Analysis of traffic flow characteristics of self-driving cars

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ABSTRACT

In order to analyze the traffic flow of self-driving cars, we modify some parameters in VISSIM’s Wiedemann model. Secondly, some values were labeled to ensure that vehicles are in an alignment, then we can simulate self-driving cars running state. Base on that, vehicles inputs is increased by 200pcu every time until traffic volume doesn’t change with it and this running state is much closer to the ideal state of self-driving cars. The evaluation files illustrate that with the increase of travel speed, the change of traffic volume is greater. The traffic volume is increased by 15% when the speed is 60km/h, and the traffic volume is increased by 54% when the speed changed to 100 km/h.

KEYWORDS: self-driving cars; VISSIM; Wiedemann model; vehicle inputs; traffic volume; traffic flow

1 BACKGROUND

Since the invention of the automobile, the automobile industry has continuously promoted the human innovation and the economic development. With the increase of vehicle output and quantity, people's travel becomes convenient and fast. Traffic congestion and traffic accidents also become a major obstacle to human civilization. With the development of computer control technology, more and more automatic control technologies have been applied to automobiles, and self-driving cars have also become a major change in the automotive industry.

Self-driving cars are also known as autopilot or wheeled mobile robot. Without human input, it can perceive the surrounding environment through vehicle sensors, and achieve unmanned driving by relying on the information obtained and intelligent driving system based on the computer system. It controls the steering and speed of vehicles based on the perception of roads, vehicle location and obstacle information, so that vehicles can run safely and reliably on roads.

It can be predicted that in the coming decades, the market share of self-driving cars will improve. Its traffic flow is different from existing road traffic flow. Therefore, it is necessary to observe self-driving cars’ traffic flow characteristics.

2 VISSIM SIMULATION

2.1 The Theory Of Simulation

Wiedemann 74: suitable for simulating driving behavior in urban area.
Wiedemann 99: suitable for simulating driving behavior in suburbs or freeway.

Table1 Wiedemann model
<table>
<thead>
<tr>
<th>parameter</th>
<th>definition</th>
<th>note</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC0</td>
<td>Average expected vehicle spacing when parking</td>
<td>No variables</td>
</tr>
<tr>
<td>CC1</td>
<td>Expected headway</td>
<td>The bigger the value, the more prudent the driver is.</td>
</tr>
<tr>
<td>CC2</td>
<td>Car-following variable</td>
<td>The driver has an additional distance to reflect the allowable distance greater than the average safety distance.</td>
</tr>
<tr>
<td>CC3</td>
<td>The threshold to enter the state of car following</td>
<td>The time for driver to respond to a safe distance.</td>
</tr>
<tr>
<td>CC4</td>
<td>The first threshold of the car to keep following</td>
<td>Control and act when the velocity difference between the two cars is negative.</td>
</tr>
<tr>
<td>CC5</td>
<td>The second threshold of the car to keep following</td>
<td>Control and act when the velocity difference between the two cars is positive.</td>
</tr>
<tr>
<td>CC6</td>
<td>Velocity fluctuation</td>
<td>Reflect the relationship between the velocity and distance of the next vehicle. The greater the distance, the greater the fluctuation.</td>
</tr>
<tr>
<td>CC7</td>
<td>Fluctuation acceleration</td>
<td>The real acceleration when the speed is fluctuating.</td>
</tr>
<tr>
<td>CC8</td>
<td>Acceleration</td>
<td>Expected acceleration when vehicle starts.</td>
</tr>
<tr>
<td>CC9</td>
<td>Acceleration when velocity is 80km/h</td>
<td>The expected acceleration</td>
</tr>
<tr>
<td>Front view distance</td>
<td>Visual distance in front of a vehicle</td>
<td></td>
</tr>
<tr>
<td>Back view distance</td>
<td>Visual distance behind a vehicle</td>
<td></td>
</tr>
</tbody>
</table>

The basic idea of Wiedemann model: according to the different driving model, the drivers are divided into 4 types.

1. **Free driving**: This driving behavior means that the vehicles ahead have no influence on the back vehicles. Under such conditions, the driver will pursue and hope to maintain a certain speed, which is the ideal speed. In fact, the driver cannot always maintain the speed of free driving. Because of the occasional improper operation of the driver, the free driving speed of the vehicle will fluctuate around the ideal speed.

