ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0020

Research on Simulation Technology of Adaptive Inductive Signal Control for Urban Road Intersections Based on VISSIM

Dejia Liu

School of Shanghai Maritime University, Shanghai, China.

1374353526@qq.com

Abstract

Under the background that traffic control technology tends to be intelligent, this paper studies the adaptive induction control logic rules for urban road intersections, and uses Visual Basic to connect to the COM interface to develop the micro-traffic simulation software VISSIM to build a single-point intersection. Adapt to the signal control simulation platform. By comparing and analyzing the simulation evaluation results of timing control and induction control, the operation efficiency of the intersection under adaptive induction control is not as ideal as that of timing control. On this basis, this paper designs a calibration program for the adaptive induction control phase switching constraint conditions. Taking the VISSIM simulation output result as the target, the particle swarm intelligent optimization algorithm is used to iteratively optimize and find the optimal parameters. The adjusted adaptive signal control scheme has obvious advantages over the timing control scheme.

Keywords

VISSIM; COM interface; Adaptive control; Particle swarm algorithm.

1. Introduction

Intersections are the interweaving points of the urban road network, where the traffic flow is divided and combined. Its complex traffic characteristics affect the operation efficiency of the entire urban road network. Therefore, the intersection is the bottleneck of the urban road network operation status. It is of practical significance to optimize the single-point signal control scheme and improve the operation efficiency of the intersection[4]. At present, the intersection generally adopts timing control or induction control, the timing signal control is simple, the cost is low, so it is widely used. Timing signal control is based on historical traffic data of urban road intersections, pre-set signal timing schemes such as green signal ratio, phase conversion time and cycle length, and the signal timing parameters will not change within a specified time period. The Webster method of the United Kingdom, the HCM method of the United States and the ARRB method of Australia are widely used[2]. Inductive signal control judges the real-time operation status of the intersection through certain detection means, and switches the signal control scheme as the operation status changes. Compared with timing signal control, the overall average parking rate of induction-controlled intersections is lower, and the adaptation to random arrivals of vehicles is greater.

Induction control can be divided into semi-induction control and full-induction control according to the layout of the detector[9]. If only a part of the entrance of the intersection is installed with the sensor signal control method is called semi-induction control, if the entrance of the intersection is all equipped with detectors It is called full induction control. Aiming at the real-time traffic status of the intersection, this paper studies an adaptive signal control scheme based on full induction, and virtually reproduces the control logic through the microscopic traffic simulation software VISSIM to study the

ISSN: 2414-1895
DOI: 10.6919/ICJE.202011_6(11).0020

feasibility of the control scheme[5]. In view of the different traffic characteristics of urban intersections, this paper designs a set of calibration procedures for adaptive induction control phase switching constraints based on particle swarm optimization.

2. The logic rules of adaptive induction signal control

Inductive signal control is a traffic control method in which detectors are installed at each entrance of the intersection to measure the arriving traffic demand, so that the display time of the signal controller changes with the fluctuation of the traffic flow. Based on the induction control, the adaptive induction control embeds a logic rule to optimize the traffic efficiency of the intersection according to the characteristics of the traffic flow at the intersection. The core of the adaptive induction control studied in this paper is to give priority to the entrance road with high saturation. Improve the utilization of green light time and avoid the phenomenon of empty green light.

