Research on Intelligent Transportation System Based on Fuzzy Neural Network

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Abstract: In the face of the increasingly serious traffic issues, this paper takes the signal control of urban single intersection as the research object, and uses the fuzzy control system to study the urban traffic signal control. The algorithm comprehensively considers the three parameters, queue length, traffic flow and speed of the intersection vehicle to determine the green light distribution time of the traffic phase. Through theoretical analysis and actual needs find the shortcomings of the algorithm. Additional, membership function and fuzzy control rules are manually set by expert experience and historical data, and the whole system lacks self-learning ability. Therefore, the neural network algorithm with self-learning function will be incorporated into the fuzzy control system to form an intelligent traffic information system which think fuzzy neural network as the core parts. It draws on the strengths of both, makes up for their respective deficiencies, and effectively improves the ability of the entire system to learn and express knowledge. The simulation results show that it is greater advantageous to apply it to the signal control of the intersection.

1. Introduction

Transportation is the basic industry of national economic and social development, and it is the main carrier of passenger flow and logistics in social economic activities. It is closely related to the development of the national economy and the production and livelihood of the people [1]. In recent years, the development of social economy and the advancement of science and technology have promoted a rapid development of the transportation industry, and transportation plays an important role in this situation. However, the rapid development of traffic has also brought about a series of problems such as traffic congestion, environmental pollution, energy consumption and traffic accidents [2], causing huge losses to the development of social economy and people's lives and property. As the bottleneck of the entire urban road network, the intersection is a key hub of urban transportation [3]. Chinese scholars Li Zhongqin and Fan Honggang have designed a four-phase two-stage fuzzy controller with single intersection, which determines the traffic rights of intersections by the priority of the traffic phase and improves the traffic efficiency of vehicles [4]. Lu Shoufeng et al. studied the offline Q learning model of intersection signal timing [5]. Therefore, this paper applies fuzzy neural network algorithm to the intersection traffic management system, aiming at alleviating traffic congestion and improving the efficiency of intersection traffic.
2. Traffic Signal Fuzzy Control Algorithm Research

The single intersection fuzzy control system can realize the intelligent green time management of the intersections according to the traffic parameter information collected in real time and the control rules in combination with the control rules [6]. Considering the urban road habits, the design of the fuzzy controller for a single intersection should consider two aspects: First, the traffic should be released in a certain phase order to ensure that the vehicles in each phase can obtain the right of passage and avoid the chaotic situation; the second is that the green light duration of the transit phase has been determined when the right is to pass, and will not be easily changed during the green light passage, which is more suitable for the traffic signal control system with the countdown display. The structure of the single intersection fuzzy controller designed in this paper is shown in Fig 1.

![Figure 1. Structure diagram of single-stage multi-parameter fuzzy controller](image)

It can be seen from the figure that the system is a three-input single-output single-stage fuzzy controller. The input variable \( j \) of the system is the length of the phase vehicle to be traversed, \( k \) and \( p \) are the traffic volume and average vehicle speed of the phase in the previous cycle, and the output variable. The length of the green light for the phase to be passed. \( j \), \( k \), \( p \) obtain the fuzzy input variables of the system through the fuzzification operation, and then use it as the input parameters of the fuzzy control system, combined with the fuzzy control rules in the knowledge base for fuzzy reasoning [6], and obtain the system fuzzy output variables, through the inverse The fuzzification operation yields an accurate output value \( t \), which is the green light delay of the phase to be passed.

3. System structure of fuzzy neural network

The fuzzy neural network system is based on the neuron and fuzzy model. The system learns and trains a large amount of sample data, which increases the adaptability of the whole system and avoids subjectivity based on expert experience modeling[7]; Firstly, the initial fuzzy push logic system is constructed according to the intersection traffic situation information, and then the connection weights and related structural parameters are continuously learned, and the membership function is adjusted and updated in the domain. A fuzzy inference system with multiple fuzzy rules. The fuzzy neural network system is based on fuzzy logic theory, combined with neural network self-correction method and self-organization, to achieve the purpose of information processing, and does not generate functions such as fuzzification, fuzzy reasoning, and clarity in the fuzzy control system. Influence, the subject is still a fuzzy control system. Its structure is shown in Fig 2.
Figure 2. Fuzzy neural network structure

As shown in the figure, we set the vehicle queue length $j$, traffic volume $k$ and average vehicle speed $p$ as inputs to the fuzzy neural network system, and the green light delay $t$ is the output. The system uses a 5-layer neural network structure. The system structure is described in detail as follows:

The variables input in the first layer are $j$, $k$, and $p$, and the fuzzification variables are obtained after the fuzzification operation;

The number of nodes in the second layer is 13, each node represents a linguistic variable value, and the membership degree of each input component is calculated by a Gaussian membership function;

The third layer has 75 nodes, representing 75 fuzzy control rules. All the control rules are stored in the network structure in the form of if and then, and the logical operation is implemented by phase and logic.

The number of nodes in the fourth layer is 75, as the fuzzy logic inference layer, the fuzzy inference is performed by the input variables to obtain the fuzzy output value;

The fifth layer is the output layer, and the fuzzy output variable is obtained by weighted averaging to obtain an accurate output delay variable.

