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Design of Coordinated Control System for Loop Traffic in Vehicle-Road Cooperative Environment

Zhiyan Jia[a], **Yong Ding**[b,*]

School of Traffic and Transportation, Beijing Jiaotong University, Beijing 100044, China

[a]17120823@bjtu.edu.cn, [b]yding@bjtu.edu.cn

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Abstract: The loop traffic congestion is often caused by excessive concentration of traffic flow due to the centripetal effect of the loop. Aiming at solving the problem of loop traffic congestion, this paper, is devoted to a loop traffic coordinated control system based on the vehicle-road cooperative environment. The design of the system mainly includes two main steps: the calculation of the guided speed and the adjustment of the dynamic signal timing parameters. Besides, on the Visual Studio 2010 platform, a simulation test is performed by virtue of the Visual Basic 2010 language and the VISSIM 4.3 COM interface. The result of the simulation shows that the coordinated control system of loop traffic based on the vehicle-road cooperative environment is better than the point control and the traditional green wave control in average delay, the average queue length and the average number of parking times and other indicators.

1. Introduction

The loop, as an important form of urban road structure, bears heavy tasks on traffic and transportation. As the rapid development of the urban motorization, the congestion of loop at the peak of the cycle has become a normal state [1]. In recent years, the vehicle-road cooperative technology has gradually matured, the technology, adopting advanced wireless communication and Internet technology, can fully implement the dynamic and real-time information interaction between vehicles and roads, and collect and integrate entire space-time dynamic information to provide technical support for easing the current traffic congestion situation. Besides, providing more accurate means for obtaining parameters of the signal control mode of the intersection. It also provides the environmental foundation for rationally coordinating the relationship among people, vehicles with roads and realizing the bidirectional optimization of vehicle running state and the timing parameters of intersections [2,3]. However, there are few researches and applications on vehicle-road cooperative technology in the loop roads.

In this paper, we study the optimization strategy to loop traffic operation and construct a coordinated control system, based on the design that vehicle-road collaborative is adaptive to the loop structure to achieve the aim of improving the traffic efficiency and ease the traffic congestion pressure of the loop.

2. System Design

2.1 Design Ideas and Principles

The loop traffic coordinated control system under the vehicle-road collaborative environment mainly includes five parts: detection system, communication system, signal control system, intelligent vehicle system and guided speed calculation system. It is assumed that all systems can satisfy the conditions, and the calculation of the guided speed and the adjustment of signal timing are the main parts. The principle is shown as follows: firstly, the communication system conveys the real-time information which originated from the detection system to the guided speed calculation system, so we can calculate the guided speed V*g*. Then, the information of the vehicle traveling in the guided area at the speed V*g* is transmitted to the signal timing system to obtain a current signal timing strategy. Finally, the current parameters from the strategy are provided by the signal to the guided speed calculation system, and the subsequent vehicles continue with the previous steps.

In this paper, the guided speed is calculated according to parameters such as the initial arrival time and the initial speed of the vehicle from the detection system, and combined with the signal control system to obtain the parameters such as the dynamic cycle, green signal ratio and phase difference of the loop traffic coordinated control system. Thus the scheme can be formed to enable vehicles to move smoothly through the intersections of the loop roads just in the green traffic phase, and realize the loop coordinated control under the vehicle-road coordinated environment.

2.2 Calculation of the Guided Speed

2.2.1 Model Establishment

To enable vehicles to pass through the signalized intersections without stopping, the driving process should be divided into two stages [4].In the first stage, the vehicles transit from the original speed to the guided speed and the second, the vehicles will pass through the intersections at the guided speed. The modeling is constructed as follows:

Step 1: Calculating the timing T*i* of the vehicle *i* passing through the stop line in the intersection by the vehicle-road coordination system.

$$T_i = T_0 + \left|\frac{v_i - v_0}{\alpha}\right| + \frac{L_k - \left|\frac{v_i^2 - v_0^2}{2\alpha}\right|}{v_i} \quad (1)$$

Where α is acceleration (m/s^2); v_0 is the initial speed (m/s); L_k is the distance from the initial position to the parking line (m); T_0 is the initial moment(s); v_i is the initial guided speed of vehicle *i* *(m/s)*.

