Influences of a Safety Assistant Driving Strategy on Microscopic Traffic Characteristics

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Abstract. In order to improve road traffic safety caused by driver's subjective factors, safety assistant driving system has become the focus of intelligent transportation research. However, there is little related work to consider safety assistant driving system in microscopic traffic flow to further study its influences. This paper introduces a safety assistant driving strategy into a car-following model to explore the impacts of the assistant driving strategy on microscopic traffic characteristics. The numerical results indicate that the join of safety assistant driving strategy will inhibit the emergence of congestion and reduce the amplitude of the oscillating phenomena, while it will also reduce the maximum traffic flow which affects the capacity of the road.

Introduction

In recent years, many scientists have put forward many microscopic traffic flow models to study various complex factors influencing traffic safety, among these models, the car-following model has been widely discussed for their convenience to describe the driver's individual behavior.

The earliest car-following theory was developed by Reuschel [1] and Pipes [2], which marked the beginning of the study of car-following theory. In 1958, Chandler et al. [3] proposed the General Motor (GM) model, where they assumed the acceleration was proportional to the speed difference between the current vehicle and its front vehicle. Since then, scholars had developed many complex car-following models to study driving behaviors, such as Gipps model [4], optimized velocity (OV) model [5], full velocity difference (FVD) model [5], generalized force (GF) model [7] and intelligent driver (ID) model [8].

Nowadays, safety assistant driving system has been widely used with the rapid development of intelligent transportation system (ITS). However, there are few related works using safety assistant driving system to discuss its influences on traffic flow. In this study, we explore the impacts of an assistant driving strategy on microscopic traffic characteristics.

The paper is organized as follows. Section 2 introduces the car-following model and the safety assistant driving strategy. Section 3 presents the simulation results which explore the impacts of safety assistant driving strategy on microscopic traffic characteristics. Section 4 summarizes the work of this paper.

Model Formulation

In 2014, Jiang et al. [9] proposed a two-dimensional intelligent driver (2D ID) model with the assumption that traffic state was allowed to span a two-dimensional region in velocity-spacing plane. The equation of this model was defined as:

\[
a_n(t) = a_{max} \left[ 1 - \left( \frac{v_n(t)}{v_{max}} \right)^4 - \frac{s_0 + v_n(t)T(t) + \frac{v_n(t)\Delta v_n(t)}{2a_{max} b}}{\Delta s_n(t) - l} \right]^2 \right]
\] (1)
Where \( a_n(t) \), \( v_n(t) \) and \( x_n(t) \) are the acceleration, velocity and position of the vehicle \( n \) at time \( t \), respectively; \( a_{\text{max}} \) is the maximum acceleration; \( v_{\text{max}} \) is the maximum velocity; \( s_0 \) is the desired gap between two neighboring vehicles in jam; \( l \) is the length of the vehicle; \( \Delta v_n(t) = v_{n+1}(t) - v_n(t) \) is the relative speed; \( \Delta x_n(t) = x_{n+1}(t) - x_n(t) \) is the spacing of vehicles; \( T(t) \) is the desired time headway, and it is a uniformly distributed random number between \( T_1 \) and \( T_2 \), and \( T(t) \) changes in this range with rate \( p \) in each time step \( \Delta t \).

The main theory of the safety assistant driving strategy can be seen in Fig. 1. we assume two vehicles drive in the same lane at the same direction, the distance between two vehicles is \( \Delta x \) and the speed of the following vehicle and the front vehicle are respectively \( v_{n+1} \) in the initial state. When the front vehicle brakes with the set deceleration \( b' \), the following vehicle also brakes with the set deceleration \( b' \) after reaction time \( \tau \). The braking distance of the following vehicle and the front vehicle are respectively \( X_1 \) and \( X_2 \).

Defining a critical value of distance \( \text{Gap}_n \):

\[
\text{Gap}_n = X_1 - X_2 = v_n(t) \tau + \frac{v_n(t)^2}{2b'} - \frac{v_{n+1}(t)^2}{2b'}
\]

The specific evolution rule of safety assistant driving strategy includes:

1. Normal driving: if \( \text{Gap}_n < \Delta x \), there is no collision risk and the following vehicle drives in accordance with the rules of 2D-ID model;

2. Dangerous deceleration: if \( \text{Gap}_n \geq \Delta x \), there is a collision risk and the following vehicle decelerates with the set deceleration, that is \( a_n(t) = -b' \).

