Research on Microscopic Traffic Simulation Model in VISSIM

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Abstract. VISSIM is a microscopic, time-interval and driving behavior-based simulation modeling tool for traffic modeling of urban traffic and public transportation operations. It can be used to analyze various traffic conditions, such as lane setting, traffic composition, traffic signals, bus stops, urban traffic and public transport operations, is an effective tool for evaluating traffic engineering design and urban planning solutions. This paper mainly studies the system architecture and simulation basic principle of VISSIM traffic simulation environment software, and introduces its core model-vehicle follow-up model and vehicle lane change algorithm in detail, and designs a simulation example plot to verify the traffic simulation model.

Introduction

Traffic simulation is an important tool to study complex traffic problems, especially when a system is too complex, cannot be described by simple and abstract mathematical models, the role of traffic simulation is more prominent. By establishing traffic simulation model, the location and cause of traffic jam can be clearly analyzed and forecasted, and the relevant schemes of urban planning, traffic engineering, and traffic management can be compared, evaluated and rehearsed, so as to avoid or prepare for the problem as far as possible before it becomes a reality.

Traffic simulation model can be divided into micro, meso and macro according to the degree of detail of the traffic system description. Microscopic traffic simulation takes individual vehicle behavior as the research object, which can describe the driving behavior and interaction relationship of each vehicle at every moment in the traffic system in great detail. Macro traffic simulation model is mainly used in urban overall planning. It takes the overall flow of vehicles as the research object and can analyze and reproduce the macroscopic characteristics of traffic flow.

At present, urban microscopic traffic simulation system has become a research hotspot at home and abroad. There are some mature commercial software abroad. Mainstream microscopic traffic simulation software in the world includes AIMSUN, TSIS, RAMICS, VISSIM, and TransModeler. VISSIM is widely used in the world. Domestic research in this area is in its infancy, and micro-traffic simulation models and systems suitable for China's national conditions are being studied and developed[1].

This paper mainly studies the VISSIM traffic simulation model from the microscopic aspect, and develops a traffic simulation environment simulation example through VISSIM traffic simulation modeling tool to verify the model.

VISSIM Overview

VISSIM software is a product of the German PTV company. It is a discrete, randomized, microscopic simulation software that takes 1/10 seconds as a time step. The longitudinal motion of the vehicle adopts the psychological-physiological car-following model, and the lateral motion (lane change) adopts the rule-based algorithm. VISSIM provides an image based interface to visualized vehicle movement visually with 2D and 3D animation. It can analyze various traffic conditions, such as lane
setting, traffic composition, traffic signals, bus stops, etc. The operation of urban public transport is a powerful tool to solve various traffic problems. The main uses of VISSIM are as follows[2]:

1. Design, evaluation and adjustment of bus priority signal control logic.
2. Evaluation and optimization of traffic control for road networks with coordinated and inductive signal control.
3. Feasibility and impact evaluation of light rail construction project in urban road network.
4. Analysis of slow traffic behavior in weaving area.
5. Comparing and analyzing traffic design schemes, including signal control intersection and stop sign control intersection, circular and interchange design.
6. Capacity and management evaluation of complex site layout for light rail and bus systems.
7. VISSIM evaluates the company's car priority solutions (e.g. queue jumping, port stop expansion, and bus lanes).
8. Using the embedded dynamic traffic assignment model, VISSIM can solve the related problems of route selection, such as the influence of variable information display, the possibility of traffic diversion to the adjacent area of the road network.
9. Pedestrian modeling and simulation.

**VISSIM Software Architecture and Simulation Principles**

VISSIM software system can be divided into four parts: traffic supply, traffic demand, traffic control facilities, data output. Traffic supply describes the physical infrastructure, including signal poles, parking facilities, bus stops, parking lots, detectors and other equipment placed on the physical infrastructure. Traffic demand generates the demand of people and vehicles running on the traffic supply. Traffic demand is determined by OD matrix and section input. The assignment model and the description of path flow are part of this module. Bus routes are defined as the sequence of sections and stations. Traffic control facilities, non-Interchange intersections by traffic control module to define the rules, four-way parking concession rules, the main and secondary roads through the gap acceptance priority rules, traffic lights control scheme. Data output includes dynamic demonstration, traffic control status, statistical data and vehicle status.

