The Braking Behavior on Highway Simulation and Analysis

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1 INTRODUCTION

During the highway trip in our vacation, we can find that somehow the cars just encounter a traffic jam at certain road section. It might derive from the car crash or just too many cars that the highway road capacity is not enough for those cars. Sometimes the traffic jams are just caused by no reason. It could result in a nonsignificant reaction of the human driver who gives a little brake. On the highway, the cars' speed is faster and the car flow is more stable. We can drive at the speed at a range of 90-110 km/hr that is a smooth flow on the Taiwan National Highway. When there are some cars just brake lightly, the car behind who did not maintain enough following gap might brake relatively. Not only the conservative human driving attitude but the human reaction time also lead the person to brake more heavily than the front car did. With this effect, it will virtually become a traffic jam with no accidental indication. The reason that triggers the driver to lightly braking is shown below. For example, there is a police speed trap, some temporary obstacle on the road, lane changing, lane contraction or reduction, merging into the lane, and even nonreason driver braking might give rise to trigger the butterfly effect or ripple effect. The worst situation is this effect may make the long traffic jam as the time goes and it needs more time to digest the car flow then return to the smooth traffic section. In this article, we want to simulate the butterfly effect of human driver braking behavior on the highway and find out a set of situations that let the traffic flow more stable but minimize the effect of it after some analysis and observation.

2 MOTIVATION

On the highway, when I met the heavy traffic jam, we have always thought that there had been a car accident or somebody who got the flat tire in front of us so that we had got the held up on the highway. Nevertheless, there were any accidental situations after we pass by the congestion section. We are always curious about why that section was so heavy that we are almost stuck in the road. Moreover, we are also curious about how long will the traffic jam be and how much time does it need to digest this traffic jam. We want to know that is there any solution that will not lead to the heavy congestion situation so that we may prevent the non-reasoning traffic jam that held up in our trip.

3 RELATED WORK

There were some interesting projects focusing on the traffic jam modeling and shock-wave phenomenon of traffic explanation.

In "Traffic Jam Modeling and Simulation"[1], it mentioned that there are several different explanations for the cause of traffic jam, it can be divided into two categories: microscopic and macroscopic. The microscopic phenomena including "lane change on a roadway with high density", "pumping effect at on ramps", "small traffic oscillations" etc. In our work, we focus on exploring the causes of traffic jams from a microscopic perspective (the braking behavior of driver).

In "Impact of traffic states on freeway crash involvement rates"[2], its target was finding out the collision rate in different situation on the highway in the real world observed data. It define the road section in Fig1(a). It use the speed(v), flow(q), and density(k) to measure the traffic. Fig1(b) shows the traffic states on flow-density plane, the flow grows when the density below at a value and it descents when its density was greater

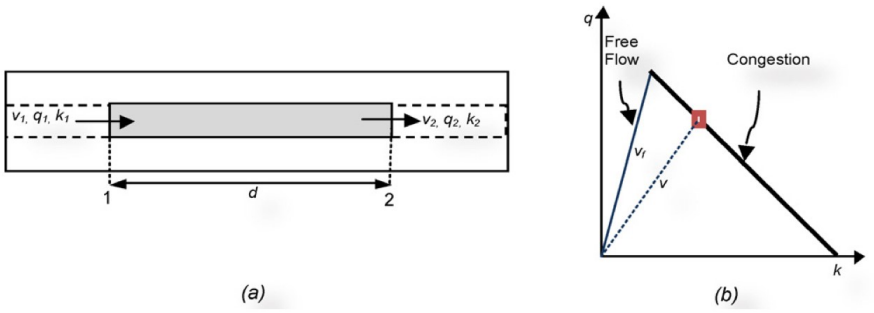


Figure 1: Definition of a road section[2]

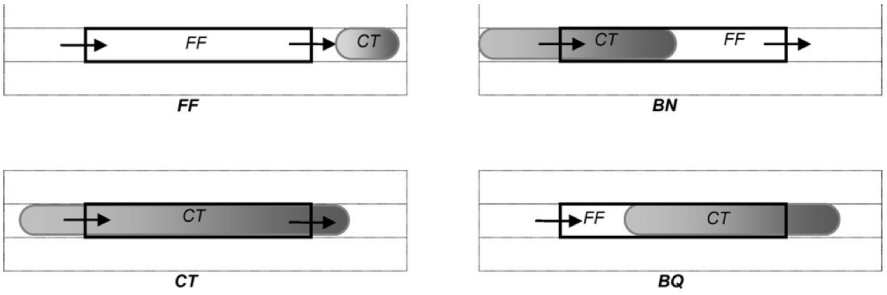


Figure 2: Illustration of traffic states for a freeway section[2]

