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Research on optimization strategy of urban trunk traffic coordination control based on traffic state discrimination

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Abstract. Nowadays, as a country with a large population, China attaches increasing importance to traffic, especially in recent years, with the continuous expansion of China's urban development scale and the continuous adjustment of spatial structure, the travel distance is getting longer, and the total volume of traffic demand continues to increase, and the imbalance between the supply and demand of transportation space and time resources is becoming more and more obvious. The research shows that it is not enough to solve the problem of urban traffic congestion only by speeding up the construction of urban roads, and it is necessary to rely on advanced road traffic management and control measures to alleviate the problem ofurban traffic congestion.This paper takes the urban road as the research object,aiming at its traffic scene and road network form,the traffic network elements and interaction mechanism of intersections and sections of urban roads are analyzed, road traffic state is discriminated,strategies for alleviating road traffic congestion is studied,effective dynamic coordination control optimization method is proposed, the research results provide technical support and theoretical basis for traffic management and control of urban road system in china.

Key words. Urban road, Traffic state, Fuzzy comprehensive Analytic hierarchy process, Control strategy, Dynamic coordination, Control optimization, Traffic wave theory.

1. Introduction

With the development of social economy, traffic congestion, traffic accidents, environmental pollution and energy shortage and other transportation related issues has become a common problem facing all countries in the world,no matter the developed countries or the developing countries, there is no exception that all countries are suffering from the constant aggravation of traffic problems,traffic problems have become the city around the world, especially one of the first problemsin big

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cities[1−3].Although governments of various countries have invested a lot of money in road construction and a large number of traffic facilities have been built around the city, traffic congestion is still very serious in many countries around the world, and has become a very prominent worldwide problem;traffic congestion significantly reduces the efficiency of vehicle transportation, it has a serious impact on the normal travel of urban residents and restricts the development of economy.At the same time, the accompanying traffic accidents, environmental pollution and energy shortage further restrict the development of the city[4−5].Take a first tier city as an example, as shown in table 1,the 2011 assessment report pointed out that traffic congestion caused a city loss of 105.6 billion Yuan, of which time value loss of 80.97 billion Yuan, fuel loss of 20.11 billion Yuan, pollution loss of 4.5 billion Yuan and residents health risk loss of 130 million Yuan.Thus, the urban road traffic problems have caused serious losses to the social economy and become one of the serious bottlenecks restricting the sustainable development of the social economy[6].

Table 1. Traffic loss table in a region

Time loss	Fuel	Pollution	Resident health	Total
80.97 billion	20.11 billion	4.5 billion	0.13 billion	105.6billion

2. Research on the Collection of Road Traffic Information

With the development of traffic control system and information technology, a large number of new vehicle detectors have been applied.Commonly used vehicle detectors are:loop detector geomagnetic detector, microwave detector, ultrasonic detector, video detector and infrared detector, etc.Among them, theloop detector and the geomagnetic detector belong to the damage detector; they are buried under the lane, which is easy to damage during use.Microwave detectors, ultrasonic detectors, video detectors and infrared detectors are nondestructive non-contact detectors. They do not need to be embedded and they are placed in the center of the road or on both sides of the road[7−8].

The vehicle detector is the information source of traffic control system; they detect traffic volume and occupancy in real time or vehicle speed and other traffic parameters,they process the sensed traffic information through the transmission facility and send it to the signal control or control center computer,it is used as the input data of the optimization scheme when the traffic signal is delivered.In this paper, the principle and application of three kinds of technologies, such as loop detector, geomagnetic detector and microwave detector, are introduced briefly[9−10].

