Electrical Insulation and Dielectrics(2019) Vol. 1: 1-5
Clausius Scientific Press, Canada
DOI: 10.23977/eleid.2019.11001
ISSN 2523-5931

Traffic Signal Optimization Control in Five-road Intersection Based on Artificial Fish Swarm Algorithm

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Keywords: Traffic signal control; five-road intersection; artificial fish swarm algorithm; dynamic-fuzzy neural network; average delay of vehicles

Abstract: The traffic signal control system plays a key role in the road network, and its control performance directly affects the traffic safety and delay time in the intersection. Traditional control in five-road intersection does not have the ability to adjust itself, which wastes green time. This paper adopts a method that use artificial fish swarm algorithm (AFSA) to optimize dynamic-fuzzy neural network (D-FNN) to achieve multi-phase and variable phase sequence intelligent control in five-road intersection. Taking the reciprocal of average vehicle delay as the food concentration of AFSA, and the weights and thresholds of the dynamic-fuzzy neural network which need to be modified are used as the individual state of artificial fish. A set of optimal dynamic-fuzzy neural network parameters are obtained through iterating and updating. After doing simulation analyses in the case of different rates of vehicles arrival, the result shows that this method is better than the traditional control in automatically adjusting the signal cycle, and it reduces the average delay of vehicles for about 11%.

1. Introduction

With the rapid increase in the number of social vehicles, urban traffic problems have become increasingly prominent. In particular, congestion at urban intersections has become more and more serious, and traffic signal control issues have received much attention. The traffic signal control system adjusts the traffic light time of the intersection to control the traffic flow, and the control precision is improved, so that the safe passage of the vehicle can be realized and the waiting time of the vehicle at the intersection can be effectively reduced. For the five-way intersection with complicated traffic flow conditions, if there is a suitable control method, the traffic conditions at the Wuyi intersection can be improved[1].

In recent years, artificial intelligence control methods have been widely used in the control of urban traffic signals. PAPIS and others took the lead in applying fuzzy control to traffic signal control at single intersection. It opened a new page for intelligent control of traffic signals, but fuzzy control lacked self-adjusting ability and self-learning ability. Zhao Runlin et al. used genetic algorithm to optimize the fuzzy membership function, which made the selection of membership function more reasonable, but the genetic algorithm optimization process was complicated. Zeng Songlin et al designed a two-level fuzzy controller, which uses the particle swarm optimization algorithm to optimize the membership function of the fuzzy controller, but the particle swarm algorithm itself is easy to premature. Ma Wenge et al. used the ant colony algorithm to improve the traffic fuzzy controller, but the ant colony algorithm has slow convergence and long search time.

Urban traffic is a nonlinear, complex, and random large system. It is difficult to establish accurate mathematical models to get the traffic light timing scheme. In view of the shortcomings of the above intelligent control methods, this paper uses dynamic fuzzy neural network to realize multi-phase phase-change sequence control of Wuyi intersection, and uses AFSA to optimize the parameters of dynamic fuzzy neural network to improve the control precision of dynamic fuzzy neural network and avoid it falling into local Minimum value[2].

2. Multi-phase variable phase sequence control at Wuyi intersection

The traffic at Wuyi Road is from the five directions of A, B, C, D, and E. In order to avoid cross-crossing between traffic flows in all directions at the intersection, reasonable phase division should be considered. According to the complicated situation of the Wuyi intersection, after the field investigation and research, the following phase division is proposed. Phase 1: A traffic flow U-turn, A to B, A to C, A to D, A to E; Phase 2: B traffic flow U-turn, B to A, B to C, B to D, B to E; Phase 3 :C traffic flow U-turn, C to A, C to B, C to D, C to E; Phase 4: D traffic flow U-turn, D to A, D to B, D to C, D to E; Phase 5: E Traffic flows around, E to A, E to B, E to C, E to D. Such a division can avoid the mutual intersection of motor vehicles, which ensures traffic safety and improves traffic efficiency. As shown in Figure 1.

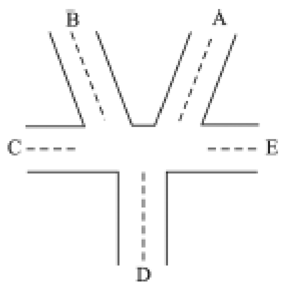

Figure1 Traffic model of five-road intersection

The randomness of urban traffic flow is very strong. For traditional phase-precision control, there are sometimes a few green-light phase vehicles, and the number of other red-light phase vehicles is large, and it is not available for a long time. In the Wuyi intersection, the fixed phase sequence control wastes the green light time utilization to a certain extent, and the actual traffic control requires more advanced phase change sequence control.

Variable phase sequence control idea: The phase selection module calculates the current urgency of each red light phase according to the vehicle queue length and the red light duration of each red light phase in the five intersections, and takes the highest urgency phase as the next green light phase. It avoids the situation that a certain vehicle has a short queue length and the red light is not available for a long time. The green light delay module calculates the green light extension time by taking the difference between the vehicle queue length of the current green light phase and the vehicle queue length of the current green light phase and the vehicle queue length of the next green light phase as input. The variable phase sequence control eliminates the disadvantages of the green light phase without the car and continues the green light, reduces the phase switching frequency, and improves the time utilization. The phase selection module and the green light delay module in the variable phase sequence control structure are respectively realized by dynamic fuzzy neural network.

