A Street lighting Control system based on holonic structures and traffic system

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Abstract— **Street lighting system is one of the main sectors of energy consumers in the area of the electrical energy consumption in the country. Since suitable lighting system plays an important role in terms of individual and social security in the city, providing an optimal management plan in line with the aim of saving consumption of electrical energy while providing appropriate lighting levels, can be a great help to the field of energy consumption. In this article we have tried to provide a comprehensive and overall plan for controlling and intelligent managing the street lighting system based on passages traffic using holonic multi agent systems. This approach controls the lighting system by intelligent agents in a holonic organization mounted on the traffic infrastructure. This control is done at different levels in centralized and distributed form. We can see two levels in our holonic multi agent system. In the high level of the system, there are geographical holons and their heads with strategic tasks. In the low level of the structure, there are learning agents with tactical tasks in geographical holons. They are main controllers installed in the streets. They form high consumption and low consumption holons dynamically, according to their decision for controlling the street lighting. The head of geographical holon also supervise the learning agents and formation of the consumption holons. We show that our approach can control the street lighting dynamically and efficiently in different conditions. The results of implementing this approach on a simulated network of streets and their traffic, shows that this method can lead to significant decreases in electrical energy consumption.**

Keywords- Smart control; street lighting; holonic multi agent system; traffic

I. INTRODUCTION

One of the significant cases in consuming electrical energy is the consumption of lighting system in the streets. So considering the significant energy consumption in this system and the importance of individual and social security provided by proper lighting system in the city, it can be inferred that the smart management of energy in this area can be helpful to for both targets [1]. On the other hand, since the lighting systems are used in the peak hours of consumption, we can prevent from problems and tensions in the network by providing a suitable model for consumption management in this field. In this work we have tried to provide a new plan for controlling and intelligent managing of street lighting system based on passages traffic using holonic multi agent systems. This plan will consist of distributed and centralized controlling in different levels.

Today intelligent multi agent systems can be used in many industrial and scientific fields. One agent is an entity that can sense the environment by some sensors and acts upon the environment using some actuators. Holonic structure is a kind of hierarchical structure and organization in multi agent systems. The holonic structure is one of the suitable structures for modeling many complicated systems such as education, transportation, traffic control systems, etc. The holonic structures are adaptive to the environmental changes, cooperative, self-organizing, flexible and reconfigurable.The fundamental units of this structure are holons. The holons may consist of subholons and also be a component of a super holon. So a tree structure called holarchy is made by holons. There are a lot of examples of holarchy such as human body. The holarchy structure can be also considered for many social organizations. Giving an education case such as university, a view of holarchy structure is shown in Fig. 1 [2, 3, 4, 5].

The smart control of lighting system will be discussed by giving a special method in this paper based on the traffic rate in the streets and using multi agent systems. In this method the traffic system is used as the default infrastructure of the street lightning control. It is worth noting that the traffic control system is itself a suitable platform for applying holonic structures. Therefore if the traffic control system is also controlled based on the holonic multi agent systems, the performance of two systems can simultaneously be suitable in the different layers.

II. RELATED WORKS

In the field of street lighting automation, we can mostly mention to the equipments and devices produced in this field. These equipments are installed on the poles or in the central control unit. None of these works, however, won't give us a comprehensive and general design based on smart controlling the whole system in different layers and creating an interactive, flexible and smart system. One sample of these equipments is the control device made in SNR company that using the light sensors. In fact, SNR device is used as a substitution for fast turning off/on the lamps, instead of the human operators. This device is capable of turning off/on the lamps after sunset and before sunrise [6].

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These are several instances made in china, same as the above-mentioned device in the market. There is another example of these devices such as SLC-02-25-GSM-insuindia made in India. Starting hours of midnight the lighting lamps power are decreased by this device, thus saving energy will happen [7]. In Iran for example we can point out performing centralized lighting control project in North Khorasan. In this research project, turning off/on the street lights can be done by remote control systems, in addition to controlling by the operators. Performing this project, in a short period of time street lights can be turned off and turned on [8]. Smart street lighting control is another project has been done in an Iranian Company (Karizan Company). In this project, it is attempted to turn off/on the lamps by remote control system, GSM network and sending message [9].