2.1. Loop detector

Loop detector is the primary tuned circuit, which is composed of an annular coil connected with a transmission feeder and a detection processing unit, and an annular coil is equivalent to an inductance component in a circuit, the capacitance in the detection processing unit depends on the capacitance in the circuit.When the loop

coil has current passing through it, an electromagnetic field is formed near it. When the magnetic field enters the vehicle, eddy current will be induced in the metal of the body, the magnetic field lines will be reduced, the annular coil inductance tuned circuit will reduce, causing the circuit harmonic frequency rise. The detection processing unit obtains the output signal of the detected vehicle by changing the frequency of the feedback circuit with oscillating frequency or the influence of the phase offset, and as show in figure.1

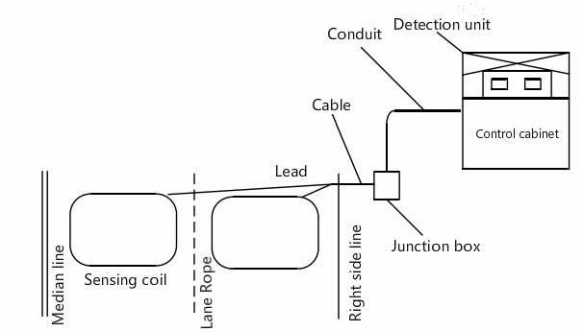

Fig. 1. Schematic diagram of loop coil detector

2.2. Geomagnetic detector

The geomagnetic detector is the core of the system. The geomagnetic sensor in the module converts the influence of the vehicle to the surrounding magnetic field into the form of voltage and sampling,the microprocessor can analyze the sampling data through the detection algorithm, which can realize the acquisition of the original detection data, such as flow counting, vehicle arrival time and departure time.The detector transmits the raw data to the main controller via the repeater, or sends it directly to the master controller, and whether the transmitted data is transmitted by the repeater depends on the link quality.The function of repeater is to forward the data sent by the detector in time, and use the active power supply or backup battery to support the solar power supply mode. The backup battery can guarantee the system to work continuously for 15 days without external power supply.The main controller can receive the original data transmitted by the detector or repeater, andfurther calculate flow, occupancy, speed and other traffic information,and the information will be transmitted to the signal needs and other management or control system, in order to meet the control requirements of traffic signal system or the information update and release of traffic guidance system.The schematic diagram of the work is shown in figure 2.

2.3. Microwave detector

The microwave radar vehicle flow detector is installed on the side pole of the road??the detector emits a microwave beam (the beam can cover eight to twelve

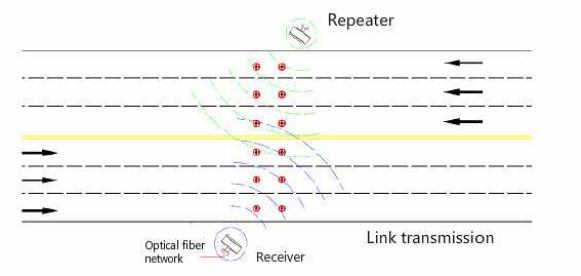

Fig. 2. Schematic diagram of geomagnetic work

lanes),having a certain angle(launching angle and azimuth angle) of view parallel to the lane and perpendicular to the lane,the microwave beam projected an elliptical microwave shadow on the road, and the microwave beam was received by the radar on the road and the lane, and the difference frequency signal was generated by mixing,the frequency of the difference frequency signal is related to the distance, and whether there is a correlation between the signal intensity and the vehicle, the traffic information of each lane is obtained based on a certain number of signal processing,the schematic diagram of the detection principle is shown in figure 3.

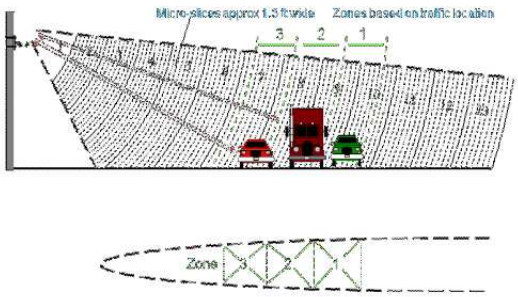

Fig. 3. Schematic diagram of microwave vehicle detection

The traffic microwave detector can be started and set up by a notebook computer. The program allows the user to define the location, number and other parameters of the lane itself.When a vehicle passes through a traffic detector in a certain lane, it will be displayed on the screen with a sign of a black rectangular block. After the departure from the detection domain, the flag disappears, and the user can identify the sign of each car on the computer screen.Then you can define the location of a lane just by moving a black rectangular box on the screen to surround the sign.When all lanes are defined, we check them by simple observation and compare them with the manual count of the traffic microwave detector??and as shown in figure 4.