![Figure 1. VISSIM software architecture diagram.](image1)

![Figure 2. VISSIM simulation schematic diagram.](image2)

The main components of VISSIM simulation principle are traffic simulator and signal state generator. Interface exchange detector plays the role of exchanging data information and signal state between them. Traffic simulator is a microscopic traffic simulation model, which includes lane change model and car following model; signal state generator is a control signal software, which can reflect the control logic of traffic flow through the signal control program, and the control program obtains detection from the traffic simulator in turn at each specific time interval. Data to determine the signal state of the next simulation second. Then the signal state information is passed back to the traffic simulator through the interface exchange detector.
VISSIM Vehicle Following Model

The traffic flow model in VISSIM is a microscopic model with driver-vehicle unit as the basic entity. It has the characteristics of time, place, discrete and random. The car following model in VISSIM adopts the psycho psychological driving behavior model established by Wiedemann in 1974. The principle of this model is that if the rear driver perceives the distance between his own vehicle and the front vehicle is smaller than the safe distance or a safe distance set by the driver's own psychology, he will choose to brake and decelerate. If the rear driver can not accurately determine the speed of the front car, he will continue to drive at a speed smaller than the front car, after a period of time, the distance between the two cars to reaches another safe distance, or another driver's psychological safety distance, the rear driver will choose to accelerate, such a cycle, It become an iterative process of vehicle acceleration and deceleration.

Vehicle Driving Condition

Behavioral threshold model is a type of physiological psychological model, which is the car following model in VISSIM software. The MISSION model proposed by Wiedemann studies the threshold of driving behavior more deeply, which is closer to the actual road driving behavior and can better express the vehicle following model. Applying perceptual thresholds to vehicle driving behavior, four different vehicle following states are defined in the vehicle following model[4].

1. Free driving: The driving behavior of the front car is not affected by the driver. In this case, the rear driver will subconsciously accelerate and try to maintain stability, which is called the expected speed. But in the actual driving of the road, it is difficult to keep the rear speed constant, generally only floating up and down within the range of near the desired speed, the maximum acceleration of the vehicle Bmax formula is as follows:

\[ b_{\text{max}} = \alpha \cdot (v_{\text{max}} - v) \cdot \frac{v_{\text{max}} + v}{(v + \beta (v_{\text{max}} - v_{\text{des}}))} \]  

Among them, \( V \) is the current speed, \( v_{\text{max}} \) is the maximum speed, \( v_{\text{des}} \) is the expected speed, \( \alpha \) is the driver's sensitivity coefficient, and \( \beta \) is the driver's personalized calibration parameter.

2. Approaching: The distance between the current rear car becomes smaller, the rear driver will choose to adjust the speed or directly take brake deceleration, until the distance between the front and rear car is close to his psychological expectations of safety distance. When braking slows down, the speed of the front and rear cars is basically the same, and the deceleration rate of \( b_n \) is as follows:

\[ b_n = \frac{\Delta V^2}{2} \cdot (ABX - (\Delta V - L)) + b_{n-1} \]  

\( L \) is the front vehicle length, the minimum distance between ABX and vehicle is expected, and \( b_{n-1} \) is the deceleration value of the front vehicle.

3. Following: The rear vehicle follows the front vehicle, and the driver has no obvious significant acceleration or deceleration behavior. The distance between the rear car and the front car basically fluctuates up and down at a safe distance. In actual driving, because of the driver's visual judgment or the driver's control force on the throttle and other factors, the speed difference between the front car and the rear car fluctuates near “0”. Generally speaking, acceleration / deceleration is in the process of vehicle driving behavior:

\[ b_n = b_{\text{multiple}} \cdot (NRND + R_3) \]  

\( b_{\text{multiple}} \) is often taken as the mean minimum acceleration / deceleration ±0.2m/s², \( R_3 \) is a random number, NRND the driver's independent parameters are between [0,1] and obey normal distribution.

