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INTELLIGENT AND INTERACTIVE HOUSEHOLD SIMULATION FOR ENERGY MANAGEMENT ALGORITHMS' EVALUATION

This work describes the progress towards creating a tool for simulating households for evaluation of energy management techniques. Proper evaluation in this area is costly, time consuming and additionally error prone due to human factors. The proposed approach aims at replacing the real users and their devices with simulated ones, but with achieving results as close to reality as possible. Further, it offers flexibility, usually not available in real test scenarios.

INTELIGENTNA I INTERAKTYWNA SYMULACJA DOMOSTW DO TESTOWANIA ALGORYTMÓW ZARZĄDZANIA ENERGIĄ

Artykuł przedstawia postępy prac w kierunku stworzenia narzędzia do symulacji domostw do testowania technik zarządzania energią. Właściwa ewaluacja w tym obszarze jest kosztowna, czasochłonna oraz dodatkowo może być obarczona bledami związanymi z czynnikiem ludzkim. Proponowane podejście zastępuje rzeczywistych użytkowników i ich urządzenia symulowanymi, przy jednoczesnym zachowaniu możliwie wysokiego poziomu realizmu. Oferuje również elastyczność na poziomie trudnym do uzyskania w prawdziwych scenariuszach.

1. MOTIVATION

The energy market is evolving and moving towards renewable energy sources. This direction is coupled with smart grid solutions that rely heavily on intelligent energy management algorithms interacting with the home appliances to control the distribution of the energy demand. Since the number of possible cases such algorithms have to cope with is large, they have to be carefully evaluated, before allowing them to manage real households. One solution is to evaluate the algorithms in controlled simulation environments, but these, in their current state, might lack especially the human factors that exist in the real-life field tests. The focus of this paper is to discuss and show potential benefits of a new approach to virtualize the residents of the simulated households. The idea is to provide an interface to the simulated household to allow the energy management algorithms to interact with residents, as well as to implement an intelligent way to simulate free human behaviour.

The work describes further extension of an existing platform, called Household Simulator that was built to provide controlled simulation environment for programmers that develop intelligent energy management algorithms. The platform was created and described in a master thesis [1]. This initial platform allowed the programmers of intelligent energy management algorithms to define programmable devices that exist in virtual households with virtual residents that interact with these devices according to a defined usage schedule. The scope of that work was highly focused on the programmability, flexibility and interactivity of the virtual devices. The behavior of the residents was neglected.

Accurate digital reproduction of real-world testing environments is crucial for reliable household simulation. Certainly, humans are not yet able to recreate human behavior as a computer program with impeccable accuracy, but it is possible to recreate the accompanying randomness of human actions to some extent. It is possible to create a tool that represents (a simplified) household resident behavior by simplifying certain life processes into virtual actions and calculations. These can then be used in the process of testing the intelligent energy management algorithms, for example, by issuing power consumption suggestions to the virtual residents. The residents can then either decline or accept the suggestion based on their current state or mood. By offering greater level of algorithm evaluation, better results can be assessed and more robust energy management algorithms can be achieved in the future.

An ideal resident behavior simulator should allow a programmer to specify an initial state for each resident and should continuously generate the further states, as it changes. Current and previous states should be presented in a clear readable form, and should be available through a generic API interface. The simulator should provide inputs for fine-tuning the simulation, i.e., to customize the course before it is executed, for example marker weight adjustment. Given that the resident simulator on its own might be insufficient as a testing environment, it is reasonable to couple it with another platform that provides further functionalities, such as device simulation or scheduling. The platform incorporating a resident behavior simulator should offer an interface for interaction with the residents in order to influence their actions based on the outputs from the energy management algorithms. Programmer using the platform as a testing environment should be able to suggest a resident to alter their daily schedule through the algorithm outputs. The resident simulation module should be able to calculate a response to the suggestion based on the resident current state. Such approach opens new ways of conducting a much wider range of tests, close to impossible in pilot programs or laboratories. For example, scenarios that may result in device damage or be a danger to human health can be performed without any constraints or safety regulations, because they are working with the virtual household residents.

2. RELATED WORK

While some virtual household simulators can be found, for example, Smart Grid Simulator or Smart Residential Load Simulator [3], resident behavior simulators are very hard to find, what makes it difficult for intelligent energy management programmers or developers to consider the human decision factor into account, when evaluating energy management algorithms using the existing solutions. Given that residents are the ones affected by the energy management algorithm in the end, it seems wise to simulate their behavior additionally to simulating the devices, when evaluating energy management algorithms.

3. PROPOSED APPROACH

The objective of the work presented in this paper is to create a module coupled with the Household Simulator that uses simplified physiological needs and character traits simulation to offer an advanced tool for evaluating the intelligent energy management algorithms. The tool allows to interact with household residents through an interface. These interactions are mostly focused on giving suggestions and hints related to energy usage and further observation of whether residents comply with the suggestions and how it influences the overall electricity usage of the affected households.

The first iteration assumes introduction of simulated physiological markers (needs) for each virtual household resident. Initially, five different markers are proposed: hunger, energy, hygiene, boredom and happiness. Markers are subject to change. Each marker is represented by its value (0 – 100) and a weight, which indicates the importance of the marker, with 0.0 for least important, and 1.0 for most important. Some of the markers have a predefined list of sub effects that affect other markers, for example high hunger level causes faster degradation of other markers.

Each marker alone or group of markers will be evaluated into the corresponding resident state components, for example, the tiredness component will be calculated based on the hunger and the energy level.

