Simulation and Application of Urban intersection traffic flow model

Yubin Li [1,a],Bingmou Cui [2,b] ,Siyu Hao [2,c],Yan Wei[3,d]

[1] Institute of Transportation Information Dept. of Traffic & Transportation Lanzhou Jiao tong University Lanzhou 730070, China

[2] Institute of Transportation Information Dept. of Traffic & Transportation Lanzhou Jiao tong University Lanzhou 730070, China

[2]School of Traffic & Transportation Lanzhou Jiao tong University Lanzhou 730070, China

[3]School of Traffic & Transportation Lanzhou Jiao tong University Lanzhou 730070, China

[a]745562353@qq.com, [b]cuibm@163.com, [c]406670977@qq.com, [d]616939890@qq.com

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Abstract. Based on the theory of computer simulation and the theory of traffic flow, the urban intersection traffic microscopic simulation model is established. Besides, the simulation system is realized on the basis of this model and the object-oriented design.

This system is implemented in the integrated development environment Eclipse3.2 for Java, and basically has the functions of the animation simulation of traffic flow, real-time rendering of the traffic volume and delay time curves, dynamic display of the numbers of vehicles in the different lanes, the simulation of traffic control, data statistics and report form printing. The correctness of the model algorithm software and the validity of the function of this simulation software have been initially confirmed through the simulation examples. Not only that, we can analyze the real-time traffic conditions via the simulation outputs and before putting the new traffic management scheme into effect and changing the road infrastructure, this simulation system can also be used to analyze and evaluate the new scheme. Besides, higher efficiency can be gained, with more waste avoided.

Introduction

With Intelligent transportation system becoming the direction of future traffic development, the applications of simulation method in intelligent transportation system fields has a broad application prospect.Traffic simulation has two forms, macro-simulation and micro-simulation. Macro-simulation studies the general law and overall performance of traffic system, and micro-simulation can further study the microscopic behavior of a single vehicle, which is an important means of traffic system optimization design [1, 2].

Intersection simulation can provide us with convenience for utilizing this simulation system to analyze and evaluate the new scheme before putting the new traffic management scheme into effect and changing the road infrastructure. Besides, higher efficiency can be gained, with more waste avoided.

System modeling of intersection

In theory this model should include travel demand model, intersection description model and scheme description model [3, 4]. The main function of each model is listed below:

(1) Travel demand model: describing how to determine the generation of the vehicle according to the traffic volume.

(2) Intersection description model: describes geometric condition of road intersection.

(3) Scheme description model: describes various traffic control and management scheme.

(4) Vehicle running model: describes the running behavior of vehicles in the access lane and intersection.

Fig.2 is the architecture flow diagram of the urban intersection traffic flow simulation model.

