Augmented Reality based on Driving Situation Awareness in Vehicle

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***Abstract*— In this paper, we introduce a vehicle augmented reality (AR) system to present information of driving situation awareness in a vehicle. Today, manufacturers related with vehicles have been pointing to AR as a next-generation visualization technology for in-car driving displays. Such in-vehicle AR-based display systems are helpful in reducing driver distractions, thereby increasing driver safety, and provide intelligent interactions for enhancing driver convenience. The proposed system offers information of driving situation and warning to a driver through the augmented reality using head-up display. The system consists of several sub-modules such as sensor, vehicle/pedestrian recognition, vehicle state information, driving information, time to collision (TTC), threat assessment, warning strategy, and display modules. We have defined the threat level and the presentation of AR information based on TTC values and driver's preference throughout experiments. The proposed system have been installed to a test vehicle with a vehicle AR information system prototype and carried out in the real road environments. The proposed system demonstrates to offer intuitively danger information according to the presentation rules to a driver on real road.**

***Keywords*— Augmented Reality, Time to Collision, Head-Up Display, Situation Awareness, Warning Strategy**

I. INTRODUCTION

In modern society, a car became very useful means of transportation with improved safety and convenience through IT convergence technology. Recently, a car manufacturer of the world has development and commercialization plans about Head-Up Display (HUD) technology to offer a driver various information related with safety and convenience such as velocity, driving direction, warning messages, etc. [1][2]. There are vehicle/pedestrian recognition technologies as representative technology of offering information. It detects and recognizes a vehicle or a pedestrian in front of the vehicle and provides the warning information about those for the driver [3][4][5]. However, HUD system mounted in a current vehicle presents not overlap information but a simple graphical information between the real world and a virtual driving information. In addition of those, the studies on the effective information expression regarding the property of information and the determination of information to help a driver are still insufficient [6][7].

In this paper, we discuss and demonstrate about the methodologies and effectiveness of dangerous situation awareness and warning for offering augmented reality (AR) information through matching the safety information of the vehicle and the real world. We propose an AR system based on driving situation awareness. The proposed system consists of sensor module, recognition module, vehicle status information module, driving information module, time to collision (TTC) module, dangerous level decision module, warning strategy module, and display module. The proposed systems recognizes a dangerous situation based on a vehicle state in the front of the vehicle and the driving state of the vehicle and presents the warning information according to danger stage to the driver. Also, we set up an indoor test bed with the prototype system and consider the possibility of improvement of driver safety using the AR technology implemented by projecting dangerous information to the windshield superimposed on the real world.

II. AUGMENTED REALITY SYSTEM BASED ON DRIVING SITUATION AWARENESS

The proposed AR system offers information (vehicle, safety, path, etc.) tailored to the driver's eye level and matched on the real world for safety and convenience of a driver such as Figure 1.

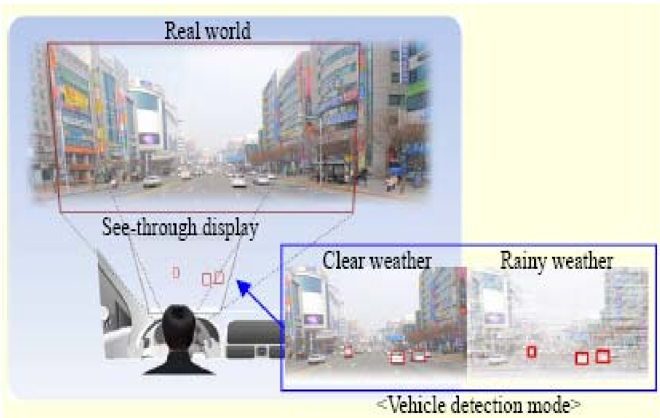

Figure 1. Augmented Reality System based on Driving Situation Awareness

A driver can get information related with the vehicle state such as velocity, RPM and fuel state from the AR system while driving and take also a guide of lane change, collision level with the front vehicle.

A. Driving Situation Awareness

To present a danger level according to driving state, the proposed system recognizes a front vehicle and decides the relation with the recognized vehicle and the self-vehicle.

