Design and Implementation of Traffic Signal Control System Based on Parallel Simulation Technology

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Abstract. A traffic signal control system based on parallel simulation technology is designed in this article. Based on the second-level acquisition of intersection data, this system builds a control algorithm matching rule base based on offline algorithm adaptive analysis. In addition, the system can select the signal control algorithm that matches the real-time traffic status online, and realize the online evaluation of the control algorithm through the online parallel simulation and control algorithm evaluation platform, and provide a decision basis for further implementation of the algorithm. This system improves some existing deficiencies in signal control systems, and also provides decision support for the application of complex control algorithms. The system is applied to the control of actual signalized intersections. Practice shows that the system can better adapt to the actual situation of signalized intersections in District, improve the capacity of intersections and the efficiency of the entire road network.

1. Introduction

As an important component of ITS, urban traffic signal control systems have always been the focus and focus of research. Among them, the TRANSYT system, the SCOOT system, and the SCATS system are more representative. The above systems have achieved certain expected results in traffic practice, but there are still some problems with these systems: (1) Offline optimization methods, which require a large amount of calculation and cannot adapt to real-time traffic flow dynamic changes. (2) On-line scheme, the system's control strategy is obtained through accurate data model simulation. The higher the model accuracy, the more complicated the structure, and the longer the simulation time, so there is a disconnection between simulation and control. (3) On-line scheme selection, the matching of control strategy and traffic flow is set offline, and there is an aging problem of the relationship between real-time traffic and control strategy. In addition, in recent years, many domestic and foreign scholars have introduced intelligent algorithms such as reinforcement learning, fuzzy systems, and genetic algorithms into the field of traffic engineering to address the shortcomings and limitations of traditional control systems, and have achieved good simulation results. Applications in the system are still difficult to implement. Based on real-time collected traffic state data, parallel simulation
technology is used to perform online real-time simulation of the selected control algorithm and generate evaluation indicators and corresponding signal control timing schemes. At the same time, the evaluation index is sent to the simulation evaluation decision support module to evaluate the quality of the control strategy and decide whether to load it into the signal machine for implementation. This system solves the problems of lag of data acquisition, asynchrony of simulation and control, and aging of control strategies in the above-mentioned system to some extent. At the same time, the system also provides decision support for the application of complex control algorithms[1,2,3].

2. System design scheme
The traffic signal control system based on parallel simulation technology designed in this article is composed of the following modules.

(1) Data acquisition module: This module collects traffic conditions at intersections through intersection detectors, and lays the foundation for further data analysis and selection and evaluation of control algorithms. In the system, the collected traffic state data is required to be accurate in real time.

(2) Data processing module: This module is to process and calculate the traffic information of intersections obtained by various collection systems in real time, obtain real-time traffic status parameters, and build a traffic data dictionary of intersections. The data dictionary includes parameters such as real-time traffic flow, time occupancy, average headway, and average vehicle speed. It provides an accurate data basis for online algorithm selection in algorithm simulation, selection, and evaluation modules. Based on the data dictionary, complete the statistical analysis of historical traffic data, obtain thresholds that can reflect the reasonable division of traffic segments of the internal structure of traffic flow data at intersections, and pave the way for the establishment of algorithm matching rule bases for algorithm adaptive analysis.

(3) Algorithm simulation, selection and evaluation module: In this module, a combination of offline algorithm adaptability analysis and online algorithm selection is used to realize the online selection of control algorithms. First, the simulation software is used to analyze the adaptability of the control algorithm for different traffic segment divisions, and a set of matching rule bases for various control algorithms and their corresponding traffic conditions are established to lay the foundation for further online selection of control algorithms. In the online algorithm selection, according to the real-time traffic flow at the intersection and according to the previously established algorithm matching rule base, a control algorithm matching the real-time traffic state is selected. At the same time, through the online parallel simulation and control algorithm evaluation platform, the online evaluation of the control algorithm is realized, and a decision basis is provided for further implementation of the algorithm. Through this module, a control strategy selection structure combining offline algorithm adaptability analysis and online algorithm optimization selection is constructed[4,5].

In order to realize this mode, the simulation software must have the following characteristics:① Because there are many possible combinations of signal control methods at intersections, and the state space that the model needs to describe is very large, the selected simulation software needs to support these huge model descriptions on the model.②To achieve parallel simulation technology, it is required that the selected simulation software has a secondary development function, which can realize human-computer interaction between decision makers and the system, and build a signal control decision support system.③To realize the online evaluation function of the control algorithm, it is required that the selected simulation software can generate an evaluation file after completing the simulation[6].

(4) Signal module: This module completes the output of the entire system. Through the communication interface provided by the signal device, it completes the implementation of the optimal control scheme of the signalized intersection.
3. System implementation

3.1 Data acquisition module
Coil detector MUD3002 was used to collect intersection coil data, and the detector's own characteristics and its openness in design were used to design an intersection microcontroller data acquisition system. Directly process the high and low level output of the detector MUD3002 through the single chip microcomputer, and design the data transmission unit to realize the return of the external field data, and return the data to the remote server through the optical terminal[7,8].

