Study on Signal Light Control of BP Neural Network Intersection Based on Swarm Intelligence Algorithms

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Keywords: BP Neural Network; Intersection Signal Lamp; Fuzzy Control

Abstract: With the development of urbanization and the popularization of private cars in China, urban traffic congestion has become increasingly prominent. How to solve this problem through practical, effective and feasible methods has attracted wide attention. In this paper, the structure of signal control system based on reinforcement learning of BP neural network based on swarm intelligence algorithm is proposed. By applying reinforcement learning, the optimal control problem of signal lamp is transformed into the decision-making problem of switching operation phase. A coordinated control method of regional signal based on BP neural network is designed. The method preserves the neural network self-learning structure and considers the number of vehicles arriving between adjacent intersections in the region. The simulation results verify the effectiveness of the BP neural network based regional signal coordination control method. The system can sense the change of traffic flow and adaptively adjust the signal switching strategy to achieve the optimal control effect. This method is feasible and has obvious advantages compared with timing control.

1. Introduction

With the development of urbanization and the popularization of private cars in China, traffic congestion in cities has become increasingly prominent. Traffic congestion not only affects the normal operation of the city, but also causes other problems, such as environmental pollution, frequent traffic accidents and so on, resulting in serious economic losses. In the process of rapid urban development, most urban road planning is not reasonable, the function of road system is not perfect, road management facilities are seriously scarce, and traffic congestion at rush hours is common in large cities. State [1]. Existing signal control methods include timing control, inductive control, optimal control, fuzzy control, and neural network control. These methods play a certain role in alleviating traffic congestion and keeping traffic flowing, but they all play a role. There are certain problems [2]. Reasonable urban strange traffic signal control can effectively alleviate traffic congestion, and traditional control methods are difficult to apply to complex traffic control problems. Therefore, it is of great significance to study urban traffic signal intelligent control methods.

In the entire urban regional traffic network, the intersection is the most basic, but also the most critical, so it is necessary to control the signal. At present, a large number of literatures have studied the signal control of single intersections and have been widely used in practical traffic control [3]. Because the transportation system is a complex nonlinear time-varying system, it has ambiguity, nonlinearity and uncertainty. It is difficult to achieve effective control by conventional control methods, and therefore, advanced intelligent control techniques such as neural networks, fuzzy control, and the like are utilized. Although BP neural network control has good mapping ability and learning ability for non-linear systems and systems that are difficult to model, it requires high computing power and speed for the hardware of signal control system [4]. Because in a city area, the change of signal timing of one intersection will affect the traffic flow of other adjacent intersections. When the control of single intersection achieves a better effect, the control effect of the whole area is not necessarily improved. Therefore, for the whole city area traffic network, the coordinated control mode of regional multi-intersection signal should be adopted.

  DOI: 10.25236/isaicn.2019.086

2. Methodology

Because of the complexity and dynamics of system parameters, traditional automatic control has low feasibility to find a mathematical model to accurately express the system. It is very weak for complex and difficult control problems. Traffic flow has the characteristics of spatio-temporal dispersion and can change with time and region. In order to carry out traffic planning or traffic design, we must grasp the trend of traffic flow development and change [5]. The emergence of BP neural network has become a reliable tool for people to further understand the mechanism of human brain activity. Although it is not a perfect model to simulate the brain, its unique ability of non-linear information processing can be achieved by learning from the outside environment and storing knowledge in the network, thus dealing with problems that are difficult for computers to deal with [6]. The essence of intersection signal control is to determine the optimal signal timing according to the change of traffic flow, so as to give full play to the road capacity and reduce vehicle delay. However, fuzzy control lacks active learning and self-adaptive ability, and gradually shows many problems in solving traffic signal control problems. In a signal cycle, in order to improve the traffic capacity of the intersection, it is necessary to reduce the delay of the vehicle as much as possible. Therefore, the signal control in this paper is to reduce the average delay of the vehicle in the cycle as the control target.

