How to Efficiently Present Driving-Safety-Information for a Driver-based HUD System

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Abstract
In this paper, we survey and discuss how to efficiently present driving information for on a driver-based HUD system for driving safety and entertainment purposes. First, we analyzed analyze the attributes of the driver vision and cognition under consideration of the driving situations. Thereafter, we surveyed in-vehicle HUD feasibility according to its size, the information amount and type.

Keywords: in-vehicle HUD, AR representation, driving safety and entertainments, vision and cognitive attributions, feasibility

Introduction
Along with the development of AR (augmented reality) and intelligent vehicles, top universities and popular vehicle manufacturers such as GM and BMW and are developing in-vehicle HUDs (head-up displays) [1-2]. The developed projection-style AR-HUDs can be classified into three types: driver-front-down, driver-front-upper, and full windshield. The driver-front-down type is a typical display designed to be 6 degrees below the center of the driver's front view, whereas, the driver-front-upper is designed within differences of the 4 degrees with located under the room mirror [3]. However, it is difficult to display collision warning information such as pedestrians or other vehicles while matching the driver’s viewpoint because these two types display the information only in a limited region of the driver’s frontal view field. Thus, the development of a full-windshield type is needed. GM has been developing an AR-HUD system since 2011, which provides lane and road signs to the driver by matching the information onto the driver’s view under poor driving conditions such as fog and rain.

We therefore define which information is to be provided to the driver through a full windshield AR-HUD in section 2 of this paper, and discuss the issues to be considered based on related studies and surveys. In sections 3 and 4, we then analyze the attributes of the driver’s vision and cognition when considering these issues, and provide a detailed explanation. Finally, some concluding remarks are given in section 5.

Driving information for driving safety and entertainment
Drivers can check the provided vehicle information such as speed, RPM, and fuel status from the dashboard while driving. In addition, the driver is provided not only the time, radio access, and temperature, but also intelligent information from various devices located in the driver’s center-right. To avoid a collision, various intelligent vehicle terminals are equipped in the dashboard, and usually provide detected obstacle information including static objects (road signs, warnings, and so on) and dynamic objects (pedestrians and other vehicles) into “bi–” sounds though an auditory interface. As shown in Table 1, we classified the two types of information as constancy and timeliness.

<table>
<thead>
<tr>
<th>Table 1. Information Type</th>
<th>Example</th>
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| **Constancy**             | - Vehicle information: vehicle speed, RPM, distance from front vehicle, and so on.  
                          | - Other information: fuel gauge, temperature, time, route, and so on. |
| **Timeliness**            | - Static obstacle information: Traffic signs, lane, traffic cones, and so on.  
                          | - Dynamic obstacle information: pedestrians, vehicles, bicycles, and so on. |

Constancy information is continuously displayed at a predefined fixed location, and thus the driver can check the information when needed. Therefore, the best way to provide this information is at the forward-looking left side so as to not block the driver’s front view as much as possible, while at the same time maintaining the driver's ability to look forward. On the other hand, timeliness information must suit the driver's field of view for minimizing driver distraction when the information is given. At this time, the information is provided by matching the driver's field of vision, but a fusion with other information toward the front of the driver should be naturally provided.

Thus, in the future, in-vehicle AR-HUDs should be developed to display information that matches the driver's field of view.
In the following sessions, we explain and prove that providing information according to its attributes makes it easier to understand and minimizes the driving workloads.

Analysis of the driver’s vision and cognition for in-vehicle AR-HUD

The visual field of the driver is determined by considering the movement of their eyes and head [4-8]. According to many existing studies, vertical eye movements of the driver of less than 15 and 30 degrees downward and upward, respectively, are considered optimal. In addition, eye movements of less than 30 degrees is optimal, but less than 60 degrees is preferred. Thus, for wide viewing angles, the driver’s head needs to move, and the viewing angle is then adjusted. The movements of the head are proper within 90 degrees horizontally and the head can move up to 120 degrees. In addition, the driver’s field of view is based on the vehicle speed, and is usually 65 degrees at a vehicle speed of 70 km/h [9]. When considering the appropriate field of vision based on the vehicle speed, it is necessary to provide information to the driver within a suitable viewing range. Thus, it is better to provide constant information within 15 degrees in front of the driver.

In addition, in conjunction with the GPS and navigation information, the AR_HUD extracts the type of road the driver is currently on, and matches the information to the driver’s view based on the extracted results and actual vehicle speed. If the information is the outside the driver’s visibility, then it is preferable for the system to provide information to the driver using a non-visual interface such as an auditory or haptic interface.

The driver should recognize the provided information and then react within 2.5 seconds [10]. Thus, it is necessary to represent the information using different type and color by considering the cognitive characteristics of the driver. In addition, the information should be provided at a different strength based on its classification and importance. BMW has released an information representation concept of an in-vehicle AR-HUD, in which information is expressed in different colors depending on the distance to the front vehicle. It first uses a green color, but when front vehicle gets closer, the color is gradually changed from green to yellow to red. Additionally, urgent information is expressed in red.

In [2], subjective assessments were conducted according to the driver’s cognitive responses to a variety of information representation, and how information should be represented based on the driver’s cognition attributes was investigated using a vehicle simulator.

Analysis of the AR-HUD’s feasibility

The scope of application of the augmented reality display was recently expanded according to the rapid developments of display technologies. There are many display types, and we classified three: projection, transparent, and flexible types. Among these, the transparent type display is described in this paper. First, we use a transparent display with 80% transparency. Furthermore, this display needs a large area, and it is necessary to develop a flexible panel. Additionally, the in-vehicle transparent display size should be sufficient to provide information suit the driver's field of view. According to a previous study [4], the suitable size of the display is calculated through Eq. (1), with the driver’s fixed head and considering the driver’s eye movements. Based on Eq. (1), Table 2 shows the display size depending on the distance.

\[
s = \tan \frac{\theta}{2} \times 2 \cdot D_{we}
\]

In Eq. (1), \( \theta \) is the view angle of the horizontal and vertical directions, \( D_{we} \)is the distance from the eye to the full windshield. Thus, \( s \) is the maximum size of the display panel.

<table>
<thead>
<tr>
<th>( D_{we} ) in cm</th>
<th>30 ( \pm 15 )</th>
<th>60 ( \pm 30 )</th>
</tr>
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<tbody>
<tr>
<td>30 cm</td>
<td>7.38</td>
<td>15.91</td>
</tr>
<tr>
<td>40 cm</td>
<td>8.44</td>
<td>18.18</td>
</tr>
<tr>
<td>45 cm</td>
<td>9.49</td>
<td>20.46</td>
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<tr>
<td>50 cm</td>
<td>10.55</td>
<td>22.73</td>
</tr>
<tr>
<td>55 cm</td>
<td>11.60</td>
<td>25.00</td>
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In addition, when considering the optimum field of view, according to [4-5], the position of the transparent display can appear in four forms, as shown in Fig. 1.

![Figure 1. Four types of transparent display.](image)

Conclusions

In this paper, we raised and discussed three issues to provide driving information more efficiently in terms of safety and convenience using an AR-HUD. For this, the type of information to be provided should first be considered. Next, the attributes of the driver’s vision and cognition should be identified. Finally, the most appropriate display under a consideration of the issues discussed herein needs to be implemented.

Considering these issues, an in-vehicle AR-HUD will be able to significantly reduce the number of accidents and promote safety and convenience by providing proper information to the driver.
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References

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