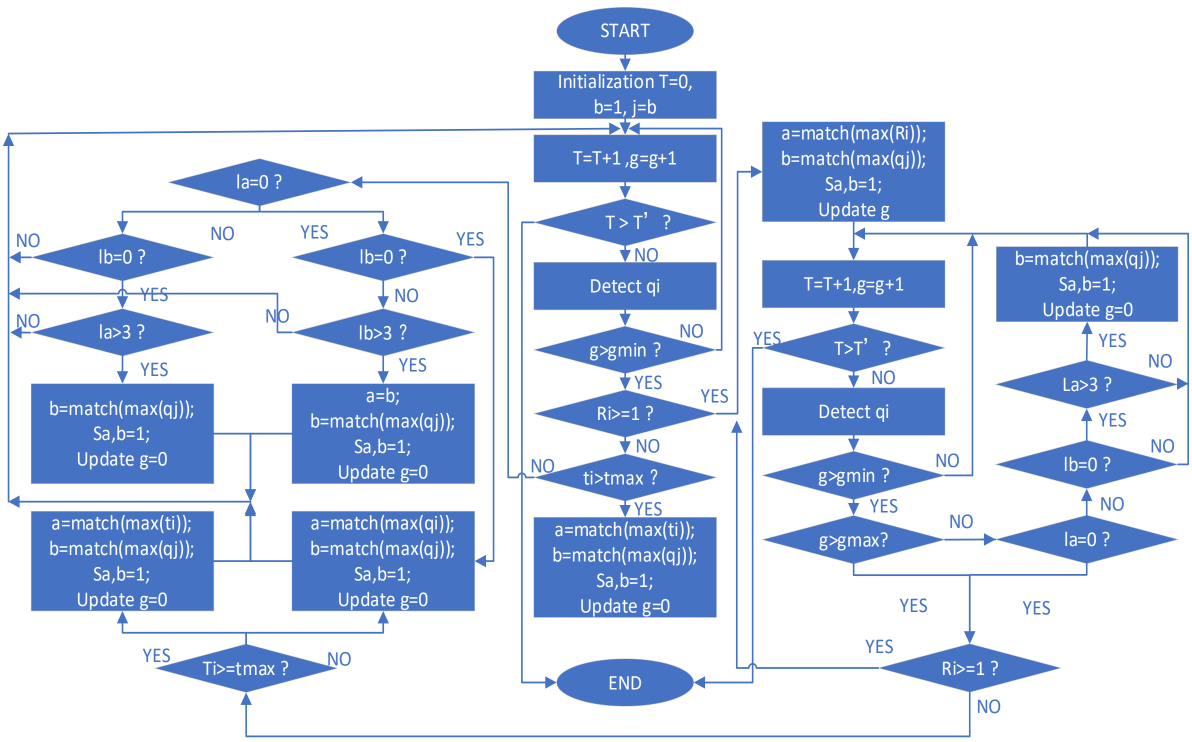

Fig.1 Adaptive induction control logic rule

Table 1 Parameter description

T	Initial control time	j	Flow of associated phases
g	Green light time	gmin	Minimum green time
S	Phase combination state	R	Section saturation
a	Green direction of key phase	t	Red light time
b	Green direction of the associated phase	tmax	Limit red light time
T'	End of control time	match()	Match the maximum value in parentheses
q	Traffic flow in a certain direction	l	Number of queued vehicles
i	Traffic flow direction of key phases	gmax	Limit green time

Figure 1 shows the detailed logic flow of adaptive sensing signal control. The signal control logic integrates single-port release and symmetrical release, and changes the phase combination form according to the change of traffic arrival rate. This release mechanism can be effective Avoid empty discharge with green light. The signal controller sets a "minimum green light time" (g_{min}) for a certain

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0020

phase. When the green light of the phase is longer than the "minimum green light time" (g_{min}), the signal controller starts to count the traffic flow rate saturation corresponding to each phase. If the phase is oversaturated, the green light of the phase with the highest saturation will turn on, and the controller will give the right to release the associated phase with the longest queue length; the priority phase does not reach the "limit maximum green time" (g_{max}) and the priority phase corresponds If there are many vehicles in the entrance lane and the vehicles in the associated phase corresponding to the entrance lane are cleared, the right of release is switched to another associated phase. If there is no phase oversaturation, the conditions for phase switching are restricted by the "limit red light time" (t_{max}) of the red lights of each phase. The phases that meet the conditions are given priority and the associated phase with the higher flow rate is also granted the right of release. ; If there is no phase that meets the conditions, the green light phase will continue to be released, and the phase combination can be flexibly changed according to the associated phase corresponding to the length of the vehicle in the entrance lane to avoid the green light empty release.

