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Optimal method of intelligent traffic signal light timing based on genetic neural network

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Abstract

In order to solve the problems of high average delay and high green signal ratio in traditional traffic signal timing optimization methods. An intelligent traffic signal timing optimization method based on genetic neural network is proposed. The basic principle of genetic neural network is analyzed, and the neural network model optimized by genetic algorithm is constructed. The optimal solution of traffic flow prediction model is transformed into the problem of calculating the best individual and its representative optimal solution. The coding genetic algorithm is used to code the random weight threshold of neural network to get chromosome coding string, calculate the error function value of neural network, and obtain all of them According to the value of fitness function, the population is operated by genetic algorithm to obtain the optimal solution of traffic flow prediction model; based on the optimal prediction results of traffic flow, the effective green light time of each phase is obtained according to the optimal time allocation period of traffic lights to complete the optimization of intelligent traffic signal light timing. The experimental results show that the minimum average delay time is about 46.8 s, and the green signal ratio of this method can reach 95%, which can effectively reduce vehicle congestion.

Keywords - genetic neural network, smart transportation, signal light timing, real number encoding

1. Introduction

According to traffic big data, vehicles are showing a linear upward trend. The increase of road vehicles makes transportation difficult, which not only prolongs the driving time of vehicles, but also leads to an increase in traffic accidents. Traffic signal lights are set at road intersections. Road control, vehicles follow the instructions of traffic lights, improve the efficiency of transportation, and enhance the utilization of traffic roads. The signal timing of road intersections has a certain influence on the strong traffic flow [4, 14, 16]. However, with the continuous growth of vehicles, the traffic flow is getting bigger and bigger, and the current road traffic flow control can no longer meet the changes in traffic flow. When people go out, they will always extend the driving time because of the unreasonable timing of traffic lights, or Vehicle stagnation causes congestion. Therefore, in view of this phenomenon, the current traffic signal light timing optimization plan is designed to achieve the optimal traffic flow. In recent years, according to the research of a large number of scholars, the optimization of intelligent traffic signal timing can not only improve the capacity and safety of intelligent traffic roads, but also lay the foundation for the construction of smart cities in my country [8].

Qiu Jiandong et al. [11] used a threshold service strategy to construct a traffic light polling control model, combined with Markov chains and probability generating functions, and applied traffic flow prediction technology to control the timing of intelligent traffic lights. The simulation experiment shows that The intelligent traffic signal light timing control effect of the method is better, and the road traffic efficiency is average. However, the green letter of this method is relatively low, and the vehicle congestion rate is high, resulting in poor traffic road utilization. Chen Haiyang et al. [1] used an improved clone selection algorithm to study the timing of regional traffic lights, and set the vehicles waiting to pass at the intersection as the optimization target. According to the traffic flow prediction results, the two-layer dynamic mutation operator was used to calculate the road traffic. The solution with the best capability is based on this solution to time the traffic lights. Through experimental comparison tests, it can be seen that the number of stranded vehicles in this method is reduced, but the method has more vehicles in line and the delay time of traffic lights is longer. Jiang and Du [5] proposed an optimization method of traffic signal control based on real-time data of laser sensor. The method collects traffic data with laser sensor, analyzes its basic principle, determines the collected data according to different environment, and sets it in the traffic flow control layout, determines the released traffic flow according to the maximum traffic flow, and completes the optimization of signal lights. This method can effectively reduce the delay time of vehicles in the traffic congestion period, but it takes a long time to optimize the timing.

