International Journal of Complex Systems – Computing, Sensing and Control,
Vol. 2, No. 1-2, pp. 59-67, 2014

A NOVEL AGENT-BASED INTERSECTION CONTROL METHOD FOR URBAN TRAFFIC

YONG ZHU[1], JIAYI DUAN[2], HONGPENG YIN[1,2]
[1]*China Merchants Chongqing Communications Technology Research & Design Institute Co., LTD., Chongqing 40000, China*
zhuyong1@cmhk.com

[2]*College of Automation, Chongqing University Chongqing 400044, China*
duanjiayi1010@163.com, yinhongpeng@gmail.com

ABSTRACT—Intersection control plays very important roles in the urban traffic. However, most intersection control using stationary signal-timing plan. It is very hard to get the optimal signal-timing plan based on the real traffic condition. In this paper, a novel agent-based intersection control method for urban traffic is proposed. All the urban traffic entities are abstracted to agent models. The real traffic conditions of intersection are analyzed by the interaction, coordination and cooperation action among these traffic entities agent models. The optimal signal-timing plan is calculated based on the real traffic conditions. Experimental results show the proposed intersection control method can get better passing rate than the conventional method.

Key Words: intersection control; agent model; signal-timing plan

1. INTRODUCTION

With the rapid development of urbanization, traffic congestion is a crucial problem affecting the quality of life in the modern cities. Instead of changing the existing structure of road network artificially, Intelligent Transportation Systems (ITS)[1,2]has been widely accepted and developed as the more advanced solution to alleviating urban traffic congestion by improving traffic transportation efficiency.

As the key component of ITS, the efficient traffic control method in the intersection is helpful in reducing the delay time of vehicles and enhancing the capacity of road traffic transportation. Consequently, various traffic control methods has been researched and proposed in recent decades, such as the method based on mathematical [3], the analytic model based on fuzzy logic [4] and the neural network control method [5]. Some of traffic control systems based on these control methods are also widely used to relieve traffic congestion and improve urban traffic conditions. However, the existing traffic signal control method can't accurately gain the individual vehicle operating data and macroscopic traffic flow state. Intersection control system does not make full use of the traffic flow information and does not change with the intersection signal control adaptively. Thus, it affects the effectiveness of the traffic signal control

In this paper, a novel agent-based intersection control method is proposed for urban traffic. All the urban traffic entities are abstracted to agent models. The real traffic conditions of intersection are analyzed by the interaction, coordination and cooperation action among these traffic entities' agent models. The optimal signal-timing plan is calculated based on the real traffic conditions. Experimental results on Netlogo platform show that in this control method pass rate of the intersection is significantly higher than traditional intersections traffic control model.

2. THE PROPOSED INTERSECTION CONTROL METHOD

The prerequisites of the proposed system can be summarized as follows:

1) All vehicles are installed car terminal with vehicle location, real-time communications, information display and other functions;

2) Intersections and road facilities installed signal communication device for the transport entity intelligent communication interaction between peers;

3) For the intersection, after determine the signal phase and phase sequence data based on transportation infrastructure, it will be unchanged the current control process.

2.1 Agent-Based Modelling for Urban Traffic Entities

The information exchange process among the traffic agents are shown in Figure 1. In the process, the information acquisition function of agents for current traffic condition makes the foundation to achieve effective control of the intersection signal. Interaction between traffic entities provided current traffic condition information for signal control system.

Vehicle agent is the basic responder and performer in the traffic control system. The main characteristics of the vehicle agent including vehicle traveling direction, capability of the vehicle acceleration, the acceptable speed limit of the vehicle driver, position of the vehicle in the road network and some other basic attribute parameters; the behavior characteristics mainly consist of the realization method for vehicle's action, reflecting vehicles' dynamic behavior space, such as the vehicle acceleration, deceleration, direction selection, the ways in obtaining the current traffic state, speed control mode, vehicle following strategy; When the vehicle agent reaches the road agent managed by the related intersection agent, the vehicle agent sends the current vehicle status information to the road agent and the intersection agent via communication units. Simultaneously the traffic state information of the current intersection area is acquired by the vehicle agent.

Road agent is the abstract of real road conditions, including static properties sections (the geographic information attributes of the sections in entire road network, road length, number of lanes, road load-bearing capacity and the logo links with other sections), road traffic information collection, road traffic data preprocessing and other functions such as communication, exchange information with vehicle agent will get the current traffic status information provided to intersection agent.

