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Development of Fuzzy Controller of Intelligent Traffic Light Based on BP Neutral Network

Wu Lurong[1*], Jing Lin[1], Wu Bizhi[1] and Wu Qidi[2]

[1]*Computer and Information College, Fujian Agriculture and Forestry University, Fuzhou, China*
[2]*Jinshan College, Fujian Agriculture and Forestry University, Fuzhou, China*
**wulurong1@sina.com*

Abstract

Through researching the traffic flow regularity of single intersection, this paper puts forward an intelligent traffic light (design) method based on BP neutral network principle and fuzzy control theory, in which the variable parameter is the dynamic change of traffic flow. The traffic light control system based on the neutral network fuzzy control technology breaks through the traditional mechanical timing pattern and general control mode. According to the real-time traffic flow, this technology can operate flexibly, and it has "Associative Memory" function when it realizes the fuzzy inference by neutral network .Thus it can meet the emergency of single transformation under any circumstance and then reach the optimum delay time of green light. The simulation result by MATLAB shows that the neutral network fuzzy control technology is superior to general fuzzy control method, which greatly improves the traffic utilization and brings the obvious economic benefit.

Keywords: *single intersection, fuzzy control, intelligent traffic light, BP neutral network, simulation*

1. Introduction

With the rapid development of automobile industry, more and more automobile industry sets foot in the intelligence field, and applies the advanced information technology to automobiles and their control. The relative statistics, in the recent five years, manifests that over 90% innovation in the field of automobile industry is closely related to automobile intellectualization that is a trend of the development of automobile[1].Automobile intellectualization is identified as a revolution in the progress of the development of automobile technology and an effective method to grasp future automobile market. Although automobile intellectualization technology has already reached a relatively mature period, the administration of road cannot be reformed temporarily, however, the overcrowding become a serious problem increasingly, and intersection of the highway is inclined to be crowded, which the vehicles in the same direction become a long queues. Traffic jam for 4-5 hours is the common phenomena in metropolis such as Shanghai, Beijing and Shenzhen. So that, here comes all kinds of thoughts of high-technology systems of Intelligence, Fuzzy, Automation to resolve the traffic jams.

At present, in our country, the traffic light controls in most cities' crossroads are still use the control system of switching time interval fixedly. With randomness, fuzziness and uncertainty, an intelligent traffic control system is complicated. It is difficult and incomplete to reflect the changes of real single intersection just by a mathematic model. However, using intelligent theory, fuzzy control theory and computerized neutral network system can build a

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relatively real model. Thus, it can reduce the delay time and the parking times in intersections, and control precisely the traffic flow with nonlinearity, randomness and uncertainty, improving the passing efficiency in intersections. According to the traffic situation in China and the length of the lines of waiting vehicles in crossroads, we get some real data. Based on intelligent theory, fuzzy control theory and computerized simulation, an automatic multiphase intelligent traffic control system can be built. Compared with the induction and timing control, an effective control system has been built [2].

2. Analysis of Intelligent Traffic Signal Control

The delay time of traffic light in single intersection is decided by traffic flow in different intersections. Figure1 is a structure chart of traffic flow in single intersection. There are 4 directions of three-line intersection. People on the road can choose 3 kinds of directions include left, right and straight. In 4 directions, the traffic flow turned right are only in conflicted with the sidewalks, and are not in conflicted with other traffic flow. We can ignore the time in the intersection when separate the stream of people from the bicycle flow[3].So we put the traffic flow turned right into the design of traffic light in sidewalks. Considering the influence of delay time of traffic light in intersection because of the number of waiting traffic flow during the red light, and the passed traffic flow during the green light, we format corresponding rules of fuzzy control, and structure fuzzy controller in intersection, to control the delay time of traffic light in single intersection.