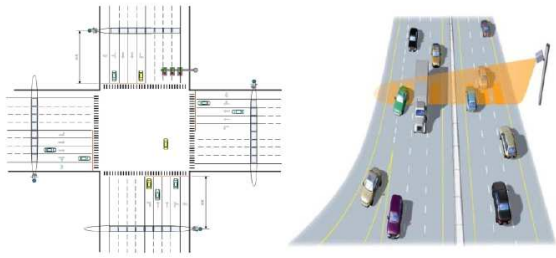

Fig. 4. Schematic diagram of microwave installation and effect simulation

3. Establishment of Traffic State Discrimination Model

3.1. Classification of road traffic state

This text is based on theactual operation characteristics of traffic flow and the division of our country on the road level of service,and it divides the urban road traffic status into four categories: smooth, slow, crowded and blocked.

Smooth: Traffic flow between free flow and stable flow, traffic participants have the maximum driving freedom, they can freely and smooth driving, without or basically not affected by other vehicles, the best service level.

Slow: Traffic flow is stable, reduce the degree of freedom driving traffic participants, vehicles affected by other vehicles, the speed is slow, the service level is second.

Crowded: Traffic flow from stable flow to unstable flow, traffic participants driving freedom is greatly constrained, the vehicle is disturbed by other vehicles, driving speed is very slow, low level of service.

Blocked: Traffic flow is extremely unstable, between unstable flow and forced flow. Traffic participants' driving freedom is extremely low. Vehicles stop and stop to form a queue, and they are in a slow driving state for a long time with the lowest service level.

3.2. Research on discrimination algorithm

In view of the shortcomings of traditional analytic hierarchy process, many scholars have introduced the idea of fuzzy mathematics and put forward the fuzzy analytic hierarchy process.The fuzzy analytic hierarchy process makes the judgment matrix more reasonable, and solves the difficulty of consistency check and adjustment effectively.The flow chart of the algorithm is shown in figure 5.

According to the algorithm flow chart, the algorithm steps of the fuzzy analytic hierarchy process are obtained:

The relationship between the indexes is defined, and the hierarchical structure system is established

The relationship between the indexes is defined and we divide each index from top to bottom into three levels: target layer, criterion layer and sub criterion layer.

