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Urban Real-Time Traffic Monitoring Method Based on the Simplified Network Model

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Abstract

In urban real-time traffic monitoring, due to the difficult of delay time acquisition at intersection, complicated calculation model, lead to inaccurate traffic discriminant. Aiming at this problem, it proposed a real-time traffic discriminant method based on the simplified network model. In traffic data collection various types of intersections are abstracted as a node in this method, and the delay time at intersection are included in the pasting time of connected roads, then conduct back-stepping calculated according to different types of nodes at monitoring, obtained the traffic conditions of regular road, rotary road and intersection, thus realize real-time monitoring. Finally, to verify the validity of the method through simulation of urban real-time traffic monitoring results.

Keywords*: Traffic monitoring; Simplified road network model; Rotary road, Overpass*

1. Introduction

Urban road traffic status information (traffic information) has been the key information of intelligent transportation systems (ITS), it is accurate, real-time acquisition and processing is the foundation of the induced traffic, traffic control and other applications. Real-time traffic monitoring service provide the received traffic information to travelers in the form of radio, SMS, roadside signage, help them to select the traffic routes so as to avoid congestion, and arrive at the destination more quickly, and for the traffic police to find the blocked section of the road and help to arrange person for traffic relief. Real-time traffic monitoring service not only requires the accuracy of data collection, but also how to represent the current situation of the urban traffic according to the collected data, including the current congestion area, traffic jam, congestion degree.

Currently, there are mainly two kinds of road traffic intelligent monitoring method, one kind is the traffic monitoring based on intelligent video [1-4]. These methods mainly adopt the method of video acquisition, using advanced technology in the field of video image processing, pattern recognition, artificial intelligence and so on, automatic analysis on the camera graphic sequence, realize the detection, classification, and tracking of targets such as vehicles and pedestrians in traffic scene, and on this basis to describe and discriminant the behavior of monitored target. Their common characteristic is the high data acquisition cost, strict hardware equipment, involving technology is more complex.

Another common traffic monitoring method is to use a fixed coil or probe vehicle to collect raw traffic data, and through designed corresponding algorithm [5-8], get the average access time or average travel speed of the section, in order to represent the congestion information of the section. Compared with the video traffic monitoring method, the data traffic monitoring based on probe vehicle (or taxi) has the advantages of

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low cost, comprehensive data collection. Its drawback is that collected data cannot accurately reflect the delay of the intersection, in calculating or ignored roads intersection delay, or estimate intersection delay data with Webster, HCM85, HCM2000 [9] model, these traditional delay model have little value in practical application of most urban roads in our country; For the complex road types, such as the rotary road, overpass, the distance between the road and road is close, with small angle difference, sometimes almost overlap when projected onto a plane [10], so the GPS data acquisition is not accurate, and affect the discrimination of road conditions.

This paper proposed the traffic calculation method based on the simplified network model [11], using GPS to collect periodically (*e.g.*, every 5 minutes) the average access time of the section to represent the road congestion information. Simplified network model features include: 1) more than one weight on a road, different weights represent the average access time from different directions into the road; 2) the rotary road and overpass was abstracted as a node (equivalent to ordinary intersection). The simplified network model simplified the traffic information collection, has been successfully applied to the real-time traffic information collection [12], real-time vehicle navigation [13] and other fields. The proposed traffic calculation method based on the simplified network model, obtained the traffic condition of ordinary road and intersection, at the same time, also addressed the road discriminant problem of complex road model as rotary road and overpass, can be used for navigation services as real-time traffic monitoring and real-time vehicle.

2. Simplified Road Network Model and Its Advantages

In simplified road network model [11], all the regular intersection, traffic light intersection, overpass and rotary road are abstracted as nodes, the one-way road between two nodes is abstracted as a directed arc, two-way road between two nodes is abstracted as two directed arc. Each directed arc weighted at least one time spend weight w_{pij}^t, where w_{pij}^t represents the actual passing time of the vehicle traveling from direction p at the starting point i to destination j of the section, that is the sum total of the passing time from start point i and passing section $<v_i, v_j>$.