III. HOLONIC MULTI AGENT SYSTEMS

A multi agent system consists of several intelligent entity called agents. These systems are used widely for the problems that centralized and integrated systems aren't capable of solving them. Since these systems have many capabilities such as being distributable, it is an efficient substitution for the classic methods in artificial intelligence. On the other hand, in some recent decades, since there are some more complicated and greater problems and consequently increasing the number of agents and interaction among them, it is difficult to solve the problems with the simple multi agent systems. In recent years, some solutions such as holonic multi agent systems have been proposed. For the first time a Hungarian philosopher used the word "holon" to introduce the regressive and self-similar structures in the social and biologic organization. The bases of the holonic structures are holons. The holon could consist of some sub holons and also be a part of a super holon. A tree structure which its members cooperate together to reach a complex goal, is made by these holons. The tree structure or holarchy has unique advantages in terms of stability and resistance to internal and external injuries and disorders. These structures are efficient in using sources and have a high adaptability against the environment changes. The idea of the holonic structures is a combination of top-down hierarchical structures and distributed control systems. In holonic multi agent systems, each holon could be a group of some intelligent agents or only consists of one agent. Since this structure is a regressive one, each holon is also considered as one agent and is shown by a representative agent called “head”. The head can be chosen among the agents in the holon or a new agent is made for this purpose as long as holon is alive. It states the intensions of the holon. The head (and only it) communicates with the outside of the holon and can negotiate with the agent’s in the holon environment. A view of the holarchy is shown in Fig. 2. There are some interesting discussions about the features of the agents such as autonomy, goals, communications and etc in holonic multi agent systems. The more concepts about holonic muti agent systems for further reading are in [2, 4, 5, 10].

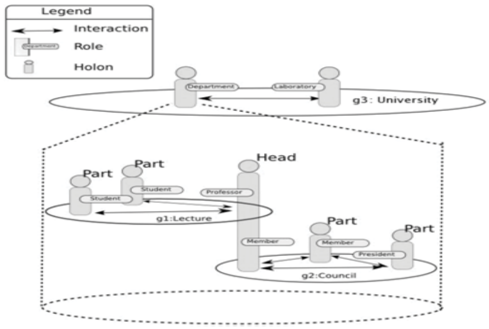

Figure 1. A view of holarchy structure in an education system

IV. SMART CONTROL OF STREET LIGHTING SYSYEM BY HOLONIC MULTI AGENT SYSTEM

In this paper we propose an architecture to control the street lighting using holonic multi agent systems and a simple learning for agents. We show that our approach can control the street lighting dynamically and efficiently in different conditions. In this approach learning agents are the main controllers installed in the streets. These controllers control the lighting of the street lamps. In the proposed approach holons are formed in two distinctive levels. Some of them are static and some ones change dynamically. This feature can cause increasing the flexibility and efficiency of the approach. In this method in the high level, a simple static structure according to the street geographical adjacency is chosen. In another word the studied area is divided in to some geographical holons. Each holon consists of some streets approximately situated in one geographical district. The streets of each holon in terms of some effective parameters such as peak hours and off- peak hours limit are somewhat similar. One example of geographical separation of Tehran districts is shown in Fig. 3. It can be used for holonification based on geographical districts. A responsible agent called “head” is considered for each geographical holon. The head of geographical holon calculate the time of turning on or off the street lamps of the holon in different seasons based on the Latitude and longitude of the district, climatic conditions and atmospheric brightness. Based on this calculation it sends the command of turning on/off the lamps to body agents in the holon. In the low level of the architecture, there are learner agents, simple inferring agents can be installed along with the traffic controller agents and use the information obtained by the traffic sensors installed in the streets. (Traffic controller agents for example can be installed in the junctions and use a kind of reinforcement learning for their operations). These inferring agents have a fuzzy inference engine consisting of some fuzzy rules based on the present state of the street lamps and the present traffic volume in the street. Table 1 shows the fuzzy rules of the inference engine. These controller agents in the low level of the architecture after receiving the turning-on command from the head in the geographical holon, start their learning and using the data received from camera sensors and based on inducing rules, control the lighting of the street lamps

