Research and Design of an Overtaking Decision Assistant Service on Two-Lane Roads

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Abstract

Overtaking is one of the common actions that the driver performs while travelling on the road. Without enough information about the road, overtaking is dangerous and causes many accidents. Although overtaking is important, little research was done in this area. Especially, there is no research focus on helping the driver to judge whether it's safe enough or not to do overtaking.

The purpose of this thesis is to provide overtaking assistant service to help the driver to do the overtaking safely. From the proposed Overtaking Decision Assistant Figure, the driver can easily determine whether the overtaking is safe or not. However, since the GPS receiver's error will influence the trajectory calculation, it has to be considered to improve the original overtaking assistant service.

Keywords: *Overtaking, Two-Lane Roads, Overtaking Decision, Assistant Service*

1. Introduction

As the performance of vehicles has improved and prices have declined, vehicles are connected with humans' daily lives. With the growth of automotive manufacturing and sales, more automotive researches, especially with regard to automotive applications, is being conducted. The overtaking of one vehicle by another is a very common situation during driving.

Overtaking is one of the common actions that the driver performs while travelling on the road but accident numbers confirm that overtaking is indeed difficult: between 1995 and 2000, about 26 (2.6% of total fatalities) traffic participants die yearly in Netherlands because of overtaking failures [1] and in the UK, 7.9% of fatal accidents are caused by overtaking [2]. Especially in the foggy day or at night, overtaking will become much more dangerous. Therefore, overtaking related researched should be done urgently. Here is the structure of this thesis: Chapter 1 is the introduction of the research topic; then Chapter 2 is review of overtaking research, after the establishment of the overtaking model in Chapter 3, Chapter 4 will related to the analysis of initial overtaking condition. In Chapter 5, we will proposed an overtaking decision assistant figure, then it will be modified in Chapter 6, and Chapter 7 will be the conclusion.

2. Review of Overtaking Research

Some researchers have attempted to show the overtaking process of drivers in 2D or 3D [3]. Some works have tried to calculate the trajectories of autonomous vehicles [4]. ther researchers have attempted to build a model in order to analyse the behaviour of drivers during the overtaking process [5-8]. However, before drivers commit to overtaking, the most important thing for them to decide is whether or not it is safe to do the overtaking. In contrast to previous works, the contribution of this paper is that more attention was devoted to a real driving environment. In addition, a safe overtaking service to help one driver overtake another vehicle safely is proposed.

3. Establishment of the Overtaking Model

In order to research safe overtaking service, an overtaking model was built based on a two-lane road with two different traffic directions as shown in Figure 1. The host vehicle “Car A” wants to overtake the object vehicle “Car B”, and there is one obstacle vehicle “Car C” which is moving in the opposite direction with Car A and B. The velocities and accelerations of Car A, B and C can be resolved in X and Y direction. In order to make the calculation of each car’s trajectory simple, we assume Car A doesn’t accelerate in X direction, thus, the velocity of Car A in X direction has to be larger than Car B. We also assume Cars B and C have constant X direction velocities. To ensure driver safety during the overtaking process, some safe distance concepts were defined. Safe distance is the minimal distance that the driver should maintain in order to avoid collision with other cars.

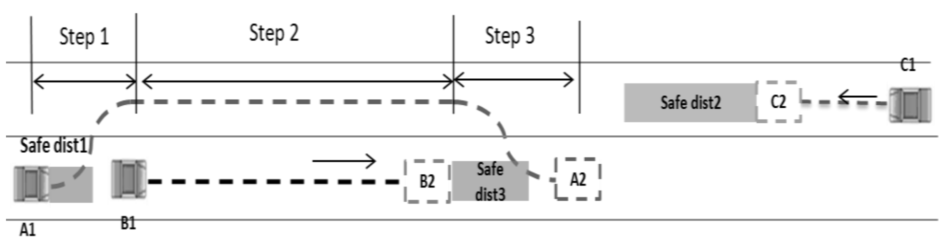
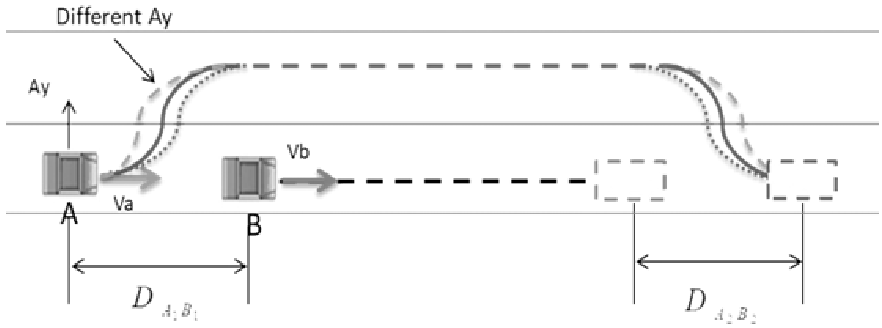