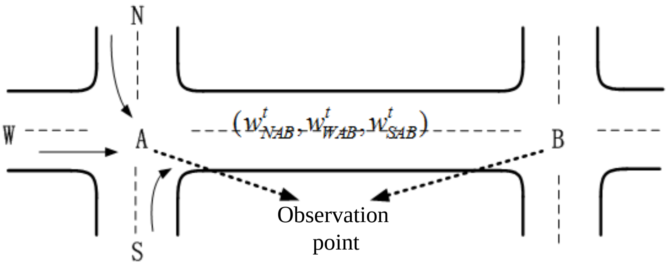

Figure 1. Adjacent Intersections Travel Time Relations in Simplified Road Network Model

Figure 1 shows the traffic connection condition of adjacent intersection A and B in urban road network, the weights of AB section are $w_{NAB}^t, w_{WAB}^t, w_{SAB}^t$, they represent the time of vehicle at direction N,W and S at t time frame through turn left, go straight and turn right bypass intersection A, and travel to intersection B, respectively. that is the sum total of the travelling time of bypassing the current intersection from different direction and travelling on the section. The number of weights of the road section depends on the number of forerunner directly to the starting point of this section.

Simplified road network model adopts a simple data collection method, to distinguish the turning delay time at intersection traveling from different direction to the downstream section and the turning time of rotary road, which considering the actual traffic condition of the time of different upstream section to bypass the intersection, rotary road and the travel time of traveling to downstream is different. The simplified road network model implicitly considered the impact of traffic waiting time and road congestion time on road traffic conditions but difficult to be measured, so it considered the above delay time at the same time simply abstracted road network model, for ITS follow-up work, such as: the real-time road traffic monitoring, vehicle real-time path planning, *etc.*, laid a good foundation.

3. Road Condition Discriminated Method Based on Simplified Road Network Model

In this paper, the urban road is divided into three types, the regular road, road located in the rotary road and overpass road. The rotary road refers to the one-way road in the traffic network, used for traffic diversion, reducing congestion. And overpass refers to modern land bridge that establishes upper and lower layers at the important traffic intersection in the city, for multi-direction traveling without inter-affect, according to with or without connection ramp between intersecting roads, ramp type and the organization form of traffic flow, can be divided into separate overpass, fully interoperable overpass, partial interoperable overpass and circular intersection, *etc.* [14].

Due to the intensive distribution rotary road, shorter distance between nodes of road nodes of rotary road, overpass, made the intersection positioning more difficult at the data collection and acquisition delay lead the error effect more apparent, easy to be offset or misalignment. Simplified road network model made up for the defects exactly, the whole rotary road and the whole overpass are abstracted as a node, no need to collect the actual passing time of each segment of rotary road and overpass, only need to record the hour of entering and leaving the rotary road and overpass, actual transit time can be obtained through a simple back calculation algorithm. Then compared the actual time with ideal passing time, you can get the traffic information of each segment of rotary road and overpass.

According to the traffic congestion level, the traffic condition can be divided into blocked, tiny blocked, slow down and unblocked state, and set three critical value a_1 、 a_2 and a_3 used in road condition representation, where, $a_1 < a_2 < a_3$, the value can be adjusted according to different urban condition. Ideal passing time of the section is T_0, $T_0 = \frac{L}{v_0}$, where, L is the length, v_0 is the limit speed of the section(related with the road level). Discrimination criteria: when the actual passing time < $a_1 * T_0$ means unblocked state, $a_1 * T_0 <$ actual passing time≤ $a_2 * T_0$ means slow down, $a_2 * T_0 <$ actual passing time≤ $a_3 * T_0$ means tiny blocked, actual passing time > $a_3 * T_0$ means blocked state. As shown in following table:

Table 1. Comparison Table of Road Actual Traveling Time and Traffic State

T actual passing time T	state
$T < a_1 * T_0$	unblocked
$a_1 * T_0 < T \le a_2 * T_0$	slow down

T actual passing time T	state
$a_2 * T_0 < T \le a_3 * T_0$	tiny blocked
$T > a_3 * T_0$	blocked

3.1. Traffic Condition Discrimination of Regular Road

For traffic condition discrimination of regular road, it requires to define the congestion degree of intersection and road section, respectively. As shown in Figure 1, it can be known from the definition of simplified road network, the weights of AB traveling from different directions w^t_{NAB}、 w^t_{WAB} and w^t_{SAB}, the traveling time of three on section AB are considered as consistent, the difference of them are the turning time of each at interaction A, that is interaction delay time.