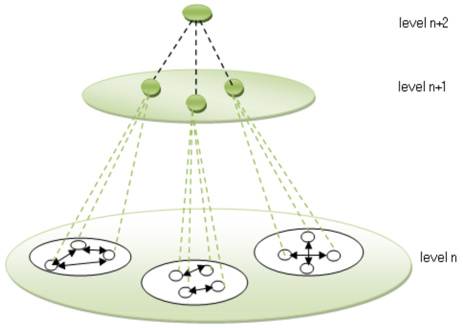

Figure 2. structure of a holonic system

appropriately. The heads of the geographical holons classifies the low-level learner agents into groups of “high” and “low” consumption and according to the streets adjacency and kind of their consumption form “high” and “low” consumption holons of the agents. This process happens every some minutes. So the consumption holons form dynamically for a period of time and after that according to the new situation, some holons may be distroyed or changed and also some new holons may be created. So a new arrangement of consumption holons will forms. The holonification of the streets in the low level of the structure is as follows:

The adjacent streets having the same consumption rate will be in one holon. Thus the head can supervise the consumption rate of holons and sometimes apply some additional necessary actions such as: increasing "low consumption" holons, stopping the dynamic changes of holons, alternatively turning off the lamps in high consumption holons in special and compulsive times. In this method if the traffic control system is also based on a holonic structure, this proposed holonic structure can be mounted on the traffic system. Thus simultaneously and efficiently the traffic and lighting system can be controlled by using a good holonic multi agent system and applying the learning methods in the different layers.

Fig. 4 shows an instance of forming high and low consumption holons in a geographical holon (geographical holon of district #1 in Tehran). In this picture, the districts with red lines represent high consumption holons and the districts with black lines represent low consumption holons. (The colorful dots in districts are just for showing the area). Fig. 5 also shows a general view of the proposed structure. Surely, this method will be more efficient and useful when it is used with a smart traffic control system, because the traffic volume is used as a parameter for controlling the lighting in this method. So a smart and efficient traffic control system can prevent from traffic jam and forming a lot of "high consumption" holons.

Table 1. Fuzzy rules

Lamps state	**Traffic Volume**	**Lighting level/ mode**
On	Low	Low / low consumption
On	high	High / high consumption
Off	-	-

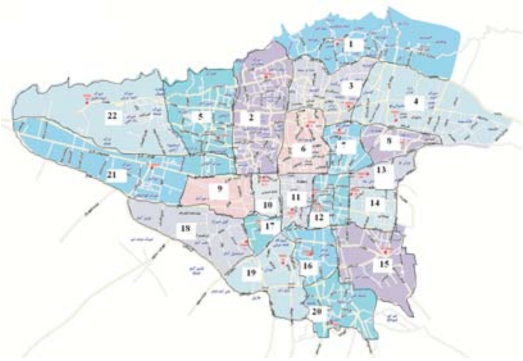

Figure 3. example of geographical separation of Tehran districts

V. Experimental Results

Simulator software Aimsun V6.1 and its AAPI environment for C++ programming are the tools have been used for implementing this method. This software is one of the good ones can be used to simulate the traffic networks. It has a lot of tools for designing, adjusting, simulating and controlling the traffic networks in different scales.

In this paper, the performance of this method is shown on a small traffic network consisting of 17 main two-way streets and 6 junctions. In this network junctions have 4 phases and the number of the signal lights; it is the number of phases. In this simulator, the entry traffic volume can be determined with two following methods:

1) origin and destination matrices
2) using "traffic State"