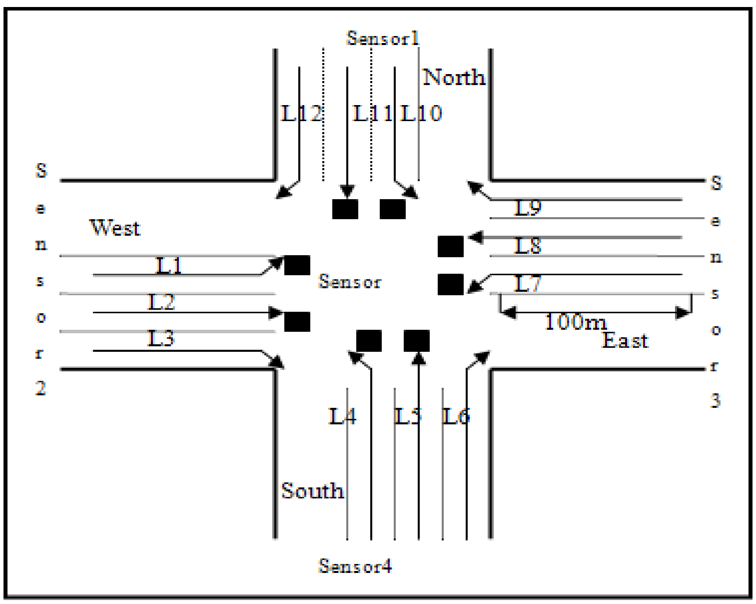

Figure 1. Single Intersection Traffic Flow Chart

The structure chart of traffic flow in single intersection indicates the influence of delay time of traffic light in intersection because of the number of waiting traffic flow during the red light, and the passed traffic flow during the green light. In reality, traffic flow is random in the stages of high peak and low peak. Figure 2 is the structure chart of overall feedback of traffic light control. In terms of it, fuzzy control of traffic light can finish intelligent feedback in different stages so that shorten the waiting time of traffic jam.

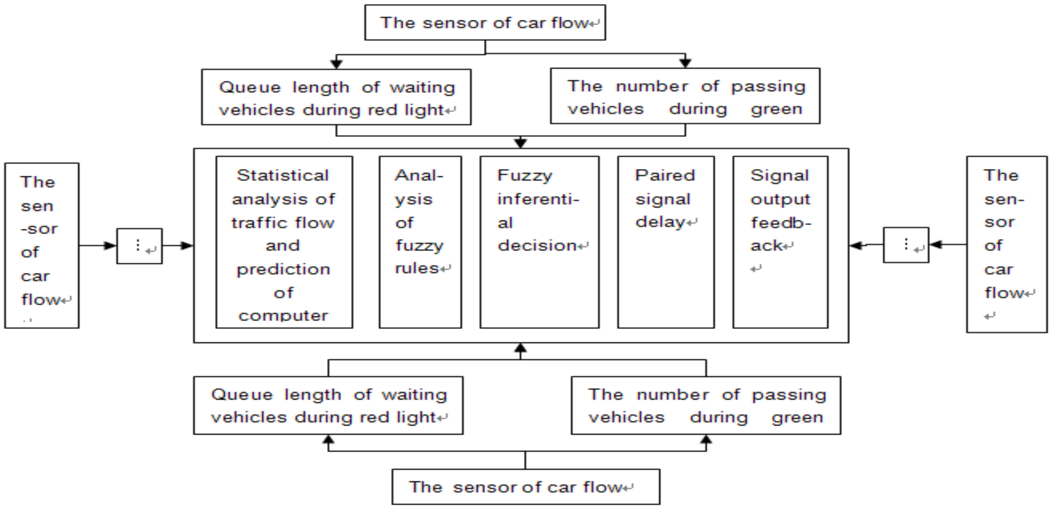

Figure 2. Flow Chart of Overall Control Feedback of Traffic Light

3. Model Design of Intelligent Traffic Light Control

3.1. Analysis of Traffic Flow Phase and the Length of Queue

In order to meet the need of delay time with intelligence and automation randomly under different circumstances, about past traffic light control system, it was generally ignored to considerate the changes of phase and the control of changes of 4 phases' period. Figure 3 is 12 phases traffic chart. In this text, the improved control method of 12 phases in random order is used: according to the statistics and analysis of traffic flow, we can find the performance phase in the next moment through fuzzy control.