Aiming at the problems of the above methods, this paper proposes an intelligent traffic signal timing optimization method based on genetic neural network. Genetic neural network is genetic algorithm and neural network, both of which can deal with nonlinear complex problems and find the optimal solution quickly. Therefore, this paper combines genetic algorithm and neural network to predict intelligent traffic flow, and optimizes the intelligent traffic signal light timing according to the prediction results. This method solves the problems existing in traditional methods and is intelligent Traffic construction has laid a certain foundation. The technical route of this paper is as follows:

1) The basic principle of genetic neural network is analyzed, and the neural network model optimized by genetic algorithm is constructed;
2) In this paper, the optimal solution of traffic flow prediction model is transformed into the problem of calculating the best individual and its representative optimal solution. The chromosome coding string is obtained by coding genetic algorithm for the random weight threshold of neural network. The error function value of neural network is calculated, and the fitness function value of all individuals is obtained. According to the value of fitness function, the population is inherited The optimal solution is obtained by the model;
3) Based on the optimal traffic flow prediction results, the effective green time of each phase is obtained according to the optimal traffic signal timing cycle, and the intelligent traffic signal timing optimization is completed.

2. Traffic flow prediction based on Genetic Neural Network

2.1. Optimization of neural network model by genetic algorithm

In this paper, genetic algorithm is used to optimize the neural network model to obtain the optimal solution. Firstly, the genetic algorithm is used to optimize the initial weight threshold of the constructed neural network model, and the optimized weight threshold is replaced by the initial weight threshold, and then the neural network model is trained to obtain the global optimal solution [12, 17-19]. The specific steps of genetic algorithm to optimize neural network model are as follows:

1) A coding method is selected to generate the initial population, and the chromosome coding string is obtained by coding the random weight threshold of neural network;
2) Based on chromosome coding, the error function value [10] of neural network is calculated, and the fitness function value of all individuals is obtained;
3) In the fitness function value, the individuals with better performance are selected and those with poor performance are eliminated;
4) According to the previous step, the population is crossed and mutated to obtain the optimal individual, and compared with the individual in the initial population, the better one is selected [2];
5) Go back to step (2) and iterate several times until the best individual, i.e. the global optimal solution, is obtained.

2.2. Calculation of optimal solution of traffic flow prediction model

The purpose of traffic flow prediction is to make as many vehicles as possible pass through in the same time. As the result of traffic flow prediction will directly affect the effect of traffic signal control and the use efficiency of traffic road [7], the neural network model optimized by genetic algorithm is used to predict the traffic flow, and the problem of calculating the optimal solution of the traffic flow prediction model is converted into calculating the optimal individual and The optimal solution is the optimal solution of the model. In this paper, the real coding method is used to encode the chromosome of the neural network weight threshold [15] to obtain the chromosome coding string :

$$A = |a_1, a_2, a_3, a_4| \quad (1)$$

$$B = |b_1, b_2, b_3, b_4| \quad (2)$$

$$X = (c, A, B) \begin{cases} c_{min} \leq c \leq c_{max} \\ 0 \leq a \leq c \\ b_{min} \leq b \leq b_{max} \\ c = \sum_{i=1}^{4} (b + l)_c \end{cases} \quad (3)$$

where a represents the traffic signal offset; b represents the green light waiting time; c represents the green light signal cycle; l represents the total time wasted waiting on the road.

According to the obtained chromosome code string, the neural network error function value is calculated, and the inverse of the obtained global error value is the fitness function value, and the expression is:

$$f = \frac{1}{1+E} \quad (4)$$

where E represents the global error. The fitness function value has a certain impact on obtaining the global optimal solution. The larger the E value, the lower the f value. Therefore, the individual with the highest value is selected for inheritance, and the probability of the individual in the population being selected is calculated:

$$p_i = \frac{f_c}{\sum_{i=1}^{l} f_c X} \quad (5)$$

where f_c represents the fitness function value of the c is training.