![Figure 1. The schematic diagram of the theory of safety assistant driving system.](image)

**Simulation Results**

In this section, we use the above model to simulate the traffic flow on a circular road to analyze the effects of safety assistance driving strategy. The initial conditions are as follows: all vehicles are homogeneously distributed on the road. In the simulation, parameters are set as follows: \( v_{\text{max}} = 120 \text{km/h} \), \( v_c = 50.4 \text{km/h} \), \( a_{\text{max}} = 0.8 \text{m/s}^2 \), \( b = 1.5 \text{m/s}^2 \), \( d_0 = 2.0 \text{m} \), \( T_1 = 0.5 \text{s} \), \( T_2 = 1.9 \text{s} \), \( p = 0.015 \), \( l = 5 \text{m} \).

Firstly we study the impact of the safety assistance driving strategy on traffic flux. In the simulation, the deceleration of safety assistance driving strategy is set to \( b' = 3 \text{ m/s}^2 \). Fig.2 shows the simulation results of flow-density diagram at different values of \( \tau \).

![Figure 2. Flow-density diagram joining the safety assistance driving strategy at different value of \( \tau \).](image)

From Figure 2, we have:

1. The flow-density diagram is same with the 2D-ID model when \( \tau \) is small, which means that
the value of reaction time $\tau$ has no effect on the traffic flow when $\tau$ is small, while it begins to work when $\tau$ is a little bigger and the maximum of traffic flow decreases with the increase of the value of $\tau$ in this case;

(2) With the increase of $\tau$, the density value of $K_c$ that wide moving jam appears is more and more large which means that the safety assistance driving strategy restrains the appearance of congestion and the stable traffic flow will stay longer.

Fig. 3 shows the spatiotemporal diagrams of velocities when the density is 30 veh/km, in which case the 2D-ID model is in wide moving jam branch. $b=3m/s^2$. From Fig.3, we can see that there is an obvious congestion phenomenon in 2D-ID model while it is eliminated after joining the safety assistance driving strategy. Comparing (b) and (c), the fluctuation of velocity becomes smaller with the increase of the value of $\tau$, which means that the greater $\tau$ will produce more stable traffic flow. That is, the application of the safety assistance driving strategy and the proper value of $\tau$ can put off the appearance of wide moving jam thus increase the stable of traffic flow.

![Figure 3. The spatiotemporal diagrams of velocity, where (a) is the 2D-ID model, (b) and (c) are the safety assistance driving strategy when $\tau=1.2s$ and $\tau=1.5s$ respectively.]

Fig. 4 shows the time serious of the velocity of each car when the density is 80veh/km in all cases the traffic flow is the same as shown in Fig.3. $b=3m/s^2$. From Fig.4, we can see that (1) the join of the safety assistance driving strategy can reduce the amplitude of the oscillating phenomena and it is smaller with the increase of the value of $\tau$; (2) the phenomenon that vehicles stop from time to
time can be relieved after joining the assistance driving strategy and choosing a relative bigger $\tau$ which will increase the comfort of passengers.

![Figure 4](image_url)

Figure 4. The time serious of the velocity of each car at different time, where (a) is the profile at 150s and (b) is the profile at 650s.

**Conclusion**

This paper bridges the linkage between intelligent driving auxiliary strategy and microscopic car-following model and forms a car-following model with the consideration of safety assistant driving system. Then, we utilize this model to simulate a circular road to analysis microscopic traffic characteristics after introducing safety assistant driving system.

The simulation results demonstrate that: (1) the safety assistant driving strategy can put off the emergence of congestion and the jam will appear later with the increase of $\tau$; (2) the amplitude of the oscillating phenomena decreases after using the safety assistant driving strategy and traffic flow will be more stable with the increase of $\tau$.

Therefore, it is possible to choose a relative larger reaction time $\tau$ but not too big considering the maximum flux in the practical application of safety assistance driving system.

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**References**