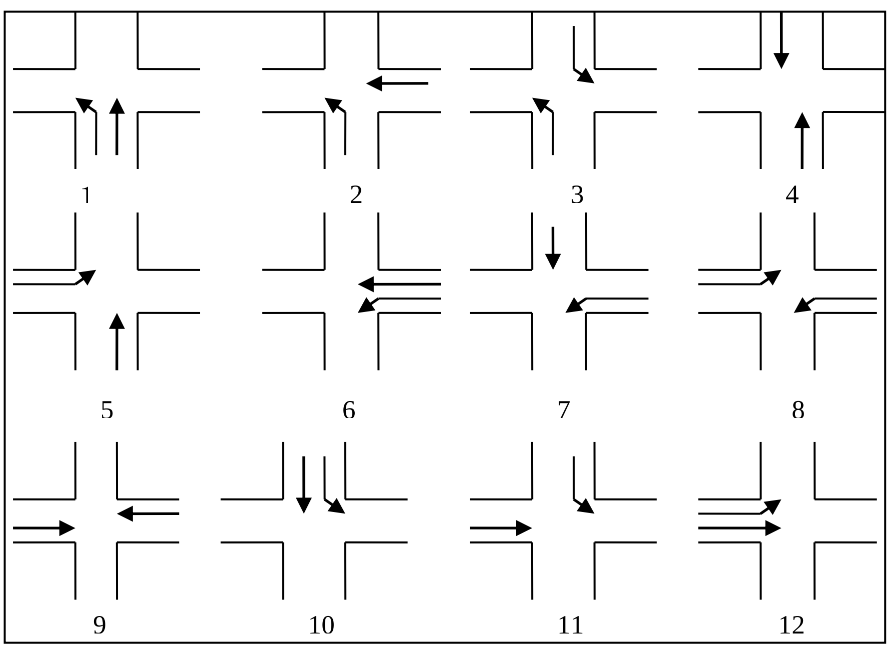

Figure 3. Traffic Chart of 12 Phases

In the Figure1, $Li,(i=1,\cdots 8)$ manifests the length of traffic flow in different lanes at present. We count the largest length available for passing at present as the traffic length; the largest length available for passing of two traffic flow in phases in the next moment, waiting time. According to the traffic chart of 12 phases, we can find the values of length of passing traffic flow and length of waiting traffic flow [4-5].

Table 1. Length of Passing/ Waiting Traffic Flow 12 Phases

Phase value	Passing traffic flow	Waiting traffic flow
1	Max（L8+L7）	Max（L1+L2+L3+L4+L5+L6）
2	Max（L8+L5）	Max（L1+L2+L3+L4+L6+L7）
3	Max（L8+L4）	Max（L1+L2+L3+L5+L6+L7）
4	Max（L7+L3）	Max（L1+L2+L4+L5+L6+L8）
5	Max（L7+L2）	Max（L1+L3+L4+L5+L6+L8）
6	Max（L6+L5）	Max（L1+L2+L3+L4+L7+L8）
7	Max（L6+L3）	Max（L1+L2+L4+L5+L7+L8）
8	Max（L6+L2）	Max（L1+L3+L4+L5+L7+L8）
9	Max（L5+L1）	Max（L2+L3+L4+L6+L7+L8）
10	Max（L4+L3）	Max（L1+L2+L5+L6+L7+L8）
11	Max（L4+L1）	Max（L2+L3+L5+L6+L7+L8）
12	Max（L2+L1）	Max（L3+L4+L5+L6+L7+L8）

3.2 Rules of Fuzzy Control of Delay Time of Traffic Light and Their Quantization

The theory of fuzzy control can transfer the strategy of fuzzy control described by natural language to the rules of fuzzy control. Through which we can achieve the goal of fuzzy control. The fuzzy controlled value includes 3 parts: obfuscation, rules of fuzzy control and clarification.

The input value in the fuzzy control is the decision based on the consideration of length of the present phase and the length of traffic flow of the next phase. In which the length can be divided into the length of passing traffic flow and the length of waiting traffic flow. The output value is the delay time T in green light stage. So we obscure the input value and the output value. Then we get the basic field of the length of passing traffic flow ｛3,6,9,12,15,18,21,24,27,30,33,36,39,42,45,48,51,54,57,60｝,the basic field of the length of waiting traffic flow ｛9,18,27,36,45,54,63,72,81,90,99,108,117,126,135, 144,153,162,171,180｝,the basic field of the delay time of green light stage ｛0,5,10,15,20,25,30,35,40｝.The corresponding fuzzy subset of the input value and the output value：{NB(few),NS(a few),ZE(some),PS(many),PB(a great many)}[6].