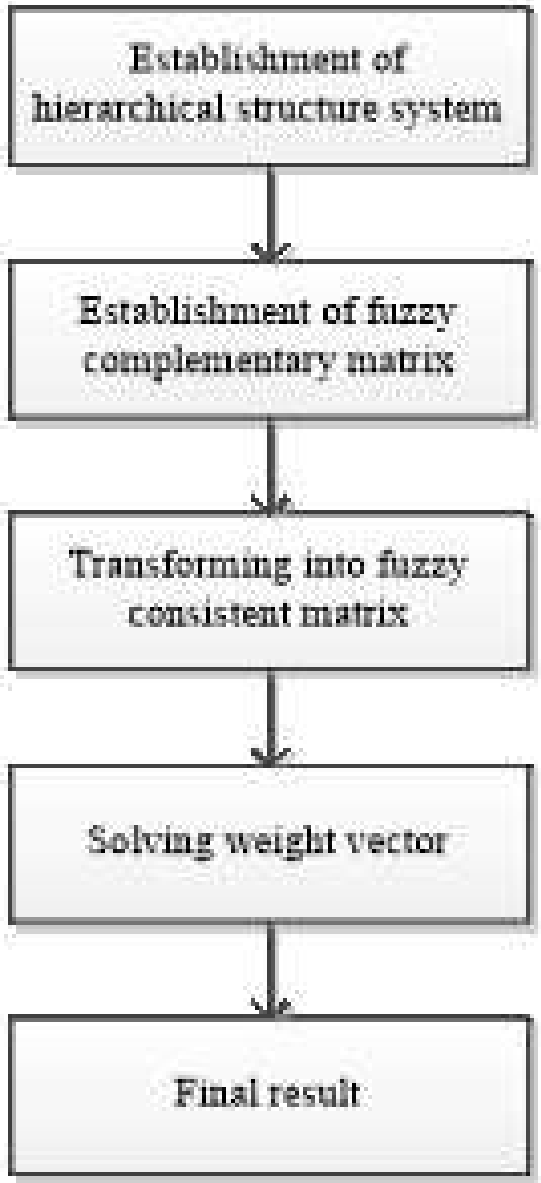

Fig. 5. Algorithm flow chart

In general, the target layer contains only one index, while the criterion layer and the sub criterion layer contain multiple indexes.

The establishment of fuzzy complementary matrix

$$\begin{bmatrix} A & a_1 & ... & a_n \\ a_1 & r_{11} & ... & r_{1n} \\ ... & ... & ... & ... \\ a_n & r_{n1} & ... & rnn \end{bmatrix}$$

The fuzzy complementary matrix is transformed into fuzzy consistent matrix

In the actual decision-making process, because of the one-sided understanding of people and the complexity of solving problems, fuzzy complementary matrix often does not have consistency.At this point, we need to adjust the fuzzy complementary matrix according to the theorem, and transform it into the fuzzy consistent matrix.

Calculate the weight vector according to the fuzzy consistent matrix

$$\begin{cases} \min z = \sum_{i=1}^{i=n} \sum_{j=1}^{n} [0.5 + \alpha(w_i - w_j) - r_{ij}]^2 \\ \sum_{i=1}^{i=n} w_i = 1, w_i \geq 0, (1 \leq i \leq n) \end{cases}$$

By adding Lagrange multiplierλ, the above constraint programming formula(2) is equivalently transformed into an unconstrained programming formula:

$\min L(w, \lambda) = \sum_{i=1}^{n} \sum_{j=1}^{n} [0.5 + \alpha(w_i - w_j) - r_{ij}]^2 + 2\lambda(\sum_{i=1}^{n} w_i - 1)$

Weight vectors are obtained by simultaneous equations:

$W = (w_1, w_2..., w_n)^T$

4. Optimal Evaluation of Urban Trunk Line Traffic Coordination Control Based on Traffic State Discrimination

In the urban road network,rationally optimizing traffic signal control parameters can greatly alleviate the problem of urban traffic congestion.In this chapter, based on the fuzzy algorithm of road traffic state discrimination and road traffic signal control strategy, the signal control parameters such as cycle, phase sequence, green signal ratio and phase difference are optimized.The dynamic coordination control is applied to the intersection with moderate distance, the probability of the vehicle meeting the red light is reduced, the travel time of the vehicle is shortened, and the service level of the road is improved.

4.1. Periodic optimization

At a certain moment,a set of determined color states of the lights at each point of the signalized intersection is called the pace,the different color states of the lamp make up different steps, and the duration of the step is called the step length. The sum of the step lengths of each control cycle is called the signal cycle, which is usually represented by C.If the signal cycle is too short, it is difficult to ensure that vehicles in each direction pass through the intersection smoothly, leading to the frequent stop at the intersection and the decrease of the utilization of the intersection.Signal period is the key control parameter to decide the control effect of traffic signal.If the signal cycle is too long, the driver's waiting time will be too long, and the delay time of the vehicle will be greatly increased.Generally speaking,for small intersections with small traffic flow and fewer phases, the signal period value is about 60s,for large

traffic flow, large number of phase of the large intersection, the value of the signal period is about 160s,the common cycle optimization diagram is shown in figure 6.