3. Parameter calibration based on particle swarm optimization algorithm

The traffic characteristics of each intersection in the urban road network are different, and the adaptive sensor signal control effect is affected by the time and space distribution of vehicles. In order to meet the different traffic needs of each intersection, the constraint conditions of the phase switching of the adaptive induction control are appropriately adjusted. The particle swarm optimization algorithm is used to calibrate the minimum green light time (g_{min}), the limit green light time (g_{max}), and the limit red light time (t_{max}).

The particle swarm optimization (PSO) algorithm is a kind of intelligence-based stochastic optimization algorithm proposed by Kennedy and Eberhart in 1995. The algorithm is inspired by the predation behavior of birds. Compared with genetic algorithm, ant colony algorithm, particle swarm algorithm has the advantages of fast solving speed, fewer parameters, easy implementation, and strong scalability, but particle swarm algorithm is easy to fall into a local optimal state[6]. The standard particle swarm optimization (SPSO) is based on the basic particle swarm optimization (PSO) to design an inertia weight w to coordinate the global and local optimization capabilities of the PSO algorithm. The implementation steps of the standard particle swarm algorithm are as follows[8]:

(1) Initialization. Set the various parameters involved in the PS0 algorithm: the lower and upper limits of the search space L_d and U_d, learning factors c_1, c_2, the maximum number of iterations of the algorithm (T_{max}) or convergence accuracy (ξ), the particle velocity range [v_{min}, v_{max}]; the location of the search point (x_i)and velocity (v_i), assuming that the current position is the p_i of each particle, find the global extremum from the individual extremum, and record the particle number (g) of the best value and its position(p_g).

(2) Evaluate each particle. Calculate the fitness value of the particle. If it is better than the current individual extreme value of the particle, set p_i to the position of the particle and update the individual extreme value. If the best individual extremum of all particles is better than the current global extremum, set p_g to the position of the particle, and update the global extremum and its serial number(g).

(3) The state of the particles is updated. Use equations (1-1) and (1-2) to update the velocity and position of each particle. If $v_i>v_{max}$,set it to v_{max}, if $v_i<v_{min}$,set it to v_{min}.

$$v_{id}^{t+1} = wv_{id}^{t} + c_1 r_1 (p_{id}^{t} - x_{id}^{t}) + c_2 r_2 \left(p_{gd}^{t} - x_{id}^{t}\right) \tag{1-1}$$

$$x_{id}^{t+1} = x_{id}^{t} + v_{id}^{t+1} \tag{1-2}$$

Among them: r_1,r_2 are random numbers distributed in the interval (0,1); c_1,c_2 usually take 2.

ISSN: 2414-1895
DOI: 10.6919/ICJE.202011_6(11).0020

(4) Check whether the end conditions are met. If the current iteration number reaches the preset maximum number (T_{max})or the final result is less than the predetermined convergence accuracy (ξ) requirement, the iteration is stopped and the optimal solution is output; otherwise, go to step (2).

The design of the inertial weight (w) affects the exploration and development capabilities of the particle swarm algorithm. In this paper, we will use linearly decreasing inertia weights. In the early stage of the algorithm, a larger weight will help to expand the global optimization. When the algorithm is iterated, the inertia weight linearly decreases to a smaller value, which makes it easy to lock the local optimal solution[6]. After many repeated experiments, Y. Shi et al. suggested to adopt a strategy of linearly decreasing from 0.9 to 0.4, which usually achieves better algorithm performance. The linear decrease formula is as follows[8]:

$$w = w_{start} - \frac{w_{start} - w_{end}}{t_{max}} \times t \tag{1-3}$$

In the formula, t_{max} is the maximum number of iterations, t is the current number of iterations, w_{start} and w_{end} are the initial inertia weight and the end inertia weight, respectively.

4. Case simulation evaluation based on VISSIM

The intersection of Tanglanghe East Road and Lushan Road in Yiyuan County is selected as the case study object. The CAD drawing and simulation diagram of the intersection are shown in Figure2.