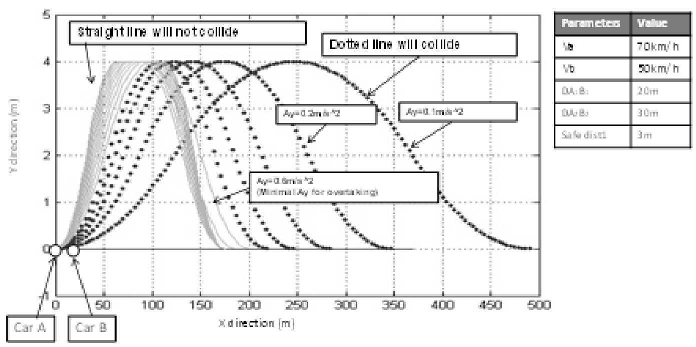
Figure 1. Trajectory of the Overtaking Process

4. Analysis of Initial Overtaking Condition

In the above assumption, A_y can influence lane changes during the overtaking process. If A_y is large, Car A will change lanes very fast, but such an action may cause the driver some discomfort. If A_y is small, Car A will change lanes very slowly, as shown in Figure 2 (a), which may cause collisions with Car B. Therefore, a suitable A_y for Car A is needed to be recommended. With different Ay, different trajectories were calculated, as shown in Figure 2 (b). The dotted trajectories mean Car A will collide with Car B, while the non-dotted trajectories mean Car A won’t collide with car B, then minimal A_y can be found. All the other A_y values which are larger than the minimal A_y can result in successful overtaking.



(a)



(b)

Figure 2. Different Trajectories with Different Ay

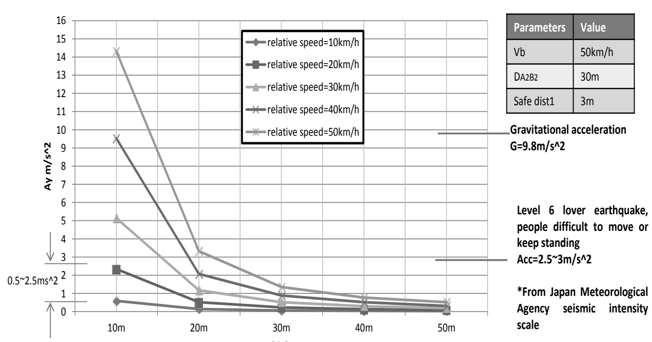
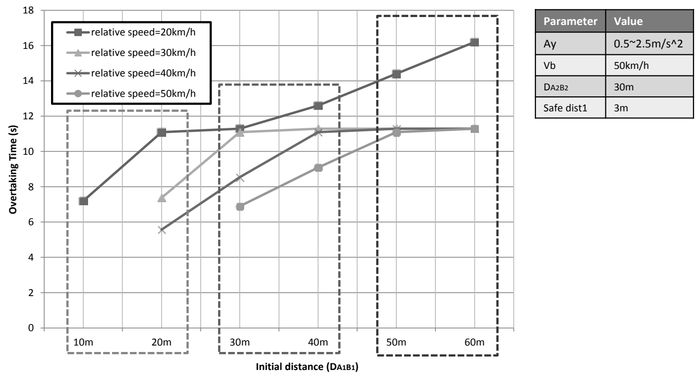


