ENERGY PREDICTION SYSTEM FOR SMART HOME

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ABSTRACT

Actually, the energy consumption prediction in a smart home is an important subject of research. In this paper, we will propose a model that based on genetic algorithm that can help inhabitants and decision-makers to make the best decision, in term of energy consumption. We will implement our system, which can help the inhabitants optimize their energy consumptions using many technics as NodeMCU, cloud computing, and genetic algorithm.

KEYWORDS

smart home; NodeMCA; Cloud computing; genetic algorithm.

1. INTRODUCTION

We leave a great development in intelligent technologies, which merged with the city to improve the citizen livings. The concept of Smart City (SC) appears to enhance the life quality of the citizen. It has been gaining increasing importance in the agendas of policymakers [1]. Thus, the City is an urban area which is composed of many factors that are in interactions as the population, many networks as energy or water network, homes…etc. actually, the smart city is designed to optimize resources like energy, water or internet connection. To optimize the energy consumption, we can set sensors and streetlights that can gather and send information. Thus, we need to connect streets in smart city. These smart connected streetlights are the core of smart cities.

In the city, there are homes, which have peak off hours. For example, if the residential buildings like building of students, during the day, the student are in their classes or studying, therefore the demand of energy is lower. However, this is the contrast in the evening. In the commercial or administrative homes, they demand a great energy during the day but in the evening, the consumption will be lower. In addition, in the same home, we can find a peak off hours and low consumption. Thus, we must create a smart model, which can manage, regulate and optimize the energy consumption of all these types of homes. Thus, smart homes require indoor environment control system to control and manage the energy consumption while maintaining the comfort level of their occupants [2].

In this paper, we propose to use an approach which permits to perform Genetic Algorithms (GA) which can optimize the energy consumption in real-time, thus adapting rapidly the energy consumption of smart homes. Then, we develop GIS system, which allows knowing the position of home for permitting to decision makers to locate each home. Each home should associated its data like id-home, energy consumption, the billing of this home, etc.

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After a deep study of the subject, we find that we have three factors that can affect the energy consumption, like the time of system peak, energy costs, peak energy demand and the quantity of energy per hours…etc. In addition, we find two main energy equipment such as HVAC (Heating, Ventilation, and Air Conditioning) system and lighting systems, we can use HVAC-L system to designate these two systems.

The intelligent technologies permit to create a smart home that can facilitate the life of their occupants'. Generally speaking, smart homes are expected to address both intelligence and sustainability issues by using advanced computing systems and intelligent technologies to achieve the optimal combinations of overall citizen comfort and energy consumption [3]. In this context, we can cite that HVAC systems and lighting systems are the main energy consumers in residential, administrative or commercial buildings, this requires a driven control measures such as turning off/dimming smart lighting systems, controlling ventilation, as well as heating and cooling supplied to homes using actual home occupancy information contributes towards improving the energy performance in homes [4]. These systems consume up to 60% of the energy for homes. The rest of the energy is consumed in different kinds of equipment depending on the functionality of the home [5].

The optimization methods are an ideal approach to model the complex system because they can address complex and adaptive situations. In this paper, we will use one of these approaches, the genetic algorithm that can manage, regulate and optimize the energy consumption in a residential home. It permits also to control environmental parameters.

The Genetic Algorithm (GA) can be used essentially to reduce energy demand in a smart home that permits to optimize the energy consumption and energy cost in condition to increase the comfort level of home occupants. In this section, we present a review of state of art that using many approaches to find a compromise between energy consumption and home occupants' satisfaction.

Hagras et al. propose to use a system to learn the thermal responses of a home to external climatic factors as well as to internal occupancy loads to reduce home energy in condition to maintain occupants' comfort [6] while Arnold and Andersson [7] have used a predictive control approach for optimizing the operation of energy hub systems. Then, Liao and Barooah develop a Multi-Agent System to simulate the behaviours of all the occupants of a home and extract reduced-order graphical models from simulations of the agent-based model [8]. Also, Joumaa et al. developed a Multi-Agent System to manage anticipatory and reactive control of HVAC and lighting systems for homes. They use the agent-based approach because home energy consumption can be modelled by distributed systems. These systems rely on integration with facility systems and appliances through HVAC-L system and sensors [9]. We can cite also, the work of Azar and Menassa, which develops a new Agent-based approach that permits to simulate the consumption energy of in commercial building. This simulation considers occupants with different energy usage characteristics as well as potential changes to occupant using due to their interactions with the home environment and with each other [10].