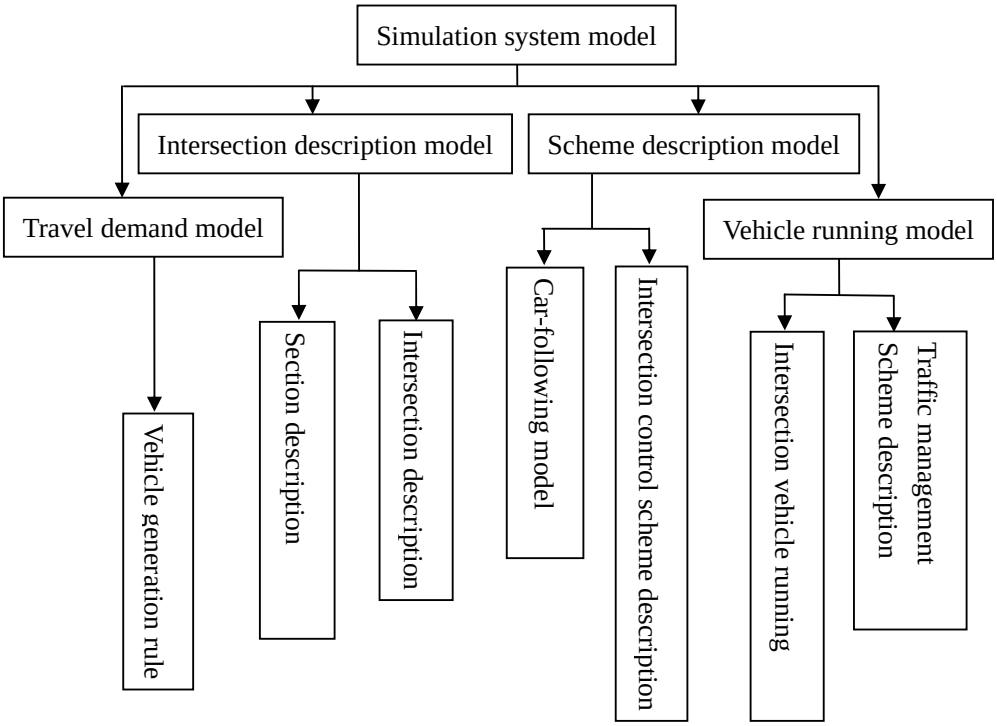


Fig.2 the simulation system model framework

2.1 vehicle generation rules

There are two ways to generate vehicles according to the traffic volume, one of them is on the basis of the time-headway, and another is random occurrence. In this system, the bearing capacity of the regional road network is taken into consideration by us, consequently, at the beginning we adopt randomization to generate vehicles, and concrete steps are as follows:

(1) To judge whether the number of vehicles input is less than 300;

(2) If the number of vehicles meets the condition that the number is less than 300, then the number of vehicles will be distributed to eight lanes randomly;

When some vehicles go out of the road network, the system will adopt the time-headway method to generate added vehicles according to the traffic flow on the network and the traffic lights of the upstream intersection.

2.2 intersection description

This system simulates cruciform plane intersection (Fig.3); the intersection model consists of the following parts:

(1) Lane number: the two main roads are labeled as lane 4, where the traffic goes from west towards east, and lane 8, where the cars head to the opposite direction. Moreover, three secondary roads are denoted as lane 1, lane 2 and lane 3 that towards south and also three secondary main roads that labeled as lane 5, lane 6 and lane 7 where the traffic goes from south to north.

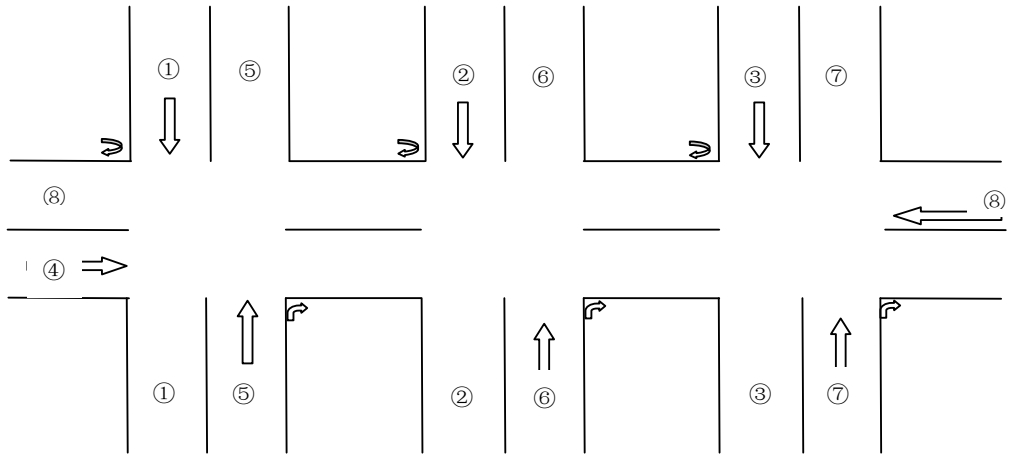


Fig.3 plane intersection simulated in the system

(2) Lane length: first of all, get the size of the screen through Dimension c = size (), then the length of the main road assignment is dimension. Width (east-west direction), the length of secondary main roads assignment is dimension. Height (south-north direction), the width of the main road and secondary main roads both are 45(unit: pixel).

(3) Lane use restriction: the maximum speed of vehicles is 90km/h.

2.3 traffic management scheme description

Common urban intersection traffic management scheme includes the turning restriction of lanes, vehicle type restriction of lanes (bus lanes) and so on. Such management measures can be implemented through the using features of lanes.

In this system, in order to simplify models, we define that simulated vehicles are all small cars and bus lanes are not taken into consideration. In addition, amber light is not set in the intersection. Vehicle model: car width = 6, car length = 9; the turning of the lanes is controlled by variable turn.