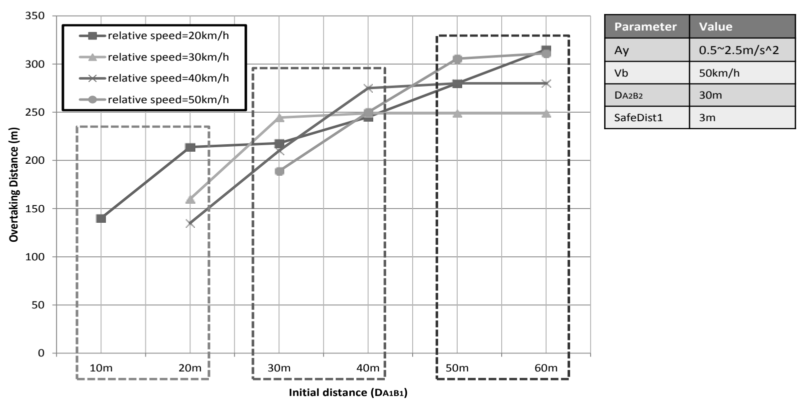
Figure 3. Minimal Ay with Different Relative Speeds and Initial Distances between Cars A and B

In addition, with different relative speeds and initial distances between Cars A and B, different minimal A_y values for safe overtaking can be calculated, as shown in Figure 3.After considering safety [9], the overtaking time, and the comfort of the driver in the simulation, we recommend an A_y range of 0.5-2.5 m/s^2. With this recommended A_y range, the driver can overtake a vehicle safely and comfortably.

Next, we consider fixing A_y to its minimal value over the time of each simulation. If we change the initial distances of Car A and Car B, we can obtain the overtaking time and overtaking distance in each simulation, as shown in Figure 4.



(a) Different initial distances and overtaking times



(b) Different initial distances and overtaking distances

Figure 4. Different Overtaking Times and Distances with Different Initial Distances

If the initial distance between Cars A and B is 10-20m, and the relative velocity of Cars A and B is over 30km/h, Car A cannot do the overtaking. However, if the initial distance is 50-60m, although Car A can do the overtaking in all relative speeds, it takes a similar time and a distance longer than the range of 30-40m to do the overtaking. However, overtaking distances are the shorter the better, therefore, the recommended range of overtaking initial distance (D_{A1B1}) is 30-40m for most common velocities. Within this range, the driver can do the overtaking more safely and with less overtaking time.

In order to consider the error caused by the data transmission delay, a simulation was conducted with Qualnet. It was concluded that one-hop communication is long enough for Car A, Car B, and Car C to get the initial information before the overtaking action. Thus, the one-hop data transmission time can be ignored.

5. Proposed Overtaking Decision Assistant Figure

Firstly, we introduce the safe interval concept, which is shown in Figures 5 and 6. The safe interval is the possible range for the final position of Car A. A safe interval value larger than zero means that there is some space available for the driver to come back to the original lane, *i.e.*, it is sufficiently safe for the driver to overtake another vehicle. In contrast, if the safe interval value is smaller than zero, it is not sufficiently safe to overtake another vehicle.

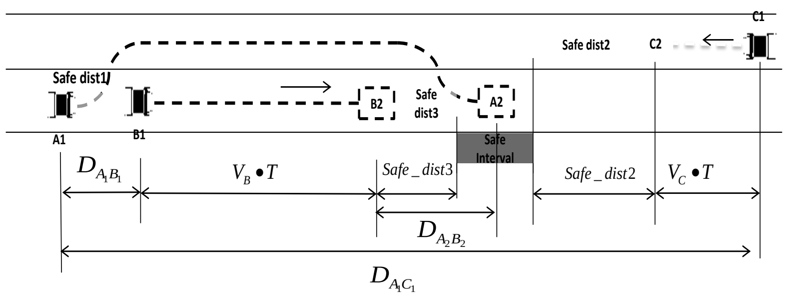


Figure 5. Interval for Car A to Overtake Another Vehicle (with safe distances)