than that value. In this paper, it separates the situations as 4 states which shown in Fig2. Free flow (FF) is the state that the drivers drive without affecting boundary. Bottle neck (BN) shows there occur some event and let the car behind be held up. As the time goes, this section become to congested traffic (CT) because the existence of movement with stop then go. Back of queue (BQ) is the state that slowly digest the heavy traffic flow. Its result shows that in different state, the crash involvement rate CT and BQ is 5 times greater the state FF. As the result, we thought that we can also separate our simulation experiment to the different states for monitoring.
In "Traffic jams without bottlenecks-experimental evidence for the physical mechanism of the formation of a jam"[3], it use the circular road to prove the shock-wave phenomenon. The vehicles move along the circular road, they found that with a density level, the vehicles can be divided into two parts, free drive part and bottleneck part, which met the stop-and-go situation. The front car start to accelerate but the last car slow down and reach the back of the cluster. Its shows that when a bottle neck occurs, the density of that road increased. In relation to the density, the traffic jam appears when it exceed the critical value.

4 Proposed Approach

4.1 Environment

To build up this environment and situation, we use SUMO (Simulation of Urban Mobility)[4] as our simulation background system and TraCi (Traffic Control Interface) as our traffic control of python package for dynamic interaction result. We set our simulation road on highway as a long distance of straight road so that there is no other unexpected affection that interfere our simulation. We set 3 lanes on our highway which is similar to the real world highway. There are different vehicle types and driving attitude in our simulation. For instance, the most type we use is normal car with lower max speed which will not exceed the limitation, the second most type in real world is sporty car which have higher max speed and higher level acceleration, bus and the trailer is the rarely appear one that have slowest speed and acceleration, and so on. Beside, we set the perfect driver scaling level in the following model to the lowest value because it is too secure for people whose driving following gap is too long so that it will not cause the situation that we want to observe.

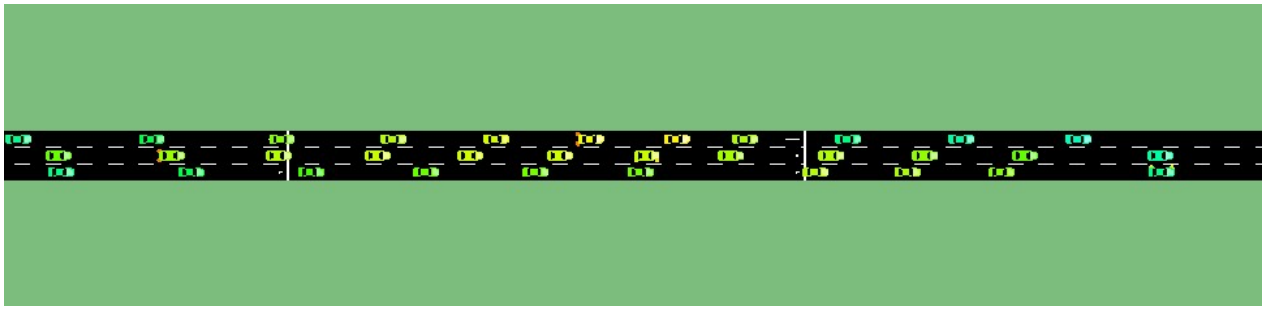


Figure 3: The simulation and visualization schematic diagram (The color means the current speed. Blue & Green car is the fastest and yellow & red is the slowest)

4.2 Experiment Model

We split our highway into 5 section. The first one is initial edge which is the start of the road. It is created for controlling the vehicle spawning frequency. The second edge is the buffer edge. It is a space that let the car speed up from 0 to a stable speed so that we can ignore this road of its actions. The third section is the first monitoring edge which we are concern about. It means that the vehicle encounter the traffic jam will be in this edge. We can observe some congestion values within this session. Next one is the braking behavior edge. This edge is set to do the braking behavior and it also means that there is a event lead the driver to slow down the car. The last edge is the second monitoring edge. To find out if the highway digest the congestion, we can observe this section as assistance.
We separate our simulation to 5 states for our experiment model. Initiate State is the car randomly spawn with initial speed 0 (km/hr) and pick the car driving type with a fix probability. Stable State is the state that we maintain a range of density of the traffic flow on the road. In this state, the vehicles moves along easily. The event trigger state is the state that there is some situation which make the driver slowing down the car at different level. The state we can observe is the affecting state. We can get some congestion measured data in this state, such as the length of the traffic jam, the average of the vehicles speed, and so on. The last state is the digesting state. We can get the data that measured in the digesting situation, like measure the time that clear the congestion, etc.