Intersection agent owes the location of the intersection in the whole road network, intersection capacity, each direction of intersections, traffic lights and other configuration. Signal control function of intersection agent mainly is used to optimize the signal period and green-time-rate of each intersection after exchanging the information with other agents. It is primarily responsible for passing control information to traffic light agent.

Traffic light agent receives the control information from intersection agent and take appropriate action for setting own color state. The state of traffic lights affects further on vehicle agent's behavior. It exchanges information with vehicle agent and provides induction control for the vehicle traveling speed.

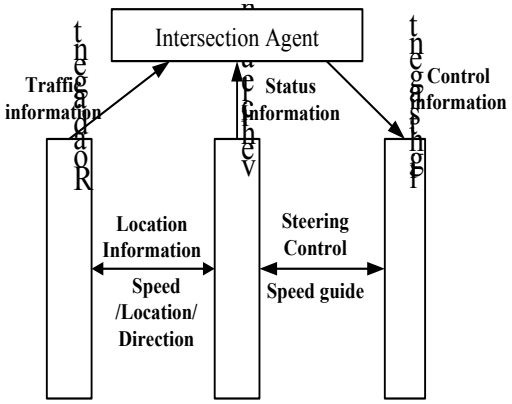


Figure 1. The information exchange process among the traffic agents.

2.2 Intersection Signal Optimization Method

In this system, the traffic information of intersection adjacent sections based on the interaction between the agents to control and adjust the green-time-ratio and signal cycle. The main purpose is to achieve the shortest waiting time of vehicles in the road network. It aims at improving the traffic rate of the intersection and maintaining the smooth operation of the road network.

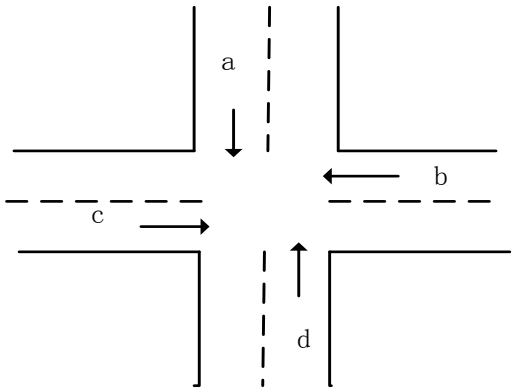


Figure 2. Intersection and traffic flow diagram

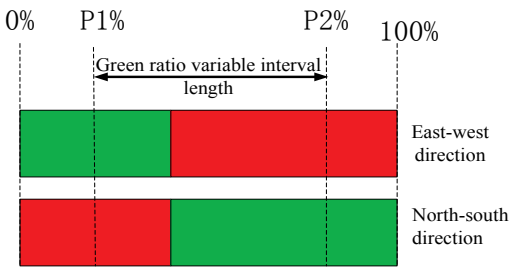


Figure 3. Intersections green ratio composition schematic.

As shown in Figure 2 and Figure 3, in the intersection signal control scheme based on real-time traffic flow information, the green-time-ratio is composed by two parts in the intersection. One is the constant value P1 to ensure the basic ability of allowing vehicles pass in the intersection, and the other is the variable value Vary determined by the dynamic intersection traffic conditions. In the view of probability theory in the intersection in Figure 3, the variable interval range splits on two principal directions should be consistent due to the presence of randomness of traffic flow distribution. When the traffic state level same as each other ideally in two main directions, the green ratio in each direction should be 50%. With the evolution of the unbalanced state distribution of traffic in both directions, the green ratio fluctuates in the range of the variable interval. Thus the upper limitation of green ratio theoretically is P2 = (50% -P1%) + 50% = 1-P1, variable interval length for Vary is Vlength = P2-P1. Therefore, the control constraint conditions for optimizing the green ratio in signal timing plan should be set as Eq (1).

$$\begin{cases} 0 < P1 < 50\% \\ 50\% < P2 < 100\% \\ 0 < Vary < Vlength \end{cases} \tag{1}$$

The variable value portion of green ratio is affected by the real-time traffic conditions in the signal control schemes. Furthermore, it is determined particularly by the distribution of the vehicles' number and the vehicles' average speed from the road agent around the intersection. In the proposed control method, the impact that the vehicles' number has on the green ratio is determined by the weight of *f*. Correspondingly, the impact of the vehicles' average speed has been defined by the weight *1-f*. As shown in Figure 2, a complete intersection is linked by eight road lanes, there are eight section near an intersection. Given that current traffic light conditions can be decided by the input traffic flows of intersection, the four road (*a*, *b*, *c*, *d*) of intersection are used finally to optimize signal lights green-time-ratio in the intersection. The number of vehicles on the four road is noted as *Na*, *Nb*, *Nc*, Nd, and the average speed of vehicles on the four road is noted as *Sa*, *Sb*, *Sc*, *Sd*. Then the green ratio determined by the number of vehicles in the north-south direction can be calculated by Eq (2).