All approaches that used previously try to find the potentially promising opportunity to reduce home energy through direct cooperation and coordination with home occupants in addition to improving control of home systems and energy resources. Nevertheless, there are not approaches that developed to optimize the energy consumption and satisfy the occupants' demand comfort. In this paper, we will propose an approach based on a genetic algorithm that permits to find the optimal plan that can increase the occupants' comfort level and optimize the energy consumption.

This paper is organized as the following. Firstly, we present some definitions for the smart home. Secondly, we describe our proposed approach, which is based on a genetic algorithm. Then, we add a conclusion and some future works.

2. SMART HOME

The notion of the smart home is introduced in the intelligent systems, which can control the energy consumption and occupants' comfort level. Thus, the smart home is able to manage, regulate and control its indoor environment via intelligent systems to optimize energy efficiency, occupants' comfort level, saving recourses and increase the total productivity of the system. The objective of these systems is to achieve reduced consumption energy, saving the resources and satisfy the demanded comfort of occupants by using recent technologies. The reduced consumption energy is achieved through intelligent system controlling the energy equipment such as HVAC system and light system. Saving resources consist to prevent the resources against dangers. Occupants' satisfaction is achieved by introducing the HVAC-L values that adapt to the home environment according to occupant's preferences. On the other hand, when the home is intelligently controlled to meet occupants' preferences by adjusting the heating/cooling level and lighting, these preferences need to be well interpreted and learned through the feedbacks or behaviours of occupants.

In order to meet the requirements of energy efficiency and occupants' satisfaction, many works need to be done for reducing energy consumption in the home and evaluating occupant's comfort level in response to changes of the home environment. However, energy consumption and occupants' comfort level usually affect each other in an opposite way [13]. Therefore, one primary goal of a smart home is to solve the conflicts between energy consumption and occupants' comfort level. Generally, the indoor temperature, the ventilation, the air conditioning and illumination level inside the home are used as environmental parameters to evaluate occupants' comfort level. In addition, the energy consumption is an important parameter to evaluate the system efficiency, also with the saving of usage devices against dangers, the determination of the control strategy is also important to reduce energy consumption in the home. These objectives can be achieved by the application of an intelligent controller that aims to reduce the energy consumption without decreasing the occupant's comfort level. Figure 1 presents a house, which uses an intelligent system.

Figure 1. A smart home.

3. Why We Use The Genetic Algorithm In Energy Prediction System

Genetic algorithms that developed in [11] to imitate the phenomena adaptation of living beings. They are an optimization technique based on the concepts of natural selection and genetics. It searches an optimal solution among a large number of candidate solutions within a reasonable time (the process of evolution takes place in parallel). Each of these solutions contains a set of parameters that completely describe the solution. This set of parameters can then be considered as the "genome" of the individual, with each parameter comprising of one or more "chromosomes". They allow a population of solutions to converge step by step toward the optimal solution. To do this, they will use a selection mechanism of the population of individuals (potential solutions). The selected individuals will be crossed with each other (crossover), and some will be mutating by avoiding, whenever possible, local optima. The Genetic Algorithms are used primarily to treat both problems [12].

• The search space is large or the problem has many parameters to be optimized simultaneously.
• The problem cannot be easily described by a precise mathematical model.

A. An Optimizer

It runs a genetic algorithm. Since heuristic algorithms do not guarantee to find the global optimal solution within the limited iterations, thus, we should run the genetic algorithm more than 100 times for increasing the possibility of achieving the global optimization, saving energy resources and meet occupants preferences. In principle, more runs of the optimization algorithm will lead to a higher probability of achieving better results, but it will inevitably take more computational time. After many trials, it was found that 100 is a reasonable number of runs for balancing the solution quality and computational time cost.

B. Simulator

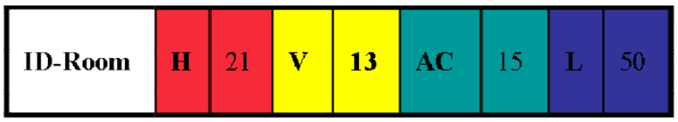
Each genetic algorithm is associated with a simulator that is used to discover the occupants' comfort level and optimized energy consumption in the prevailing conditions. The results of simulator could be optimized to achieve a satisfactory balance between discovery time and system performance. The optimizer repeatedly runs the energy flow simulations for every time and calculates the satisfaction of occupants comfort. The best occupants' comfort level is then used to generate the subsequent generation of general occupants comfort levels, and over a number of generations, the best candidate comfort level is identified.