2.4 intersection control scheme description

1) Determine signal phase scheme

In this system we adopt two-phase bit timing, as shown in the Fig.4

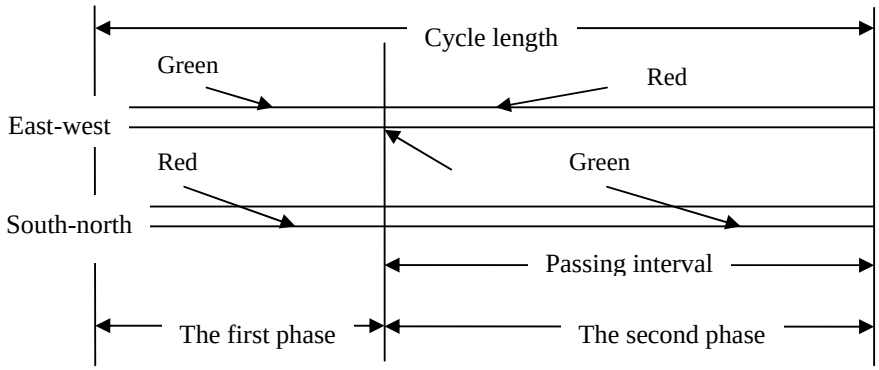


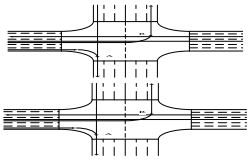
Fig.4 two-phase bit timing diagram

The first phase in the diagram turns on the green light of east-west road lamp and turns on the red light of south-north road. Control state is that give east-west traffic right of way. The second phase turns on the green light of south-north road lamp and red light of east-west road lamp instead, which means that give south-north traffic the right of way.

2.5 car-following model

Linear car-following model is the first car-following model which its starting point is to maintain a certain distance from the front vehicle to avoid a collision. But it ignores the behavior of the actual impact of the individual characteristics of vehicles. Therefore, it has its inherent flaws to use this nonlinear model in the microscopic traffic simulation model [5].

So, in this system, we use the model which has been applied widely at present called Herm model [6]. This model take different characteristics of acceleration of car-following and slow down car-following into consideration, the model is shown below:



(1)

(2)

2.6 avoid car rules

When going straight vehicles and left turns meet at the conflict point or going straight vehicles and right turns meet at the junction point, the conflict will occur, as shown in Fig.5. In the simulation model, since the vehicle, each direction, travels along the fixed orbit, then after the crosses situation are given. The points of conflict and convergence are fixed. When the vehicle is at a distance from these points, it is necessary for a vehicle to observe the opposite direction vehicle to avoid conflict, and this distance is called collision detection distance.

(1) The conflict of the vehicles turn left and straight

When the vehicle enters the conflict detection distance, it has to do following judgments every step forward:

1) When the distance from the vehicle to conflict point is less than the opposite direction vehicle to the conflict point, the vehicle continue driving.

2) When the distance from the vehicle to conflict point is more than the opposite direction vehicle to the conflict point, the vehicle will decelerate near the conflict to stop and wait for opposite direction vehicle to pass.

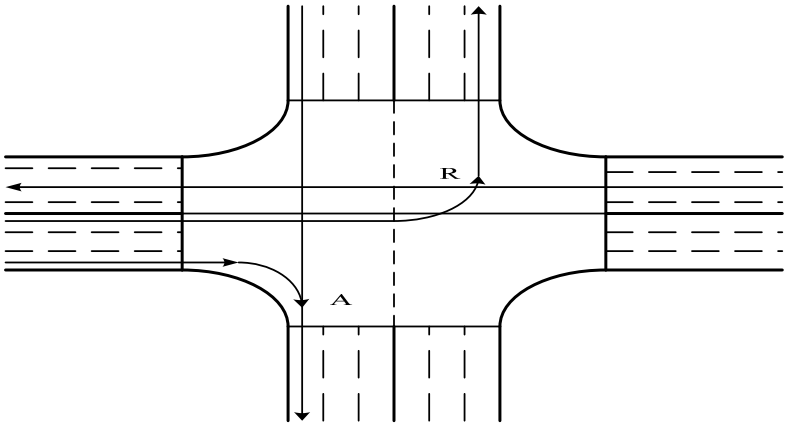


Fig.5 the conflict point schematic diagram

3) When the distance from the vehicle to conflict point is equal the opposite direction vehicle to the conflict point, accord the principle of straight line priority, the vehicle will continue driving if it straight forward. But it will decelerate to stop if the vehicle is a left-turning vehicle.