According to the acquired genetic probability, crossover and mutate the current generation population, and calculate the adaptive crossover rate p_c and mutation rate p_m:

$$p_c = \begin{cases} k_1(f_{max} - f')/(f_{max} - f_{avg}) f' \geq f_{avg} \\ k_2 \quad f' \leq f_{avg} \end{cases} \tag{6}$$

$$p_m = \begin{cases} k_3(f_{max} - f)/(f_{max} - f_{avg}) \geq f_{avg} \\ k_4 \quad f \leq f_{avg} \end{cases} \tag{7}$$

where k_1 k_2 $k_3 k_4$represents a random value in the numerical range of 0 and 1, f' represents the maximum f value obtained after the two chromosomes are crossed, f_{max} represents the highest value of the fitness function, and f_{avg} represents the average value of the fitness function. If the p_c and p_m values are low, it indicates that the individual has better performance and allows the individual to enter the next generation; if the p_c and p_m values are high, the individual will be eliminated according to the rule of survival of the fittest [6, 13, 20, 3, 9].

The optimal individual obtained above and the optimal solution represented are the optimal solution of the traffic flow prediction model.

3. Intelligent traffic signal light timing optimization

According to the optimal solution of the traffic flow prediction model calculated above, the traffic signal light timing optimization is performed to obtain the optimal traffic signal light timing period.

Set o as the road intersection and i as the phase of the road intersection. When the vehicle is in t_n time and the i phase of o is green, then all vehicles arriving before time $t_n$will pass after the green light. When the vehicle is in t_n time and the $i + 1$ phase of o is green, then the queue length $Q_{oj}(n + 1)$ of the i phase waiting at time t_n is expressed as follows:

$$Q_{oj}(n+1) = \begin{cases} \eta_j(v_i)p_c + \mu_j(\mu_i)p_m & j = i \\ Q_{oj}(n) + \eta_j(v_i)p_c + \mu_j(\mu_i)p_m & j \neq i \end{cases} \tag{8}$$

where v_i and μ_i represent the green waiting time and yellow waiting time of phase irespectively; $\eta_j(v_i)$and $\mu_j(\mu_i)$ represent the queue length of vehicles in the green waiting time and yellow waiting time of phase j respectively.

According to the above formula, at time t_n, the queue length of phase j vehicles is the total number of vehicles queuing in phase j and the total number of vehicles arriving at phase i within the green and yellow light time of phase i, then at time t_n, when the green light of phase i is on, the average queue length of vehicles in phase j of Road intersection is:

$$g_i(i) = \frac{\alpha_i \lambda_i \sum_{l=1}^{N} \gamma_l}{1 - \sum_{l=1}^{N} \rho_k Q_{oj}(n+1)} \tag{9}$$

where α is the degree of average delay time of signal lights; λ is the average number of stops; γ is the weight value of λ; ρ_k is the traffic effect; N is the total number of phases.

After the next green light, all waiting vehicles in phase i can pass through in the average period. Therefore, according to the average period and the total number of vehicles queuing up, the optimal traffic signal timing period is obtained

$$T = \frac{g_i(i)}{\alpha_i \lambda_i} = \frac{\sum_{k=1}^{N} \gamma_k}{1 - \sum_{k=1}^{N} \rho_k} \tag{10}$$

According to the above formula, to obtain the total effective green light time, the expression is:

$$G = T - L \tag{11}$$

where L represents the total lost time at the intersection.

Set the flow ratio of phase i to y_i, and all flow ratios to y, then the effective green time of each phase is:

$$g = G \times \frac{\max[y_i]}{Y} \tag{12}$$

In the process of intelligent traffic signal timing optimization, firstly, according to the optimal solution of traffic flow prediction model, the waiting vehicle queue length is determined. Then, according to the average cycle and the total number of vehicles queuing, the optimal traffic signal timing period is obtained to realize the intelligent traffic signal timing optimization.

4. Simulation experiment analysis

The experiment adopts the intelligent traffic signal timing optimization method based on genetic neural network, the intelligent traffic signal control method based on traffic flow proposed by literature [11] and the real-time traffic signal timing method based on improved clone selection algorithm proposed by literature [1] to carry on the simulation experiment analysis.

