Academic Journal of Computing & Information Science
ISSN 2616-5775 Vol. 5, Issue 4: 35-40, DOI: 10.25236/AJCIS.2022.050406

Intelligent Street Light Control System Based on Fuzzy Control Technology

Pengjun Yan[1], Jingsong Wang[2]

[1]College of Information Science and Technology, Taiyuan University of Science and Technology, Taiyuan, Shanxi, 030024, China
[2]College of Mechanical and Electrical Engineering, Heilongjiang Institute of Technology, Harbin, Heilongjiang, 150000, China

Abstract: *Aiming at the problem of low intelligence and single control mode of traditional street lights in the city, which causes serious power waste, we design an intelligent street light control system based on fuzzy control technology, use fuzzy control algorithm to control the street light system, design the light fuzzy controller and vehicle speed fuzzy controller respectively, and conduct simulation experiments by Matlab software. The experiments show that the system has a good effect of saving electric energy, and to a certain extent, it improves the intelligence of street lights and saves management and maintenance costs.*

Keywords: *Intelligent Street Light System; Fuzzy Control Algorithm; Matlab Simulation; Energy Saving*

1. Introduction

With the development of society, urbanization is becoming faster and faster around the world, and at the same time, the problem of electrical energy consumption in cities is becoming more and more serious. The energy problem has now caused great concern worldwide [1] [2] [3]. Especially, the problem of electric energy scarcity is very serious. The shortage of electric energy in today's society, where electricity is indispensable everywhere, can cause great trouble to people's life. Urban street lighting is an indispensable and important part of a city and plays an important role in the traffic safety of the city. However, due to a large number of urban street lights, the wide still control mode of street lights in most cities is to use centralized timing power supply and timing power off. This management method has great limitations and can cause serious power waste problems. Therefore, it has become a hot topic to improve the existing street light control method and realize an energy-efficient street light control system based on ensuring the city lighting demand.

At present, some developed countries have made good progress in the intelligent control of street lights, Japan's Panasonic has developed an intelligent lighting and control system, basically intelligent control of lamps and lanterns. ABB of Germany has designed a centralized switch control system for street lighting based on the I-BUS bus. But most of these control systems are only in the street light control of the transmission method of transformation, in the specific control scheme, is far from the degree of intelligence. Fuzzy control technology has been widely developed after L.A. Zadeh formally proposed fuzzy set theory in 1965 [4]. In the last decade of development, many scholars have conducted research in this area because fuzzy control does not require an exact mathematical model and allows nonlinear control [5]. Currently, fuzzy control has a more complete theoretical system. Since the lighting requirements of urban streetlights are often influenced by various environmental factors, such as the light intensity of the environment, pedestrians, vehicles, etc., and these influencing factors cannot be precisely modeled mathematically, fuzzy control technology is very suitable for application in the field of streetlight control. In this paper, we design an intelligent street light control system based on fuzzy control technology, which makes the automation and energy saving of street light control greatly improved.

2. Overall System Design

The demand for an intelligent street light control system is mainly analyzed from two aspects: First, from the degree of intelligence, we need to solve the problem that traditional street lights cannot be turned on in time in different seasons or special weather. Therefore, the intelligent street light system needs to be able to realize the intelligent adjustment of street light brightness according to the current

ISSN 2616-5775 Vol. 5, Issue 4: 35-40, DOI: 10.25236/AJCIS.2022.050406

environmental light condition, to ensure that the street light can be adjusted in time to switch on and off under different weather conditions. Second, from the perspective of energy saving, most of the traditional street lights are still high-pressure sodium lamps, high-pressure sodium lamps have a short life and low reflector efficiency, there is a serious waste of problems, at the same time when the street lights are turned on, high-pressure sodium lamps need a certain start time, which not only causes a waste of electricity, but also affects the intelligent response time of street lights, and traditional street lights often take the strategy of timing the lights on and off, in the pedestrians and vehicles are few in the latter half of the night, the street lights can be turned on and off. Therefore, on the one hand, we need to choose a more energy-efficient and correspondingly rapid street light source, on the other hand, the intelligent street light system needs to be able to identify the passing pedestrians and vehicles, and automatically reduce the brightness of the street light when there are no pedestrians and vehicles in the current environment.

For the above requirements, in the selection of street light fixtures, we can choose LED street lights, LED street lights are powered by DC, which can respond faster when starting, and there is no problem of needing start time, meanwhile, LED has rich colors and good weather resistance. In terms of energy consumption, LED street lights also show great advantages, and the comparison of energy consumption between high-pressure sodium lamps and LED lamps are shown in Table 1 [6].

