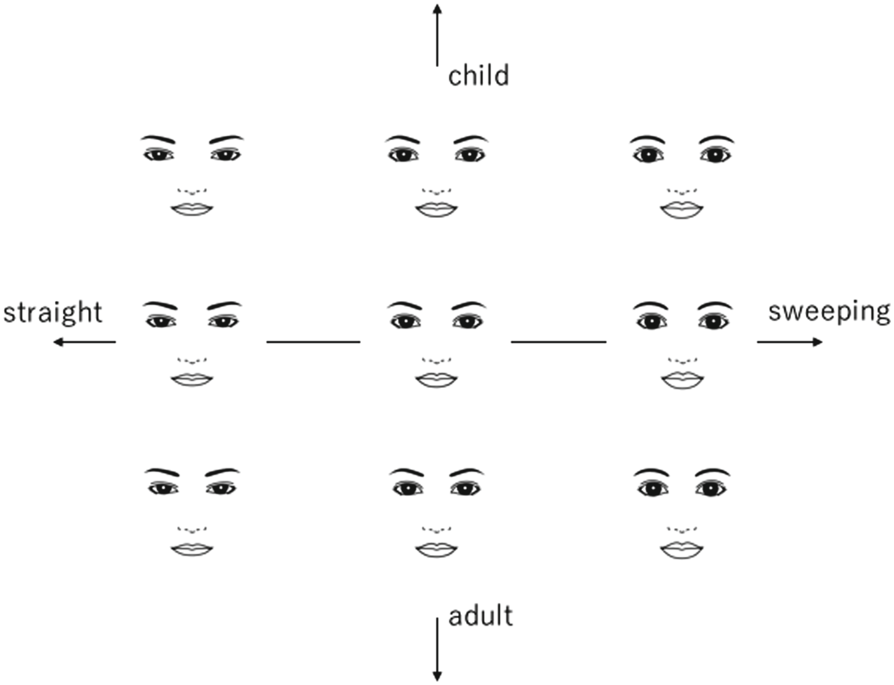

Fig. 2. Image map.

is lower than other faces, and calculates impression intensity and complexity for each face using the field of visual perception. Moreover, the system is capable of analyze what impact the faces will receive and what kind of hairstyle it is good to follow the cute face by adding some hairstyle.

In the image, at right side, outlines of the face parts are curved. As it is to the upper side, the arrangement of the face parts seems to be a child. Therefore, cute face is at upper right.

3 Conclusions and Future Work

The work is currently at a stage where the manually available face data set has been classified. From the presented scheme, the prediction must be evaluated [4, 10]. It is based on the application of the different proposed filters and algorithms for the classification, so that both the Filter agent and the Classifier agent can determine precisely which filter to apply. To this end, we will study the use of artificial intelligence systems, such as artificial neural networks (ANN) [5,25] or case-based reasoning (CBR) systems [4,7,9,27] in distributed environments [34].

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Tracking Objects with Vacuuming Robots

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Abstract. During the last decade, vacuuming robots have become very popular, mainly because of their performance. However, due to the sensors that it includes, its size and its price, many researches have appeared applying this kind of robots in different studies. The present study aims to get the robot to follow an object (a ball) inside an enclosure, without colliding with any object.

Keywords: Visual analysis · Prediction · Multi-agent systems

1 Problem Statement and Hypothesis

Research for the use of vacuuming robots in different contexts in the industry becomes to the present paper, which pretends to include this devices in the context of Smart Rooms [15,30]. The main idea is to follow a ball in a room identifying and mocking its movement patterns. By this way, in addition to get a tracking path of the followed object [13], the vacuum robot can perform a defined path similar to some pattern previously detected, with an aim according to the necessities. For the process of the objects detection, OpenCV is an open source computer vision library that contains the implementation of multiple algorithms for the recognition of objects and their features. One of the most common algorithms for the objects detection used by OpenCV allows to identify objects of a certain color, as well as the calculation of the position from the object to the camera of the robot, a mechanism that together with machine learning techniques can be a base for the investigation of the present work [32–34].

2 Proposal

In spite of the large number of sensors [20] that this kind of robot includes, it is necessary to make certain modifications to achieve the current objective. In this sense, the inclusion of a camera capable of capturing real-time moving images is required. In addition, a small board computer (SBC) [25] or a smartphone, capable of running the control software, based on OpenCV, is also needed [28]. In our case, a Raspberry Pi 3 has been used, mainly because of its price and

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because it provides enough processing capacity so it can process the algorithms in real time [29]. In addition, it includes Bluetooth connectivity that allows to control the vacuuming robot, and Wi-Fi connectivity that allows to monitor the robot in real time from a computer [2].

Therefore, in the Raspberry Pi, a web server is deployed. It receives updated information from the robot which is provided to web users in real time by using websockets technology. The camera used to capture images is a Raspi-Cam. Figure 1 shows the proposed architecture diagram.