The ratio of the effective green time to the signal period for each phase during a signal period is the green signal ratio. Such asFormula (1).

$$\sigma = \sqrt{\ln(1+\frac{\mathrm{v}_r}{m^2})} \tag{1}$$

Where σ represents the effective green time of the mth signal period, and v_r represents the green signal ratio of the mth phase.

Timing control is a control mode with fixed timing scheme and no time-varying. It is generally used at isolated intersections. That is to say, the phase time and the signal period remain unchanged. As shown in the following formula.

$$\mu = \ln(\frac{m^2}{\sqrt{v_r + m^2}}) \tag{2}$$

In the above formula, μ represents the total loss time of a period, and m^2 represents the sum of the maximum values of the phase of each signal constituting the signal period.

Saturation is for each lane. It refers to the number of vehicles actually passing through each lane and the maximum lane.The ratio of the number of vehicles that can pass (that is, the saturated flow of the lane). As shown in the following formula.

$$S_N(k) = \frac{\left|\Delta N / N_0\right|}{\left|\Delta k\right|/(k_{\max} - k_{\min})} \tag{3}$$

In a normal set, for a given universe, the relationship between any element and set is only in and out of the two cases. When planning urban road network or controlling regional traffic flow, it is necessary to predict the traffic data of downstream intersections in advance, and the forecast of traffic flow must be based on real-time performance. In the standard BP algorithm, the initial weight of the BP neural network is randomly generated, and the overall distribution of the BP neural network's connection weight and the threshold determines the fitting effect of the data. Therefore, different initial weights will affect the network. The probability of the training process falling into local minimum values, the convergence speed and accuracy of the network, and so on. Because of the randomness of traffic flow changes, the control system is expected to be able to perceive the changes of traffic environment, and change the timing of signal lights to achieve the optimal control effect according to the real-time learning control mode of the environment. As long as the number of nodes in the hidden layer is sufficient, the neural network can approximate any required

non-linear continuous function on the closed set and achieve any accuracy requirements. These values are matched with the database of fuzzy rules, and logical reasoning is carried out. After the result is clarified, an accurate control instruction is obtained, which is similar to the process of logical reasoning in human brain. However, a single neuron activity can not meet the needs of the brain activity of organisms. It is not a simple accumulation of the functions of each part, but the coordination of many units and various human processing systems to meet the needs of human life activities.

Vehicle queue length refers to the maximum length of vehicle queue in each lane of the study object when the green light time begins. The average queue length is the average of its calculation. As shown in formula (4). The time unit of the queue length is calculated in one cycle. There are two evaluation indicators that the average queue length of the vehicle and the vehicle delay time are consistent.

$$\mathrm{k} = \frac{S_N(k)}{\sum S_N(k_i)} \tag{4}$$

Capacity is based on saturated flow, and capacity is closely related to saturated flow. The total capacity of the intersection is the sum of the capacity of each lane group at the intersection. The capacity of lane group is expressed by formula (5). Among them, R_i represents the capacity of the vehicle group and M_i represents the saturated flow of the vehicle group.

$$R_i = M_i \sum_{i=1}^{N_r} \hat{R}_{i,r} \tag{5}$$

For traffic signal control system, the controlled object is traffic flow, and the control actuator is signal lamp. The optimal control effect is achieved by switching the phases of the control signal lamp. The training start data processing module extracts the life data from the system database as training samples and inputs them into the BP neural network. The maximum queue length of each phase at the beginning of the current cycle is used as the input of the neural network, while the phase timing scheme, namely the green light time of each phase in the current cycle, is used as the output of the neural network. That is to say, human language is transformed into symbols that can be recognized by computer, and the process of thinking is replaced by computer processing. Moreover, the modes in which these processing units process information are very similar. Therefore, the process of processing information in parallel by neurons is relatively stable, and even if it causes small interference, it will not cause too much error, and at the same time, relevant information can be quickly processed. Therefore, it is expected that the traffic control system not only has the ability to recognize the state, but also has the self-optimizing ability of the control system and the ability to adapt to the environment. The training of the neural network is also completed at the intersection machine. If the neural network training in the idle state is completed, the neural network switching is performed, that is, the trained neural network is used for actual signal control, and the other neural network is in idle or learning state.