Table 1: Energy Consumption of LED and HPS (high-pressure sodium lamps)

Light Source	Rated Power(W)	Power Consumption(kW h)/day
LED	400	5.6
HPS	150	2.1

The composition of the intelligent street light control system designed in this paper is shown in Figure 2. Overall, it can be divided into the information acquisition layer, control layer, and algorithm layer. The data layer mainly consists of various sensors to collect various environmental information, which will be used as input parameters for the algorithm layer, and the intelligent control algorithm will output the predicted street light control parameters, which will be passed down to the control layer to control the street light.

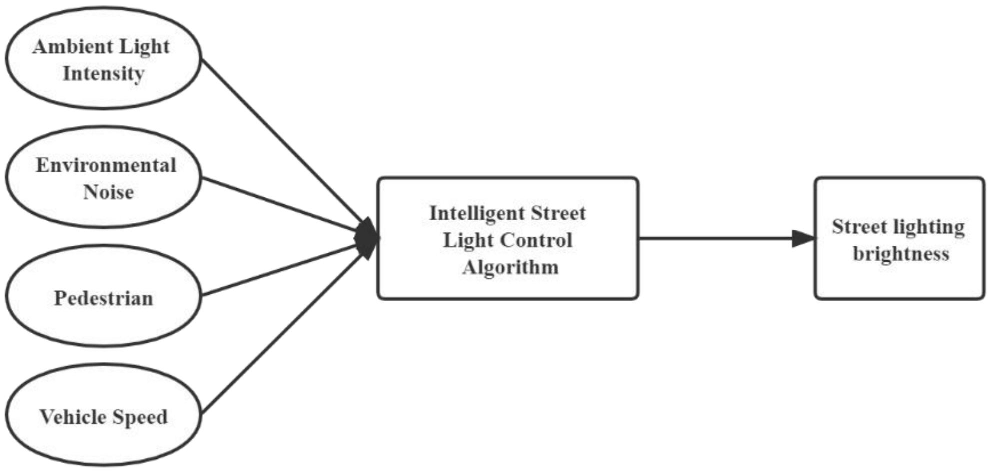

Figure 1: Intelligent Street light control system architecture diagram

3. System Design Details

3.1. System Software Design

The workflow of the intelligent street light control system designed in this paper is shown in Figure 2.