4.1. Traffic flow data acquisition

As the banks, government and schools are all located near the feijiaying cross of Anning West Road in Anning District of Lanzhou City, the traffic flow is large. Therefore, this paper takes feijiaying cross intersection of Anning West Road in Anning District of Lanzhou City as an example, and the schematic diagram of feijiaying cross is shown in Figure 1.

Using SCATS data acquisition software to collect traffic flow data from 6:00~20:00 at Feijiaying intersection from June 3 to June 9,2019, The acquisition time is set to 5 minutes per interval, And using MatLab simulation software to simulate and analyze the collected data, Simulation time set to 2400 s, The simulation diagram of traffic flow change curve at Feijiaying cross intersection is shown in Figure 2 and 3.

Through the collected traffic flow curve of Feijiaying cross intersection on Monday ~ Friday, it can be seen that the traffic flow data change curve fluctuates greatly, the traffic flow rises faster, and the curve change trend is consistent. Saturday and Sunday curve fit is higher, traffic flow rises slower than Monday to Friday, and curve changes fluctuate less, indicating that traffic flow on rest days is smaller than traffic flow on work day.

4.2. Comprehensive comparison results

Four phases are set at the cross intersection of Feijiaying, and the phase diagram is shown in Figure 4.

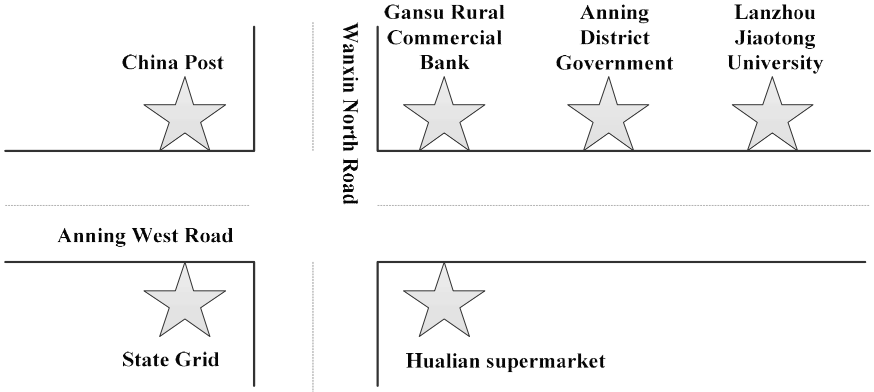

Fig. 1 - Schematic illustration of the Fei Jia Ying Crossroads

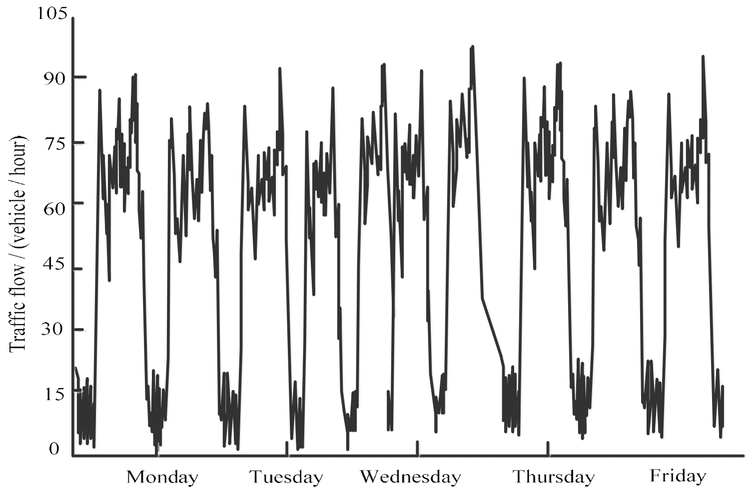

Fig. 2 - Traffic curves Monday ~ Friday

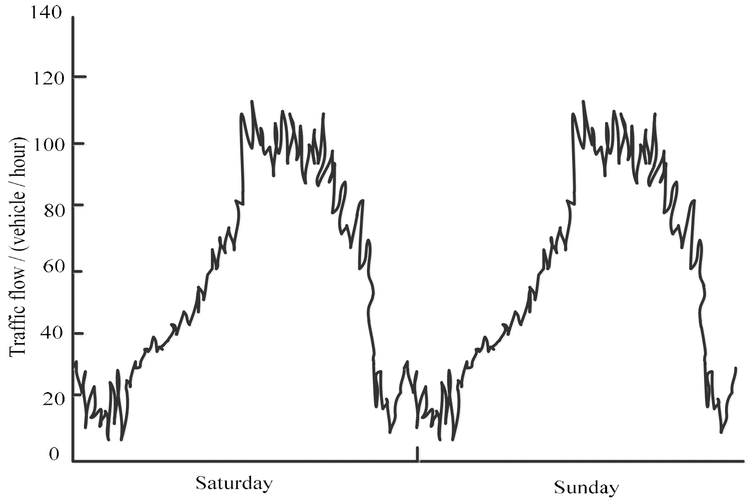