C. Comfort Model

The comfort model permits to control the indoor environment in the smart home via computer techniques to optimize energy consumption, satisfy occupants' comfort, saving energy resources and increase the system productivity. In order to meet the compromise between energy efficiency and occupants' comfort level, the sensor of the home needs to evaluate the energy consumption and occupant's comfort level in real-time in response to changes of the indoor environment. Occupants' comfort level is related to both the condition of the environment and occupant's preferences over the environment. In order to evaluate the occupants' comfort in the living environment, environmental parameters can be used as indices to form the function of occupant's comfort by using the actual value of the corresponding environmental parameters and occupant's preferences of these parameters. Generally, the indoor temperature, the illumination level, the air conditioning and ventilation inside the home are used as parameters to evaluate occupants' comfort level.

D. Chromosome Structure

To apply the genetic algorithm, we should define the genes' and the chromosomes' structure. The gene can be characterized by its identifier and a set of values of HVAC-L systems that can be applied to perform the optimal energy consumption and satisfy the occupants' comfort level. We use multiple forms to coding the genes. Firstly, we use the strings to coding the identifiers, and then we use a real number for coding the values of temperatures, the ventilation, the air conditioning, and lighting system. Figure 2 presents the structure of the gene.



ID-Room : room identify in the building,

H: heating system,

V : ventilation system,

AC: Air Conditioning system,

L: light System.

Figure 2. Genes' structure of the room.

The chromosome represents a sequence of genes of the different room that can be the best solution of the HVAC-L system values. To identify the best chromosome from the population, the optimizer runs a genetic algorithm with its different classic steps, as selection, crossover, and mutation. Each home has a simulator, which permits it to identify the best available solution from the population; the optimizer repeatedly runs the energy consumption simulator for each HVAC-L system in a given generation. The values that are found by their optimizers are used as sub-values to generate the final solution of the current energy consumption of HVAC-L system. After a number of generations, the best candidate values of HVAC-L system are identified. Figure 3 shows an example of a solution that is found by the genetic algorithm.

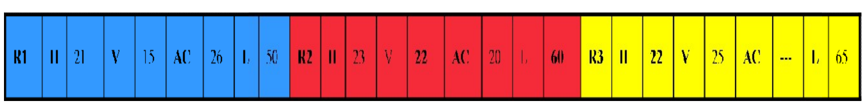


Figure 3. the Chromosome of the solution.

E. Genetic Algorithm Steps

a) Initialization

The initialization operator determines how each chromosome is initialized to participate in the population of the genetic algorithm. Here, the chromosome is filled with the genetic material from which all new solutions will evolve. In this work, we will use the Steady State to initial the generation process and select the population of the genetic algorithm for the next generation. First, Steady State creates a population of individuals by cloning the initial chromosomes. Then, at each generation during evolution, it creates a temporary population of individuals, adds these to the previous population and then removes the worst individuals in order that the current population is returned to its original size. This strategy means that the newly generated offspring may or may not remain within the new population, dependant upon how they measure up against the existing members of the population.

b) Crossover

The crossover operator defines the procedure for generating a child from two parent chromosomes. The crossover operator produces new individuals as offspring, which share some features taken from each parent. The probability of crossover determines how often crossover will occur at each generation. In this approach, we will use the single point crossover strategy was adopted for all experiments. In this paper, the results for all experiments presented were generated using a crossover percentage of 50%, which is to say that at each generation 50% of the new population is generated by splicing two parts of each chromosome's parents together to make other chromosomes. Figure 4 shows the crossover operator.