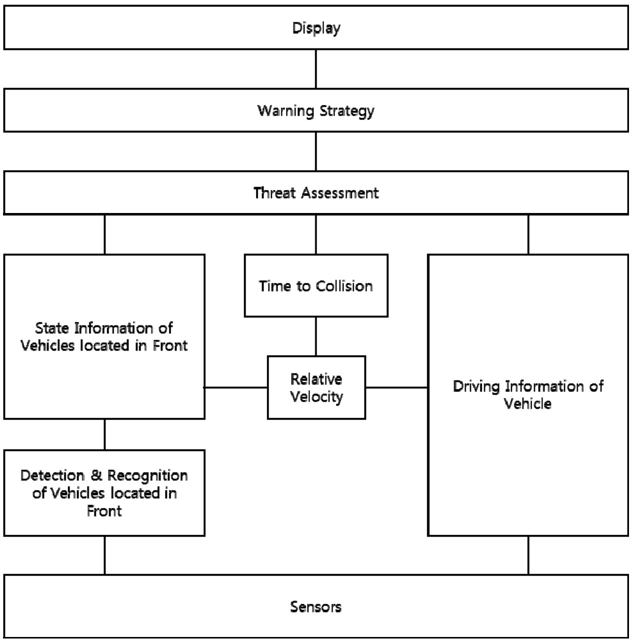

Figure 2. Block Diagram of Driving Situation Awareness

Figure 2 illustrates the system diagram of driving situation awareness to determine a danger level while driving. To recognize driving situation, sensor module acquires the front situation and the state of the driving vehicle from image sensor and velocity sensor, respectively. A vehicle or a pedestrian in the front of the driving vehicle is detected and recognized from the acquired images [8]. The State Information of Vehicle module extracts the information of the distance between from the driving car, position and cut-in state from the recognized objects.

In Driving Information of Vehicle module, Safe Distance and Braking Distance are calculated from the velocity of the vehicle gotten by sensor, and the driving information is collected.

$$\begin{cases} SD = \left(\frac{V}{10}\right)^2 = \frac{V^2}{100} & V \geq 50\,km/h \\ Ds = \frac{V}{2} & others \end{cases} \tag{1}$$

$$BD = \frac{V^2}{2\mu g}[m] \tag{2}$$

where, SD is safe distance, BD is braking distance, μ is coefficient friction, g is acceleration of gravity and V is velocity. In here, we use 0.7 as the value of coefficient friction.

In the Relative Velocity module, a relative velocity is computed from the distance.

$$RV = \frac{\Delta D}{\Delta t} = \frac{D_{t2} - D_{t1}}{t2 - t1}\left[m/s\right] \tag{3}$$

where, RV is the relative velocity, D is distance between the driving vehicle and the recognized vehicle, D_{t2} is the distance at the current time, D_{t1} is the distance at the previous time, t2 is the current time, and t1 denotes the previous time. RV>0 means that the driving vehicle decelerates or the front vehicle accelerates. RV < 0 indicates the status of the acceleration of the driving car or the deceleration of the front car. The velocity of the driving car and the front car are same in case of RV = 0. Time to Collision (TTC) is gotten by the TTC module as follows.

$$TTC = \frac{D}{|RV|}[s], \qquad (RV \neq 0) \tag{4}$$

B. Warning Strategy

We assess dangerous grade based on the driving information (velocity, safe distance, braking distance, etc.) and state information (distance, position, relative velocity, cut-in state, etc.) and TTC in Threat Assessment module, and then, the method of presentation of warning according to the assessed dangerous level is determined in Warning Strategy. Lastly, the warning information is offered to a driver by augmented reality through head-up display.

In order to determine a dangerous level, we experimented about TTC threshold. The database for the extraction of TTC threshold have been built as data for about 18 hours including about 500 vehicles with lower velocity than 60km/h and lower distance than 100 m on roads and highways. Table 1 shows TTC threshold resulted from subjects (drivers) participated in the experiment based on database.

