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Hybrid Approach for Optimize Energy of Electric Vehicle battery in Smart Cities

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***Abstract*— the electric vehicle will be the most used in smart city. Thus, the management of its battery is the most attractive subject specialty in the last decade. Thus, if a driver wants to use an electric vehicle, he wants to find an optimal method which permits optimizing the using of an energy battery of its electric vehicle. In this paper, we propose a hybrid approach which based on the Multi-Agent system and the algorithm genetic (MAS-GA) permit optimizing the using of energy battery.**

***Keywords*—**Smart city, electric vehicle battery, energy consumption, Multi-Agent System, Genetic Algorithm.

I. INTRODUCTION

The Smart City (SC) is an urban area that is a means to enhance the life quality of the citizen. SC is a concept which is appeared to have made a city more alive and more liveable. This new concept has gained increasing importance in the agendas of policy makers [8]. The policy maker should introduce Electric Vehicles in smart city to replace traditional vehicles to reduce air pollution, improve energy efficiency and avoid the congestion in road traffic. We will treat in this paper, this main question: what is the optimal method to manage, reduce and control the energy consumption of the battery?

The electric vehicles are quickly merged in the smart city, but many problems are appearing as the high consumption cost, the limited capacities, and the long recharge time of their batteries. To increase of these batteries, multi-battery systems that combine a standard battery with super-capacitors are currently one of the most promising ways to increase battery life's and reduce consumption costs. However, their performance essentially depends on how they are designed. In this paper, we focus on a complementary aspect of the problem that is optimizing the energy consumption of batteries in electric vehicles.

This paper is organized as the following. Firstly, we will present a state of the art review for optimization of energy consumption of battery in electric vehicle. Then, we describe our proposed approach which is based on two approaches, the Multi Agent System and Genetic Agent (MAS-GA). Finally, we add a conclusion.

II. STATE OF THE ART FOR ENERGY MANAGEMENT

Several works are introduced to address the different aspects of this problem. In particular, there are many researches aiming to improve the navigation systems with novel routing algorithms by taking into account the capacity of electric vehicles' battery, and the real-time data of traffic lights in all the road conditions.

Masjosthusmann et al. take into account of the advantage of the heating Vehicle system's power control to develop a vehicle energy management for a single source Battery Electric Vehicle [1].

Roscher et al. also used the cooling system's power control to reduce the overall energy consumption and increase the battery health of Battery through an adaptive control of the heating, ventilation and air conditioning of the vehicle (HVAC system), depending on the driving situation [2].

Kachroudi et al. propose to use online particle swarm optimization (PSO) method to optimally control the energy flow between the power train and the other vehicle's auxiliaries for a given Battery [3]. Thus, using a PSO algorithm to search for a global optimum relative to specific objective functions, which take into account battery autonomy, driving comfort indexes, and travel time. According them decrease the vehicle's energy consumption, and at the same time maintain the comfort of the passengers, by providing some suggestions to the driver.

III. THE PROPOSED APPROACH

In this paper, we will propose an approach based on multi-agent system and genetic algorithm (MAS-GA).

A. *Multi agent System*

An agent is a software system that is situated in some environment [5], and that is capable of autonomous action in order to meet its design objectives [7]. In this work, we use the multi-agent system because it provides numerous advantages in the domain of energy consumption and passengers' and drivers' comfort level.

B. *Genetic algorithms*

Genetic algorithms are developed in [6] to imitate the phenomena adaptation of living beings. They are an optimisation 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). The Genetic Algorithms are used primarily to treat both problems [4].

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1. The search space is large or the problem has a lot of parameters to be optimized simultaneously.
2. The problem cannot be easily described by a precise mathematical model.

We will combine Multi-Agent Systems with Genetic Algorithms (MAS-GA), for permitting the agent to choose the optimal actions. Therefore, our proposal model is based on the three following points.

1. Vehicle Agent is a software agent which can manage, control the local optimization process and exchange relevant information with neighboring Agents.
2. Genetic patrimony which is transformed between agents, are used as inputs to the genetic algorithm. This genetic patrimony represents values of energy consumption of HVAC-L system that are collected by sensor system.
3. Genetic Algorithms is used to find the optimal solution for the current configuration, this is composed of the two objective functions, the energy consumption and the passengers' comfort level.