Thus, it can determine the traffic condition of the road by comparing the relations of each precursor weight. Algorithm procedure as shown in Figure 2, and the specific steps as follows:

Step 1: compared the minimum time spend weight $T_{\min} = \min\{w^t_{pij} \mid v_p, v_i, v_j \in V\}$ with $a_1 * T_0$, if $T_{\min} < a_1 * T_0$, then go to step 2, otherwise to step 3.

Step 2: To determine whether there is time spend weight larger than $a_2 * T_0$ time spend weight, existence means the start point of this section is at blocked state, inexistence means the starting point of the section is at unblocked state;

Step 3: To determine whether $T_{\min}$ smaller than $a_3 * T_0$, if it is smaller, means this section is at tiny blocked state, otherwise at blocked state.

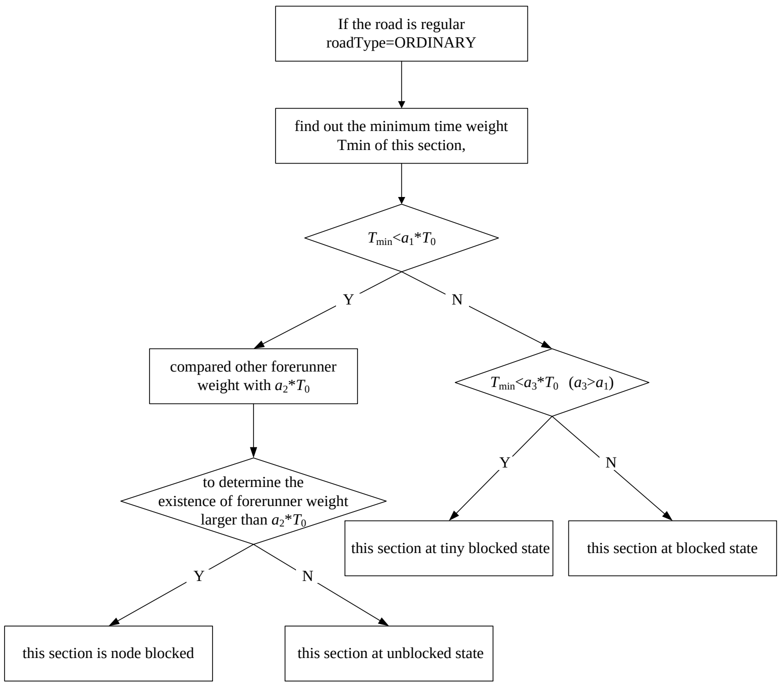

Figure 2. Traffic Condition Discrimination Flow Chart of Regular Road

3.2. Traffic Discrimination of Rotary Road

In simplified road network model, the rotary road is abstracted as a node, as shown in Figure 3. Before 环 rotary road simplified, the original rotary road V_r is divided into four arc sections according to different traveling directions: arc section R_2 from node V_2 to node V_1, arc section R_1 from node V_1 to node V_4, arc section R_4 from node V_4 to node V_3, arc section R_3 from node V_3 to node V_2. The simplified rotary road as shown in Figure3-(2).