3. Result Analysis and Discussion

Fuzzification is the process of mapping the exact amount of input into a fuzzy quantity. The range of input quantity can be divided into several fuzzy sets, each of which represents a linguistic variable. By continuously training the neural network with data from the historical database, the neural network automatically builds a model to describe the training data when enough training times are reached. The learning system selects the behavior according to the traffic flow state information detected by the traffic flow state detector according to a certain principle, and the system performs the action; the traffic flow changes state due to the execution of the action, and the reward and punishment value after the execution of the behavior is calculated. It adaptively changes with the strength of the external excitation signal. Each neuron presents two states of excitation or inhibition with the comprehensive results of various excitation signals received, which is the

learning process of human brain. The human brain consists of innumerable neurons. Once a neuron is damaged, it will not affect the overall performance of the neural network system. Artificial neural network is similar, even if a part of the system can not work due to hardware and software failures, the whole system can still run smoothly. If a large number of queuing vehicles in the current direction have been evacuated and the number of vehicles in the other direction is increasing, he will allow vehicles in the other direction to pass. If the number of vehicles in all directions is large, the travel time is relatively long; if the number of vehicles in all directions is small, the relative travel time is also relatively short.

Using scattered measurements as initial boundary values, traffic data can be estimated by numerical interpolation based on the approximate traffic equation, as shown in Figure 1.

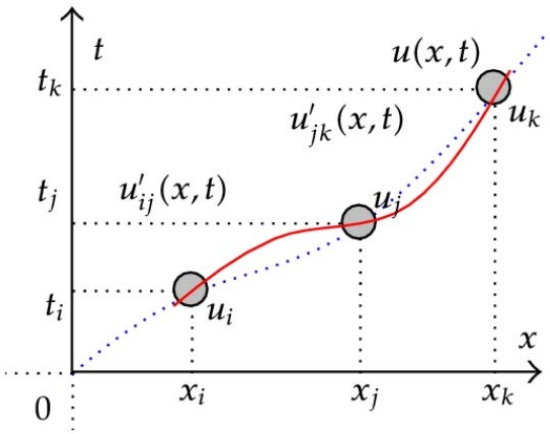

Fig.1. Scattered data that coincides with adjacent points

On the basis of given initial conditions, a virtual traffic dispatch simulator is established. The traffic equation, congestion factor and cost function are analyzed theoretically. For straight lane traffic, considering continuous traffic flow and red light congestion, the congestion factor and cost function can be simulated. The results are shown in Figure 2.

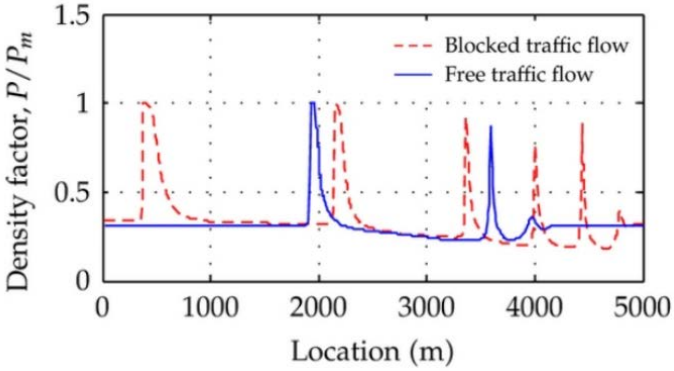

Fig2. Observation point traffic congestion factor

For the actual control of each intersection in the region, the neural network self-learning control structure in the neural network self-learning control is also adopted. At this point, the training of the neural network is done in the regional computer. When a neuron receives an excitatory input that is greater than the suppression input, it transmits a signal to other neurons through the axon. This process continues at other neurons, creating a vast network of parallel neurons. In this type of neural network model, each neuron starts from the input layer and produces the output of the next stage while receiving the input of the previous stage, which is passed in turn until it is communicated to the output layer. In this way, learning will be realized by using BP neural network, and the decision will be made once every time step to decide whether to switch the green light phase at that time step. Finally, the best green light time of each phase will be obtained. There are not only information exchanges between intersections and regional computers, but also information exchanges between intersections and adjacent intersections. The neural network is trained according to the previous