4. Traffic Signal Control Performance Simulation of ANFIS Fuzzy Neural Network

4.1. Data loading

ANFIS uses the self-learning function of neural network to train a large number of traffic parameter data and learn the structure of fuzzy logic system to construct a fuzzy inference system [8]. Before this, traffic parameter sample data needs to be loaded into ANFIS for learning and training. The sample data of the traffic parameters is actually detected by machine vision technology. There are 600 sets of data, and each set of data includes three input variables and one output variable. The input variables are the queue length of the vehicle to be transited, the vehicle flow rate and the average vehicle speed, and the output variable is the green light extension time. The loaded data will be retrieved by random extraction for 300 pairs of sample data for system training, and the remaining 300 pairs of sample data are used for performance testing of the trained system. The data loading interface is shown in Fig 3.

4.2. Generation of fuzzy neural inference system

After the data loading is completed, the model structure diagram of the fuzzy neural inference system generated based on the traffic parameter sample data is shown in Fig 4. The first layer is the input layer, which contains three nodes representing three input variables, and is fuzzified to generate fuzzy variables. The second layer has 13 nodes, each of which is used to calculate the membership function value of the input component. The third layer of nodes is 75, generating 75 fuzzy control rules. The fourth layer is the number of nodes in the fuzzy inference layer, which is 75. The fuzzy
inference is obtained from the input variables to obtain the fuzzy output value. The fifth layer is the output layer, which is processed by defuzzification to obtain an accurate output value.

![Figure 3. Data Loading](image)

![Figure 4. Model structure diagram of the fuzzy neural inference system](image)

4.3. Network training

ANFIS learns the original fuzzy neural inference system in the network during training, and continuously corrects the initial parameters according to the sample data to optimize the connection weight and related parameter values, and automatically updates the membership function and fuzzy control rules, optimization [9]. According to the sample data, the generated membership function and fuzzy control rules are trained, which avoids the subjectivity of experts and traffic police experience to a certain extent. The optimization method selected by the system is BP neural network algorithm, which has faster convergence speed, strong computing power and high learning efficiency. The error accuracy of the system is set to 0, and the number of trainings is 1000. The system training error curve is shown in Fig 5. The training frequency converges around 600 times, and the error do not have changes. The error after training is error=0.64523.

4.4. System testing

Under common circumstances, if the collected traffic parameter data can reflect various traffic situation information at the intersection, the better the effect of the fuzzy neural control system can obtain after training on the intersection traffic control [10]. However, the sample data of the training is unlikely to reflect the full status information of the intersection traffic. Therefore, the test data will be loaded to perform performance tests on the trained system. Fig 6. is the test result graph, the icon is '*' for the actual output result value, and the icon " is the sample output value of the test data. The system test result graph can be used to understand the actual output value of the system and the target value of the test data. The performance is very good, the test error error=0.57666, which shows that the trained fuzzy neural inference system has better performance and has a good control effect on the effective traffic of the intersection vehicles.

![Figure 5. System Training Error Curve](image)

![Figure 6. System test results](image)
4.5. Simulation results and analysis

After the establishment of the fuzzy neural network inference system based on the single intersection, in order to verify the control performance of the intersection traffic signal, the simulation analysis is carried out under three traffic conditions: low peak period, mid peak period and peak period [10]. And in the same traffic flow state, simulation comparison analysis with timing control and fuzzy control traffic signal control mode. The subject selected vehicle average delay as a performance indicator for traffic control. The simulation diagrams for the three traffic flows are shown in Fig 7, 8, and 9, respectively.

![Figure 7. Simulation diagram of traffic flow at low peak](image1)

![Figure 8. Simulation diagram of the traffic flow in the middle peak period](image2)
Traffic signal control system performance simulation uses vehicle average delay as a technical indicator. The larger the average delay of the vehicle is, the worse the traffic control effect of the traffic signal control system will be and vice versa. From the performance simulation diagrams of the three traffic flows, the average delay curve of the vehicle is on the rise at the beginning, and gradually becomes flat after a period of time. At the same time, regardless of the traffic flow situation, the average vehicle delay based on the time-controlled traffic signal system is the largest among the three, and the average delay of the fuzzy-controlled vehicle is less than the timing control, and the traffic signal designed by the subject The average delay of the control system is minimal. The simulation data is now summarized in a table 1.

### Table 1. Analysis of simulation results under three traffic flows

| Traffic flow     | Average vehicle delay (s/PCU) and relative improvement rate |
|------------------|----------------------------------------------------------|
|                  | Timing control | Fuzzy control | Fuzzy nerve | Fuzzy relative control | Improvement of fuzzy control |
| Low peak period  | 27.2           | 24.8          | 22.7        | 8.8%                   | 8.6%                        |
| Mid-peak period  | 34.2           | 30.1          | 27.6        | 11.2%                  | 8.3%                        |
| Peak period      | 43.2           | 38.2          | 35.6        | 11.8%                  | 6.8%                        |

### 5. Conclusion

Through delay comparison, it can be found that the average delay of the fuzzy control relative timing control data shows that the average delay of the low peak vehicle is reduced by 8.8%, the mid-peak period is reduced by 11.2%, and the peak period is decreased by 11.8%; while the fuzzy neural network is relatively fuzzy. Control, the average delay of vehicles in the low peak period decreased by 8.6%, the mid-peak period decreased by 8.3%, and the peak period decreased by 6.8%. The three control methods are in different traffic flow conditions, and the traffic signal control performance of the traffic control system based on the fuzzy neural network algorithm is the best. Because the fuzzy neural network considers the actual traffic conditions of the current intersection, by learning the fuzzy inference system and training the traffic parameter sample data, adjusting the release and update control rules of the membership function in the domain, the control strategy can be real-time according to the current traffic conditions. The adjustment makes the whole system adapt to the randomly changing traffic flow, so it has more efficient control performance.
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