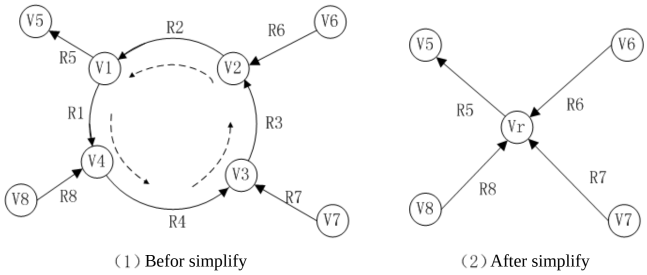

Figure 3. Comparison Diagram of Rotary Road Before and After Simplify

Take section R1 for example, on directed arc $<V_r,V_5>$, the time spend weight w_{6r5}^t 、 w_{7r5}^t and w_{8r5}^t, comparison Figure 3-(1), relation expression as follows:

$$\begin{cases} w_{6r5}^t = w_{R2}^t + w_{R5}^t & (1) \\ w_{7r5}^t = w_{R3}^t + w_{R2}^t + w_{R5}^t & (2) \\ w_{8r5}^t = w_{R4}^t + w_{R3}^t + w_{R2}^t + w_{R5}^t & (3) \end{cases}$$

Formula (2)-formula(1), where:

$$w_{R3}^t = w_{7r5}^t - w_{6r5}^t$$

Formula(3)-formula(2), where:

$$w_{R4}^t = w_{8r5}^t - w_{7r5}^t$$

The actual passing time of arc section R3 and R4 are obtained respectively. Compared the obtained actual passing time T with ideal passing time T_0: $T < a_1 * T_0$, represents this arc section at unblocked state; $a_1 * T_0 < T \le a_2 * T_0$, represents this arc section at slow state; $a_2 * T_0 < T \le a_3 * T_0$, represents this arc section at tiny blocked state; $T > a_3 * T_0$, represents this arc section at blocked state; the rest can be done in the same manner, through two subtraction of different directed arc weights, the traffic condition of rotary road can be concluded.

3.3. Traffic Condition Discrimination of Overpass

Due to various of overpass type, the inner structure are quite different. The traffic condition discrimination are not carried on each ramp of the overpass, while make discrimination on the route of the overpass. If weighted on the same directed arc, the minimum time spend weight as $T_{\min} = \min\{w_{pij}^t \mid v_p, v_i, v_j \in V\}$, set the corresponding forerunner node as *p*. Under such circumstance, the ratio of the travel time of passing ramp and travelling on the road is small, set the time of vehicle from direction *p* passing start point node *i* is 0(即 that is passing time of overpass), the minimum time spend weight $T_{\min}$ indicates the passing time of vehicle spent through route $<v_i, v_j>$.

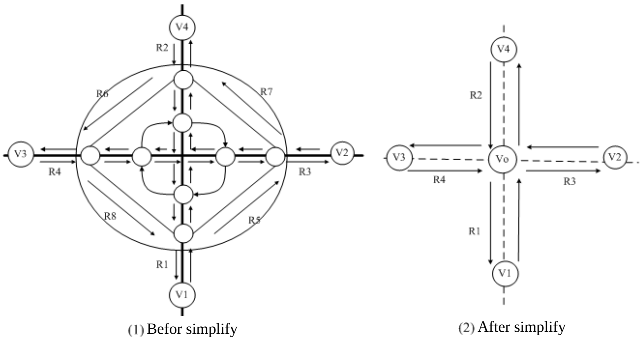

Figure 4. Comparison Diagram of Overpass Before and After Simplify

Other time spend weight w^t_{pij} on directed arc subtracted by the above minimum time spend weight $T_{\min}$, then the actual passing time T of other routes of the overpass can be obtained; compared the actual passing time T of each route and unblocked passing time T_0, then the traffic condition of each route of the overpass can be obtained. Finally, it marked the state of each arc on the overpass as the state of the route.

As shown in Figure 4, except the section R1、R2、R3、R4 in and out overpass, other arc section as the inner arc section of the overpass (arc section in black circle of the overpass before simplify in Figure 4).Take R2 for example, the time spend weight of weighted to directed arc $< v_0, v_2 >$ are w^t_{1o2} 、 w^t_{3o2} and w^t_{4o2} , set the time of minimum time spend weight $T_{\min} = \min\{w^t_{1o2}, w^t_{3o2}, w^t_{4o2}\}$ passing node v_o as 0, that is the travel time of overpass as 0, then the minimum time spend weight $T_{\min}$ represents the time spend of the vehicle passing road section $< v_0, v_2 >$ (that is the passing time of road section R2). Each time spend weight $w^t_{1o2}, w^t_{3o2}, w^t_{4o2}$ of directed arc $< v_0, v_2 >$ subtracted by $T_{\min}$ respectively, then obtained the actual passing time of each section the vehicle from direction V1、V3、V4 into overpass to section R2. The state of the arc section on the overpass is the state of the route.