And then we get the Table 2. Rules of fuzzy control of delay time as follow.

Table 2. Rules of Fuzzy Control of Delay Time

T / L	NB	NS	ZE	PS	PB
NB	NB	NB	NB	NB	NB
NS	NS	NB	NB	NB	NB
ZE	ZE	NS	NS	NB	NB
PS	PS	ZE	ZE	NS	NB
PB	PB	PS	ZE	ZE	ZE

3.3. Self-feedback of Algorithm of Traffic Light Control of BP Neutral Network

We can find that the decision based on input value and output value of the present phase of passing traffic flow and the conclusion of the fuzzy field and the fuzzy subset are consistent. This text analyses the topological structure based on the self-feedback of BP neutral network. The topological structure as following Figure 4:

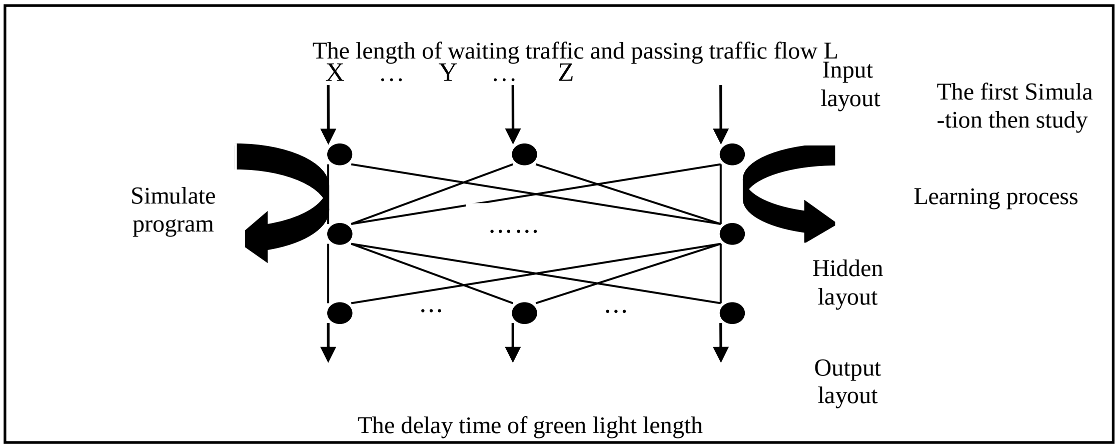

Figure 4. Topological Structure of BP Neutral Network based on the Theory of Fuzzy Control

Achieve the model training of neutral network, combining PLC hardware circuit, and the control system under the cross-platform [7].Algorithm steps of the process of achieving control as follows:

(1) Choose phase i in the Picture 3 randomly and analyze. Counting the maximum delay time of green light stage in the appointed phases, $T_{i\ \max}$.

(2) Count and analyze a certain single intersection, put the value into the minimum time of green light in the present phase i, $T_i = c$ (constant).

(3) During the fixed passing time c, if the quantity of the passing traffic flow in the lanes meets the relative traffic demand, set the traffic physical quantity as s_i.

(4) If s_i less than a certain value k or accumulated time of green light $T_i = T_{i\ \max}$, turn the green light into next phase. Put it into Step (2) and recount it. Otherwise, go on count it.

(5) Under the circumstance that the above conditions are met, the flag value s_i defines the next delay time c of green light. If s_i is small, delay time of green light should be adjusted slightly; If s_i is large, delay time of green light should be adjusted drastically. Thus, structure and adjust the criteria of fuzzy control. When delay time of green light is $T_i + c \geq T_{i\ \max}$, make $c = T_{i\ \max} - T_i$;otherwise the delay time of green light in the phase $c + T_i$, and turn it into Step (3) to count.

According to above algorithm process, we can input fuzzy subset in which the value is length of traffic flow. Make it as $x_1 \sim x_{21}$;the value of output, the length of delay time of green light $y_1 \sim y_9$.Trained with the samples relay on rules of fuzzy control, BP neutral network system begin to has the memory of rules of fuzzy control and the function of associative memory. We divide neutral network into 3 layers of topological structure. As shown in the Picture 5, we can find that there are 21 nodes in input layer, 22 nodes in hidden layer (interlayer) and 9 nodes in output layer.