Fig. 3 - Traffic flow curves for Saturday ~ Sunday

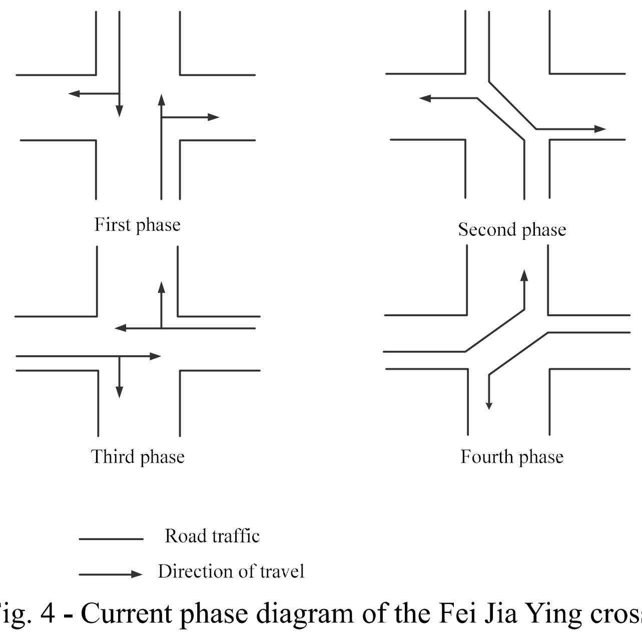

Fig. 4 - Current phase diagram of the Fei Jia Ying crossroads

Tab. 1 - Comprehensive comparison of the three methods

Method	Effective green time of the first phase / s	Effective green time of the second phase / s	Effective green time of the third phase / s	Effective green time of the fourth phase / s	Cycle length	Average delay / s	Queue length / vehicle	Capacity (vehicle / hour)
Method of literature [11]	43	46	48	49	182	53.6	321	4218
Method of literature [1]	38	40	43	45	135	50.2	305	4168
Method of this paper	20	24	21	24	115	46.8	270	4301

Using the method proposed in this paper, the method of Qiu et al. [11] and the method of Chen et al. [1], the average delay, queue length and traffic capacity of traffic signal lights at Fei Jiaying cross intersection are compared and analyzed. The comparison results are shown in Table 1.

According to Table 1, the average delay time of traffic lights at feijiaying cross in this paper is 46.8s, while that in Qiu et al. [11] is 53.6s, while that in Chen et al. [1] is 50.2s. The average delay time of traffic lights in this method is higher than that in Qiu et al. [11] and Chen et al. [1] The average delay time of traffic lights in Chen et al. [1] method is 6.8 s and 3.4 s lower, and the queuing vehicles of this method are 270, 321 and 305 respectively. The queue length of this method is shorter than that of Qiu et al. [11] method and Chen et al. [1] method, while the vehicle capacity of this method is 4301 vehicles per hour The traffic capacity of this method is higher than that of the two literature methods.