In this research, the second method is used for determining the traffic volume entering to the network. The simulation time is 10 hours and the interval of checking the traffic volume of the streets according to the streets length and network size is 30 minutes. In this network sodium 250 W lamps are used for the streets equipped with double-side poles installed in the middle of streets. Fig. 6 shows a view of the designed network in the software and some of the "low" and "high" consumption holons formed in the simulation time. In Fig. 6 the yellow districts with the red lines represent the high consumption holons and the blue districts represent the low consumption holons. Based on the results of the simulation, many streets can be in low consumption mode instead of high consumption mode in the simulation time and this can contribute to save the energy consumption significantly. The energy is consumed by a street lamp is computed in Watt Hour (Wh) as follows:

$$E = P \times t \qquad (1)$$

E is the consumed energy, P is the power in Watt and t is the time of energy consumption in hour. The energy consumed by the network in the simulation time while using the proposed method, is calculated as follows:
The consumed energy of street #1 is:

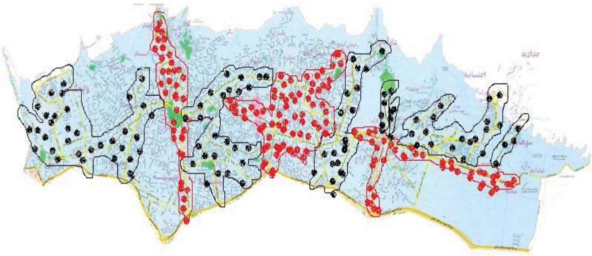

Figure 4. a sample of forming high and low consumption holons

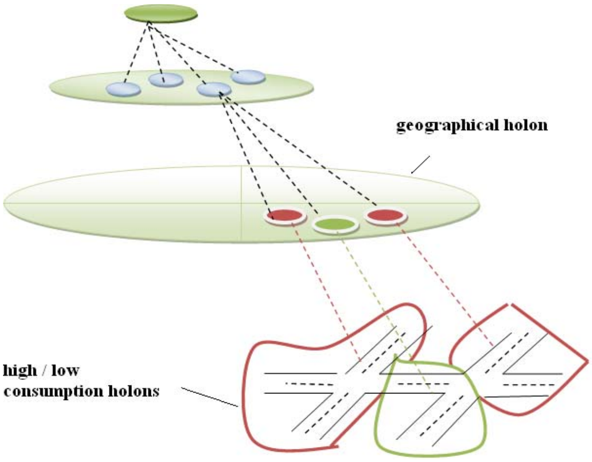

Figure 5. a general view of the proposed structure

Number of poles in this street: 20
Band #1: 20 * [10* 125] = 25 kWh
Band #2: 20 * [10 *250] = 50 kWh
25+50 = 75 kWh

The consumed energy of other streets also computed the same as the above example. The energy consumed by lighting system of the streets with the proposed method in 10-hour simulation is in table 2. The Fig. 7 shows a comparison of energy consumption of the streets in normal mode and when using the proposed structure. The diagram of Fig. 7 shows that using this method can cause a significant energy saving in the street lighting system.

VI. Conclusion and Future Works

Providing a solution for economizing the electrical energy in the street lighting systems can help significantly the energy saving in the country. The results of the implementing the proposed approach shows that performing this approach on the street lighting system and simultaneously controlling traffic will result in saving energy properly.

Since the proposed structure for smart lighting control is on the traffic volume of the streets, using a smart traffic control will result in saving more electrical energy. Some of the holonic structure characteristics are flexibility, dynamism and capability of hierarchically controlling and these characteristics make proposed approach more efficient.

Table 2. energy consumed by street lighting system

Street	Number of poles	Energy (kWh)
1	20	75
2	20	75
3	30	114.25
4	20	75
5	30	118.125
6	20	75
7	20	75
8	25	104. 6875
9	25	87.5
10	25	85.9375
11	20	75
12	20	75
13	30	75
14	20	75
15	30	75
16	20	75
17	20	75

Another advantage of this approach is giving a complete and a comprehensive design for creating a great flexible, interactive smart system. Some of the future projects are generalizing this smart control structure to all of thoroughfares such as alloys, parks and other places.