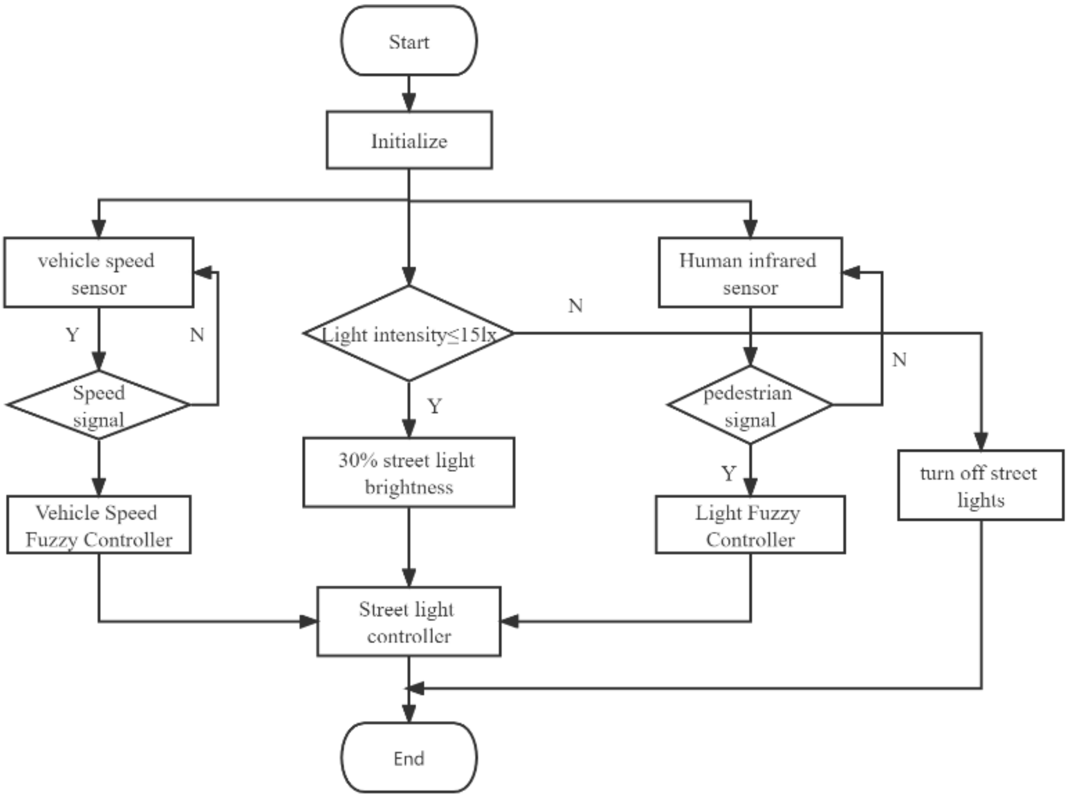

Figure 2: Intelligent Street light energy-saving control system workflow diagram

After initialization of the system each module enters into a normal working state, the light sensor will detect the current ambient light intensity in real-time. When the ambient light intensity decreases to 15lx, the street light will be turned on and the brightness of the street light will be adjusted to 30% of the rated brightness by pulse width modulation. Meanwhile, the vehicle speed sensor and human infrared sensor will continuously detect pedestrian and vehicle speed information. As the speed of different vehicles is different, when the vehicle speed is slow, the continuous high brightness time of the street light should be longer when passing by the street light, and when the vehicle speed is fast, the continuous high brightness time of the street light should become shorter, so the speed fuzzy controller will project the continuous working time of the street light with rated brightness in front of the vehicle according to the vehicle speed information so that the vehicles with different vehicle speeds can get the best driving view when passing by. When a pedestrian passes by, the human infrared sensor sends a signal to the light fuzzy controller, and the fuzzy control algorithm will project the appropriate street light brightness based on the current ambient light and noise situation and pass it to the street light controller for downward control.

3.2. Control Algorithm Design

3.2.1. Illumination Fuzzy Controller

The ambient light intensity received by the light sensor and the ambient noise received by the noise sensor is used as the outputs of the light fuzzy controller. The range of light intensity L is set to $\{0 \leq L \leq 30\}$ and fuzzified into five fuzzy subsets {lower, low, medium, high, higher}, and the range of noise N is set to $\{0 \leq N \leq 100\}$ and fuzzified into five fuzzy subsets {lower, low, medium, high, higher}. The output variable of the illumination fuzzy controller is defined as the duty cycle P of the effective level when the LED brightness is adjusted by pulse width modulation, and the range of the duty cycle is [0 1000] because the street light is at the lowest brightness when the duty cycle is 300, so the range of the output variable P is set to $\{300 \leq P \leq 1000\}$ and fuzzified as {lower, low, medium, high, higher}. Using the fuzzy logic box provided in the Matlab toolbox for testing, a new Mamdani-type fuzzy inference system is created by selecting the triangle as the membership function. Figures 3(a), (b), and (c) show the membership functions of ambient light intensity, ambient noise, and output duty cycle, respectively.