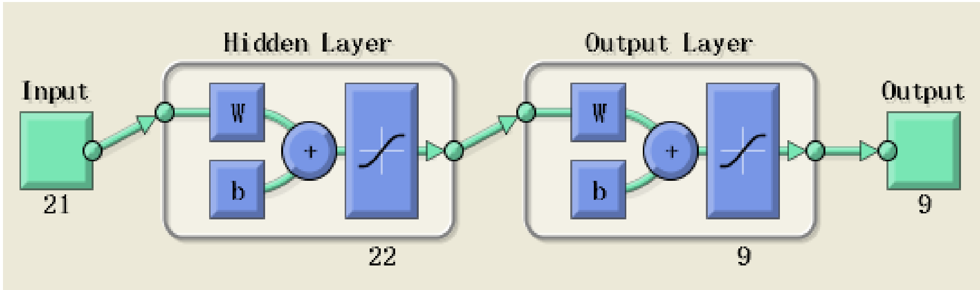

Figure 5. 3 Layers of Topological Structure of BP Neutral Network

4. Experimental Simulation

Analyzed and structured theoretically the fuzzy neutral network of traffic light, with consideration of traffic flow, we build a reference library based on rules of fuzzy control. Unite BP neutral network with fuzzy control in MATLAB, with the aid of programming toolbox GUI of MATLAB, we can get the membership function of the length of traffic flow based on real data and the membership function of the delay time of green light. The corresponding membership function image has been drawn as following Figure 6 and Figure 7.

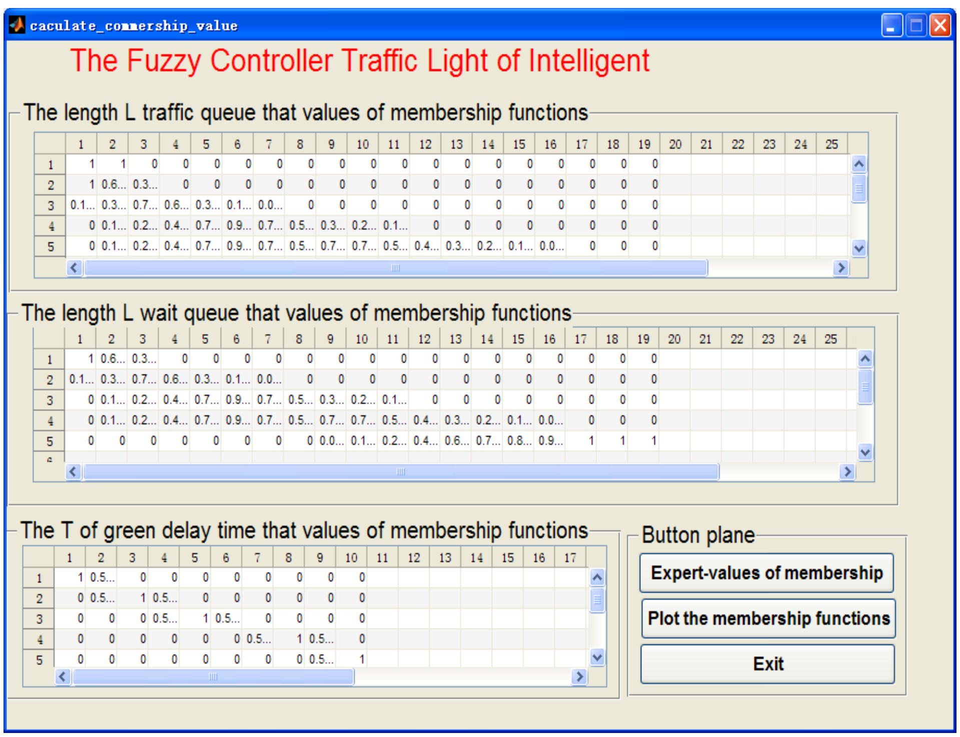

Figure 6. Values of Membership Functions of the Length of Traffic Flow and the Delay Time of Green Light