$$P_n = P1 + (P2 - P1) \times \frac{N_a + N_d}{N_a + N_b + N_c + N_d} \tag{2}$$

The green ratio determined by the average speed in the north-south direction can be calculated by Eq (3).

$$P_s = P1 + (P2 - P1) \times \frac{S_a + S_d}{S_a + S_b + S_c + S_d} \tag{3}$$

The green ratio the intersection updates for the signal lights in the north-south direction can be obtained finally according to the weights for *Pn* and *Ps* as shown in Eq (4).

$$P = P_n \times f + P_s \times (1 - f) \tag{4}$$

After the green ratio in the north-south direction is calculated, the corresponding green time can be set according to the signal cycle length. The lights' corresponding status in west-east direction can also be determined based on the mutually exclusive relationship between north-south direction and west-east direction. Thus, the overall function of intersection agent's signal control can be achieved as the above process in the traffic system.

2.3 Intersection Speed Guide and Optimization

In real urban traffic, a situation appears occasionally, when a road lane owes the long vehicle queues waiting for the arrival of green light time and there are little vehicles on the other adjacent road lanes. In order to solve the problem of the waste of green time for passing vehicles, the green light switching approached based on the green time optimization are used to induce vehicles' action.

For all vehicle agent in each phase of the current intersection, the distance away from the stop line, the current traveling speed and other information can be acquired according to the information interaction between the vehicle agent and the road agent. In this paper, the time prediction window is used to label the arriving vehicles in the intersection and induce the vehicle's state. As shown in Figure 4, the size of time prediction window is set as the minimum green time length. For the vehicles in the current phase of green time and the time prediction window, whether a vehicle can pass the intersection can be predicted in advance according to the speed and location of the vehicle and the remaining green time. Thus, the speed guidance information can be passed for the vehicle agent to ensure that the vehicle will pass the intersection under a safe driving speed.

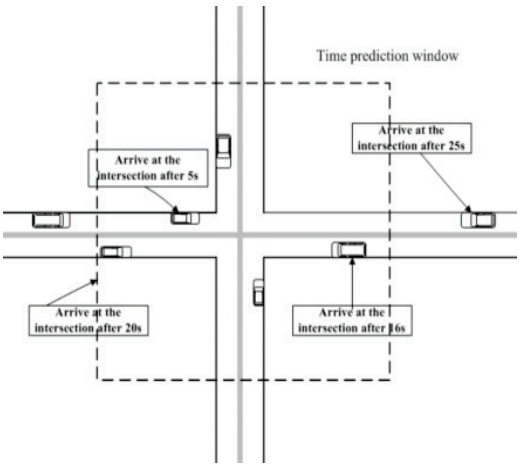


Figure 4. The time prediction window.

If the car can't pass the intersection in the predict time window under the green light, it means that the car flow is far away from the intersection and cannot reach the stop line under the current green time condition. If the vehicle on the conflict phase shown in Figure 5 can reach the stop line in a shorter time than the green time at this moment, the corresponding green time for the conflict phase is switched and the vehicles are given a speed guidance to ensure that it can pass the intersection under a safe driving speed.

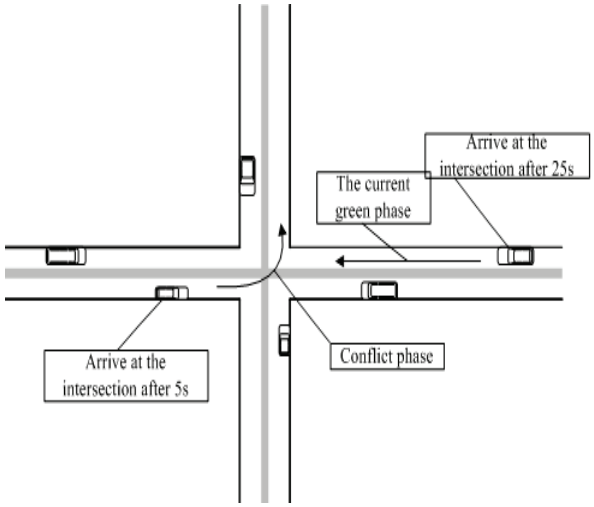


Figure 5. Conflict phase.