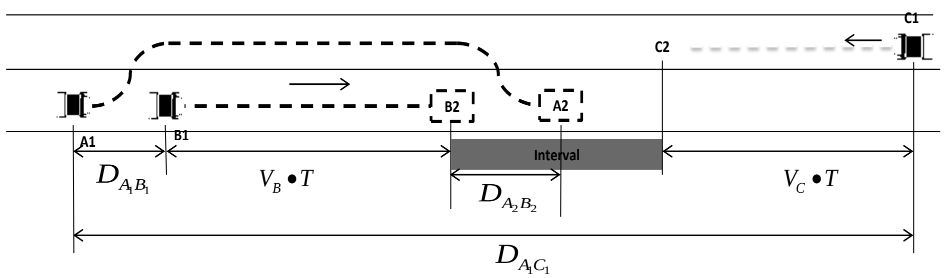


Figure 6. Interval for Car A to Overtake Another Vehicle (without safe distances)

As considered in chapter 4, if A_y is different, the total overtaking time will also different. If the overtaking time is changed, the safe interval will change accordingly, thus, different safe intervals exist. In order to judge whether or not the safe interval is larger than zero, we introduce the Safe_Interval_max concept. If Safe_Interval_max is smaller than zero, all safe intervals are smaller than zero and there is no safe interval over which the driver can overtake another vehicle. Consequently, overtaking will be dangerous. In addition, if Safe_Interval_max is larger than zero, there will be at least one safe interval over which the driver can overtake another vehicle. This means that the safe interval value can at least be equal to Safe_Interval_max and thus, there is some space available for the driver to come back to the original lane.

By fixing V_a=80 km/h and varying the velocities of Car B and Car C, two simulations with and without the safe distance concepts were run; the results are shown in Figure 7. Of course, if V_a is different, the results shown in the figure will also be different.

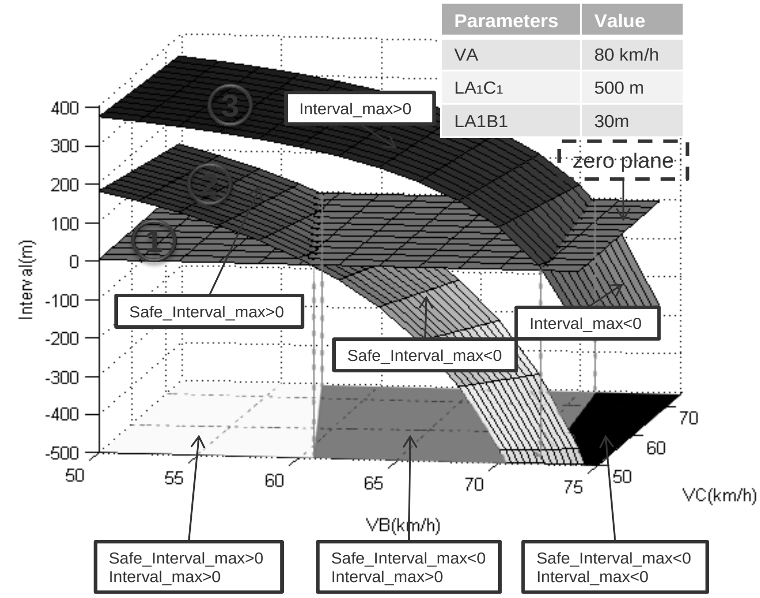


Figure 7. Different Values of Safe_Interval_max and Interval_max with Different Vb and Vc Values

In Figure 7, Plane 1 is zero plane, Plane 2 represents the values of Safe_Interval_max with the safe distance concepts, and Plane 3 is the values of Inter_max without the safe distance concepts. For the Safe_Interval_max plane, the region above the zero lane means it is safe to overtake another vehicle, while the part below the zero plane indicates that overtaking is dangerous. For the Interval_max plane, the region above the zero plane shows that there is no risk of collision while overtaking, while the region below the zero part warns of a collision.