4. Braking: When the rear driver perceives that the distance between the two vehicles is less than his psychological expectation of the safe distance, he will choose to brake deceleration, the deceleration value of the vehicle will gradually transit to the maximum value, the deceleration formula is:

\[ b_n = \frac{\Delta V^2}{2} \cdot (ABX - (\Delta V - L)) + b_{n-1} + z_n \]
$$z_n = b_{\text{max}} \cdot (\Delta V - L)/BX$$  (5)

$$b_{\text{max}} = b_{\text{min add}} - b_{\text{min mult}} \cdot R_3 + b_{\text{min mult}} \cdot V$$  (6)

$b_{\text{max}}$ is the maximum braking deceleration, $b_{\text{min add}}$ and $b_{\text{min mult}}$ are the adjustment parameters.

**Driving Behavior Area**

Wiedemann 74 model is mainly suitable for urban road traffic. The model distinguishes different driving behaviors by setting threshold. The model includes six key thresholds and five driving behavior areas [3], the threshold curve is shown in Figure 3.

![Figure 3. Wiedemann74 threshold curve of car following model.](image)

1. AX is the desired distance of a stationary vehicle, including the length of the front car and the expected distance of the front and rear cars. It is determined by the driver and obeys normal distribution. The calculation method is as follows:

$$AX = L + AX_{\text{add}} + RNDI(I) \cdot AX_{\text{mult}}$$  (7)

Among them: $AX_{\text{add}}$, $AX_{\text{mult}}$ adjustment parameters and additional multiplication factors; $RNDI(I)$ values in the normal distribution between [0,1].

2. ABX is the minimum expected value of car following distance at a relatively low speed, including AX and speed dependent.

$$ABX = AX + BX$$  (8)

$$BX = BX_{\text{add}} + BX_{\text{mult}} \cdot RNDI(I) \cdot \sqrt{v}$$  (9)

Among them: $BX_{\text{add}}$, $BX_{\text{mult}}$ adjustment parameters and additional multiplication factor, $V$ is the front speed in the approximation process, $V$ is the rear speed in the distance process.

3. The dimension of the SDV is speed, which is the critical value of the velocity difference between the front and rear vehicles in the following condition with a large distance between the front and rear vehicles.

$$SDV = (DX - AX)/CX$$  (10)

$$CX = CX_{\text{add}} + CX_{\text{mult}} \cdot [RNDI(I) + RND2(I)]$$  (11)
Among them: $C_{\text{add}}$, $C_{\text{mult}}$ adjustment parameters, $D_X$ is the actual distance before and after the car, $RND_2(I)$ for the driver's evaluation distance.

4. $S_{DX}$ is the threshold value of the distance between the driver and the driver before and after the car following.

$$S_{DX}=A_X+EX+BX$$ \hspace{1cm} (12)

$$EX = EX_{\text{add}} + EX_{\text{mult}} \times [NRND-RND_2(I)]$$ \hspace{1cm} (13)

Among them, $EX_{\text{add}}$, $EX_{\text{mult}}$ are adjusting parameters.

5. $CLDV$ is a short range, the rear drivers perceive the speed difference is very small and the distance between the front and rear vehicles is reduced, it is essentially similar to the $SDV$, but the range of change in the range is relatively large.

$$CLDV = SDV \times EX^2$$ \hspace{1cm} (14)

6. $OPDV$ is the difference between the driver's attention at close range and the negative speed of the vehicle in front of him. This threshold is the difference between the driver's attention and the speed of the expressway ahead.

$$OPDV = CLDV \times (-OPDV_{\text{add}} - OPDV_{\text{mult}} \times NRND)$$ \hspace{1cm} (15)

Among them, $OPDV_{\text{add}}$, $OPDV_{\text{mult}}$ are adjusting parameters.