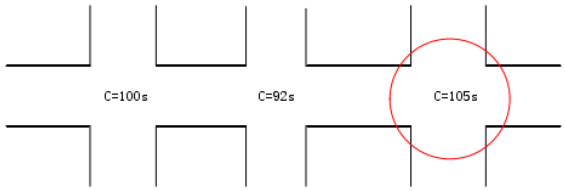

Fig. 6. Public cycle optimization diagram

4.2. Phase sequence optimization diagram

Phase sequence design of intersection is the basic work of execute signal control. Scientific and reasonable phase sequence is of great significance to avoid vehicle interleaving conflict and improve road traffic efficiency.The intersection phase sequence design usually follows four basic principles, such as reducing the conflict, ensuring the capacity of the intersection, ensuring the safety of pedestrian crossing and avoiding setting the phase for pedestrians separately.The optimization of the phase sequence of this part is mainly motor vehicle, and the phase of non motor vehicle is not set up separately. The phase of non motor vehicle should be considered separately according to the actual situation in the project,before and after optimization comparison chart shown in figure 7.

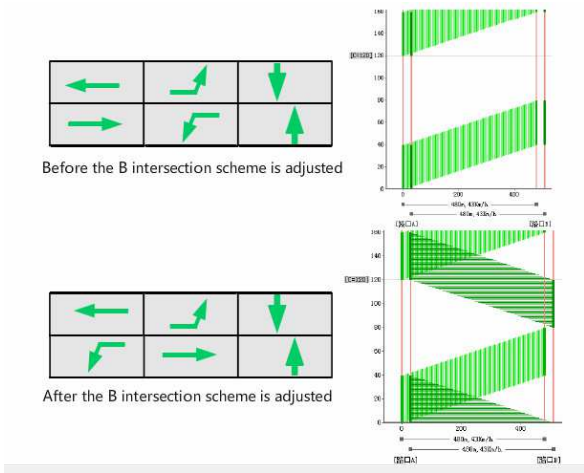

Fig. 7. Comparison chart of coordination effect before and after phase sequence adjustment

4.3. Optimization of arterial dynamic coordinated control

At present there are two kinds of coordinated control strategy, a low level of implementation of peak green wave coordinated control, the other is the peak congestion control implementation.Green Wave coordinated control of the vehicle from the coordination of the road after the first green light pass and can make the vehicle all the way green light through the follow-up multiple junctions,the congestion linkage control makes the vehicle pass from the first intersection green light of the coordination Road, enter the downstream section, follow the front of the vehicle queue tail almost cannot stop to the stop line, the road queue is not overflow.When it is detected that there is a risk of overflow in the longer queue, the way of congestion control is to let the first wave of vehicles go first and then the next wave of vehicles go forward.The principle of coordinated traffic jam control and green wave control is similar, andthis paper give a unified based on traffic wave theory.As shown in figure 8.

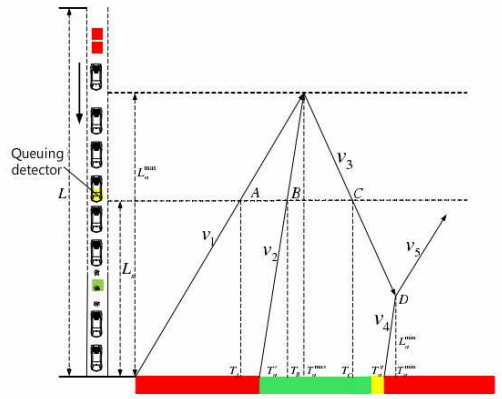

Fig. 8. Arterial dynamic coordinated control optimization diagram

5. Conclusion

The normal and efficient operation of urban road traffic signal control system is an important foundation to ensure the safety and smooth operation of urban road traffic,the dynamic coordinated control optimization of arterial road based on road traffic state identification is of great significance to improve the management and control level of road traffic.This paper takes the city main road section and intersection of import and export of this complex traffic scene as the research background,the road traffic information collection and characteristics of parameters, the state of road traffic identification methods, road traffic signal control strategies and trunk dynamic coordination control optimization methods are studied,and it has made great progress, and laid a theoretical foundation for the future urban trunk line traffic research.

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