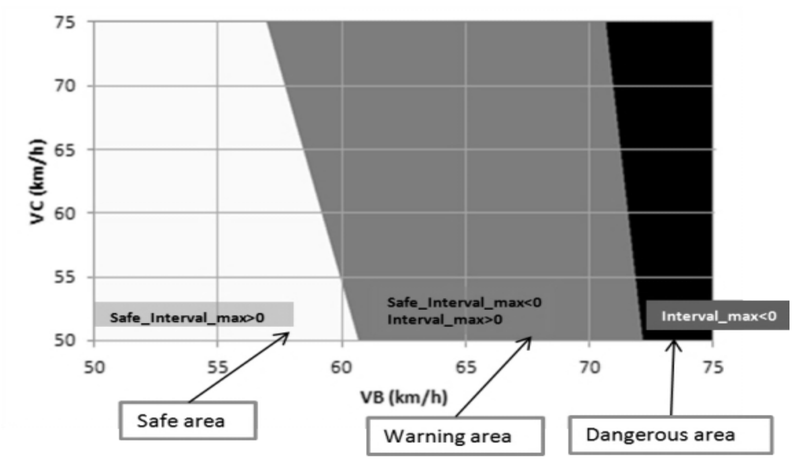


Figure 8. Overtaking Decision Assistant Figure (ODSF)

If we project these two interval planes onto the V_b-V_c plane, and take out this projected result, it can be shown as Figure 8. This is rightly the overtaking decision assistant figure. The white area in Figure 8 is called safe area, it means Safe_Interval_max > 0 and Interval_max > 0. Thus, Car A can perform the overtaking safely. The grey area in this figure is called warning area, it means Safe_interval_max < 0 and Interval_max > 0. In this region, Car A may overtake another vehicle without collision, but it is not sufficiently safe to do so. The black area in Figure 8 is called dangerous area, it means both Safe_interval_max < 0 and Interval_max < 0. In this area, Car A cannot overtake another vehicle without causing a collision.

6. Modification of the Overtaking Decision Assistant Figure

The position of the vehicles should be known before the trajectory is calculated. In order to obtain the positions, GPS receivers should be used. However, every GPS receiver has some error that will change with different environments. The overtaking assistant service model is modified by considering the GPS errors; as shown in Figure 9.

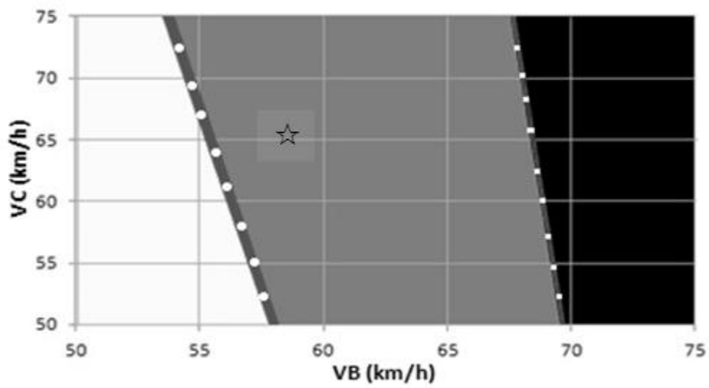


Figure 9. Modification of the ODSF

In Figure 9, the dotted area is caused by the GPS error, and the star is the real location of Car A. If the star is located in the white area, it is very safe for the driver to do the overtaking. If the star is located in the grey area, the driver can overtake the vehicle if he or she is a skillful driver. In this grey area, the closer the star is to the white area the better, because it will be much safer to perform the overtaking. If the star is located in the black area, it is very dangerous for the driver to overtake another vehicle. Therefore, if a driver were to have the proposed overtaking decision assistant figure while driving, he or she could easily make a decision on whether or not to overtake another vehicle.

7. Conclusion

The purpose of this paper was to provide an overtaking assistant service to help a driver overtake another vehicle safely. In order to achieve this goal, an overtaking assistant service model based on a two-lane environment was constructed. The initial range of accelerations for Car A and the initial distance between Car A and Car B were recommended.

After analyzing the relationship between the overtaking interval and the different velocities of Car B and Car C, an overtaking decision assistant figure was proposed to help the driver make a decision on whether or not to overtake another vehicle. Overtaking assistant service is well provided by this overtaking decision assistant figure.

Overtaking is one of the common but dangerous actions that a driver can perform while traveling on a road. With the algorithm proposed in this paper, the driver can make a safer decision on whether or not to overtake another vehicle. As a result, the number of catastrophic accidents can be reduced.

Acknowledgements

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