ISSN 2616-5775 Vol. 5, Issue 4: 35-40, DOI: 10.25236/AJCIS.2022.050406

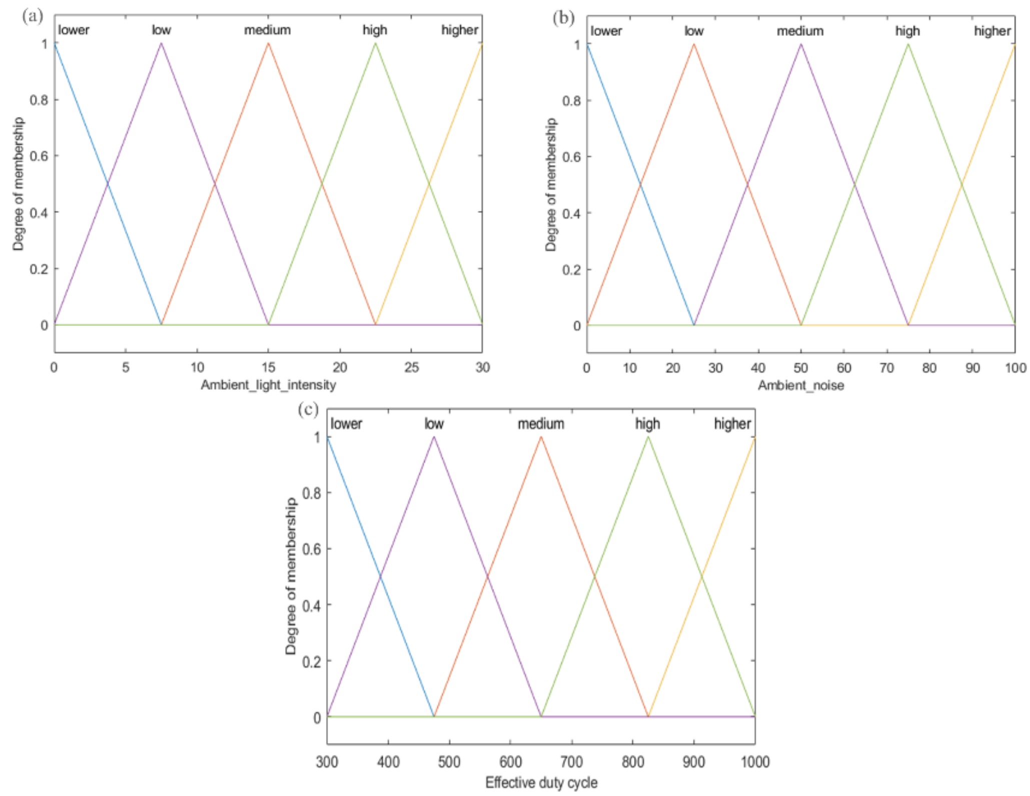

Figure 3: (a) membership function of ambient light intensity. (b) membership function of ambient noise. (c) Affiliation function of output duty cycle.

3.2.2. Vehicle Speed Fuzzy Controller

According to the regulations of vehicle speed on urban roads, the speed should be 30 km/h on roads without a road centerline, and 50 km/h on roads with only one motorway in the same direction, so the range of input speed V of the speed fuzzy controller is set to $\{0 \leq V \leq 50\}$, and the range of output variable street light continuous high light time T is set to $\{0 \leq T \leq 15\}$, both The output variable T is set to $\{0 \leq T \leq 15\}$, which is fuzzified into three subsets {low, medium, high}, and the same triangle is chosen as the affiliation function to create a new Mamdani-type fuzzy inference system. Figure 4(a) and (b) show the membership functions of vehicle speed and highlight duration, respectively.

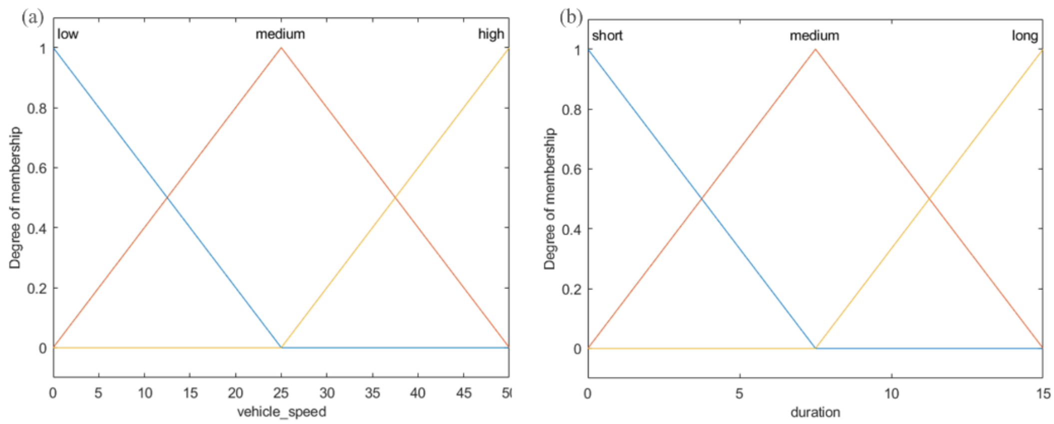

Figure 4: (a) The membership function of vehicle speed. (b) The membership function of highlighting duration.

4. Algorithm Simulation and Effect Analysis

The algorithm simulation is verified using the fuzzy logic toolbox in Matlab software. In the algorithm editing tool of Matlab fuzzy logic toolbox, the relationship between each variable can be seen

ISSN 2616-5775 Vol. 5, Issue 4: 35-40, DOI: 10.25236/AJCIS.2022.050406

by visualizing it by clicking on View Surface. For example, Figure 5 (a) and (b) show the relationship between input variables and output variables of the light fuzzy controller and vehicle speed fuzzy controller, respectively.