2. **Approaching the vehicle ahead**: It occurs when the speed of the vehicle at the back is higher than the front. During the approaching process, the vehicle behind must slow down to keep the safe distance between vehicles.

3. **Car-following state**: This driving behavior refers to a car going after the front without any obvious acceleration or deceleration to keep a safe distance. However, there are always slight velocity differences between the two cars due to the driver's operation or judgment.

4. **Braking**: If the distance between the two cars is below the safe distance, the vehicle will brake at once. It is usually due to the sudden change of the lane of the vehicle.

For each driving mode, the acceleration of the back vehicle is determined by the speed and velocity difference, the distance between two cars, and the personality characteristics of the driver and vehicle.
When driver reaches a threshold that represent a certain speed difference and distance, he will change from one driving mode to another. Since the Wiedemann model takes the psychological and physiological constraints of the driver into account, it is called a physiological - psychological model.

2.2 The Simulation Steps

**Step 1** We create a new vehicle type to simulate the driving behavior of the self-driving cars by modifying its parameters and proprieties in VISSIM.

**Step 2** We create a two-lane road and input traditional cars, self-driving cars in lane1 and lane2 respectively.

**Step 3** We suppose the design speed which self-driving cars can keep during the simulation. The velocity of traditional cars will drive according to the Table2.

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expectation speed (km/h)</td>
<td>60–85</td>
<td>80–100</td>
<td>95–115</td>
<td>115–130</td>
</tr>
</tbody>
</table>

**Step 3** After running the simulation, we can get the traffic volume, spot speed and travel delay.

2.3 The Modification Of Parameters

The simulation of the driverless lane is mainly to modify the driving behavior parameters in VISSIM, as well as the front and back range of visibility, the amount of vehicles that the driver can observe. Then we set up the expectation speed of the self-driving cars to keep a constant value, so that we can simulate the self-driving cars’ driving mode on the road. Due to the limitation of the version, we only study the road condition under the single lane traffic environment, and the actual traffic flow is far greater than the road capacity.

CC3, CC4, CC7’s value is equal to 0. The front and back range of visibility of self-driving cars is larger than the traditional cars. And the amount of vehicles which can be observed is 5pcu in order that self-driving cars are in a alignment. It is convenient for the research and avoids a series of problems caused by the limitation of VISSIM version.

2.4 The Analysis Of Simulation

![Figure1: Traffic volume-traffic flow under 60km/h](image)
Figure 2: Travel delay under 60km/h

Figure 3: Traffic volume-traffic flow under 80km/h

Figure 4: Travel delay under 80km/h

Figure 5: Traffic volume-traffic flow under 100km/h
From the figures above, we can get some conclusions as follows.

First, the self-driving cars couldn’t give full play to desired speed advantage under the free flow. It can also attribute to the limitation of VISSIM version so that we can’t carry out a more detailed simulation on the driving behavior of self-driving cars. When traffic volume exceeds the traffic capacity, the self-driving cars are in a alignment. It can be seen from the fold graph of Figure 1, 3 and 5, the traffic volume in self-driving lane is far larger than another.

Second, when vehicles are in a alignment, the travel delay in traditional lane is large. This is because the traditional vehicle model is consistent with the driver's physiological and psychological model, which makes the traditional lanes in a congestion, and self-driving lane is different. In this simulation, CC4, CC5 and CC7 are equal to 0, which ensures that the driverless car always keeps the same speed of the front car at all times and there will be no acceleration fluctuation in the process of car following. Therefore, we get the travel delay figure 2, 4 and 6. There exists no delay behavior in the self-driving lane.

Third, we can find from the figure1,3 and 5, with the increase of vehicle input, the amount of self-driving cars is a constant value, which indicates that the traffic volume in self-driving lane only depends on the speed of the first car. Comparing the longitudinal data, when the number of input cars is fixed at 5300pcu, the travel speed increases from 60km/h to 100km/h and the traffic volume improves 41%.

3 CONCLUSIONS

With the maturity of autopilot technology, self-driving cars are getting closer and closer to us. It is becoming more and more important to understand the influence of self-driving cars on traffic flow. Our research will guide how self-driving cars relieve traffic pressure and solve the traffic jam. Further research is necessary, self-driving cars will be in what form on the roads in the city. This paper has just completed a simple simulation task.

4 REFERENCE