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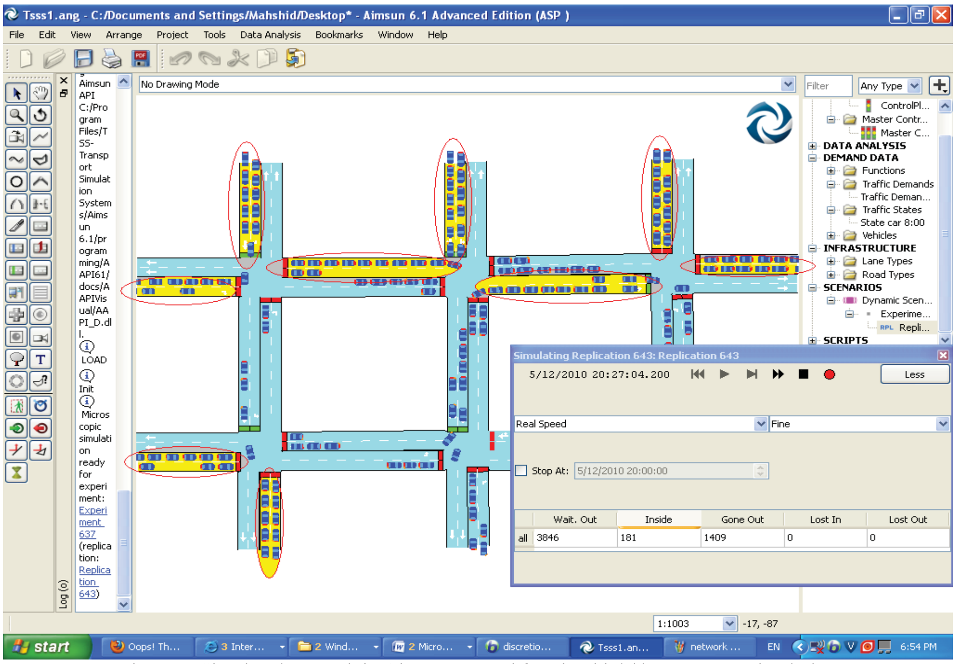

Figure 6. Simulated network in Aimsun 6.1 and forming high/ low consumption holon

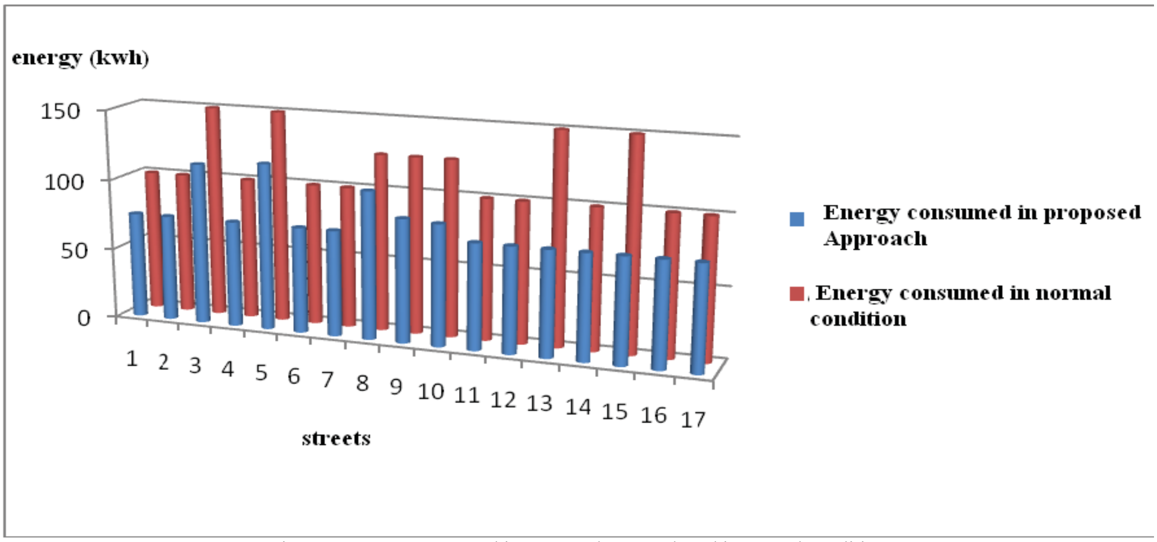

Figure 7. Energy consumed in proposed approach and in normal condition