Simulating the Optimization of Energy Consumption in Homes

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1 Introduction

According to Brazilian National Electric Energy Agency (ANEEL), the electric energy consumption is one of the main indicators of both the economic development and the quality of life of a society. However, the electric energy consumption data of individual home use is hard to obtain due to several reasons, such as privacy issues [1]. In this sense, the social simulation based on multiagent systems comes as a promising option to deal with this difficulty through the production of synthetic electric energy consumption data.

In the context of Artificial Intelligence, agents are defined as computational entities, embedded in an environment, which are able to perceive it and act on it. A computational agent has specific properties, such as: it operates under autonomous control, perceiving its environment, persists for a period of time, adapts to changes and it is able to accept goals [2]. There are several programming environments that are designed to work with agent-based modeling, however with different advantages, as shown in [3]. MultiAgent System (MAS) ofter a computing environment where programs that has a certain degree of autonomy (agents) interact with each pther in fulfillment of individual and collective goals [4].

The main categories that are associated with techniques for residential demand modeling are: top-down and bottom-up [5]. The top-down model uses total consumption of energy estimates of the residential sector, along with other relevant macro variables, for example, assigns the power consumption to the housing sector characteristics [5-7]. On the other hand, the bottom-up model identifies the contribution of each end-user consumption of total residential sector energy [8-9]. Bottom-up approaches refine the modeling of energy consumption, allowing the simulation of the effect of technological improvements and policy decisions in the household electricity consumption.

The authors [7, 10] have conducted studies aimed at reducing consumption by persuasion of residential consumers of electricity. About 20 years ago, there were few examples of persuasive technologies influencing the human decisions. The web was not ubiquitous, and the systems were not designed to change behavior, for they were more focused on data processing and increased productivity. Currently, experiments

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with the persuasive technologies are emerging via the web (from e-commerce to social networks), video games (Wii Fit, Dance Dance Revolution), smartphones (applications in general) and specialized electronic devices (pedometers, smart TV), [11].

This paper proposes a multiagent bottom-up approach to model the behavior of residential energy consumers' in Brazil, the model's name is SapiEns. Consumers and their behavior household are modeled by multiagent techniques calibrated using data provided by the Brazilian Program of Household Estimate (POF), [12].

The authors chose to use the NetLogo simulator to implement the scenario analysis. Our approach differs from other methods on four main issues. First, some of the model parameters, which make the simulation, are easily calibrated by using the average data of the literature [12]. Second, the same system may be applied in different simulation environments involving degree of scalability (from several hundred million), the heterogeneity of individuals and home profiles. Thirdly, the MAS approach is responsible for simulating the complexity of the system by sharing use of the equipments and the relationship between the consumers. Finally, we used the concept of persuasion to optimize the power consumption by sending messages to the consumer when he leaves home and forgets connected equipment.

2 Main Purpose

The proposed of SapiEns system is to understand the triggers was sending to the user, and they can make decisions based on these messages. The system should select the message according to a classification created for each user (pre-defined according to the persuasion theory [13,14]) and send these triggers in order to obtain the best possible result, that is, the largest number of positive responses. If this happens, the system must understand that there is a repetitive behavior of the user, and thus developing into an autonomous system which is able to make decisions without consulting the user. However, if the triggers receive a greater number of negative responses, the system must understand that the user prefers leave equipment switched on during that time, so removing the trigger related to the equipment in question.

Our approach is to generate profiles based on the responses of electricity consumers for each message answered by the user. This paper simulates the final consumer and residential appliances through the energy consumption data of parameters obtained from the literature [12]. This will allow the consumer behavior analysis (cognitive agents) according to the equipment located in their homes (reactive agents). The consumer is defined at the beginning of the simulation, as a cognitive agent who can forget any connected equipment when you go out or asleep. For the construction of this method the following design decisions were taken:

– Users and equipments are modeled as computational agents. This decision was taken to make it possible to simulate the behavior of consumers in their homes and the interaction with each other household members. Thus, it becomes possible to analyze the complex behaviors that arise from the interactions of the agents;

– Each household has at least one and up to three people. This decision was based on the average number of people per household found in the literature [12];
– Sending of messages is done randomly, so there's not a predefined period for submission of messages;

3 Demonstration

The authors conducted a case study involving nine equipment on the Intelligent Automation Core Laboratory of the Federal University of Rio Grande (Nautec - Furg), among them: two refrigerators, two air conditioners and five computers. The equipments remain connected for up to eight hours in the laboratory, being under the use of researchers. Were performed twenty simulations over a period of 24 hours. In ten of these users answered the messages of triggers and another ten consumers did not respond.

The simulator allows to simulate one or more residences according to need user. In addition, it allows you to select the maximum number of consumers for each simulation. In addition, the tool saves the consumption and response messages every minute simulated in a text file, allowing a detailed analysis of the behavior of consumers throughout the simulation.

Simulating could persuade consumers to disconnect the equipment answering message of the triggers, there was a consumer 3,33kWh. We consider the price per kWh as R $ 0.47, so consumers spent on average R$ 1.57 per day. Furthermore, the simulations where users were not convinced to turned off the equipments there was a consumption of 4.64 kWh, doing the same analogy of the price per kWh, consumers spent an average of R$ 2.18 per day. From these two types of simulation we can conclude that persuaded users consumed around approximately 28% less than the others.

4 Conclusion

In this work we chose to POF data because it is a study that enables the analysis of various issues in Brazil. This proposal is based on data that were collected throughout the Brazilian territory (urban and rural) allowing the analysis of expenses, income and household consumption. However, we found a problem with the lack of data as the standard deviations for the means that were not provided, which limits the usefulness of the statistics. The objective is to build a simulation methodology for consumers of electricity, which is a simplification of the real world and on the basis of information obtained from the literature.

Thus, as can be seen from the presented results, the use of the agent paradigm and the NetLogo tool is a viable alternative for simulations of electric user profiles. This is due to the fact that many utility company behaviors inherent in this service may be mapped to different types of agents which are inserted respectively in a virtual environment. From the foregoing, the project is considered relevant and continuity can bring benefits to distributors, through better planning of distribution network, and for users, as an educational tool for better use of energy. Through the survey, the following topics were identified that could be realized as an extension to this work: Construction of fuzzy logic for the development and demonstration of consumer profiles; and improving communication between the tool and NetLogo database.

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