4. Experimental Result

Based on the proposed simplified network model of the real-time traffic calculation method, the simulation experiment was carried out. Experiment using Mapinfo format map of a certain area in Chongqing, the development environment and tools include: 1) the Windows 7 operating system, 2) visual studio 2008, 3) Mapx plug-in. Real-time traffic data using simulated data from the literature [11].

There are total 573 road nodes and 1090 sections in experimental map road net, of which 2 rotary roads, 5 overpasses. After simplifying, the number of road section in the network structure are 969, reduced by 11%, while minimizing the amount of data collection, at the same time also reduced the network storage space.

To distinguish the traffic information through different colors on the map, the green represents unblocked; Yellow means slow; Blue stands for tiny blocked; Red stands for blocked.

Figure 5. Traffic Condition at 00: 00

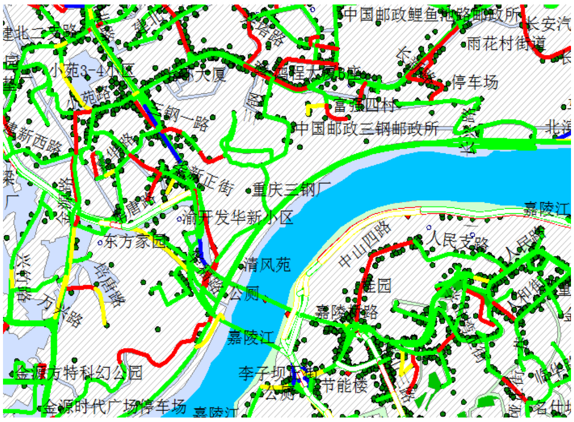

Figure 6. Traffic Condition at 7:50 AM

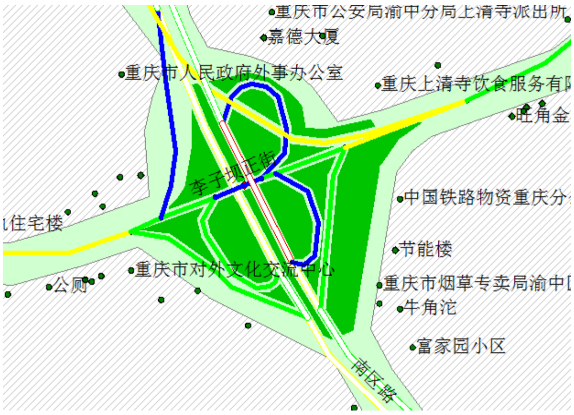

Figure 7. Traffic Condition of Overpass at 8:30 AM

Figure 5 shows the morning traffic condition, almost all sections are at the unblocked state; Figure 6 shows road conditions at 7:50 AM, due to the peak time of work or school, most of the roads are at the blocked state; Figure 7 shows the traffic condition of Niu Jiaotuo overpass of Yuzhong district in Chongqing at 8:30.

5. Conclusion

This paper proposed a simplified network model oriented traffic monitoring method, the purpose of reappearance of the current traffic conditions on the electronic map can be realized only through the comparison of the travel time from different precursor into the road. And the required data can be easy collection, any on-board equipment with a GPS positioning function or the driver's personal phone can provide data source for the information center, road network simplification also greatly reduced the required data collection, this provides a new train of thought for the urban traffic information collection and processing. Through the experiment, verified the feasibility and effectiveness of the method. However due to the collected GPS data coverage is limited, this paper adopted simulated data, after the acquisition technology based on GPS terminal and simplified network model [12] matured in study group, it will further verify the method, adjust the algorithm according to the actual situation, make traffic calculation more accurated.

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