3. THE PROPOSED INTERSECTION CONTROL METHOD

To test the superiority of the control method, experiments are conducted in the Netlogo platform using the computer with Intel (R) Core (TM) i3-2375M, CPU@1.50GHz, 2.0GHz memory, Win 7 operation system. The proposed algorithm is implemented as follows:

Step 1: Intersection agent initializes the basic green ratio P1 and variable interval length in the north-south direction.

Step 2: Intersection agent initializes with the weight f, reflecting the impact that vehicles' number has on the green ratio is determined.

Step 3: Intersection agent exchanges information with vehicle agent to get the traffic information of each lane;

Step 4: Intersection agent statistics vehicle information and obtain the number of vehicles on the north-south lane Na, Nd and the number of vehicles in the west-east direction Nb, Nc;

Step 5: Intersection agent statistics vehicle information and obtain the speed of vehicles on the north-south direction road, Sa, Sd and the speed of vehicles in the west-east direction, Sb,Sc;

Step 6: Intersection agent calculates the green ratio determined by the number of vehicles in the north-south direction in the data processing unit according to Eq (2);

Step 7: Intersection agent calculates the green ratio determined by the speed of vehicles in the north-south direction in the data processing unit according to Eq (3);

Step 8: Intersection agent calculates the green ratio in the north-south in the data processing unit according to Eq (4).

Step 9: Intersection agent calculates the green ratio in the east-west direction according to the appositive relationship of the signal between the east-west direction and the north-south direction in the data processing unit;

Step 10: Intersection agent exchange information with traffic light agent to set the appropriate lights green ratio.

After the end of Step 10 and setting the signal cycle, signal control system adaptively switch the signal lamp to avoid the waste of green time by the time predict window.

The simulation platform interface is shown in Figure 6, the buttons and switches are used to initialize the parameters. Here, three kinds of signal control models are used based on different methods. Model 1 takes a fixed green ration; Model 2 is using the proposed dynamic optimization

green signal ratio control method; Model 3 owns the speed guide and optimization in the control period based on Model 2.

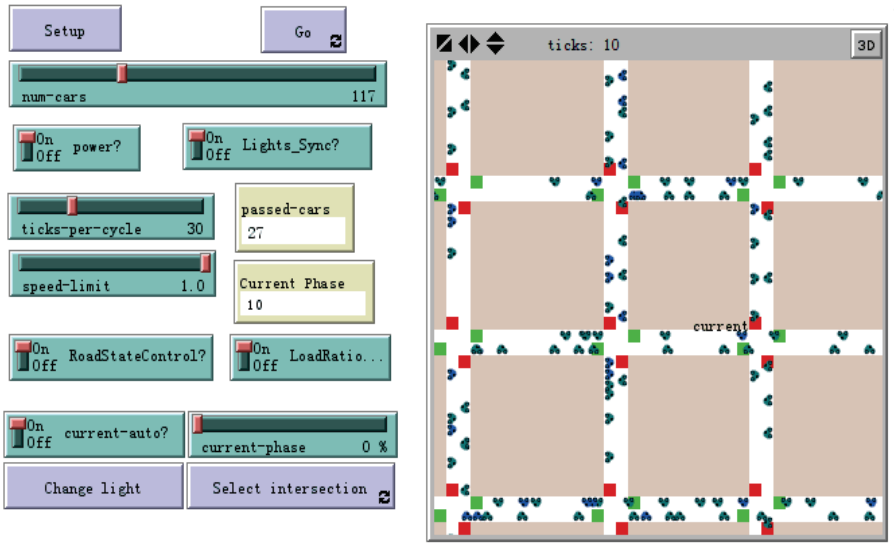


Figure 6. Traffic simulation system.

Figure 7 shows the line chart for the total number of vehicles, which pass one intersection by twenty groups of experiments in three different modes. In each experiment, 200 vehicles are initialized and randomly assigned in a double-lane road network including nine intersections. The signal period is initialized as 30 seconds and the total simulation is set as 500 seconds. As shown in Figure 7, the car-passing number of the intersection are improved significantly when the proposed optimization approaches are used in this system.

