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# Control Concept for Forward Collision Warning and Mitigation

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**Abstract:** The forward collision warning and mitigation system is one of the key technologies for the active safety passenger cars. In this system, the false warning or false actuation caused by the misjudgment of the collision risk is fatal to the system reliability. Therefore, the system should be designed to minimize the false operation and maximize the system performance. This paper describes the control concept for the collision warning and mitigation system. The control concept includes the control strategy, system structure and hazard assessment method. Each element of the proposed concept is designed to satisfy the above system requirements.

## 1. INTRODUCTION

The forward collision warning and mitigation system warns the driver of coming into collision with the forward hazard object. Besides, if necessary, this system reduces the collision speed utilizing the automatic emergency braking. The system consists of the following steps: obstacle detection, hazard assessment and warning/actuation. This system requires preventing the false warning or false actuation and not disturbing the driver's ordinary driving. In this research, the control strategy, system structure and hazard assessment method to minimize the false operation and maximize the system performance are proposed. The hazard assessment method is designed based on the distance to avoid by braking and the distance to avoid by steering. The proposed method is more effective to determine the collision risk for a moving object as well as a stationary object.

## 2. CONTROL STRATEGY

The system operates the collision warning or automatic braking according to the collision risk level when the hazard collision is expected in front of the ego-vehicle. However, the early operation causes to interfere with the driver's ordinary driving, on the contrary, the late operation causes to fall off the effect of the system. Therefore, the appropriate decision of the collision risk level is very important to increase the system performance. In this research, the system is designed with the following control strategy in order to minimize the false operation and maximize the performance.

● Collision warning at the minimum distance available to avoid the collision by driver's braking or steering

● Collision avoidance inducement by the driver's immediate braking or steering response after collision warning

● Adaptive brake assist in order to maximize the braking force for driver's braking response

● Collision speed reduction by automatic emergency braking in case of driver's non-response after collision warning

● Brake pre-fill for the fast brake actuator response of the automatic emergency braking

● Seatbelt pretension in order to protect a driver during vehicle's hard braking

## 3. SYSTEM STRUCTURE

The structure of the system is proposed as shown in Fig. 1. The control state is divided into three steps according to the collision risk level as follows: Pre-CW (Collision Warning), CW, CMbB (Collision Mitigation by Braking). Figure 1 shows the functions applied at each state.

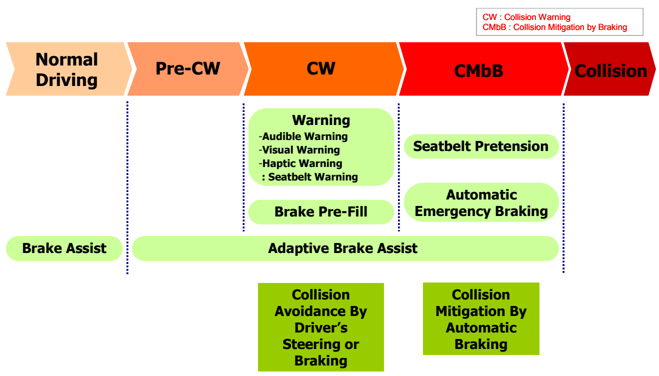


Fig. 1 System structure

In the CW state, the collision warning is performed utilizing the audible and visual methods. In addition, the haptic warning method such as brake-pulse warning or seatbelt warning can be considered. From these warning, the collision avoidance is expected by driver's braking or steering response. The brake pre-fill is executed for the fast braking response of the automatic emergency braking. In the CMbB state, the automatic emergency braking is activated for collision speed reduction and the electric seatbelts are pretensioned for a driver and a passenger protection. The ABA (Adaptive Brake Assist) system is applied from the Pre-CW state to the CMbB state and generates the full braking in spite of the driver's slight braking. The ABAS is activated by pre-determined threshold with respect to the driver's braking pressure and pressure slop. The thresholds are adjusted gradually from the Pre-CW state to the CMbB state.

## 4. DETERMINATION OF COLLISION RISK LEVEL

Each control state is determined by the collision risk level. Generally, the TTC (Time-To-Collision) have been utilized as an index for representing the collision risk. However, the TTC is insufficient to represent the collision risk for a moving object such as front high deceleration vehicle because it does not consider the deceleration of a front object. In this research, the distance to avoid by braking and the distance to avoid by steering are utilized as an index for representing the collision risk. The collision risk level can be determined by the comparison the distances to avoid with the range of the object.