IV. System architecture

The objective of our proposed system is in one hand to optimize the energy consumption of battery and increase the battery live through an optimal distribution of energy on the different systems of electric vehicle as the heating, ventilation and air conditioning (HVAC) system and lighting system. In the Fig.1, we present the architecture of our system. In this system, we are principally three agents, profile agent, vehicle agent.

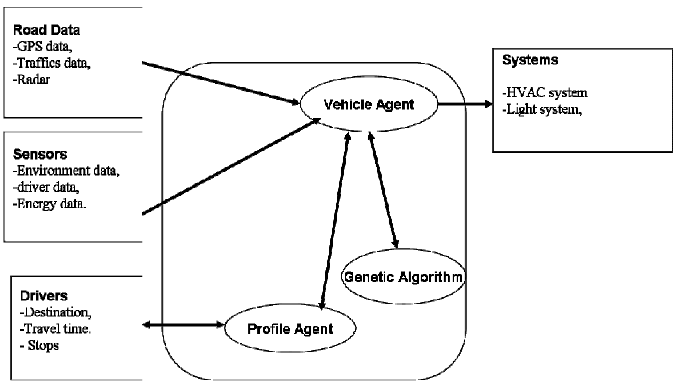

Fig 1. Architecture of our system.

V. Vehicle Agent

As we tell previously, a vehicle agent is able to manage, control and regulate its indoor environment of electric vehicle to optimize energy consumption, satisfy the occupants' comfort, saving battery and increase the efficiency and productivity of systems. Therefore, the main objective of a vehicle agent is to solve the conflicts which can be occurred during energy consumption and satisfaction of passengers' and drivers' comfort. Passengers' and drivers' comfort satisfaction is related to both the conditions of the environment and passengers' or drivers' preferences over the environment. In order to evaluate the passengers' comfort level in the electric vehicle, environmental parameters can be used as indices to form the function of passenger's comfort by using the actual value of the environmental parameters and passengers preferences of these parameters. Therefore, the vehicle agent has been designed with three components for controlling and regulates its indoor environment that can optimize energy consumption. These components are an optimizer, simulator and comfort model.

A. *An optimiser*

It runs a genetic algorithm. Since heuristic algorithms have no guarantee to find the globally optimal solution within the limited iterations, in this research GA runs 100 times in each time step to increase the possibility of achieving the global optimization, saving battery and meet passengers preferences. In principle, more runs of the optimization algorithm will lead to higher probability of achieving better results, but it will inevitably take more computation 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 vehicle agent has a simulator that are used together to discover the passengers' 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 passengers' comfort.

C. *Comfort model*

The passengers' comfort model permits to control the passenger cabin in electric vehicle via computer techniques to optimize energy consumption that satisfies passengers' comfort, saving battery and increase the efficiency and productivity of the system. In order to meet the compromise between energy efficiency and passengers' comfort level, vehicle agent needs to evaluate the energy consumption and passengers' comfort level in electric vehicle in response to changes of the indoor in the electric vehicle.

VI. Optimization process of electric vehicle

As we say previously, the vehicle Agent has an optimizer and simulator that are used together to discover the values of HVAC-L system that they can optimize the energy consumption in the prevailing conditions and also satisfy the comfort level of drivers and passengers. Thus, each vehicle agent executes a genetic algorithm to find the optimal values of HVAC-L systems that can be attributed to each system to

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perform optimal energy consumption and increasing the passengers' or drivers' comfort level.

A. *Chromosomes' structure*

To apply the genetic algorithm, we should define the genes. 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 passengers' or drivers' comfort level. The Fig. 2 presents the structure of the gene.

ID-vehicle	H	21	V	13	AC	15	L	50

ID-Vehicle : electric vehicle identify,

H: heating system,

V : ventilation system,

AC: Air Conditioning system,

L: light System.

Fig 2. Gene structure's.

