AKILLI ŞEBELERDE GELECEĞİN AYDINLATMA KONTROLÜ İÇİN HESAPLAMA ARAÇLARININ KARŞILAŞTIRILMASI

COMPARISION OF COMPUTING TOOLS FOR CONTROL OF FUTURE ILLUMINATION IN SMART GRIDS

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ÖZETÇE

Gün geçtikçe artan çevresel duyarlık ile beraber elektronik ekipman fiyatlarındaki azalma, yakın gelecekte aydınlatma sistemleri işletiminin ve tasarımının da değişeceği beklentisini oluşturmuştur. Bu çalışmada, akıllı cadde aydınlatması kavramı üzerinde durulmuştur. Çevrim tablosuna göre girdileri ve çıktıları belirlenen Yapay Sinir Ağları ve Bulanık Mantık algoritmaları bir cadde aydınlatma kontrolörünün davranışı simüle edilerek karşılaştırılmıştır.

ABSTRACT

The design and operation of the street lights are expected to change in near future with the influence of reducing electronic component prices and increasing environmental consciousness. In this paper, networking intelligent street light (ISL) concept is discussed. The capabilities of look up table, neural networks and fuzzy logic are compared when they are used for a simulated street light controller. The look up table was the easiest to develop. The neural network smoothed the response curves and provided continuous transitions between the modes. The fuzzy logic allowed integration of many sensors more easily. However, evaluation and perfection of the responses when all the possible inputs were concerned were difficult.

Keywords*—Street light, neural network, fuzzy logic, solar cell, LED lights*

1. INTRODUCTION

The concept of smart grids aims efficiently deliver sustainable, economic and secure electricity supplies. A smart grid employs innovative products and services together with intelligent monitoring, control, communication, and self-healing technologies. One of the subjects of the smart grids is energy efficieny. Hence, improving of illumination lights control technology are also very important part of the energy efficiency on the utility networks.

The cost of the electronic components including lights, sensors, and solar cells have been drastically reduced in the last decade. The light emitting diodes (LED) with very small light output and very limited colors have transformed into powerful and economical illumination sources. Their light colors were adjusted to be acceptable at many applications. The immediate response characteristics of the LEDs allow design of simple electric circuits to adjust their light intensity continuously without wasting any power by using the pulse with modulation (PWM). In this paper, intelligent computational tools will be discussed for control of the intensity of LEDs.

Among the 150 W light sources the low-pressure sodium (LPS) provides the lowest cost per lumen and the shortest typical life among the popular street light sources with 20,000-40,000 hours [1,2]. The similar cost for the high pressure sodium (HPS) and Light Emitting Diodes (LED) are almost the twice of the LPS lights while the typical life increases to 50,000 hours. The same cost for the induction fluorescent (IFL) lights are slightly higher than LEDs but the operation life is the highest (100,000 hours). Based on the operation cost, typical life, and steep slope of the development curve of the LEDs, they may be used for street lights and they will position themselves much better in near future.

For reduction of the operating cost of street lights many researchers studied remote control of lights [3, 4], managing the conventional street lights as a network [5], dimming of high pressure sodium lights [6, 7], control of the lights with a timer and turning them on when the vehicles and pedestrians go through the streets [8, 9]. Recently, LEDs became an alternative light source for street lighting [10] and many studies have started for intelligently management of them and their integration with wireless sensor networks [11]. More advanced optimization algorithms and fuzzy logic have been used for traffic lights to optimize the operation [12, 13].The street lights at the isolated locations may be powered with solar cells [14, 15]. Solar powered street lights may be used even in the cities if the prices of solar cells come down further.

In the following sections, intelligent street light system will be briefly introduced. Three methods will be compared for the control of the light intensity of ISLs.

2. PROPOSED INTELLIGENT STREET LIGHT SYSTEM

The diagram of the proposed intelligent street light (ISL) network is shown in Figure 1. The system will have multiple ISLs which communicates with each other wirelessly. Each ISL will have a solar panel to generate its own power. The generated electricity will be saved at the battery during the daytime. At the night time, the controller of the ISL will monitor the available power at the battery, ambient light, moving vehicles and pedestrians. Photocell, infrared and range controlled PIR radar motion sensors will be used with this purpose. The controller will adjust the light intensity according to the available power and need.