data, and the weights and thresholds of the connections are adjusted continuously through continuous learning. It can better adapt to the changing situation of the controlled object. It can be seen that when the traffic flow is saturated, the algorithm is obviously better than the timing control. It also shows that the traffic flow increases suddenly, the system will gradually adapt to the change, and finally the optimal control strategy can be obtained by self-optimization.

Because the green light opening time in the current phase of the local intersection is related to the number of vehicles arriving at the local intersection in the current phase, and the number of vehicles arriving at the local intersection in the current phase is affected by the traffic flow at the adjacent intersection. Neural network is composed of innumerable neurons, so the whole neural network is an interactive system. Non-convexity means that the transfer function and energy function of the neural network have multiple extremes and can present a certain stable state. Since the BP network structure may be different, when the network structure is different, the convergence effect of the output of the same sample under the same weight and threshold conditions is different. Then, the purpose of the signal control is changed to determine whether the phase currently being used should be switched according to the actual collection of the traffic flow. Therefore, the main function of the neural network predictor is to use the green light duration of the phase of the current intersection and the current vehicle departure rate to predict the number of vehicles between the local intersection and the adjacent intersection, thereby localizing The current phase of the intersection and the number of vehicles arriving at the preliminary phase are predicted.

4. Conclusion

At present, traffic congestion is becoming more and more serious, and traffic accidents are frequent, which not only affects people's daily life but also restricts the development of China's economy. Based on this, an urban short-term traffic flow prediction model based on BP neural network is established and optimized by genetic algorithm and thought evolution algorithm. The method predicts the number of vehicles arriving at the local intersection from the adjacent intersection day in the current phase by the current green light duration information of the adjacent intersection, thereby adjusting the input of the neural network controller, and finally improving the control precision. Because the fuzzy control does not need to establish an accurate model of the controlled object, and has good control effect, it is especially suitable for traffic control, while the neural network has learning ability and strong adaptability. When a certain phase runs, all possible jumps form an action set, so that the optimal control strategy including phase sequence changes can be realized, and the above control effects can be further improved. Fuzzy and neural network hybrid control method of regional multi-intersection signal can further reduce the average vehicle delay at each intersection in the region. At the same time, the control performance of fuzzy and neural network hybrid control is better than that of neural network coordinated control.

References

[1] Zhou J, Wang Q, Yi M, et al. Acoustic emission signal recognition based on wavelet transform and RBF neural network[J]. Journal of Qingdao University of Science & Technology, 2015, 8(3):80-85.

[2] Liu S J, Li S L, Jiang M, et al. Quantitative Identification of Pipeline Crack Based on BP Neural Network[J]. Key Engineering Materials, 2017, 737:477-480.

[3] Wang C, Wu F, Shi Z, et al. Indoor positioning technique by combining RFID and particle swarm optimization-based back propagation neural network[J]. Optik - International Journal for Light and Electron Optics, 2016, 127(17):6839-6849.

[4] Cui H Y, Xu Y P, Yang J J, et al. A Fault Diagnosis Method in VSC-HVDC Simulation System Based on BRBP Neural Networks[J]. Advanced Materials Research, 2013, 860-863:2269-2274.

[5] Peng Z Q, Cao C, Huang J Y, et al. Seismic signal recognition using improved BP neural

network and combined feature extraction method[J]. Journal of Central South University, 2014, 21(5):1898-1906.

[6] Han B, He B, Nian R, et al. LARSEN-ELM: Selective ensemble of extreme learning machines using LARS for blended data[J]. Neurocomputing, 2015, 149:285-294.