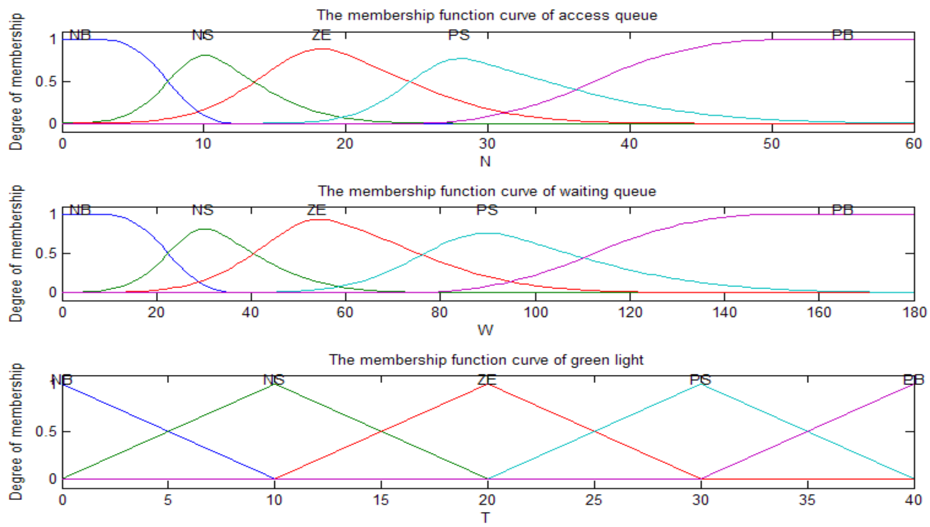

Figure 7. Chart of Membership Functions of the Length of Traffic Flow and the Delay Time of Green Light

According to 3 layers of topological structure of BP neutral network and the network structure of Picture 5, we can find that there are 21 nodes in input layer, 22 nodes in hidden layer. For hidden layer, we use tansig as transfer function of neuron traffic. Training grammar: net = newff (minmax (p),[22,9],{'tansig', 'logsig'},'traffic'). Through MATLAB, debugging constantly the performance of control system [8], we get find the maximum error is not more than 0.12 in BP network. The performance is controllable, namely its convergence is good. Through general fuzzy control and BP neutral network fuzzy control, at the beginning, the each quantity of traffic flow in all different lanes has been random generated by random function in MATLAB. If the speed of each departing vehicle is one second per vehicle, the quantity of coming traffic flow in each lane by half hour has been generated by random function [9], Figure 8 Network training convergent graph, Figure 9 Comparison chart of general fuzzy control and BP neutral network fuzzy control as follow.

