Design of Traffic Coordination Control Structure Based on Multi-Agent

Huang Yong 1; Gan Li 2
Guangzhou International Economics College
Guangzhou, CHINA
E-mail: 1457412162@qq.com, 7429491@qq.com

Abstract-Urban transport, one of the city’s important infrastructures, which plays an important role in the normal functioning of the city, has become the focus of attention and discussion in the whole society. Restricting to the sustainable development of urban economy, the traditional solution to the urban traffic problems can no longer meet the development requirements of existing urban traffic. Given the complexity of urban transport, the limitations of traditional traffic control methods and the popularization and application of mature artificial intelligence technology, this paper discusses the collaborative framework of traffic control and induction on the base of multi-Agent technology and make researches on the structural design of urban traffic coordination control, thus building a simulation model for the single intersection. The simulation experiment was carried out by using the Q learning algorithm.

Keywords-traffic system; Multi-Agent; Coordinated control; Induction; Simulation

I. Introduction

Being the main link of the system in the intelligent transportation system, urban traffic control is one of the important ways to improve the efficiency of urban traffic operations, it is also an important symbol of modernization and intelligence of urban transportation. With the rapid development of information technology and knowledge economy, the pace of the city is getting faster and faster, the traditional traffic control methods can no longer effectively solve problems encountered in traffic control. To realize the orderly and smooth traffic, an effective method is to make full use of existing transportation facilities to assist in reasonable traffic control and induced decision making through advanced traffic management in intelligent transportation systems. Application of detection technology and information technology in traffic monitoring system helps to realize the collection of a large amount of real-time traffic data needed in traffic management, as well as the forecasting of traffic flow and travel time. All collected traffic information must be promptly transmitted to the traffic control center so as to correspondingly form a dynamic traffic management strategy. Before developing a corresponding solution strategy to solve traffic problems, the key to achieve timely, efficient and effective management is how to analyze traffic conditions. The goal of an advanced traffic management system is to provide effective strategies to influence the behavior of travelers, reduce traffic congestion and achieve smooth traffic, the realization of these goals depends on the intelligent decision support system in the traffic management system.

The development of intelligent technology and software engineering provides a technical guarantee for the establishment of intelligent decision support systems in traffic management systems. In recent years, multi-Agent based intelligent decision support systems have been used more and more in the transportation field. The system not only reduces the complexity involved, but also supports dialog-based decision interaction. At the same time, with the ability to support traffic prediction and management, many traffic simulation software is also becoming more mature. For example, the simulation module can realize the simulation of traffic dynamic allocation. Establishing an intelligent decision support system in an advanced traffic management system is a guarantee to fully utilize the functions of the traffic management system.

II. Collaborative framework of traffic control and induction based on multi-agent

Traffic control and traffic guidance are two important components of traffic management. Therefore, in the process of establishing intelligent decision support system in traffic management, it is necessary to fully consider the realization of traffic control and induction and the joint work of the two.

As a complex large system, the hierarchical intelligent control mode should be carefully considered in building the model of multi-Agent based transportation system. Saridis proposed that the hierarchical intelligent traffic control system consists of three levels: organization level, coordination level and control level, which have the ability to reduce the dimensionality of the problem, get real-time control solutions with less computing resources, and be able to respond quickly to traffic events. In the traffic control and induced collaborative system model constructed by combining multi-Agent technology and hierarchical structure, road segment Agent, intersection Agent, regional Agent and central Agent are set up in the system. The structure is shown in Figure 1.
The distributed hierarchical control system adopts the design principle of decomposition and coordination. The control action is decomposed to different levels through horizontal space decomposition and vertical functional decomposition and the local coordination is used to realize complex control tasks and goals. It solves the dimensional disaster and reliability problems of giant complex control systems. This method draws on the idea of hierarchical coordination control of control and induction, and combines the characteristics of independent and integrated modes. Adopting the concept of "distribution" in traffic control and induced coordination, the specific meaning is "scatter"----- using the independent control mode of control-induced decomposition before the traffic flow is crowded, "set"---- when congestion is about to occur, a control mode that integrates control and induction is adopted. By seeking a “point” where traffic flow is about to become crowded, a collaborative model of control and induction is established.