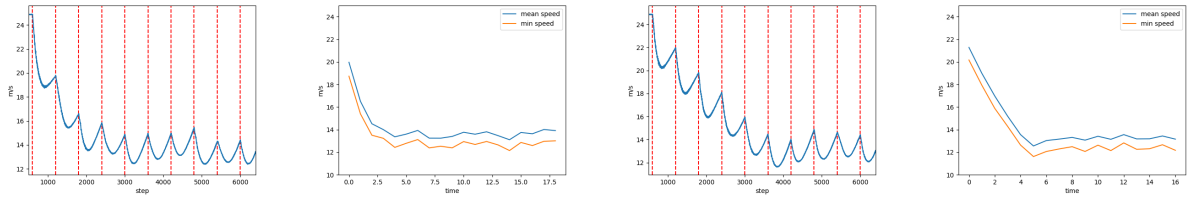
4.3 Definitions and Parameters

The following model is the attitude of the simulated vehicles. There is something we need to definite. To observe this phenomenon, our simulated driver must not be too comply with the rules as a safety driver. If every driver always reserve a wide minimum gap when standing, the vehicles will have a buffer range to maintain the emergency situation that they might not slow down the car than the previous car did. In relation to this phenomenon, we also need to set a proper acceleration and deceleration which gives different level of influence. In most of the time, lane changing might be a factor which lead to slow down the car. In our simulation, we found that the default lane changing system was not suitable on the highway. It change lane without acceleration. If we let all vehicles feel free to change the lane to the current lowest traffic lane in relative, the vehicles behind the lane changed one will slow down heavily so that all cars want to change the lane but everyone was held by others. We set the lane changing speed gain, lane changing willingness, the probabilities, and some other parameters to set our following system and lane changing in a proper value similar to real world for observation.

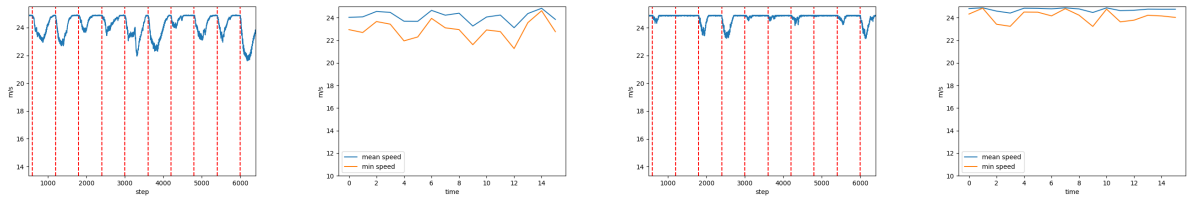
5 EXPERIMENT RESULT

The first things we want to know is the relation between the velocity and time during the periodical event trigger with different density. In Fig4, it shows the average speed with different traffic flow. There are 4 kinds of flow from 9000 cars per hour to 6000 cars per hour. The vertical axis in those figures are all velocity in this monitoring section. The horizontal axis in Fig4.(a), (c), (e), and (g) are the steps which is the minimum resolution of the time. The red line is the event trigger period. As we can see, the speed will drop steeply in the beginning then it will rise a little bit to digest the jam, but the next event period occurs. In consequence,

it will converge to a range at a lower speed and it will not digest if the car flow always that much. In 6000 cars per hour experiment, we can find that the braking event will not affect the average speed of this section that the vehicles drive smoothly on the highway. In our experiment setting, the critical flow value is at about 7000 cars per hour. That is a suitable and acceptable flow that have the maximum capacity without occurring the jam.



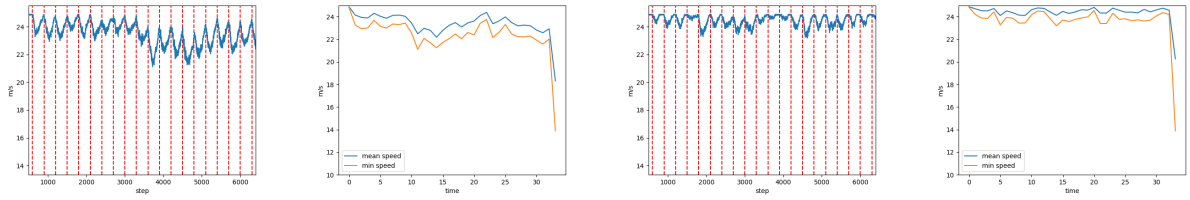
(a) 9000 cars/hr (b) a-periodical avg. (c) 8000 cars/hr (d) c-periodical avg.