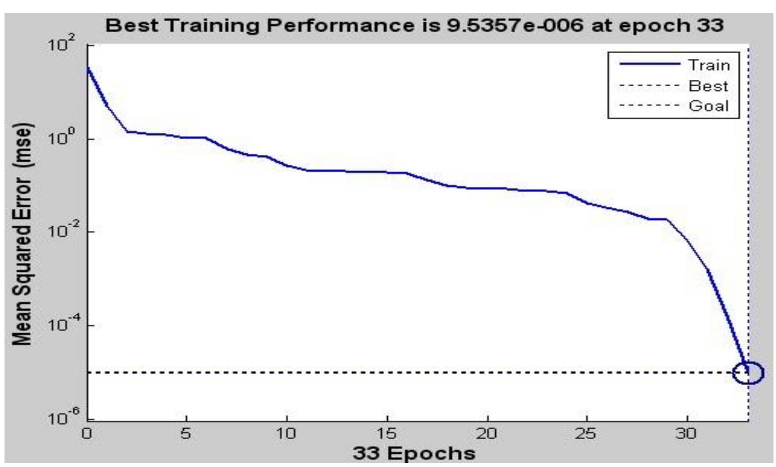

Figure 8. Network Training Convergent Graph

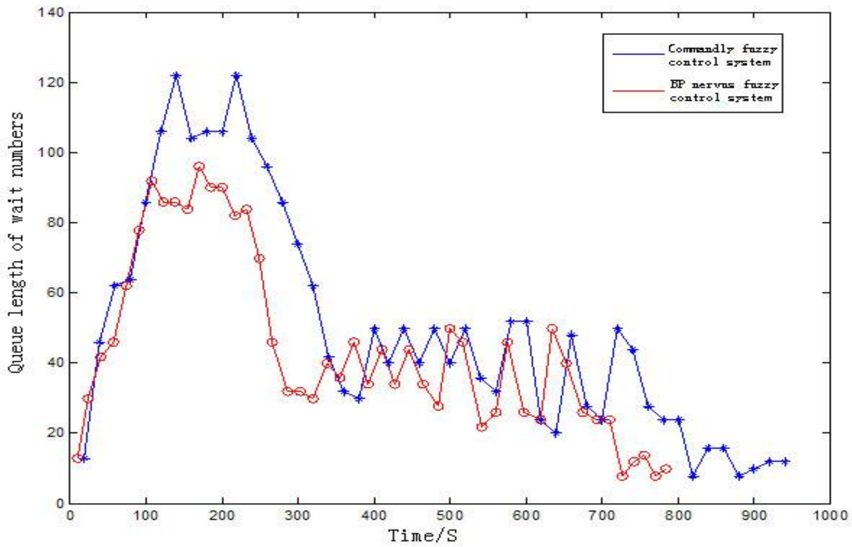

Figure 9. Comparison of General Fuzzy Control and BP Neutral Network Fuzzy Control

Above simulate analysis indicate general sensing fuzzy control is inferior to BP neutral network fuzzy control when input traffic flow is bigger or smaller than output traffic flow.

In addition, we use Monte Carlo method in combination with MATLAB to carry out simulation data, in order to reflect the uncertainty and mathematical regularity of traffic flow. We find that BP neutral network traffic light fuzzy control is superior to general sensing fuzzy control [10].

Simulation of traffic flow is based on on-the-spot and long-time statistical traffic flow volume, MATLAB simulation and Poisson distribution rule, generating a large amount of simulation data. In MATLAB, we can use the function of POISSFIT (X) to obtain the sample X, and calculate the point estimate of parameter λ in Poisson distribution, thereby calculating the Poisson parameter estimation function. We can use [LAMBDAHAT, LAMBDACI] = POISSFIT(X,ALPHA) to get the value of sample X. Calculate the parameter point estimate of Poisson distribution LAMDA and its confidence coefficient and we get interval estimation 100(1-ALPHA). Use the sample data to replace X in matrix form and we get the sample value of ALPHA and then use the formula R=POISSRND (LAMBDA, M, N) to get Poisson distribution lamda=LAMDA and random number matrix of line M and row N. Generally, the M in random number matrix is set as 1, then in the process of determine N, a certain amount of random number can be simulated. Here we set N as 10000, that is, there will be a random number of 10000 vehicles passing through the intersection.

Table 3. Monte Carlo Simulation Results

The last N second of green light	General sensing traffic light fuzzy control		BP neutral network traffic light fuzzy control	
	Number of stopping vehicles	Average vehicle stopping time	Number of stopping vehicles	Average vehicle stopping time
1	1086	189.3	924	147.4
2	919	148.4	813	129.5
3	853	125.4	787	108.7
4	732	109.6	642	106.3
5	658	94.7	532	84.4
6	692	95.2	586	93.5
7	774	112.1	667	90
8	832	123.2	795	109.8
9	982	152.8	960	134.6
10	1053	186.3	1024	162.4

According to the above simulation analysis, it is evident that no matter the input flow and output flow are known/certain or unknown/random, general sensing fuzzy control is inferior to BP neutral network traffic light fuzzy control.

5. Conclusion

It is feasible for traffic control in single intersection that the method of fuzzy mathematic and neutral network to structure intelligent fuzzy delayed controller of traffic light. The project about the intelligent controller of traffic light, given by this text, is relatively efficient. Furthermore, with function of memory and emulate, strict dependence and traffic regularity, the controller get rid of the limitation of time, district or weather is universally practical.

Whether traffic high peak or low peak, the advantage of veracity and intelligent memory and emulate of BP neutral network fuzzy control reflect in the period of complicated, traffic situation in intersections. Under the unbalanced circumstance of traffic flow in different directions in the same phase, the waiting time may not be delayed in other phases. It is the advantage of this project, with which the delay time may not be lengthened. The traffic light in single intersection being analyze in the text, the design of the traffic light in multiple intersections to be researched in the future.

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Author

WU Lurong is working for Fujian Agriculture and Forestry University, Fuzhou, China, as an associate professor. His research is mainly on prediction of traffic accidents, and urban traffic intelligent control system.