TABLE 1. RELATION WITH TTC AND DANGEROUS LEVEL

Dangerous Level	TTC
Level 1 : Risk	0.0 ~ 1.08
Level 2 : Warning	1.08 ~ 2.52
Level 3 : Note	2.52 ~ 5.0

TABLE 2. RELATION WITH TTC AND DANGEROUS LEVEL

Dangerous Level	Threat Assessment
Level 1 : Risk	D ≤ BD
Level 2 : Warning	TTC < 3
Level 3 : Note	Others
Level 4 : Safe	D ≥ SD

The analysis of relation with TTC threshold, braking distance and safe distance provides that the thresholds of Risk level and Warning level are similar with the times about braking distance and the distance between safe distance and braking distance, respectively. In this paper, we redefine the dangerous level based on those as shown in Table 2. In addition, we consider the position and the movement of the front vehicle for the determination of a danger level as shown in figure 3. If the position of the front vehicle is not on the driving lane, then the danger level is lower than the last level status. If there is the cut-in vehicle, then the danger lever is higher than the last danger level.

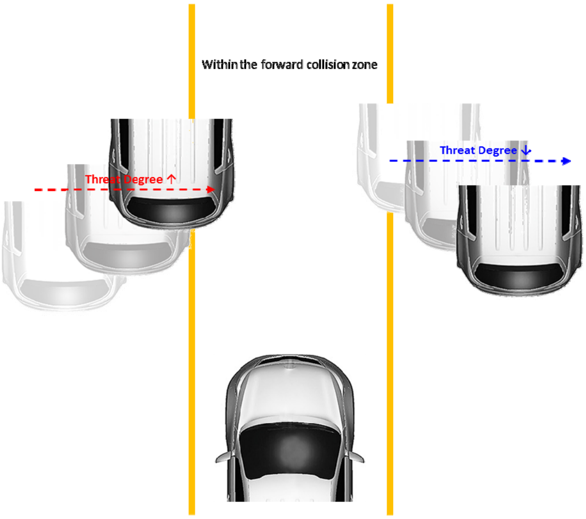

Figure 3. Threat Assessment According to Vehicle State Information

III. EXPERIMENT

Augmented reality information is presented on a windshield of a vehicle for the each level in warning strategy module. The presentation method should be selected so that a driver can cognize easily and intuitively warning information when augmented reality information is presented to prevent collision with the front vehicle. In this paper, we defined the presentation rules with type of shape, colour, width of line, etc. to express the significance of the dangerous level as shown in Table 3.

TABLE 3. PRESENTATION OF AUGMENTED REALITY INFORMATION

Level 1	Level 2	Level 3	Level 4	Application
			NONE	

Figure 4 is the results expressed as augmented reality which is aligned at driver's eye. The proposed AR system recognized the front vehicles while driving on the road and then determined a danger level for the recognized vehicle. The augmented reality warning information with a danger level is presented by HUD according to the presentation of augmented reality information as shown in Table 3. Augmented reality information is transferred from the image coordinate of the image acquired by sensor to three dimensional virtual coordinate based on a driver's eyes and projected on windshield of a vehicle for the overlap with real world.

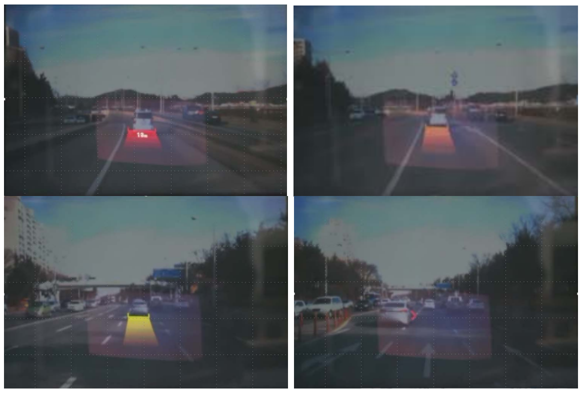

Figure 4. Augmented reality information on Road

IV. CONCLUSIONS

In this paper, we proposed an augmented reality system with driving situation awareness and warning strategy to provide augmented reality information for the collision warning while driving. The proposed system offered a driver the warning information with a danger level. The warning information is determined by analysing the state information of a front vehicle and the driving information of the vehicle gotten from each module of the system. We have confirmed that it can improve intuitive cognition of a driver and reduce the distraction of a driver through an experimentation. As a future research, we will embrace studies on the improvement of performance and ergonomic information representation for determining information.

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