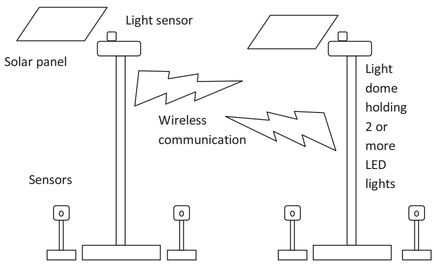

Figure1: The simplified diagram of the proposed intelligent street light (ISL) network.

3. THEORETICAL BACKGROUND

Artificial neural networks (ANN) were developed to simulate the operation of the brains of animals. Instead of the rule based decision making or using analytical models, massive networks are created by parallel connecting very simple neurons [16]. ANNs learn after or during a training session. Once the training is completed ANNs quickly map or classify the given cases.

There are many ANN methods. The Levenberg–Marquardt algorithm [17] was also used for calculation of the parameters of the ANNs [16]. In this study the Artificial Neural Network toolbox of the MATLAB was used for implementation of this algorithm. Fuzzy sets may be used to build more flexible control systems compared to the rule based approach [18]. In this study, the Fuzzy Logic toolbox of the MATLAB was used for implementation of the controller of an ISL. The integrated fuzzy logic development packages allows the designer to work with a visual interface to establish membership functions, to set up the rules and to evaluate the performance of the controller [19]. The same package may even prepare program and download it to the chips.

4. INTELLIGENT DECISION MAKING TOOLS

In this study three computational tools were selected for evaluation of the operating conditions and selecting the intensity of the LEDs. The first approach used look up table which defines need index according to operating conditions and light output. The look up table, the operating conditions and light intensity levels are presented in Table 1.

The second approach used the Levenberg-Marquardt type ANN of the MATLAB package. The matrix in the Table 1 was taught to the ANN. The output of the neural network is presented in the results section. The third approach used the Fuzzy Logic Toolbox of the MATLAB package. The rules of the fuzzy logic are presented in Fig.2.

Time	Condition	Need index	Available power level at the battery									
			10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Day	Any	1	0	0	0	0	0	0	0	0	0	0
Sunrise and sunset	Any	2	0	0	0	0	0	0	0	0	0	0
Twilight	Any	3	0	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Night	None	4	0	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Night	Heavy vehicle traffic	5	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Night	Bad weather & confusion	6	0	0	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Night	Heavy vehicle traffic and pedestrian	7	0	0	0	0.5	0.6	0.6	0.8	0.8	0.8	0.8
Night	Light vehicle	8	0	0	0	0.5	0.6	0.6	0.8	1	1	1
Night	Pedestrian	9	0.8	0.8	0.8	0.8	1	1	1	1	1	1
Night	Light vehicle and pedestrian	10	0.8	0.8	0.8	0.8	1	1	1	1	1	1

Table1: The need index at different operating conditions and power output.

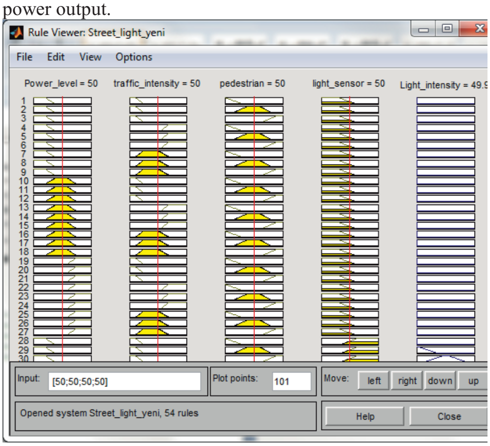

Figure2: The rules of the fuzzy logic.

5. RESULTS AND DISCUSSIONS

The performances of three methods were compared. The outputs of the look up table are presented in Fig.3. The development of the response matrix at different operating conditions was very easy and the results were very predictable. However, the outputs were not continuous.