Step 2: Calculating the timing T_k of the vehicle i to travel from the initial speed v_0 to the stop line.

$$T_k = T_I - T_0 \quad (2)$$

Step 3: Calculating the guided speed v_g of the vehicle *i*.

$$v_g = v_0 \mp \alpha T_k + \sqrt{\alpha^2 T_k^2 \mp 2\alpha T_k v_0 \pm 2\alpha L_k} \quad (3)$$

2.2.2 Model Solving

According to the above mentioned model of guided speed, the process of solving the guided speed is designed as follows:

Step1: When the first vehicle parking, the stop line time equals to the start time of the green minus the loss time and minus the head time, otherwise it is equal to the current time plus the saturation headway. Step2: The time of the back arrives at the line equals to the current time plus the saturation headway. Step3: If the line time is equal to the green start time that is no more than the green effective time that we can calculate the guided speed Vg. Step4: When $V_g \geq V_{max}$, we can adjust signal timing and back step3; When $V_g \leq V_{min}$, we assumed the $V_g = V_{min}$; When $V_g \leq V_{max}$ and $V_g \geq V_{min}$, we can get the guided speed and calculate the next car Vg.

2.3 Generation and Adjustment of Signal Timing Scheme

Based on the parameters such as the guided speed, cycle and green signal ratio under the initial signal timing scheme, the dynamic signal timing is performed by the following three steps and the adjusted dynamic parameters are obtained [4].

Step1: Priority area setting. It sets 200m behind the line is defined as the priority area which provides the adjustment space for the signal timing parameters, and the rest is only used for speed guidance.

Step2: Vehicle detection and priority pass judgment. The time and speed of each vehicle entering the test area are required to be accurately confirmed.

Step3: Green light compensation time setting. Taking the sum of the phase differences between upstream and downstream as an integral multiple of the cycle and the longer actual green time g_i of the phase i than the shortest green time g_{min} as the constraint, the study makes an adjustment to the dynamic signal timing according to the delay of the vehicle acceleration and deceleration and the flow to the intersection to get the adjusted dynamic cycle, green signal ratio, phase difference and others.

3. Simulation Test and Analysis

3.1 Timing Calculation

This paper is based on the simulation study of the loop in Xigu District of Lanzhou City, Gansu Province. First, channelization design was made for all the intersections involved in the loop, and then, the timing parameters were calculated in the circumstance of the point control and the traditional green-wave control timing scheme respectively. The calculated results are shown in Fig. 1 and Fig. 2.