(2) Collision avoidance of right -driving confluence

As shown in the figure, right-turning cars will be driven into the straight traffic flow, which people think as like that the vehicles at the entrance of highway will be driven into traffic flow. The right turning vehicles will detection straight traffic clearance continuously when they drive into the conflict detection range. They will be driven into flow if the length of clearance can meet the demanded safe length, or they will wait for the next flow.

The design of the simulation system

Software structure (Fig.6):

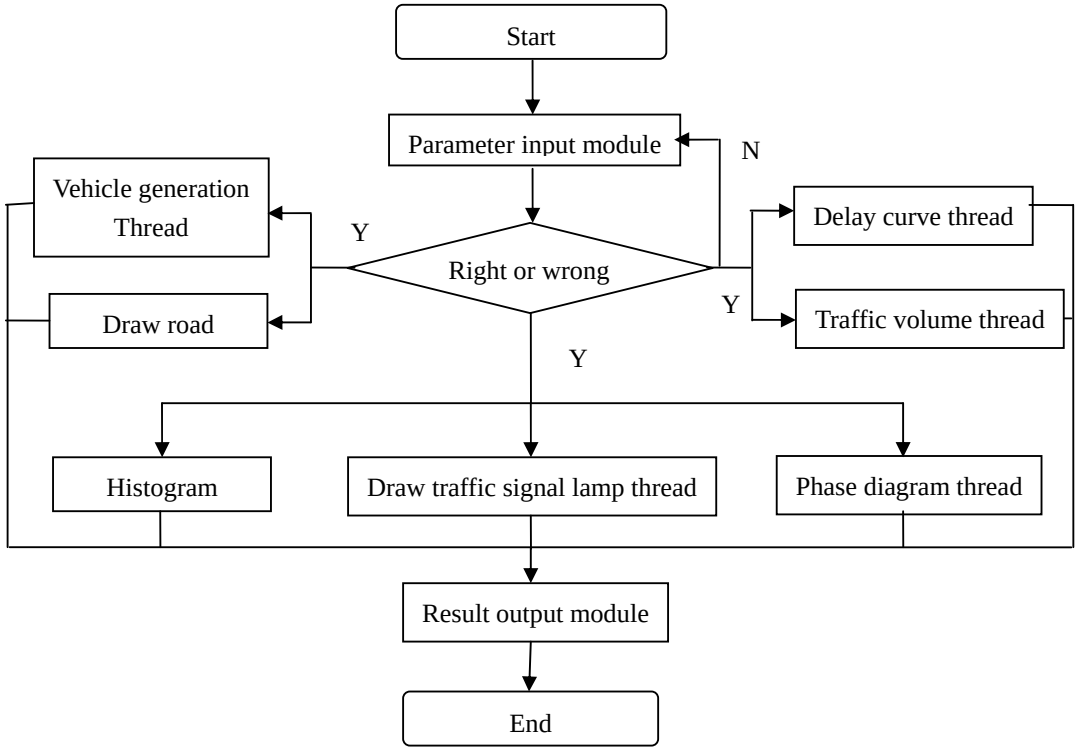


Fig.6 program structure diagram

This system is based on multi-thread mechanism [7], so it can share resources and improve computing speed. The function of each thread is as follows:

Thread 1: Draws a static road map. Activate this tread when the widow is resized or redrawn.

Thread 2: Vehicle generation thread. Starts this thread once per second and then put the new car into the corresponding array of vehicle objects.

Thread 3: Draws traffic signal lamp thread. Once the program is running, it calculates the conversion time of traffic lights of each road according to the signal-timing parameter.

Thread 4: histogram thread. When the vehicle generation threads starts, the histogram is drawn according to the vehicle numbers on different tracks at different time.

Thread 5: phase diagram thread. Draw the phase diagram of traffic lamps according to the input signal parameter (split).

Thread 6: traffic volume thread. The real-time traffic volume diagram is drawn according to the number of vehicles, the velocity of vehicles and input signal parameters (split).

Thread 7: delay time thread. Draw the real-time delay curve according to the vehicles and road conditions of the intersection.