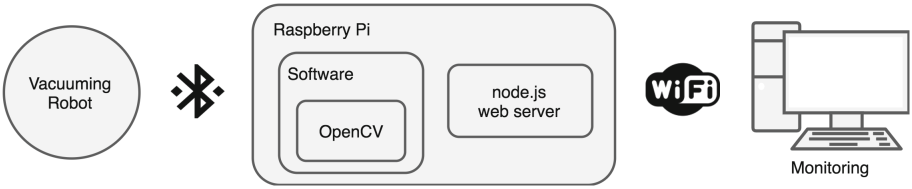

Fig. 1. Architecture diagram.

To analyze the image in real time, a software has been implemented. This software: (i) detects the proximity of the ball based on the size it occupies within the image; (ii) calculates the direction in which the robot must go to center the ball inside the image; (iii) finds the ball in 360° in case it leaves the image. In case the ball is hidden behind an obstacle, the robot will enter a search mode, and navigates the inner space until the ball appears in the image. Using this schema, an algorithm has been implemented. It uses the infrared sensors of the robot vacuuming to avoid collisions and it also uses the system of detection of objects to determine the movements of the robot [24]. In this way, if an obstacle gets in the way, the robot is able to get around it and recover its trajectory.

3 Conclusions and Future Work

Some own algorithms have been proposed which have shown good results under controlled situations, but there are still some situations, such as that the robot does not have enough space to follow the ball [31]. In this case the robot enters a navigation mode, the same mode that would use if it did not see the object. However, the position of the ball is known but the possible trajectory to reach it is unknown, so the situation is not the same. The current work focuses on solving these kind of solutions in an optimal way. In addition, once trajectory problems are solved, it is intended to incorporate technology based on agents [6,8,14], multi-agent systems [3,5,11,18,26] or virtual organizations [4,21], so that a swarm [23] of vacuuming robots can perform tasks in a collaborative way [16,17]. To this end, we evaluate the incorporation of social behavior techniques, artificial neural networks [10] or case-based reasoning systems [1,9,19,22], which would add some intelligence to the behavior of robots [12,27], beyond the algorithm designed.

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Real-Time Implementation of Demand Response Programs Based on Open ADR Technology

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Abstract. In the Demand Response (DR) concepts, we witness several barriers that need to be addressed such as, data transferring from promoting entities to demand side. The Open Automated Demand Response (Open ADR) standard specification is a solution for overcoming these barriers. This PhD work proposes a real business model for DR implementation based on Open ADR technology.

1 Introduction

The new and advanced technologies promote a revolution in the power system's implementation, aiming the enhancement of the wholesale market efficiency [1]. Interactive participation of the demand side, such as residential consumers, has a key role in this context [2]. DR is one of the concepts present in these technologies that begin to be widely used nowadays [3]. A DR event can be transmitted from the grid or market operator to the demand side, due to economic or technical problems [4]. The practical implementation of DR programs, raises the following issues: What is the framework for DR data transmission from the promoting entities to the end-user? Is there any standard for bidirectional communication between promoting entities and demand side? Open ADR is a comprehensive solution for these questions and is referred to a methodology for the transmission of DR events data between the utility operators, aggregators, and consumers [5]. Open ADR offers a data transmission framework for DR, allowing communication between the promoting entity (Virtual Top Node – VTN) and the consumer's end-node (Virtual End Node – VEN).

[6] implements an ADR solution for the home energy management system for dynamic pricing. [7] develops a software tool for Open ADR in the smart grid context. Additionally, [8] proposes the most complete tools for Open ADR, which includes the VTN and VEN behaviors. However, till the present, limited business models regarding the integration of Open ADR with real hardware resources have been carried out.

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Therefore, this limitation motivated the candidate to focus on this subject in order to develop software and hardware tools for implementing the Open ADR technology in the real resources.

2 PhD Research Focus

The main objective of this PhD research is to develop an architecture for real implementation of DR programs based on Open ADR concepts and framework. The current project includes two main sections: grid and demand side infrastructures. The grid infrastructure contains the VTN, which is owned by the grid operator. This entity will be responsible for the DR event's definition and transmitting it down to the demand side infrastructure (VENs) via Open ADR standard. A MATLAB™ algorithm combined with a graphical interface will be developed for this system in order to define the DR events and sending them to the other subsets (including VENs) via Open ADR standard based on eXtensible Markup Language (XML). The demand side infrastructure consists of several end-node devices (VEN) merged with several hardware resources, which will simulate different types of consumers, such as residential consumers, commercial buildings, and office buildings. The VENs will communicate with upstream players of the grid (VTN) using Open ADR standard. The VENs are accountable for receiving the Open ADR payloads, obtaining the required information and practically executing them on their available controllable loads. Each player has an independent VEN associated with the VTN and Each VEN is configured to receive the XML payload transmitted by the VTN, convert it to executable commands and act on its controllable loads.

Currently, the hardware sections of this project have been implemented, which include the installation of Programmable Logic Controller (PLC) and other microcontrollers for load controlling in each VEN. Moreover, the elementary model regarding the graphical interface and MATLAB™ algorithm have developed, which causes to obtain the primarily results of this PhD work.

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