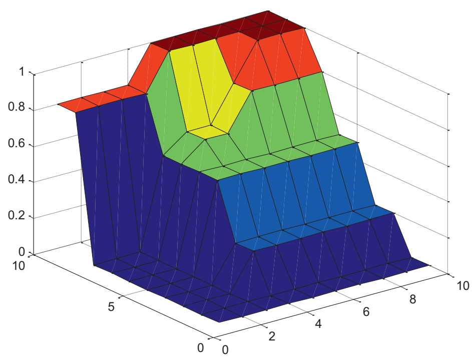

Figure3: The expected outputs with the look up table.

The Levenberg-Marquardt algorithm smoothed the expected outputs of the look up table when the values from the Table 1 were used for training of the ANN. Eight hidden nodes were used and accuracy of the estimations were acceptable. The performance of the neural network is presented in Fig.4 and Fig.5.

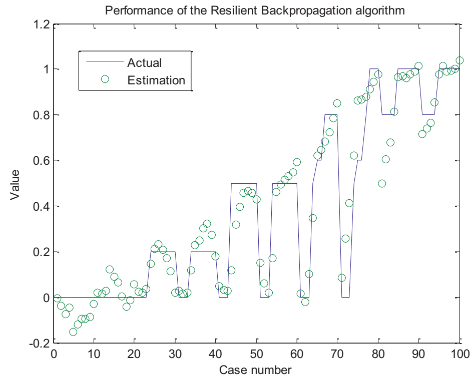

Figure4: Comparision of the training cases and neural network's estimation after the training.

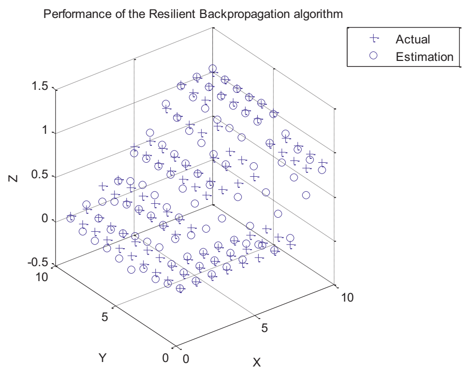

Figure5: The 3D visualization of the data presented in Fig.4.

The Fuzzy Logic Toolbox of the MATLAB allowed consideration of sensors and let the user to give the instructions by simply setting up the membership functions and establishing the rules. The surface plots between the two operating condition and light intensity levels are presented in Fig.6-8.

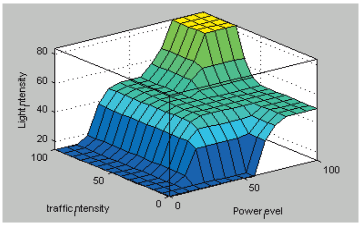

Figure6: The variation of light intensity according to trafic intensity and power level.

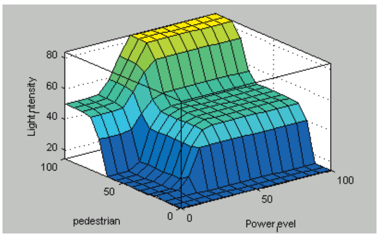

Figure7: The variation of light intensity according to pedestrian corossing and power level.

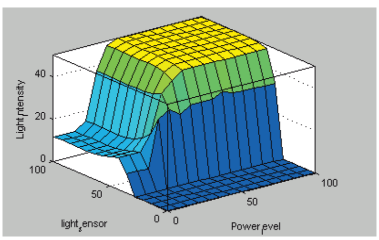

Figure8: The variation of light intensity according to light sensor reading and power level.

6. CONCLUSION

The capabilities of widely used three approaches were studied for control of the light intensity level of an intelligent street light (ISL). All the approaches were found feasible according to the needs.

The look up table approach was the easiest to design and implement as long of all the operating conditions are represented in a 2D table. When there are more than two inputs, multiple inputs should be represented at the single axis. The outputs are very predictable but the discrete.

The Levenberg-Marquardt algorithm of the MATLAB represented the 2D look up table very smoothly. It may accommodate more than 2 inputs; however, the number of training cases and hidden nodes should be increased exponentially and consistency of the outputs should be carefully inspected before using the system.

The fuzzy logic toolbox of the MATLAB was very convenient to make the initial setup and establishment of the initial rules. However, smoothening and improvement of the multi-dimensional response curves to achieve the desired light intensities at different operating conditions was very time consuming and required extensive user experience.

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