3.2 Data processing module
This module transfers the level data obtained by the data acquisition module, and transmits it after verification. Based on detailed statistical analysis of the data, a real-time traffic information data dictionary for each signalized intersection is established, and historical data is detailed based on the data dictionary. Through analysis, the traffic segment division threshold of each intersection is obtained, which lays the foundation for further selection of control strategies. Extract real-time high and low level data from the database to complete the following data statistical analysis and processing: The first is real-time data processing, using the extracted real-time high and low-level data to identify traffic parameters that can reflect the real-time traffic status of the intersection, such as real-time traffic flow, time occupancy, headway, vehicle speed and other intersection traffic information. The second is statistical data analysis. Its main function is to analyze the data dictionary of each intersection by using clustering analysis and other analytical methods to obtain the characteristics of the traffic data at the intersection, and establish a reasonable threshold for dividing the flow segment that can reflect the internal structure of the intersection data. To lay the foundation for algorithm adaptive analysis. Based on the statistical analysis of the actual intersection 24h and the traffic flow every 15min as a data point, the data is analyzed using fuzzy clustering to obtain a reasonable flow segmentation threshold that reflects the internal structure of the intersection traffic flow data (Figure 1). A statistical database reflecting the statistical characteristics of traffic flow at the intersection, laying the foundation for the adaptive analysis of the algorithm.

![Figure 1. Clustering result](image)

3.3 Algorithm evaluation selection module
This module mainly completes the online selection, parallel simulation and online evaluation of control algorithms, and establishes a signal control decision support system. In order to meet the huge state space description of intersection signal control methods and realize the parallel simulation technology and algorithm online evaluation function, Paramics is selected as the simulation software. Paramics comes with a road network evaluation function. The generated simulation evaluation report is divided into simulation calculation report, statistical report, analyzer report, and GEH
calibration evaluation. The evaluation data report is generated synchronously based on the data simulated by PARAMICS. The report can also be read by EXCEL and so on. It is convenient to link with the simulation evaluation platform built by MATLAB to realize the online evaluation function of the signal control algorithm. The entire algorithm selection module includes two parts.

1) Research on offline algorithm simulation

Based on the reasonable flow segment division of each intersection obtained from the statistical data processing in the data processing module, using parameter simulation software, offline simulation studies the adaptability of different control algorithms with respect to the characteristics of traffic conditions at the intersection, so as to establish The optimal traffic flow matching relationship establishes a matching rule base of intersection traffic segments and signal control algorithms, as shown in Figure 2. The research and implementation of any control algorithm requires the adaptive analysis of the control algorithm based on parameter simulation software, and the analysis results are stored in the database, and the matching relationship between various control algorithms and traffic status is established offline. For example, at the intersection of Highway Bureau, try to use "traffic signal control based on game theory" — a new signal control algorithm. Based on parameterics, a simulation road network is established, and the phase number of the intersection is set according to the actual situation. The intersection has two phases: straight, left, straight, and right. After simulation research, it can be found that the control algorithm is suitable for asymmetric traffic flow. When the east-west traffic volume is 800veh / h and the north-south traffic volume is 200veh / h, the algorithm is more suitable (see Figure 3). In this way, for different control algorithms, after a large number of simulation studies, matching traffic flow matching relationships can be established to provide a basis for the use and implementation of control strategies.

![Diagram](image)

**Figure 2.** Offline processing to establish algorithm matching rule base

![Graph](image)

**Figure 3.** Control effect of cooperative game cooperative solution algorithm
(2) Online algorithm selection processing

Based on the real-time data obtained from the data processing module, according to the control algorithm adaptive matching rule base established by the control algorithm simulation research institute, the real-time traffic data matching signal control algorithm is selected online. In order to ensure the effectiveness of the control algorithm, a parallel decision support evaluation system based on paramics is applied. Online evaluation of the effectiveness of the control algorithm under the current real-time traffic conditions provides a basis for users to decide whether to apply the algorithm. Figure 4 is an evaluation diagram of the control effect of the cooperative game cooperation algorithm when the actual intersection is 800veh / h in the east-west direction and 200veh / h in the north-south direction.

![Figure 4. Evaluation of control effect](image)

4. Conclusion

This paper designs a traffic signal control system based on parallel simulation technology, and applies this design idea to build and complete the urban signal control system. Practice has shown that the system can achieve second-level data collection, comprehensive and meticulous grasp of intersection information, and solve the bottleneck problem of parallel simulation technology. Using a combination of offline algorithm adaptability analysis and online algorithm selection, the control algorithm is implemented. Online selection to avoid the aging problem of control strategies in the previous system; the application of Parallel Decision Support System based on Parallels to achieve online parallel simulation and online evaluation of control algorithms to solve the problem of simulation and control derailment; meanwhile, the algorithm matching was established offline The idea of the rule base makes the system also provide decision support for the application of complex control algorithms. In addition, the system is highly scalable. Once a new algorithm is generated, it can be analyzed offline and embedded in the algorithm matching rule base.

In addition to collecting coil data in the data acquisition module, the signal control system designed in this article can also return video information, and return to the traffic parameters at the on-site intersection through the processing of the video information, such as the current queue length of each channel. Whether the algorithm of the algorithm really runs according to the expected effect, once there is a large deviation, you can choose the backup algorithm to run, making the system closer to the closed-loop adaptive control.
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