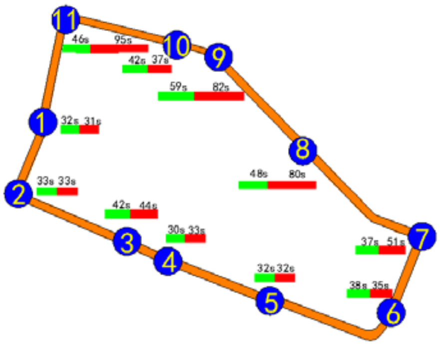

Fig.1 The point control timing result

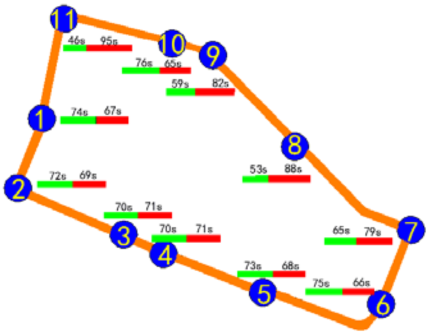

Fig.2 The traditional control timing result

3.2 Simulation Test

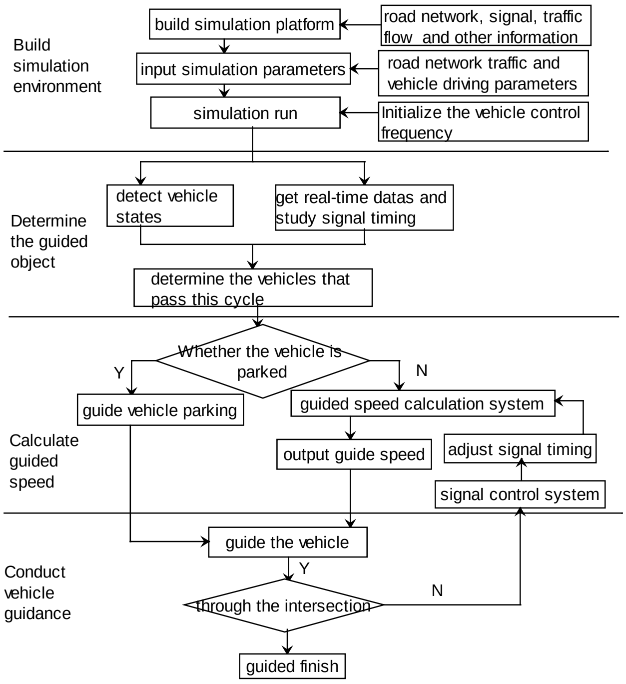

Fig.3 Simulation flow chart

Fig.4 Vissim simulation video screenshot

The vehicle-road coordination guidance strategy is applied through simulation means, including four phases: building the simulation environment, determining guiding objects, calculating the guided speed and conducting vehicle guidance. The corresponding simulation flow chart is shown in Fig. 3. According to different speeds, the vehicles travel in concert with the following three strategies:

When $v_g < v_{min}$, vehicles must stop; When $v_{min} \leq v_g \leq v_0$, vehicles pass the intersection without stop; When $v_0 \leq v_g \leq v_{max}$, vehicles pass the intersection at an acceleration.

Based on the platform of Visual Studio 2010, the joint simulation programming by combining Visual Basic 2010 language with VISSIM4.3 COM interface, the simulation test is performed under the vehicle-road cooperation environment. When the vehicle reaches the detection point in the simulation environment, assuming that the system shows that its initial speed is 35 km/h, the guided speed in this state can be calculated to be 40 km/h, and it needs to accelerate to pass through the intersection smoothly. The corresponding simulation effect of this process is shown in Fig. 4.

3.3 Results Analysis

After many simulation tests, the simulation results are shown in table 1. According to the figure, all indicators in the loop green-wave control scheme in the vehicle-road cooperative technology and the traditional scheme have been significantly improved, compared with the point control scheme. Besides, all indicators of the loop green-wave control scheme based on the vehicle-road cooperative environment are significantly higher than those of traditional green-wave, such as the average delays, the average number of stops and the average queue length are reduced by 35.6%, 28.9% and 36.9% respectively. It is proved that the loop green-wave control scheme under the vehicle-road cooperative environment can significantly improve traffic efficiency.

Table 1 The Simulation results

Indicators / Modes	Average delays(s)	Average queue length(m)	Average number of stops(times)
The point control	84.6	22.7	1.15
Traditional green-wave	19.4	6.5	0.45
Vehicle-road cooperative green-wave	12.5	4.1	0.32

4. Research Results And Application Prospects

4.1 Research Results

In this paper, we aim at the traffic congestion in the loop traffic, develop a loop traffic coordinated control system based on the vehicle-road cooperative technology. Many simulation results show that the system is superior to the traditional coordinated control system with main lines.

4.2 Application Prospects

In this paper, we develop the coordinated control system can realize the monitoring and prediction of the loop running state, it also can realize the recommendation of the guide speed and the dynamic adjustment of the signal timing scheme. It is expected to be applied to some urban loop roads and improve the traffic efficiency of the loop roads.

Acknowledgments

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