Distance to avoid by braking

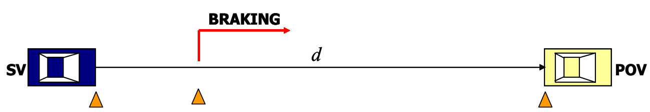


Fig. 2 Distance to avoid by braking

When a vehicle begins to decelerate after delay time as illustrated in Fig. 2, the distance to avoid by braking can be calculated with respect to the induced deceleration utilizing the velocity / acceleration of the subject vehicle, the relative velocity / relative acceleration from the range sensor and delay time.

Distance to avoid by steering

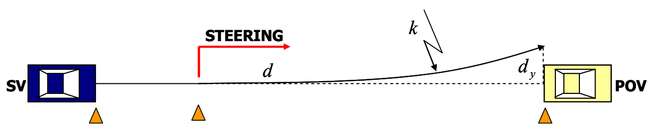


Fig. 3 Distance to avoid by steering

When a vehicle turns with lateral acceleration, the trajectory curvature can be calculated utilizing the velocity and lateral acceleration of a vehicle. The lateral displacement ahead of a vehicle can be calculated from the predicted curvature. When a vehicle begins to steer after delay time as illustrated in Fig. 3, the distance to avoid by steering is determined with respect to the induced lateral acceleration from the curvature, lateral displacement and delay time.

Figure 4 shows the distances to avoid by braking of 0.8g and steering of 0.7g for a stationary object according to the relative speed. As shown in Fig. 4, the distance to avoid by braking is increased with the square of relative speed. Therefore, in high relative speed, the distance to avoid by braking is not suitable to determine the collision risk level because that distance is sufficient to avoid by steering. In this research, the distance to avoid by braking is utilized to determine the collision risk level in the low relative speed and the distance to avoid by steering is utilized in the high relative speed.

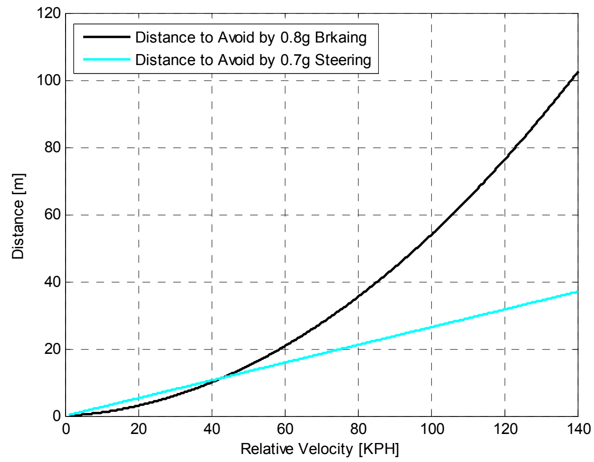


Fig. 4 Distances to avoid by braking and steering

## 5. EXPERIMENTS

The experiments are conducted for various driving condition. The CMbB result for a stationary object is illustrated in Fig.5. As shown in Fig.3, the CW and CMbB states are triggered depending on the collision risk. The brake pre-fill is activated in the CW state and the automatic emergency braking is activated in the CMbB state. As a result, the collision speed is reduced about 17 kph by the proposed system.

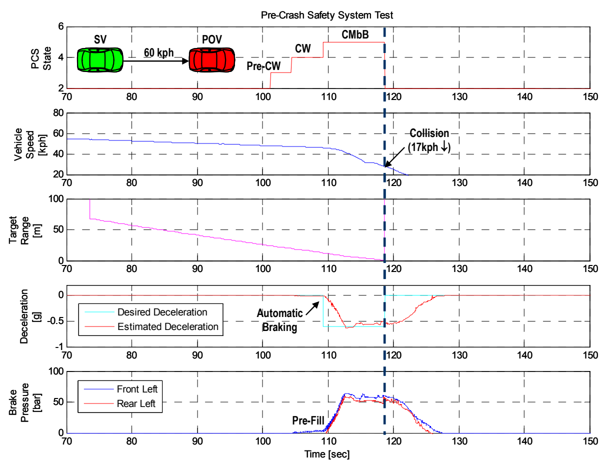


Fig. 5 CMbB result for stationary object

## 6. CONCLUSIONS

In this paper, the forward collision warning and mitigation system is designed. The control strategy, system structure and hazard assessment method are proposed for minimizing the false operation and maximizing the system performance. The collision risk level is determined based on the comparison the range of object with the distance to avoid. It is thought that the proposed system is driver-friendly and feasible to adapt to the complex traffic condition.