4.3. Comparison of green letter ratio

The green signal ratio is the percentage of the optimal timing period between the effective green time and the traffic signal light. It is an important time parameter for the traffic signal light timing. The expression is as follows:

$$\beta = \frac{t}{T} \tag{13}$$

where t represents the effective green time. In a certain phase, the higher the value of β, the higher the green light utilization rate, indicating that the higher the road resource utilization rate, the lower the vehicle congestion rate.

Therefore, using the green letter ratio as the experimental index, the green letter ratio of the proposed method, the Qiu et al. [11] method and the Chen et al. [1] method is compared and analyzed, and the comparison results are shown in figure 5.

According to figure 5, with the increase of the number of experiments, the green signal ratio of the three methods is gradually increasing.

The green signal ratio of the intelligent traffic signal timing optimization method based on genetic neural network proposed in this paper can reach up to 95%, while the green signal ratio of Qiu et al. [11] method and Chen et al. [1] method is only 45% and 30%.

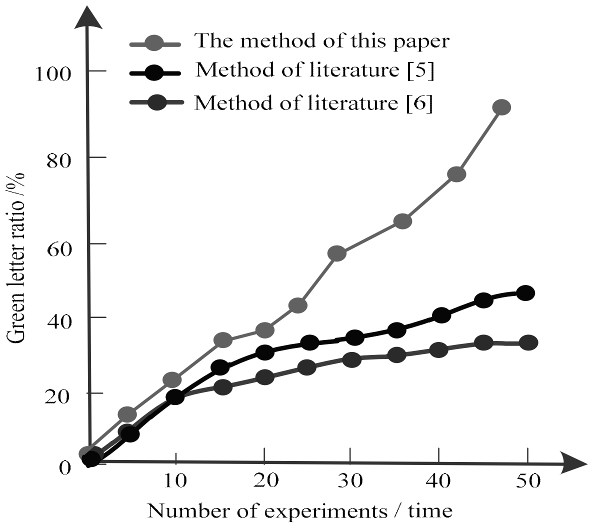

Fig. 5 - Comparison of green letter ratio of three methods

The intelligent traffic signal timing optimization based on genetic neural network proposed in this paper The green signal ratio of this method is 55% and 70% higher than that of Qiu et al. [11] and Chen et al. [1], and the utilization rate of road resources in this paper is higher than that of Qiu et al. [11] and Chen et al. [1]. It shows that the intelligent traffic signal timing optimization method based on genetic neural network can effectively reduce vehicle congestion.

5. Conclusions

Intelligent transportation is a kind of intelligent transportation which is completed by people and scientific and technological means. With the continuous growth of people's economy, the number of vehicles is also increasing linearly. At present, urban traffic vehicles have reached saturation state, which leads to congestion on the road. Accurate prediction of traffic flow and effective control of traffic signal timing can reduce vehicle congestion, To improve road utilization and enhance vehicle capacity, intelligent traffic signal timing has become the top priority of current research.

Therefore, aiming at the problems of high congestion rate, poor traffic capacity and long queue length of vehicles existing in the traditional intelligent traffic signal timing optimization method, this paper uses genetic algorithm to optimize the neural network model to study the intelligent traffic signal timing optimization. Firstly, the problem of calculating the optimal solution of traffic flow prediction model is transformed into the problem of calculating the best individual and its representative optimal solution. The neural network model is optimized by genetic algorithm to obtain the global optimal solution. Then, the traffic signal timing is optimized according to the optimal prediction results, and the optimal timing period of traffic lights is obtained, which realizes the dynamic addition of green time, which is similar to the traditional method Compared with the proposed method, it has the following advantages:

1) The average delay time of traffic lights in the experimental site is 46.8s, and the traffic capacity of this method is 4301 vehicles per hour;
2) The highest green signal ratio of the proposed method is about 95%, which reduces the probability of vehicle congestion.