III. Design of Traffic Coordination Control Structure Based on Multi-Agent

Consisting of a large number of intersections, road traffic networks in large and medium-sized cities which bear the main functions of urban transportation usually contain a large number of intersections. Such a complicated traffic network must control the traffic flow through traffic signals. Unlike single-segment traffic control, multi-junction traffic networks have interactions between traffic flows at intersections. Only considering the traffic problem of a single intersection does not make the entire network optimal. How to improve the coordination between intersections under the premise of ensuring the smooth flow of traffic at each intersection so as to increase the traffic capacity of the entire road network is the key to coordinated traffic control. From the development of urban traffic control itself and the requirements of modern society for urban transportation, the complexity of traffic and the limitations of traditional traffic control methods force people to apply more intelligent techniques to solve control problems. Realizing the intelligent control of the city's overall transportation network will be the inevitable development. The transportation system has a distributed nature of topology, therefore, the application of multi-Agent distributed processing and coordination technology to solve traffic problems, especially for traffic situations with drastic changes, has greater potential. At the same time, it also provides a solution for the coordinated control and modeling of the transportation system, a typical distributed system with great abruptness and randomness, and provides reference for the realization of intelligent traffic control.

A. Agent control authority

To introduce multi-Agent technology into traffic control, in the existing traffic control structure, there are three ways to handle the control of the Agent according to the model structure of the multi-Agent:

a. Single-route single Agent control

Set a control Agent for each intersection to be responsible for the control of all phases of the intersection, that is, each controlled intersection or node is an Agent. They can control the intersection by virtue of their intelligence and autonomous ability, or by coordinating with agents at adjacent intersections and relying on their cooperation. The system can run without relying on a privileged Agent as there is no hierarchy between Agents in this type of control. On the basis of game theory, local and global intelligent control is realized through negotiation and cooperation between Agents of equal relationship. The coordination of interests between phases is used as an ability of Agent to realize the coordination between intersection Agents to achieve global optimization.

b. Single intersection multi-Agent control

Set multiple Agents at each intersection. Treat each phase as an Agent, thus, it is required to add different numbers of phase Agents for intersections with different shapes and different phases. In this way, the phase Agents in each intersection need to cooperate. And to coordinate with the intersection Agent, for different intersection Agents, they must also coordinate with each other. In order to maximize the overall benefits of the control area, adopting this control method will inevitably increase the number of Agents included in the control system and the coordination between Agents has become more complicated. As the number of intersections in the control road network increases, the timeliness of control will also decrease, and the control cost will also increase.

c. Sub-area single Agent control

Each sub-area is provided with a control Agent and each
Agent is responsible for the control of one or more intersections. The coordination between the Agents is represented by the coordination of interests between the sub-areas. This control method is based on the sub-area division of the entire control area. Moreover, after sub-area division, it is impossible to adjust in real time according to changes in actual traffic conditions.

In summary, it can be seen that the three methods of processing control rights have their own advantages and disadvantages. It can also be seen at the same time that the introduction of multi-Agent technology in traffic coordination control and reasonable formulation of the control scope of each Agent are the key to the structure of the entire control system. Therefore, when designing the traffic coordination control structure, the Agent control permission setting adopts the single-port single-Agent control method described above, that is, each Agent represents and controls an intersection. In order to avoid the frequent and complicated interaction and coordination between Agents due to the increasing numbers of intersections in the controlled road network, it is stipulated that the Agent only cares about the traffic situation of Baiji and adjacent intersections. Each intersection Agent only communicates and cooperates with the adjacent intersection Agent. By reducing unnecessary communication between Agents and coordinating with the intersection Agents that are adjacent or have strong correlation with the Agent, it helps to implement local traffic control solutions and ensure overall optimization.

B. Structure of the intersection Agent

The intersection plays an important role in the transportation network because traffic flows in all directions converge here, and traffic phenomena such as diversion and collision of vehicles also form here, meanwhile, It is mainly at intersections that traffic congestion and traffic accidents often occur in the urban transportation system. Therefore, the intersection control Agent is an important part of the traffic coordination control system. It is the most basic and main part of the entire traffic coordination control system, and is the backbone of the transportation network. The intersection control Agent is mainly responsible for the operation management of the vehicle at the intersection. Control decisions can be made based on your goals, abilities, knowledge, perceptions, and data. It can request additional information or accept other targets and commands and coordinate with the adjacent intersection control Agent when necessary. The functional structure of the intersection control Agent is shown in Figure 2.

![Fig. 2. Intersection Control Agent Structure](image)

Traffic information is traffic flow information on various imported vehicles at intersections. Combined with the signal timing optimization algorithm and the intersection traffic information based on intersection as well as knowledge of traffic control pre-stored in the control strategy library, the strategy and specific scheme of signal control are determined through calculation. To achieve the minimum vehicle delay or the shortest queue length in urban traffic, The negotiation and communication part mainly completes the exchange and negotiation of the intersection information and the surrounding Agent information. Then develop appropriate control strategies to maintain the benefits of the entire system. The traffic light is a traffic signal display device, which uses red, yellow, green and other different color lights to indicate the right of each access road at the intersection. According to the control strategy formulated by the intersection control Agent, the traffic of the vehicle at the intersection is controlled by the length of the color change time.

