Collision Avoidance Timing with a Driving Situation Assessment Algorithm

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Abstract. In this study, a method was proposed to assess the safety of a driving situation using an algorithm to determine collision risk in real time. Existing driving situation assessment-related studies calculate the moving time and distance in the lateral direction prior to a lane change; hence, there is a limitation in determining collision risk in real time for various situations. To overcome this limitation, this paper proposes a method to utilize surrounding information via vehicle-to-vehicle communication and to determine driving situations of a vehicle and its surrounding vehicles in real time. Furthermore, the proposed driving situation assessment algorithm was verified by applying risk situation scenarios. Through this study, the application of the driving situation assessment algorithm to a collision avoidance system was confirmed.

Keywords: situation assessment, TTC(Time to collision), collision avoidance

1 Introduction

To improve vehicle safety, some of the core technologies discussed in recent years include active safety and advanced driver assistant systems (ADASs). Among the ADASs, collision safety systems in the longitudinal and lateral directions include the following technological developments: collision warning, collision avoidance systems, and brake assist systems. The collision safety systems in the longitudinal and lateral directions are critical components directly related to driver safety; thus, studies on the development of technologies to assess road driving situations and risk of collision are highly important [1].

In previous studies, collision risk has not been calculated in real time, and as such, future risk cannot be responded to properly [3][4]. Furthermore, previous studies had a limitation based on the dependence on geometric calculations from driving scenarios [5][6]. To overcome this limitation, a time to collision (TTC) that represents the collision risk between vehicles and a driving distance $D_{xt}$ that would prevent a collision through a steering maneuver at the relative speed can be utilized to determine driving situations in real time.

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In this study, information about surrounding vehicles (relative distance, relative speed, and acceleration) was applied to the risk driving situation assessment algorithm for collision avoidance. Furthermore, a method that calculates driving situation assessment information (safety section) from the driving situation assessment algorithm was proposed.

2 Situation Assessment Algorithm for Collision Avoidance

In this paper, the driving situation assessment algorithm for collision avoidance in real time was implemented as shown in Fig. 1. By utilizing location information about a driver’s vehicle and location information about surrounding vehicles via vehicle-to-vehicle (V2V) communication, certain sections were divided. Sections were divided based on the driver’s vehicle, which is utilized to assess conditions about vehicle safety. Next, a TTC that represents collision risk between the driver’s vehicle and another vehicle was utilized to assess driving situations in the longitudinal direction. According to the relative speed, a driving distance $D_{st}$ that would prevent a collision through a steering maneuver was utilized to assess driving situations in the lateral direction. A section of the surrounding vehicle identified based on the current vehicle location, a TTC to assess driving situations in the longitudinal and lateral directions, and a moving distance in the lateral direction for a lane change can be used to assess driving situations in real time. The driving situation assessment algorithm calculates a safety section, safety distance, and safety guarantee time.

![Fig. 1. Overview of the situation assessment algorithm for collision avoidance](image)

To assess driving situations in the longitudinal direction, a TTC can be calculated, as shown in Eq. (1), using a collision risk that represents the time before a collision with a surrounding vehicle. A TTC refers to the ratio of the relative distance to the relative speed between a vehicle and a surrounding vehicle. In addition, a method proposed by the Continental's ESA (Emergency Steer Assist) was utilized to calculate a moving distance in the lateral direction for a lane change [7]. Using a distance $D_{br}$ that would prevent a collision by braking, based on the relative distance between a driver’s vehicle and surrounding vehicles, and a driving distance $D_{st}$ that would prevent a
A section of the surrounding vehicle identified based on the current vehicle location, a TTC to assess driving situations in the longitudinal and lateral directions, and a moving distance in the lateral direction for a lane change can be utilized to assess driving situations in real time, as shown in Fig. 2. Once this assessment is considered safe based on above calculation, the driving situation assessment algorithm calculates the safety section.

Fig. 2. Stateflow for the judgment of the situation assessment

3 Simulation and Results

Using the PreScan simulation tool, V2V communication environment configuration and driving environment modeling were conducted, and the driving situation assessment algorithm was implemented using MATLAB/Simulink. In order to assess driving situations, scenarios of risk situations that can occur during driving were implemented via the scenario environment, as shown in Fig. 3.

Through defined the scenarios, simulation results of the driving situation assessment algorithm can be verified. Table 1 shows the safety evaluation results in
consideration of the available lane change distance to avoid a collision by applying the driving situation assessment algorithm. Through the sign of the relative distance value, a location between two consecutive vehicles is identified, and based on this information, the safety assessment criterion is applied differently. Fig. 4 (a) shows a TTC based on relative speed and relative distance. Fig. 4 (b) shows the safety section in consideration of the available lane change distance, identification of surrounding vehicle locations, and TTC.

![Image](image.png)

**Fig. 3.** The driving environment and initial scenario condition

**Table 1.** The results of the situation assessment for collision avoidance.

<table>
<thead>
<tr>
<th></th>
<th>Vehicle1</th>
<th>Vehicle2</th>
<th>Vehicle3</th>
<th>Vehicle4</th>
<th>Vehicle5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative velocity [m/s]</td>
<td>3</td>
<td>-7</td>
<td>-2</td>
<td>-4</td>
<td>0</td>
</tr>
<tr>
<td>Possibility for the Lane Change</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>possible</td>
<td>-</td>
</tr>
<tr>
<td>Possibility for the Safety</td>
<td>safe</td>
<td>unsafe</td>
<td>unsafe</td>
<td>safe</td>
<td>safe</td>
</tr>
</tbody>
</table>

![Image](image.png)

**Fig. 4.** The results of the simulation; (a) TTC (b) safety region
4 Conclusion

In this study, information about surrounding vehicles (relative distance, relative speed, and acceleration) was applied to a driving situation assessment algorithm for collision avoidance. Furthermore, a method that calculates driving situation assessment information (safety section) from the driving situation assessment algorithm was proposed. Existing driving situation assessment algorithms are limited in the assessment of collision risk and the application of real time information from driving situations. In contrast, the proposed driving situation assessment algorithm for collision avoidance utilizes information from the surrounding environment based on V2V communication, thereby determining driving situations in real time through a TTC and the minimum distance required for a lane change. The simulation results showed that the proposed system was able to assess surrounding situations correctly to determine when collision avoidance was needed. Through this result, the driving situation assessment algorithm for collision avoidance can be applicable to path planning systems in various driving environments.

For future studies, driving situations assessed with probabilistic models will be conducted, rather than using a method that calculates a geometric-based available lane change distance in the longitudinal direction.

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