**Vehicle Driving Behavior Decision**

The driving behavior decision making process of the model is shown in Figure 4 below.

![Diagram](attachment:diagram.png)

Figure 4. Wiedemann74 driving behavior decision making process.

**VISSIM Lane Changing Model**

Vehicle lane-changing behavior is also very important to traffic flow operation, and it is one of the core models of microscopic traffic simulation software. The lane changing behavior of vehicles may occur in such situations as steering, overtaking or evading vehicles. The lane-changing model is more complicated than the following model, because when the vehicle changes lane, it should take into account the surrounding vehicles and traffic environment, and at the same time, combined with their own driving conditions, make changes to their own driving behavior.
Lane Changing Algorithm

VISSIM also has corresponding rules to simulate lane change behavior on a multi-lane section. Lane change in VISSIM will take place in the following two situations [2]:

1. Free lane change

The scenario mainly describes the lane-changing choices of vehicles in order to obtain more driving space or speed, such as increasing speed, overtaking and other vehicle behavior. In this case, drivers have sufficient time to consider Lane change, and the process can be divided into three steps: demand generation, feasibility detection and execution. When the driver is unsatisfied with the current speed and the estimated speed on the remaining lanes is greater than the current speed, the driver will need to change lanes. The driver will evaluate the feasibility of lane change by judging whether the gap between the front and rear of the target lane meets the acceptable minimum gap. When the constraint is met, lane change will occur.

2. Necessary lane change

The situation mainly describes the scenario of vehicles passing through connectors to the next section of the road during route selection, such as the interlaced vehicle behavior in the interlaced area, the inbound vehicle behavior in the ramp, the vehicle behavior avoiding obstacles in front of the vehicle and the lane change before turning, etc. Compared with the above freeway lane change behavior, the necessary lane change needn’t to produce this process, and the core of its research is the acceptable minimum gap. During the simulation process, the vehicle detects the lane clearance on the target lane continuously, and once it finds that the lane change condition is satisfied, the lane change behavior will start, and the detection behavior will stop accordingly.

Lane Changing Process Model

The process of lane changing model is shown below:

![Lane Changing Process Model Diagram](image-url)

Figure 5. Lane changing process model.
Simulation Example

This paper takes the intersection of JingHan Road and YouYi Road in Wuhan as an example, and uses VISSIM for simulation modeling. The intersection is mainly composed of cars and buses. In the CAD plan shown in Figure 8, the North-South entrance road of the intersection is four lanes, the exit road is three lanes, the East-West entrance road is three lanes, the exit road is three lanes, and the East-West entrance and the exit direction is a non-motorized lane. After a statistical survey of the traffic volume data at the intersection, the road and traffic flow data are obtained as shown in Table 1. The basic data came from Wuhan traffic control bureau.

Following parameters: following model Wiedemann 74, forward looking distance of 0 to 250 meters, rear looking distance of 0 to 150 meters, temporary distraction duration and probability of 0, average parking distance of 2 meters, safety distance of the additional part of 2.0, safety distance multiplier of 3.0.

Lane change parameter settings: the general behavior is free lane selection; the necessary change lane itself to exceed and fall behind the car exceeded the maximum deceleration are -4m/s^2 and -3m/s^2, -1 m/s^2/distance are 100 meters, acceptable deceleration is -1m/s^2, the waiting time before disappearance is 60 seconds, the minimum headspace (The former/rear is 0.5 meters, the safety distance reduction coefficient is 0.6, and the maximum braking speed of the coordinated brake is -3m/s^2.

Table 1. Road and traffic flow data.