To identify the best chromosome from the population, the optimizer runs a genetic algorithm with its different classic steps, as selection, crossover and mutation. The electric vehicle agent has a simulator that 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. After a number of generations, the best candidate values of HVAC-L system are identified.

B. *Initialisation, Crossover and Mutation*

Firstly, the initialization operator determines how each chromosome is initialized for participate in the population of 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 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, dependent upon how they measure up against the existing members of the population.

Then, 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 in 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 in each generation, 50% of the new population were generated by splicing two parts of each chromosome's parents together to make another chromosome.

Finally, the mutation operator will be applied. 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 an each genome's genetic material is altered, or mutated. If mutation is performed, part of a 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, utilizing a single case of vector HVAC-L system of electric vehicle.

C. *Evaluation of solutions*

The purpose of evaluation system is to provide a measure for any given solution that represents its relative quality. The objective functions used to evaluate solutions require a number of definitions that model the problem underlying structure, specifically:

- $EV = \{EV_1, EV_2, EV_3, ... EV_n\}$ is the set of all electric vehicle in the road,
- $H = \{H_1, H_2, H_3, ... H_n\}$ is the set of all heating systems in the electric vehicle,
- $L = \{L_1, L_2, L_3, ... L_n\}$ is the set of all illumination systems in the electric vehicle,
- $A = \{A_1, A_2, A_3, ... A_n\}$ is the set of all air conditions in the electric vehicle,
- $V = \{V_1, V_2, V_3, ... V_n\}$ is the set of all ventilation system in the electric vehicle,
- H_m, L_m, A_m ,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 ,V_c are the comfort values of the temperature, the illumination, and the indoor air quality, respectively.
- $[C_{min}, C_{max}]$ represents the comfort range. This range can be defined by customers.
- $[E_{min}, E_{max}]$ represents the energy consumption range.

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

In this context, we have mainly two important functions *f(C)* and *f(E)* which permits evaluating the performance and

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efficiency of the proposed approach. These two functions are calculated by building agent.

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

$$f(C) = C_1 * {H_c}/{H_m} + C_2 * {L_c}/{L_m} + C_3 * {A_c}/{A_m} + C_4 * {V_c}/{V_m} \quad (1)$$

C1, *C2*, *C3* and *C4* 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]. Passengers or drivers can set their own preferred values in different situations according to the season or the travel period. As we say previously, since the travel period has a profound influence on energy savings, it should be taken into account in the control strategy design. Generally speaking, in the occupied hours, the vehicle agent activates the optimizer to tune the set point in order to obtain the acceptable indoor visual comfort with minimized energy. Otherwise, the vehicle agent turns off all the resource lights and keeps the blind position to save energy if there are no passengers in the electric vehicle. 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 passengers play via graphic interface, it has an important role in achieving the control goal. Thus, it permits increasing the passengers comfort level and optimize the energy consumption.

The second objective function permits controlling the energy consumption in electric vehicle. 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.

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

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

VII. Experimentation and Results

In this section, we present a two case studies that illustrate how to design the different agents of our system and show collaboration between them. We use Jade to implement the different agents, vehicle agent, profile agent and station agent. Also, we use Java to implement the different steps of genetic algorithm as crossover operator, mutation operator and the evaluation function.

Firstly, the vehicle agents use the sensor to learn the HVAC-L data and motor energy consumption which can use as input in the genetic algorithms. The passengers and drivers can introduce their preferences in the profile agent via a graphic interface. The vehicle agent runs a genetic algorithm that can find the optimal values of HVAC-L system and Motor energy consumption which permit optimizing the energy consumption and increase the passengers or drivers comfort level. In the table 1, we introduce the different intervals of passengers' satisfaction and the energy consumption.

Tab 1. Intervals of passengers' satisfaction.

Evaluation Parameters	Unacceptable	Less satisfaction	Highly satisfaction
passengers' satisfaction	[0,2]	[2.25,3.5]	[3.75, 5]
Battery Energy Consumption (v)	[2.5,4.0]	[2.0,2.5]	[1.5,2.0]

To control the different systems, vehicle agent uses a data of the HVAC-L system and motor energy consumption. As we know, to maintain a higher passengers' comfort level, we must increase the energy consumption. Whereas, the electric vehicle agent tries finding a compromise between the energy consumption and the higher passengers' comfort level. Thus, it should find the optimized values to determine energy consumption dispatched to both the HVAC-L system and motor energy consumption.