In order to reduce the average vehicle delay, this paper gives the following control algorithm:

Step1 starts from the i phase and gives the shortest green time imin G and the longest green time imax G for each phase. The shortest green time for each phase is 15 s and the longest green time is 50 s.

Step 2 gives the initial green time i imin G = G of the i phase.

Step3 At the end of the green time, the highest urgency phase is selected according to the vehicle queue length and red duration of the four red lights phases, and the vehicle queue length i L of the current green light phase and the vehicle queue length of the highest urgency phase are obtained.
Step4 If i L is 0, convert the green light to the next phase and go to Step1; otherwise continue[3].

3. Dynamic Fuzzy Neural Network System Design

3.1. Rule formation criteria

(1) system error. The number of rules is too small and the input-output state space cannot be fully included. Too many rules not only make the system more complicated, but also increase the amount of calculation and make the generalization ability of the fuzzy neural network worse. Therefore, the output error is an important factor in determining whether to add a new rule. Systematic error criterion: In the i-th observation data (,) i i X t , i X is the input vector, i t is the desired output, and i y is the output of the current structure of the D-FNN. Define i i i e = t - y , if i e e >k , plan to add a new rule. The e k value here is pre-selected according to the accuracy expected by the D-FNN.

(2) Can accommodate the border. The boundary criterion can be accommodated: the distance between the input vector i X and the center j C of the current RBF unit ( ) idj , ie ( ) , 1, 2 , , iiidj , is calculated for the i-th observation data ii X t = X - C j = ... s, where s is the number of RBF units. Calculate (( )) min argmin i d = d j . If min d d >k , add a new rule. Otherwise, Xi is represented by the current nearest RBF unit. Here, d k is the effective radius at which the boundary can be accommodated.

3.2. Hierarchical learning

This method is based on a decreasing monotonic function that continually reduces the error and effective radius of each RBF unit. At the beginning, the value is large, and the whole learning is carried out. As learning, the value is continuously reduced, and local learning is started: .According to the field investigation and actual traffic control experience, a better sample set data was obtained through research and used as the training set data of the system. The following parameters are pre-determined in the MATLAB program: maximum length max 5 dk = , minimum length min 0.5 dk = , attenuation constant γ = 0.95, maximum error max e = 1.5, minimum error min e = 0.1, convergence constant β = 0.9 The width of the initial rule is 0 width = 3, the overlap factor k = 1.1, the constant wk = 1.1.

4. Parameter Optimization Based on Artificial Fish Swarm Algorithm

4.1. Parameter definition

When using AFSA to train dynamic fuzzy neural networks, each artificial fish represents all the parameters that need to be corrected in a dynamic fuzzy neural network. The food concentration C of the current position of the artificial fish is the reciprocal of the average vehicle delay. Taking the

5-layer dynamic fuzzy neural network in the paper as an example, the parameters to be corrected are 12 weights of the second layer, 12 thresholds, and 6 weights of the fifth layer. Define the state of two artificial fish as m F and n F , and Fm +Fn or Fm - Fn still represent a dynamic fuzzy neural network. The distance between the two artificial fish, m, n d is: $c_Y = \frac{(p_F + \tau_F)E_F + (P_R - \tau_R)E_R}{Y}$.

4.2. Behaviour description

(1) Foraging behavior and random behavior. The current state of artificial fish is m F, and another state n F is randomly selected within its field of view distance. If the food concentration n C of n F is higher than the food concentration m C of m F, it is further toward the direction of n F; Otherwise, a random behavior is performed, that is, a state is randomly selected within the field of view distance and moved in this direction. The process of artificial fish training i w m is: $Y = \left(\alpha E_F^{\frac{\sigma-1}{\sigma}} + (1-\alpha) E_R^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$.

(2) Clustering behavior. The artificial fish state in the field of view is m F, which has: $T = \tau_F E_F + \tau_S E_F - \tau_R E_R$. After scanning all artificial fish in the field of view, calculate the c F parameter of the partner center position in the artificial fish field of state m F according to the following formula: $\max \int_{t=0}^{\infty} e^{-\rho t} U(C) dt$.

(3) Rear-end behavior. The artificial fish with the highest food concentration among all the partners in the field of artificial fish is max F. If the food concentration max C satisfies the following formula, it indicates that the artificial fish has a high food concentration of max F and the artificial fish parameter iw changes as follows. Otherwise, artificial fish conduct foraging behavior: $H_F = B_F H_F^{\theta F}$.

5. Conclusions

For non-linear and complex five-way unbalanced traffic flow, traditional timing control has been difficult to meet current needs, and intelligent control has greatly improved the control effect. The dynamic fuzzy neural network combines the TSK fuzzy system with the extended RBF neural network to apply to the intelligent control of the Wulu intersection, overcoming the intelligent control of the fuzzy traffic signal lacking self-learning and self-adjustment, and dynamically adjusting the green light extension time. The real-time control of traffic flow effectively reduces the average delay of the vehicle, improves the self-adaptive ability, improves the utilization time of the green light, and compensates for the defect that the traditional control lane has no vehicle but the signal light is green.

Acknowledgements

This article was specially funded by Dalian University's 2019 Ph.D. Startup Fund (20182QL001) and 2019 Jinpu New District Science and Technology Project.

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