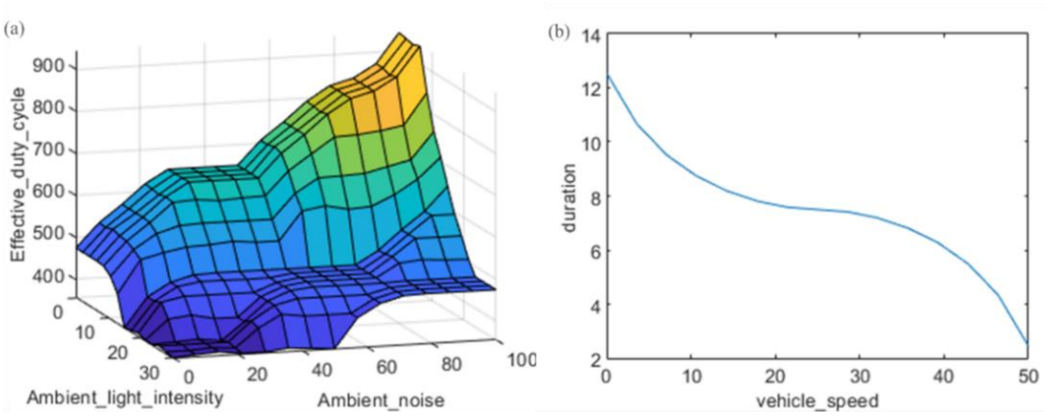

Figure 5: (a) The relationship between the input and output variables of the illumination fuzzy controller. (b) The relationship between input and output variables of vehicle speed fuzzy controller.

Figure 5(a) shows that when the human infrared sensor detects pedestrians, the ambient light intensity and noise are inversely proportional to the effective level duty cycle of the light fuzzy controller output as a whole, which is consistent with our overall requirements, when the light intensity of the target area is lower, the brighter the street light is, the greater the noise is thought to be the more pedestrians passing by, and at this time, to ensure road safety, the street light should also be brighter. Figure 5(b) shows that the speed of the vehicle and the continuous high light time of the street light also shows an inverse proportional relationship, when the speed of the vehicle, passing through the street light time is short, the required high light time is short, the speed of the vehicle, passing through the street light time is slow, the required high light duration of the street light is longer. This is also consistent with our original design intention.

5. Conclusion

Street light is an important part of the city, and it plays an important role in the traffic safety of the city, but the existing street light control system can cause a lot of power waste problems. Therefore, this paper designs an intelligent street light control system based on a fuzzy control algorithm, and after simulation verification, it shows that the system not only plays a strong energy-saving effect but also the control mode of street light becomes more intelligent and more reasonable. There is still a lot of room for development in the field of intelligent street lighting, and the scheme proposed in this paper will put forward a new development direction for street lighting control.

References

[1] Elvidge C D, Baugh K E, Kihn E A, et al. Relation between satellite observed visible-near infrared emissions, population, economic activity and electric power consumption [J]. International Journal of Remote Sensing, 1997, 18(6): 1373-1379.

[2] Lisin E, Shuvalova D, Volkova I, et al. Sustainable development of regional power systems and the consumption of electric energy [J]. Sustainability, 2018, 10(4): 1111.

[3] Shi K, Yu B, Huang Y, et al. Evaluating the ability of NPP-VIIRS nighttime light data to estimate the gross domestic product and the electric power consumption of China at multiple scales: A comparison with DMSP-OLS data [J]. Remote Sensing, 2014, 6(2): 1705-1724.

[4] Zadeh L A. Fuzzy sets as a basis for a theory of possibility [J]. Fuzzy sets and systems, 1978, 1(1): 3-28.

[5] Precup R E, Hellendoorn H. A survey on industrial applications of fuzzy control [J]. Computers in industry, 2011, 62(3): 213-226.

[6] Dinglin Ban. Research on Energy Saving Control System of Intelligent Street Lamp Based on Neural Network [D]. School of Automation Engineering, 2019.

[7] Ai M, Wang P, Ma W. Research and application of smart streetlamp based on fuzzy control method [J]. Procedia Computer Science, 2021, 183: 341-348.

ISSN 2616-5775 Vol. 5, Issue 4: 35-40, DOI: 10.25236/AJCIS.2022.050406

[8] Zeng J, Ni W, Zhang R, et al. Intelligent Street Lamp Control System with Dynamic Light Control Function [C] //2018 17th International Symposium on Distributed Computing and Applications for Business Engineering and Science (DCABES). IEEE, 2018: 181-183.
[9] He J, Zhu Z, Wang F, et al. Illumination control of intelligent street lamps based on the fuzzy decision [C] //2019 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS). IEEE, 2019: 513-516.