<table>
<thead>
<tr>
<th>Direction</th>
<th>Number of lanes</th>
<th>Single lane width</th>
<th>Traffic flow</th>
<th>Total traffic flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight</td>
<td>2</td>
<td>3.5m</td>
<td>533</td>
<td>780v/h</td>
</tr>
<tr>
<td>Straight+right</td>
<td>1</td>
<td>3.5m</td>
<td>247</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1</td>
<td>3.5m</td>
<td>266</td>
<td>1372v/h</td>
</tr>
<tr>
<td>Straight</td>
<td>2</td>
<td>3.5m</td>
<td>727</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>1</td>
<td>3.5m</td>
<td>379</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1</td>
<td>3.5m</td>
<td>160</td>
<td>933v/h</td>
</tr>
<tr>
<td>Straight</td>
<td>1</td>
<td>3.5m</td>
<td>404</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>1</td>
<td>3.5m</td>
<td>369</td>
<td></td>
</tr>
<tr>
<td>North</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1</td>
<td>3.5m</td>
<td>150</td>
<td>912v/h</td>
</tr>
<tr>
<td>Straight</td>
<td>2</td>
<td>3.5m</td>
<td>412</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>1</td>
<td>3.5m</td>
<td>350</td>
<td></td>
</tr>
</tbody>
</table>

The intersection of JingHan Road and YouYi Road is controlled by four signals. The signal timing is shown in Table 2. The duration of yellow lights in each phase is 3 seconds. The duration of traffic lights varies according to the traffic flow.

Table 2. Signal timing data sheet. (s).

<table>
<thead>
<tr>
<th>Signal light group</th>
<th>Green long</th>
<th>Yellow long</th>
<th>Red long</th>
<th>Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>YouYi Road Straight</td>
<td>33</td>
<td>3</td>
<td>104</td>
<td>36</td>
</tr>
<tr>
<td>YouYi Road Left</td>
<td>30</td>
<td>3</td>
<td>107</td>
<td>33</td>
</tr>
<tr>
<td>JingHan Road Straight</td>
<td>40</td>
<td>3</td>
<td>97</td>
<td>43</td>
</tr>
<tr>
<td>JingHan road West left</td>
<td>25</td>
<td>3</td>
<td>112</td>
<td>28</td>
</tr>
</tbody>
</table>

Vissim is used to simulate the intersection of JingHan Road and YouYi Road. Travel detectors and queuing counters are set up at four intersections to record the travel time, average delay and average queuing length of vehicles traveling in all directions of the East, West, South and North Entrance Road. The data of the output files are sorted and analyzed, and the travel time, average delay and average queue length of each imported vehicle are obtained as shown in Figure 6, 7, and the simulation image as shown in Figure 9.
Figure 6. Travel and Delay time. Figure 7. Average queue length of vehicles.

It can be seen from the picture that the right turn and straight lanes at the intersection of JingHan Road and YouYi Road are merged with those at the West and East entrances. Because the vehicles that go straight affect the vehicles that turn right, their travel time, average delay time and average queue length are also the longest of the four intersections under the same signal timing. The right-turn lanes at the entrance and the north entrance are not affected by other lanes and traffic lights. Their travel time, average delay time and average queue length are also the smallest of the four intersections. This phenomenon is consistent with our actual situation in the field investigation.

At the end of the entrance lane on the East and west sides of JingHan Road, there is a right turning and straight traffic on the previous intersection, which needs to turn right or left to its YouYi Road. When the traffic flow is large, serious congestion occurs at the changeable lane of JingHan Road, which is a very realistic imitation phenomenon.

Summary

Based on the research of microscopic traffic simulation model of VISSIM and the investigation of relevant traffic data, this paper establishes the simulation model of the plane intersection of JingHan Road and YouYi Road by using the software VISSIM and conducts traffic analysis.

The results show that the VISSIM micro-simulation model has the characteristics of dynamic, intuitive and high precision. It can relative objectively reflect the actual traffic state of the intersection, find the existing problems and improve the areas. It can also evaluate the average delay and queue length according to the evaluation function of the software system. It can be used to compare and select the traffic schemes and optimize the crossing design scheme.
References