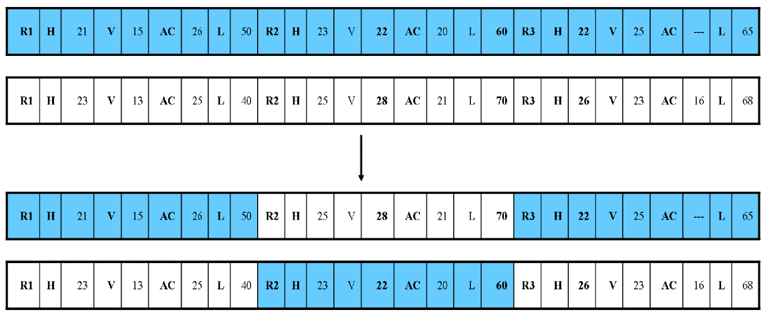


Figure 4. Crossover operator.

c) Mutation

The mutation operator is very important. It defines the procedure for mutating the chromosome. Mutation, when applied to a child, randomly alters a gene with a small probability. It provides a small amount of random search that facilitates convergence at the global optimum. The probability of mutation determines how much of each genome's genetic material is altered, or mutated. If the mutation is performed, part of the chromosome is changed. The mutation should not occur too often, as this would be detrimental to the search exercise. In this work, the results presented here were generated using a 1% mutation probability, which was determined experimentally, using a single case of vector HVAC-L system. We present the random mutation in Figure 5.

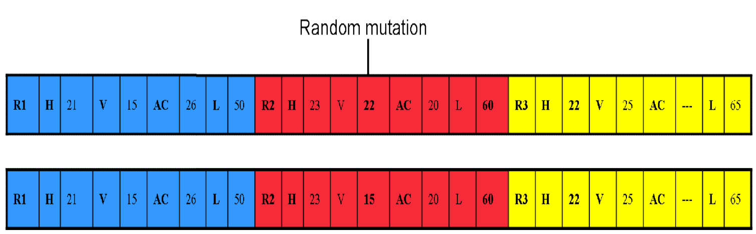


Figure 5. Mutation operator.

d) Evaluation of Solutions

We can say that the success of any discrete optimization problem rests upon its objective function, the purpose of which is to provide a measure for any given solution that represents its relative quality. In our resolution method of consumption energy problem in smart homes, the objective function used here works by calculating and summing the penalties associated with the temperature, the illumination, the indoor air quality and ventilation within our state representation. Thus, we will use the objective functions to evaluate solutions of the energy consumption problem and examines the weighted relationship between the actual measured values of the temperature, the ventilation, the indoor air quality, illumination level and values of occupants' comfort level according to these four parameters. The objective functions used to evaluate solutions requires a number of definitions that model the problem underlying structure, specifically:

- $R = \{R_1, R_2, R_3, ...R_n\}$ is the set of all room in the home,
- $H = \{H_1, H_2, H_3, ...H_n\}$ is the set of all heating systems in the home,
- $L = \{L_1, L_2, L_3, ...L_n\}$ is the set of all illumination systems in the home,
- $A = \{A_1, A_2, A_3, ...A_n\}$ is the set of all air conditions in the home,
- $V = \{V_1, V_2, V_3, ...V_n\}$ is the set of all ventilation system in the home,
- H_m, L_m, A_m ,and V_m are the measured values of the temperature, the illumination, and the indoor air quality and ventilation respectively.
- H_c, L_c, A_c ,and V_c are the comfort values of the temperature, the illumination, and the indoor air quality, respectively.
- N1, N2, N3, and N4 is the all number of the temperature, the illumination, and the indoor air quality and ventilation system respectively.
- [T_{min}, T_{max}] represent the interval time where the values of three parameters were measured.
- [C_{min}, C_{max}] represent the comfort range. This range can be defined by customers.
- [E_{min}, E_{max}] represent the consumption energy range.

Two important parameters are in our approach, the assigned energy to the HVAC system E_H and the assigned energy to the lighting system E_L.

In this context, we have mainly two important functions f(C) and f(E) which permits to evaluate the performance and efficiency of the proposed approach. These two functions are calculated by the genetic algorithm.

The objective of this optimization mechanism is to maximize occupants' comfort f(C) and to minimize the total energy consumption f(E) for evaluating the performance and the efficiency of our system. Firstly, we have

$$f(C) = C_1 * {}^{H_c}\!/_{H_m} + C_2 * {}^{Lc}\!/_{L_m} + C_3 * {}^{A_c}\!/_{A_m} \tag{1}$$

C1, C2 and C3 are the user-defined weighting factors, which indicate the importance of three comfort factors and resolve the possible equipment conflicts. These factors take values in the range of [0, 1]. Occupants can set their own preferred values in different situations according to the season or the occupancy period. As we said previously, since occupancy period has a profound influence on energy savings, it should be taken into account in the control strategy design. In the occupied hours, the genetic algorithm activates the optimizer to tune the set point in order to obtain the acceptable indoor visual comfort with minimized energy. Otherwise, the genetic algorithm turns off all the resource lights and keep the blind position to save energy if there are no occupants in the home. The objective function is defined in equation (1), and the optimization goal is to maximize these objective function. Since the ratio between the measured value and comfort value determined by occupants introduced via a graphic interface, it has an important role in achieving the control goal. Thus, it permits to increase the occupants' comfort level and optimize the energy consumption.