Table 1

List of markers with respective parameters
Lista markerów wraz z poszczególnymi parametrami

Marker Name	Initial Value/Weight	Related Devices	Effect	State Component	Decision Making Effect
Hunger	50/1	Fridge, Stove, Microwave, etc.	Other markers decrease faster	Tiredness 0-100%	More eager to use devices related to hunger, energy
Energy	50/1	Bed, Chair, etc.	-		
Hygiene	50/1	Shower, Washer, etc.	-	Filthiness 0-100%	More eager to use hygiene related devices
Boredom	50/1	TV, PC, etc.	More or less eager to do perform certain actions	Willingness 0-100%	More eager to use boredom related devices
Happiness	50/1	TV, PC, etc.	-	Happiness 0-100%	More eager to use happiness related devices

Table 1 shows the initial list of markers with their default values and weights. The *Related Devices* column represents the group of devices that should be present in a virtual household in order to replenish markers. The *Effect* column contains any special effects on the resident when certain level is reached. The *State Component* column represents components that are calculated for each marker or a group of markers. Further calculated components can include comfort and others. The *Decision Making Effect* column shows how each state component affects the behavior of the resident.

Additionally, a concept of character traits is introduced, which allows further customization of the residents. A predefined list of traits will be assembled through conducting a statistical survey with real people that answer questions related to physiology and decision making process. The purpose of character traits is to introduce an additional factor in virtual resident decision. By that, given two residents with their physiological needs completely fulfilled, assigned character traits can influence the variation of resident response even further. For example, those virtual residents have setup an intelligent washing machine operation with different timeframes, in which the washing program should complete. The algorithm suggests both residents that moving the timeframe could lower electricity costs. If one of the residents has a trait that represents high technology interest, she might be more eager to accept the suggestion compared to a resident that is only interested in getting their laundry done.

Fig. 1 shows consecutive steps of the process of calculating current resident state in each resident state update. First, the physiological needs are updated, and then respective components are updated. Finally, current character traits are calculated. Each step is based on calculations from previous steps.

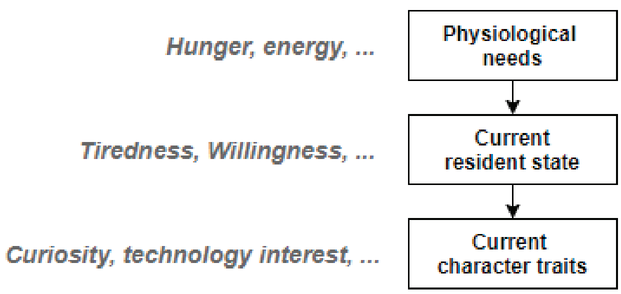

Fig. 1. Steps of resident state evaluation
Fig. 1. Kroki wyznaczania stanu rezydenta

Fig. 2 shows a simple diagram that represents a high-level concept and location of an interface allowing communication between the energy management algorithms and the Household Simulator.

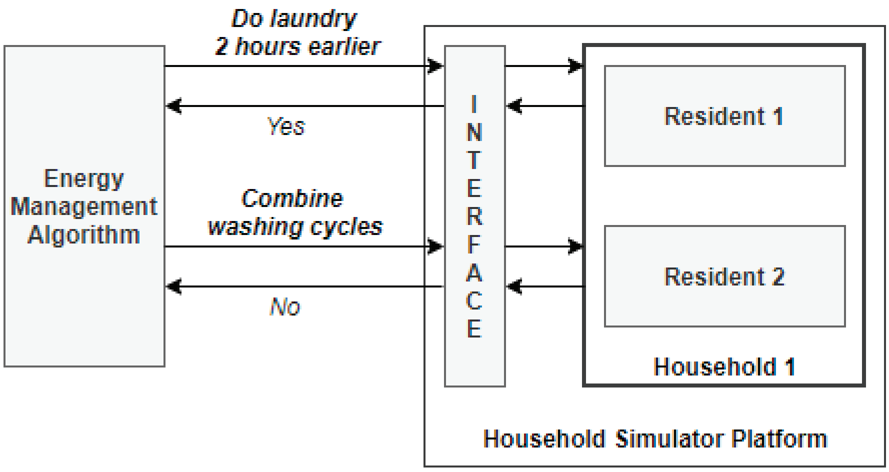

Fig. 2. Interaction between an algorithm and household residents through the interface

Fig. 2. Interakcja między algorytmem, a rezydentami domostwa poprzez interfejs

Combining the simulation of user devices with the possibility to influence the user behavior opens new ways for defining and evaluating energy management algorithms.

4. FURTHER STEPS

The solution described in this paper is a work in progress with still many open problems. Some things might be subject to changes and some of the answers to the problems might have to be answered by conducting psychological studies or asking field experts. This work will result in a PhD thesis of the first author, on *Intelligent and Interactive Household Simulation for Energy Management Algorithms' Evaluation*.

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REFERENCES

1. Koropiecki I.: Realization of the simulator of user behaviour for Smart Grids, Master Thesis, University of Zielona Gora, 2019.
2. Naveed A., Usman A., Fahad J.: A Highly Configurable Simulator for Assessing Energy Usage, The Mediterranean Green Energy Forum 2013, MGEF-13, 2013.
3. Gonzalez López J., Pouresmaeil E., Cañizares C., Bhattacharya K., Mosaddegh A., Solanki B.: Smart Residential Load Simulator for Energy Management in Smart Grids, IEEE Transactions on Industrial Electronics, 2019.