The objectives of this optimization mechanism is to maximize passengers comfort level and to minimize the total energy consumption of the electric vehicle . In the Fig. 3, we state that there is difference in passengers' comfort level in the two approaches, with MAS-GA and without MAS-GA. With MAS-GA, the system achieves a higher passengers' comfort level compared to the second approach, without MAS-GA. Thus, the passengers' comfort level in the MAS-GA has been improved rapidly compared to the second approach.

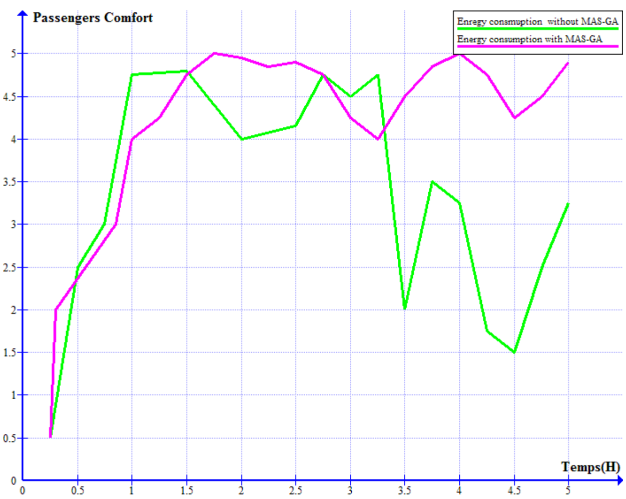

Fig 3. Passengers' comfort level with and without MAS-GA.

The Fig. 4 shows that when we use our proposed approach, the energy consumption has been improved compared to classic approach which can be used to decrease

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the energy consumption. Thus, when we use MAS-GA approach, we can higher minimize the energy consumption, thus, the MAS-GA approach permits optimizing the energy consumption compared to the classic approach, without MAS-GA.

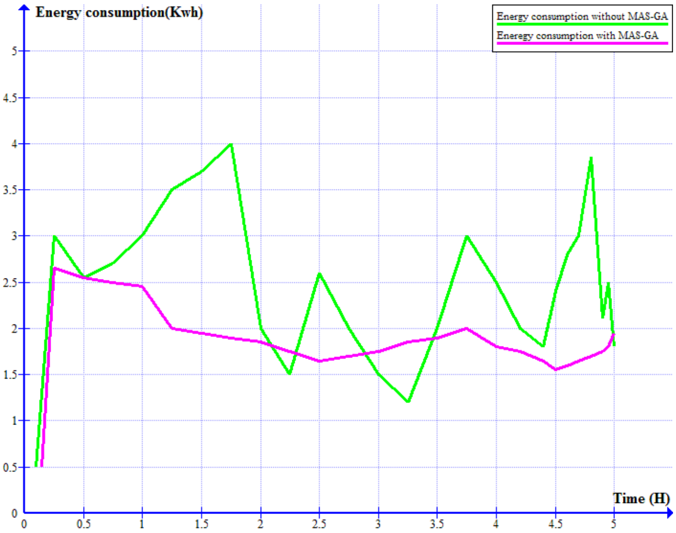

Fig 4. Energy consumption with MAS-GA and without MAS-GA.

The SMA –GA is designed to enable the interactions between the occupants and the environment by learning the occupants' behaviours. According to the case studies and simulation results, the proposed MAS-GA is capable of managing, regulate and controlling the building effectively to satisfy occupants' comfort and optimize energy consumption.

VIII. CONCLUSION

In this work, we present a hybrid approach (MSA-GA) to control, manage and regulate the energy consumption in an electric vehicle in a way that a reduction of electrical losses within the HVAC-L system in condition to satisfy the passengers and drivers' comfort level. To save the energy in the electric vehicle, we have to regulate the maximum energy consumption of the HVAC, depending on the energy demand of the driver and passengers. The proposed approach can also save the battery of electric vehicles.

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