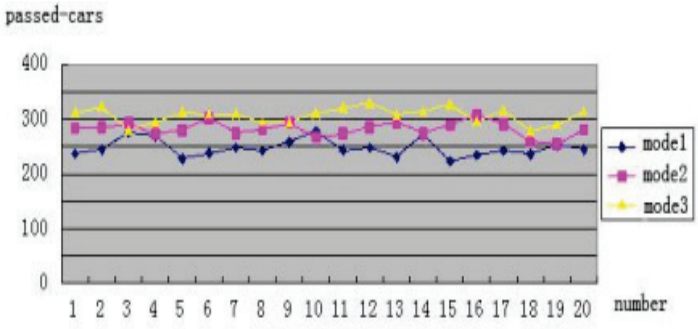


Figure 7. The total number of vehicles through the intersection.

4. CONCLUSION

Intersection is a key of urban traffic control system. The traditional control methods using fixed intersection signal-timing plan are difficult to adapt the real-time change in traffic demand. A novel agent-based intersection control method is presented. Real-time traffic condition

information can be managed by the coordination and cooperation action among those traffic agent models. Intersection control system can adaptively adjust the signal control strategy using the proposed optimization approaches. Experimental result shows the proposed intersection control methods can obtain the better car-passing performance in the intersection than the conventional method.

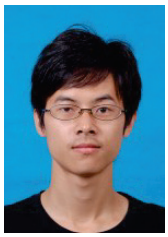
ACKNOWLEDGMENT

We would like to thank the supports by Scientific Research Innovation Capacity Special Funds of China (2014EG124042), Fond National Engineering and Research Center for Mountainous Highways (GSGZJ-2014-07).

REFERENCES

1. S. Tang, F. Wang, G. Wang, X. Jia, and F. Liu, Development and Research of Intelligent Transportation Systems in China's Tenth Five-Year Plan, Proc. of the IEEE ITSC 2006, Canada, pp. 377-382, 2006.
2. X.P. Yan, H. Zhang, and C.Z Wu, Research and Development of Intelligent Transportation Systems, 2012 11th International Symposium on Distributed Computing and Applications to Business, Engineering & Science. 321-326, 2012.
3. B. Wu and Y. Li, Traffic management and control (the third edition). [M]. Beijing: China Communication Press, 2005.
4. H.Y. Wen, H.B. Yin, and J.M. Xu, A Method of Fuzzy Traffic Control of Signalized Intersection, Journal of South China University of Technology(Natural Science Edition). Vol .29, No. 12, 2001.
5. L.H. Xu, L.S. Zhong, and J.M. Xu, Multi-phase Fuzzy Control Based on Neutral Network, Systems Engineering Theory and Practice, NO.7, 2014.
6. X.J. Kong, G.J. Sen, and Y.X. Sun, Dynamic intelligent coordinated control with arterial traffic based on multi-agent, Journal of PLA University of Science and Technology (Natural Science Edition) Vol. 11, No. 5, 2010.
7. L.S. Feng, Y.Z. Sheng, and L.X. Min, Synergy of traffic signal control and route guidance based on multi-agent system, Journal of Jilin University (Engineering and Technology Edition), 2006.
8. H.L. Tan, P.H. Huang, H.B. Li, M.R. Liu, and L.J. Kong, A study on the traffic flow of the main road under the traffic light control, ACTA PHYSIC ASINICA, Vol. 52, No. 5, 2003.
9. S.C. Li, L.J. Kong, M.R. Liu, and R.S. Zheng, The effects of intelligent traffic light on the crossing traffic flow, ACTA PHYSICA SINICA, Vol. 58, No. 4, 2009.
10. R.S. Zheng, L.J. Er, L.H. Zhu, S.D. Chen, and Q.S. Pang, Intersection effects of arterial road for traffic flow, ACTA PHYSICA SINICA, Vol. 58, No. 8, 2009.
11. B.L. Huang and J.B. Yang, Research on the Cooperation between the Self-organization and Organization in Traffic Systems, Systems Engineering Theory and Practice, No. 8, 1997.

ABOUT THE AUTHORS



Y. Zhu received the B.S. and M.S. degrees from the Department of Transportation Engineering, Beijing Institute of Technology, Beijing, China, in 2011 and 2014, respectively. He works as an Engineer in the Intelligent Transportation Research Center, China Merchants Chongqing Communications Technology Research & Design Institute Co. Ltd. His research interests include intelligent transportation systems, traffic control technology and system engineering. E-mail: zhuyong1@cmhk.com

J. Duan was born in 1992. She is studying in Chongqing University. Her main research field is intelligence control theory, machine vision and pattern recognition. Email: duanjiayi1010@163.com

H.P Yin was born in 1981. He is a PhD. and an Associate Professor in Chongqing University. His research interests include Intelligent Transportation System, intelligence image processing and machine vision, pattern recognition and artificial intelligence. Email: yinhongpeng@gmail.com.