The second objective function permits to control the energy consumption in the indoor environment of the home. The objective of this function consists to minimize the total energy consumption of HVAC-L system. Thus, we can define this objective function as the following.

$$f(E) = E_{HVAC} + E_L \qquad (2)$$

E_{HVAC} and E_L represent the consumption energy of HVAC system and the lighting system, respectively.

4. RESULTS AND DISCUSSION

In this section, we present a case study that illustrates how to design the genetic algorithm of our system. In addition, we use Java (https://www.java.com/fr/) to implement the different steps of the genetic algorithm like a crossover operator, mutation operator, and the evaluation function. Thus, in the experimentation, we use a residential building; it aims at providing a comfortable environment for all occupants inside the home. Firstly, the room uses the sensor to learn the HVAC-L data, which can be used as input in the genetic algorithms. The occupants (users) can introduce their preferences in the profile via a graphic interface. The genetic algorithm runs the optimizer that can find the optimal values of HVAC-L system, which allow optimizing the energy consumption and increasing the occupants' comfort level. Figure 6 shows the graphic interface.

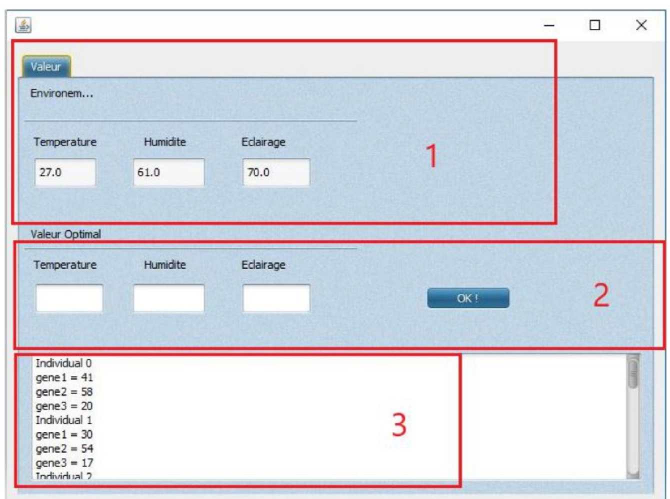


Figure 6. Graphic interface (1) sensor values (environment), (2) results of GA, (3) fitness.

The data which used in the simulation, they were gathered in the period 01 June – 30 July with a calculation frequency of 20 iterations per hour. The simulation was started in June because, during this period, south zones consume more energy. To calculate the comfort function f(C), we will use two parameters; temperature, lighting and air quality, thus the vector of weighting factors is $(C_1, C_2, C_3) = (1, 1, 1)$.

In this simulation, we use the air quality index, which presented respectively in Table 1.

Table 1. Air quality index.

Air quality index	category
1-50	Good
51-100	moderate
101-150	unhealthy
151-200	Very unhealthy
201-300	Extremely Unhealthy

Most occupants in a home can tolerate a certain degree of discomfort. This is mainly because most people are insensitive to temperature variations within several Celsius degrees. Therefore, instead of a single temperature point, a range of temperature may be felt comfortable for occupants. The temperature outside of this range will be felt uncomfortable for most occupants, and user's satisfaction will decrease dramatically with the temperature that goes far from the comfort range. In Table 2, we present the different intervals of temperature values.

Table 2. Intervals of temperature values.

Temperature interval	category
[-3,-1]	Very cold
[0,7]	Cold
[8,16]	Slightly cold
[17,31]	Good
[32,41]	hot

In Table 3, we introduce the different intervals of occupants' satisfaction and the energy consumption.