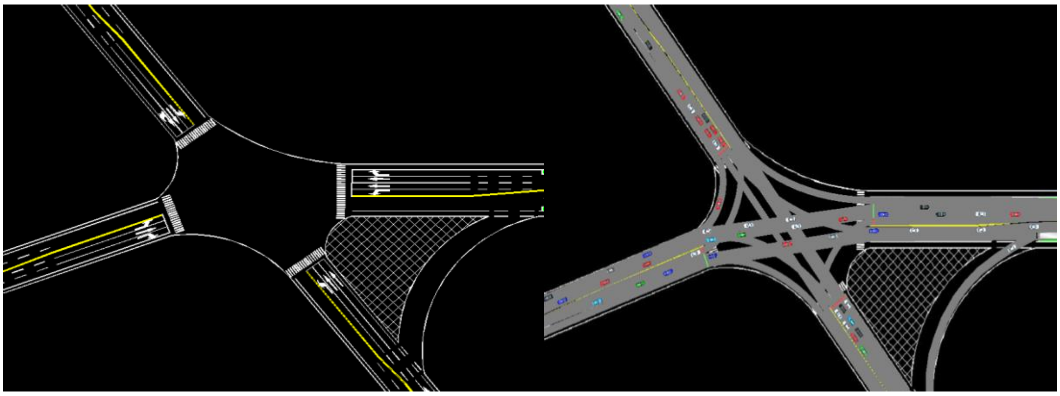

Fig. 2 Intersection of Tanglanghe East Road and Lushan Road

The flow of the adaptive induction signal control simulation technology studied in this paper is shown in Figure 3. According to the traffic survey data, the intersection model is established in VISSIM[1], including road network, signal lights, route decision, vehicle information, signal detector, travel time detector Wait. Load the road network file through the Visual Basic docking VISSIM-COM interface, and use a single step to start the simulation and execute the adaptive sensing signal control logic in Figure 1[7]. The simulation time is 3600 seconds, with an interval of 600 seconds, a 3D particle (g_{min}, g_{max}, t_{max}) is randomly generated through the particle swarm algorithm and brought into the adaptive signal control logic, and the overall vehicle delay at the intersection within 600 seconds is taken as a feasible solution , So the first-generation particle swarm composed of 6 particles can be obtained after one simulation, and the minimum delay of the simulation output is the objective function of the particle swarm. Iterative simulation until a satisfactory parameter set is found.

The timing signal control is calculated by the Webster timing method, because the goal of this method is to minimize the delay, which is consistent with the design goal of the adaptive induction control in this article, and has reference value. The signal control scheme calculated by using symmetrical discharge and Webster timing method for the example intersection is shown in Table 2.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0020

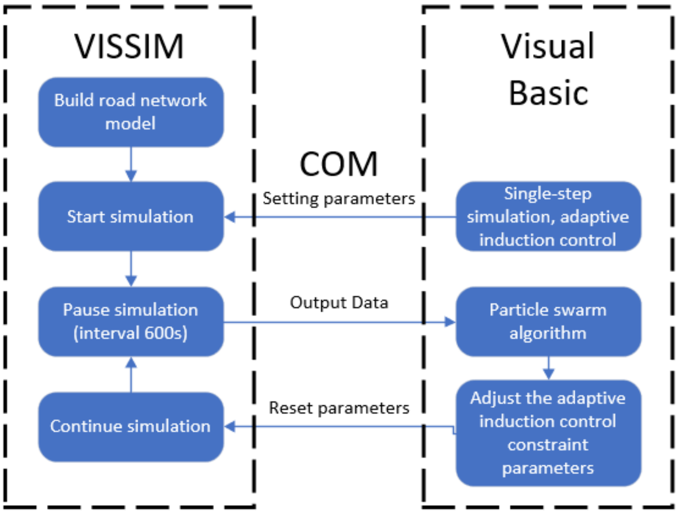

Fig.3 Flow chart of adaptive induction control simulation technology

Table 2 Signal control scheme based on Webster timing method

N-S&S-N	N-W&S-E	E-W&W-E	W-N&E-S	interval
32s	22s	36s	25s	3s

The minimum green time, limit green time, and limit red time of the initial adaptive induction control are 20s, 50s, and 80s, respectively. After calibration by the particle swarm optimization algorithm, they are 18s, 60s, and 90s. Figure 4 shows the overall average delays and the average number of stops at intersections for the three signal control schemes through simulation output. As shown in the figure, the traffic efficiency of the intersection is the best under the improved adaptive sensor signal control scheme.