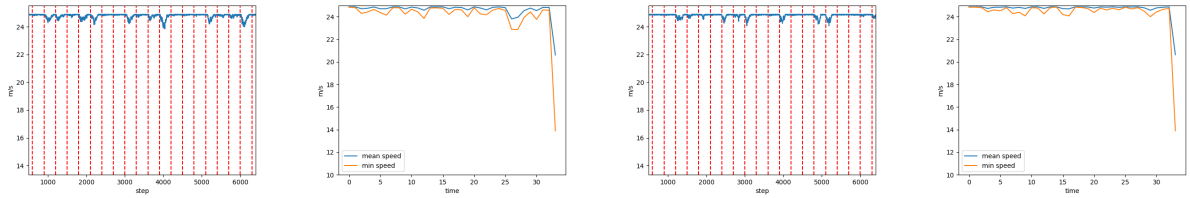
(e) 7000 cars/hr (f) e-periodical avg. (g) 6000 cars/hr (h) g-periodical avg.

Figure 4: The average velocity in different traffic flow

In Fig5, the x-y axis is similar to the previous one. In this segment, it presents the relation between time and velocity in different ratio based on the braking intention which means the probability of the person slow down the car when they meet the event trigger situation. We knew that the more people slow down the car, the more time it needs to digest the traffic jam and the more range that the speed dropped. In contrast to these measurement, we can find that the road section can accommodate about 33% people slow down their car in this section as the same time.



(a) 100 percentage (b) a-periodical avg. (c) 50 percentage (d) c-periodical avg.

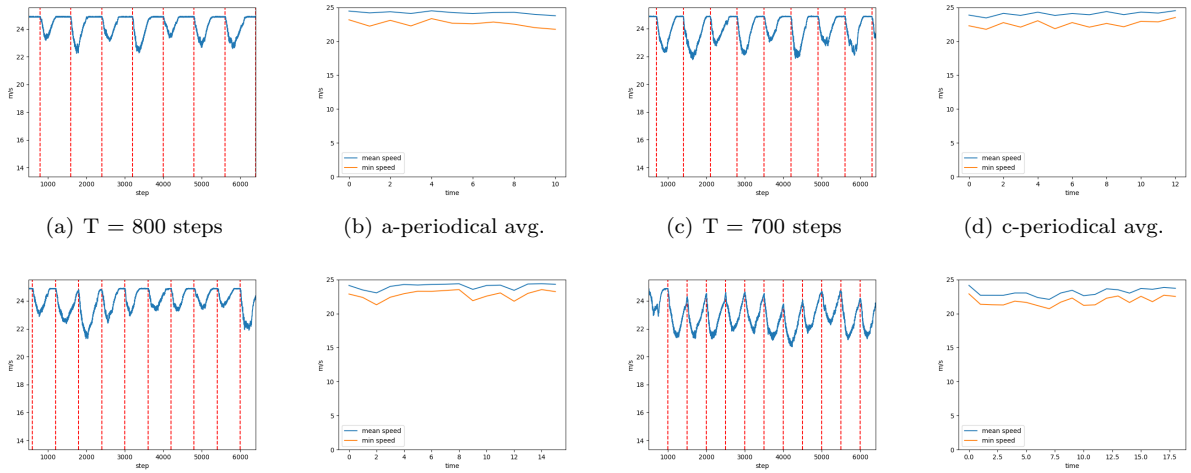


(e) 33 percentage (f) e-periodical avg. (g) 25 percentage (h) g-periodical avg.

Figure 5: The average velocity with different ratio based on the braking intention

In Fig6, we want to discuss the relation between the frequency of triggering random braking events and the mean velocity on the affected section. According to our observation, the higher braking frequency cause the lower velocity on the affected section. It is worth noting that when the period is between 500 and 600 steps, the recovery time required for the traffic jam cause by the randomly braking has not kept up with the

speed of generation of the traffic jam. When the period exceeds 600 steps, the recovery time will get shorter and shorter as the frequency decreases.



(a) T = 800 steps (b) a-periodical avg. (c) T = 700 steps (d) c-periodical avg.

(e) T = 600 steps (f) e-periodical avg. (g) T = 500 steps (h) g-periodical avg.

Figure 6: The average velocity with different braking period

6 FUTURE WORK

In our analysis, we can get some extreme values in different situation and simulate the periodic braking behavior as a frequently met event. Such as after passing through the speed trap but there is a interchange lane merging event in front of it or it meet somebody do the lane change without reserving the safety following gap. In addition, we found that some given parameters were not act as real as the real world did. With our simulation system, we need to set our following system with some non safety driver factor to act as a driver who did not reserve a long distance. Even though we can find the extreme value to make the highway drive smoothly with different situation, the data was still too ideal. Hence, we can get some real world observed data or find the extreme value for higher capacity with some mathematical model.

7 APPENDIX

7.1 Contributions

Shao-Yang Chen : Survey, Concept Development, Text Writing
Yi-Jung Ho : Survey, Code Building

7.2 Type of This Project

Research

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