C. Multi-Agent traffic coordination control structure

The idea of multi-Agent coordinated control system for urban traffic is mainly operated with the characteristics of the network topology and the traffic volume of the network in the urban transportation network, thus a series of important nodes are identified. As a single Agent, the purpose of overall optimization control is achieved through the coordination and cooperation between Agents with intelligent body as the control unit which is on the base of intersection control Agent, multi-Agent urban traffic coordination control. There is no central control room, therefore the traditional centralized control is transformed into a control mode with distributed control as the main body. The traffic coordination control structure of multi-Agent with the intersection control Agent as the unit is shown in Figure 3.
In the system structure, each intersection control can act as a control center for a small area around the intersection at any time and control strategies can be developed based on the importance of pre-defined intersection. At the same time, the autonomy and flexibility of the Agent can also be fully reflected as each intersection Agent control represents the interests of an intersection and serves the relationship of autonomy and equality between intersection control.

The ultimate goal of the system is not to maximize the benefits of a single intersection but to maximize the benefits of the entire control area. In order to achieve coordination between intersection Agents, the intersection Agent can exchange information with the adjacent intersection Agent through its respective communication and coordination parts. Through the cooperation with each other, the overall optimization effect of the system is achieved.

IV. Simulation

This paper uses the traffic flow at the intersection of Guangcong Road and Guangzhou Beita Road as the study of self-learning control of single intersection. The intersection, a crossroad junction with three lanes in the entrance lanes of all the four directions, uses a four-phase setting. Using the genetic algorithm to optimize the membership function for simulation to get the traffic intensity of the current intersection. With the current strength as the state variable of the Q learning algorithm, the self-learning ability of the intersection can be realized.

In order to verify the validity of the Q learning control algorithm, the single cross simulation model is established on the microscopic traffic simulation software VISSIM. Simulation experiments were carried out on three control methods based on Q learning, timing control and fuzzy control and the average delay of the three control modes under different traffic flow conditions is calculated with the results shown in the figure and table respectively. When using the timing control method, the signal timing is obtained by the Webster algorithm for calculating the theoretical optimal period according to the traffic volume. When the fuzzy control mode is selected, the maximum green time is 50 seconds and the minimum green time is 20 seconds and the unit is 3 seconds when the green light is extended. The control strategy is signal control when convergence tends to converge after a certain signal period.
Table 1. Average vehicle delay time for three control methods under different traffic flow conditions

| Traffic flow | Timing control(s) | Fuzzy control(s) | Q learning(s) | Degree of improvement% |
|--------------|-------------------|-----------------|---------------|------------------------|
| Mild         | 15.72             | 13.46           | 10.96         | 30.28                  |
| Moderate     | 27.95             | 22.63           | 19.85         | 28.98                  |
| Severe       | 34.25             | 33.11           | 26.64         | 22.22                  |

As can be seen from the figures and tables, the fuzzy control is better than timing control, the Q learning control method is superior to fuzzy control and timing control. With the increase of traffic volume, the effect of fuzzy control gradually approaches the timing control. When the traffic volume is saturated, the two curves almost intersect. The Q learning control method only slightly changes the average delay time of the vehicle when the traffic volume is small relatively with fuzzy control at a certain moment, but with the increase in traffic, the control effect of the Q learning control method has changed significantly. Relative to timing control and fuzzy control, the average improvement was 27.16% and 16.79% respectively. The experimental results prove that, it is a better method to use Q learning algorithm to control in a single intersection, which is better than traditional control methods.

V. Conclusions and Outlook

Through the Internet, the Internet of Things, and the connection of mobile wireless networks, the autonomous Agent will fill the entire transportation system. To play a bigger role, it is also necessary for the Agent to fully consider the characteristics of the urban transportation system in the actual environment thus reducing the amount of computation and coordination complexity, optimizing the system organization, the research direction of multi-Agent in urban transportation is as follows:

1. Improve road network operation efficiency by sharing the information fusion of multiple Agent systems, such as traffic management systems, navigation systems, intelligent parking systems;

2. Research multi-Agent system structure and coordination algorithms for specific application areas and form a standardized technical system, including communication environment, modeling method, evaluation method, etc.

3. The widespread application of Agent will bring more artificial intelligence, system engineering, control theory, optimization algorithms and distributed computing technology into the actual traffic problem solving and at the same time provide more new ideas for the specific application of Agent.

References

[1] Gao Yang, An Bo. Multi-Agent System and Application. First Edition, Tsinghua University Press, Beijing, 2015.
[2] Qi Bin. Research on Coordination Control Consistency Problem of Multi-Agent System, JianNan University, WuXi, 2015.
[3] Fei Fu Qiang. (9 pt Regular) Multi-Agent Event Trigger Control, Engineering Technology, Vol. 13, Issue 1, 2017.