Table 3. Intervals of occupants' satisfaction and the energy consumption

Evaluation Parameters	Unacceptable	Less satisfaction	Highly satisfaction
Occupants' satisfaction	[1,4.5]	[5,8]	[8.5, 10]
Energy consumption (KWh)	[25,30]	[20,25]	[15,20]

To control the different systems, the genetic algorithm uses some data of the HVAC-L system. As we know, to maintain a higher occupants' comfort level, we must increase the energy consumption. Whereas, the GA of smart home tries to find a compromise between the energy consumption and the higher occupants' comfort level. Thus, it should find the optimized values to determine energy consumption dispatched to both the HVAC system and the lighting system.

Remember that the objectives of this self-optimization mechanism are to maximize occupants' comfort level and to minimize the total energy consumption of the smart home. In Figure 7, we state different values of parameters; temperature, light and humidity.

Figure 7. Values of parameters.

Figure 8 shows the evolution of Fitness values. Figure 8. Evolution of fitness.

According to the case studies and simulation results, the proposed approach is capable of managing, regulate and controlling the home effectively to satisfy occupant's comfort and optimize energy consumption.

5. CONCLUSION

In this work, a GA is developed to manage, control and regulate the home indoor area. The genetic algorithm used for optimizing consumption energy of the homes and increase occupants' comfort level. The simulator, which associated with the genetic algorithm, can execute a simulation that permits to find the optimal scheme that can save the energy resources in the home and increase their performances. In addition, the occupants of the smart home can introduce their preferences and a substantial degree of intelligence enhances the operability of the control system via the graphic interface. Our proposed approach provides a strong and open architecture in which the genetic algorithm can be easily configured, and new function can be added without changing the architecture of the system. Thus, the proposed approach has attained the compromise between the energy consumption and occupants' comfort level. The main problem of the genetic process is consumption time. In future works, it would be of great importance to analyze the execution time of different tasks in the genetic process. In addition, we can propose to use the same approach in the water consumption because it presents a great problem for the citizen in the smart cities.

REFERENCES

[1] Paolo N., Alberto De M., Anna C., Giulio M., Francesco S. 2014, Current trends in Smart City initiatives: Some stylised facts, Cities, 38 , 25–36.

[2] Al-Daraiseha A. , El-Qawasmeha A., Shah N., Multi-agent system for energy consumption optimisation in higher education institutions, Journal of Computer and System Sciences, 81 (2015) 958–965.

[3] Wang Z, Wang L, Dounis AI, Yang R. Multi-agent control system with information fusion based comfort model for smart homes. Appl Energy 2012, 99: 247–54.

[4] Spataru C., Gauthier S., How to monitor people 'smartly' to help reducing energy consumption in homes? Archit Eng Des Manag, 2014,10 (1–2):60–78.

[5] Labeodann T., Aduda K., Boxem G., Zeiler W., On the application of multi-agent systems in homes for improved home operations, performance and smart grid interaction – A survey, Renewable and Sustainable Energy Reviews, 50 (2015) ,1405–1414.

[6] Liao C., Barooah P., An integrated approach to occupancy modeling and estimation in commercial homes, American Control Conference (ACC), 2010 (2010) 3130–3135.

[7] Arnold M, Andersson G. Investigating renewable infeed in residential areas applying model predictive control. In: Power and Energy Society General Meeting, IEEE, Minneapolis, MN, USA; 25e29 July 2010. p.1e8.

[8] Hagras H., Packharn I., Vanderstockt Y., McNulty N., Vadher A., F. Doctor, An intelligent agent based approach for energy management in commercial homes, FUZZ-IEEE 2008, IEEE World Congress on Computational Intelligence, IEEE International Conference on , (2008) 156–162.

[9] Joumaa H., Ploix S., Abras S., De Oliveira G., A MAS integrated into Home Automation system, for the resolution of power management problem in smart homes, Energy Procedia,6, 2011, Pages 786–794.

[10] Azar E., Menassa C., An agent-based approach to model the effect of occupants' energy use characteristics in commercial homes, American Society of Civil Engineers (ASCE) (2011) 536–543.

[11] Holland J., 1975, Adaptation in Natural and Artificial Systems", University of Michigan Press, Ann Harbor.

[12] DeJong K. and Sarma J., 1993, Generation Gaps Revisited, "Foundations of Genetic Algorithms 2", D. Whitley, Morgan-Kaufmann Publishers, San Mateo.

[13] Yang R., Wang, L., Development of multi-agent system for home energy and comfort management based on occupant behaviors, Energy and Homes, 56 (2013) 1–7.