Simulation software function test and verification

The interface of the traffic flow simulation is shown below (Fig. 7), mainly including setting the related parameters, the control of intersection signal lights and the animation simulation of the real-time operation of vehicles [8, 9].

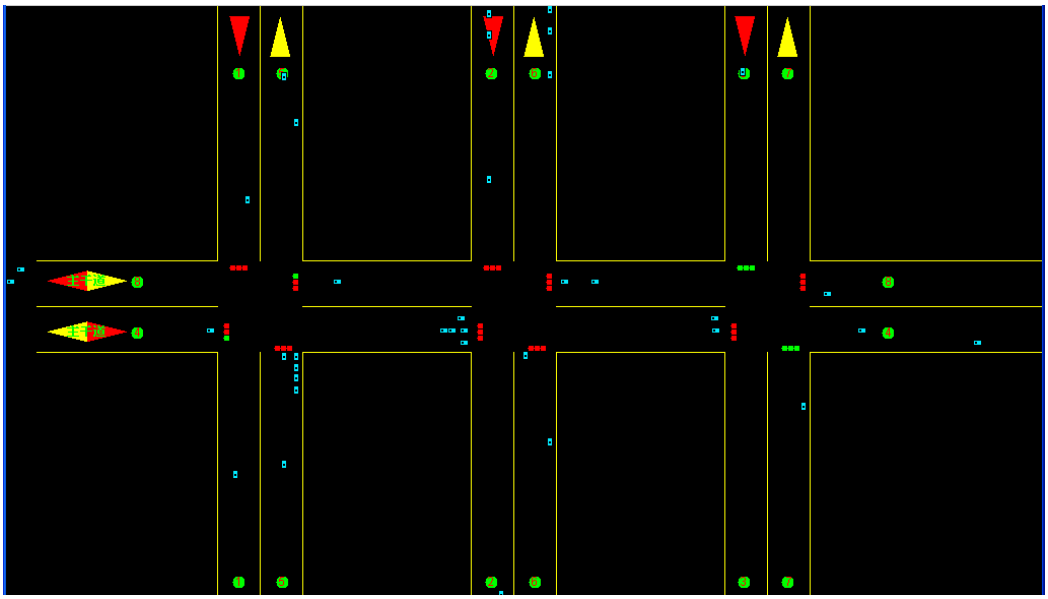


Fig.7 traffic flow simulation diagram

The interface of the real-time information rendering is shown as follows(Fig. 8), mainly including the rendering of the traffic volume and delay curves, signal phase diagram and dynamic display of the number of vehicles in the different lanes.

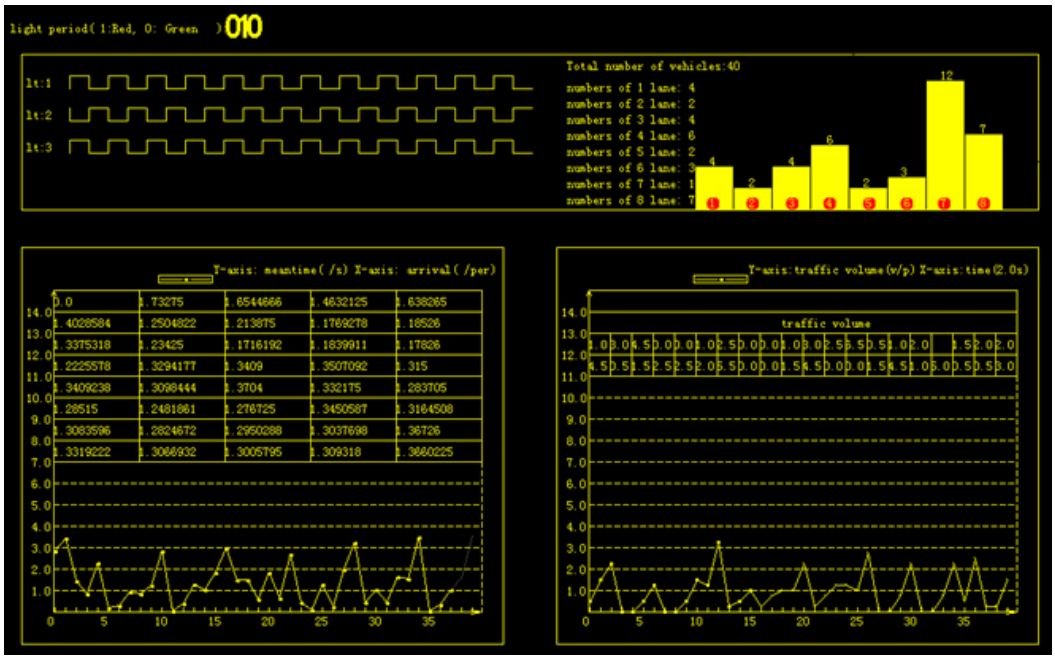


Fig.8 real-time information rendering

Analysis of simulation result

The statistical result is shown in the following table (Table1):