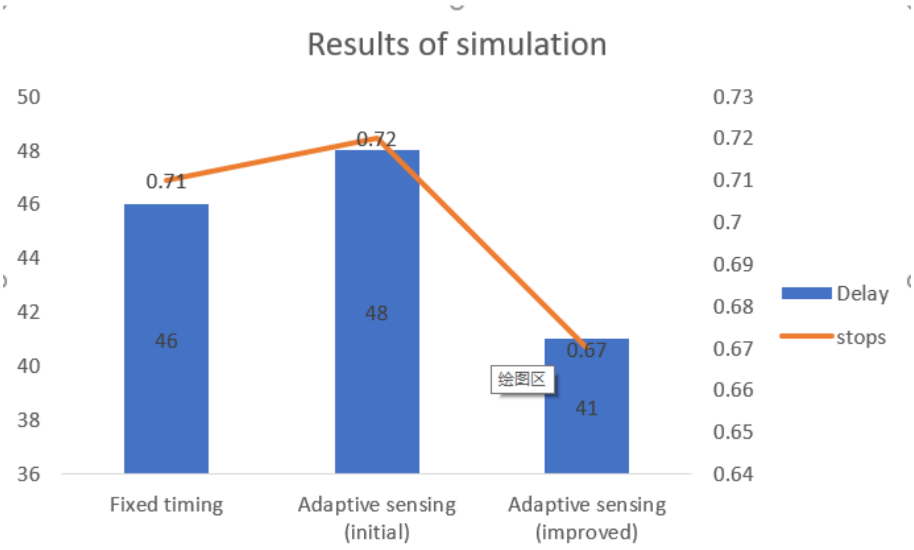

Fig. 4 Comparison of simulation evaluation output results of three signal control schemes

5. Summary

In this paper, a virtual simulation environment for adaptive sensing control of urban intersections is built through Visual Basic docking with VISSIM-COM interface, and a set of adaptive sensing

ISSN: 2414-1895 DOI: 10.6919/ICJE.202011_6(11).0020

control parameter calibration program is designed based on particle swarm optimization algorithm. Among them, the particle swarm algorithm adopts the standard particle swarm algorithm, and the inertia weight adopts a linear decreasing scheme. The intersection of Tanglanghe East Road and Lushan Road in Yiyuan County is selected as the research object. The experiment shows that the adaptive induction control after parameter calibration performs best in both the average vehicle delay and the average number of parking times.

References

[1] Ptv Traffic Mobility Logistics. Vissim5.0 user manual[Z]. Karlsruhe:[s.n.],2007.

[2] Yewei Xiao,Xuefeng Guo,Huixian Huang,et al.Design of self-adaptive intelligent traffic signal machine system[J]. Computer Engineering,2009,35(7):220.

[3] Jian Sun,Xiaoguang Yang,Haode Liu.Study on microscopic traffic simulation model systematic parameter calibration[J]. Journal of System Simulation.2007,19(1):48.

[4] Kevin Fchon,P.E.,Principal,DKS Associates.Adaptive Traffic signals are we missing the boat[J]. ITE District, Annual Meeting,2004,6.

[5] VISSIM5.2-05COM user manual PTV AG.

[6] Lijuan Zhou.The combination of improved PSO and hybrid ant colony algorithm used in text clustering[J]. Journal of Changchun University of Techonology,2009,30- (30):341.

[7] Park B,Schneebcrger J.Micro scope simulation model calibration and validation:cas-e study of VISSIM simulation model for a coordinated actuated Signal system[J].Tr-ansportation Research Record 1856, 2003:759-765.

[8] Li Li,Ben Liu, Particle swarm optimization algorithm[M]. Metallurgical Industry Press,2010.

[9] Chang Liu, Research on Simulation Technology of Adaptive Signal Control for Urban Road Intersections Based on VISSIM[D]. East China Jiaotong University, 2015.