Table 1 the simulation system data table

Number of vehicles	Green ratio	speed	Maximum traffic volume	Average traffic volume	The average delay time
50	0.2	10	1.5	0.5	0.635
	0.4		2	0.47	0.384
	0.6		1.5	0.35	0.171
	0.8		2	0.37	0.104
100	0.2	20	6	1.17	0.162
	0.4		4	1.06	0.120
	0.6		4	1.12	0.196
	0.8		3.5	1.04	0.192
200	0.2	30	10	2.23	0.214
	0.4		8.5	2.28	0.138
	0.6		7.0	2.32	0.152
	0.8		7.5	2.40	0.092

The diagram is drawn according to the data in the table above and it is shown in Fig. 9:

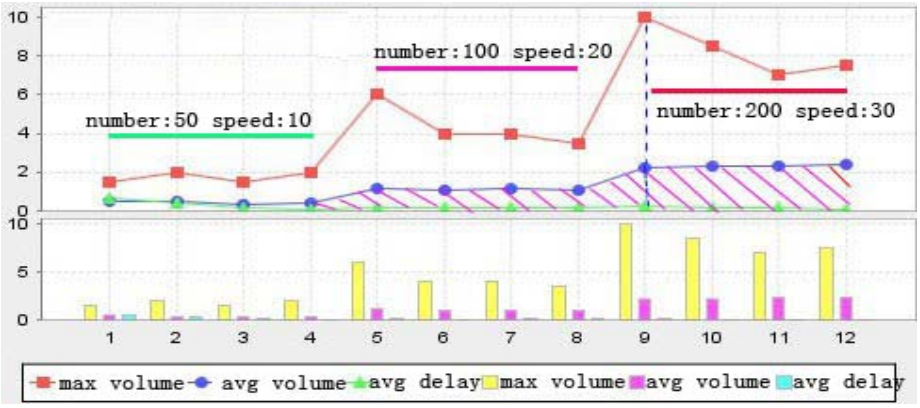


Fig.9 average traffic volume and average delay time relationship diagram

Since the faster computing speed of the model, the realistic image animation, the intuitive statistical data and charts in the traffic simulation system which provide the system good conditions to analyze various inputting schemes, Through the results we can also see the significance of coordinated control of urban traffic.

Summary

This text is based on the core model of the urban network traffic simulation system and use object-oriented software to simulate the traffic rules, signal control and the behavior of each single vehicle from microscopic view. Therefore, it is able to reproduce the local real situation of urban

traffic. The correctness of the model algorithm software and the validity of the function of this simulation software have been initially confirmed through the simulation examples. In addition, it also can analyze the real-time traffic conditions via the simulation outputs.

Before putting the new traffic management scheme into effect and changing the road infrastructure, this simulation system can be used to analyze and evaluate the new scheme. It also can improve efficiency and avoid waste. The main work of this text may be summed into following aspects:

(1) The urban microscopic traffic simulation software is divided into two subsystems, the traffic animation simulation system and the real-time information display system, so it solves the problem of the modularization design of the software system and embodies the object-oriented design.

(2) This text refers to a variety of theories of related disciplines in order to select and improve various traffic volume simulation models that are suitable for computer simulation and also simplify the models that are not suitable for simulation and initially establish a simulation model.

(3) According to the theoretical basis, the simulation system is established. This system can help to solve the traffic problem of multiple intersections of main roads and evaluate the current control scheme and guide traffic planning through animation showing and data outputs. Besides, we analyze the function of the software though the experiments and the validity of the algorithm of the model is also verified.

(4) This system paves the way for the study of microscopic traffic flow simulation. It makes the microscopic traffic flow model get more visualized through the simulation programming. Besides, it also lay a solid foundation for continuing to improve the simulation program in the future.

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