Efficient Information Representation Method for Driver-Centered AR-HUD System

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Abstract. Providing a suitable and efficient representation of a driver's perspective is a way to reduce traffic accidents. In this paper, we first introduce a driver-centered AR (augmented-reality) HUD (head-up-display) system that superimposes augmented virtual objects onto a real scene under all types of driving situations including unfavorable weather (such as rainy, foggy, overcast, and snowy) conditions. We next explain the scenario and method used in our comparative experiments on a method for improving both the cognitive usability and visibility of drivers. For this, we comparatively analyzed not only information display locations but also information representation for six information types using a driving simulator with thirty subjects. For the effects on safety, the situational driver awareness of safety-related road events was measured. To determine the differences in the visual cognitive workload placed upon drivers, we tracked their eye movements. The subjective workload of the participants was assessed using the RSME (Rating Scale Mental Effort).

Keywords: Efficient Information Providing Method, Information Representation, Information Display Location, Driver Centered System, AR(augmented reality), HUD(head up display), Vehicle Simulator, Cognitive Usability, Visibility, Subjective Workload.

1 Introduction

1.1 Motivation

Necessity for the development of AR-HUD for Driving Safety. Popular vehicle manufacturers around the world are currently commercializing HUD technologies as a part of their premium strategies. In 2001, the first HUD system was mounted into a GM Cadillac [1, 2]. Thereafter, HUD systems have been equipped mainly in advanced vehicles. BMW developed an LED-based HUD, which displays various information for driving safety such as the vehicle speed, driving direction, cruise control information, and a variety of warning messages [3,4]. However, all developed commercial HUDs do not provide by superimposing information between the real world and virtual 'safety driving information' like AR-HUD. Such HUD systems have a problem in terms of cognitive workload caused by a mismatch between virtual

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objects and the real scene. To solve this problem, GM has started the development of a full-windshield HUD system, which provides an augmented lane or road signs by superimposing virtual objects onto the real world seen through the windshield under conditions of poor nighttime visibility [5].

Importance of Information Type Provided. In an AR-HUD system, it is important to not only provide information suitable to the driver's field of vision, it is also very important to provide necessary information to the driver through an efficient information representation. To improve driving safety and minimize the driving workload, the information provided should be represented in such a way that it is more easily understood and imposing less cognitive load onto the driver. It is therefore necessary to classify the characteristics of the information given, and find a way to represent the information according to these characteristics. In addition, research needs to be conducted into both the amount of information that can minimize a driver's cognitive load and the types of representation that can minimize the driver's visual load.

1.2 Hypothesis and Goals

Hypothesis. The representation method used for each type of information differs depending on the characteristics of the information. Therefore, we need to research a type of representation that allows for a faster recognition that is easy to understand. Thus, we divided the provided augmented safety information in the AR-HUD system into six categories, and displayed the various representation methods to suit the characteristics. In this case, we comparatively analyzed the experimental results of the driving performance, information comprehension, and driving workload based on the measured driver cognitive reaction rate, simulator-based driving variables (steering angle, brake, etc.), and driving workload.

Goals. The goals we are trying to achieve in this work are as follows:

- How information representation in the AR-HUD affects driver performance.
- How information representation in the AR-HUD affects driver understanding.
- How information representation in the AR-HUD affects driver workload.

2 Driver-Centered AR (Augmented-Reality) HUD (Head-Up-Display) System

2.1 Overview

Figure 1 shows an overview of the proposed system, and figure 2 provides a system flowchart. The results in figure 1 show a detected lane, vehicle, and obstacle. The system is composed of five main modules: vehicle position estimation, 3D object recognition, view tracking of the driver, registration, and projection and display.

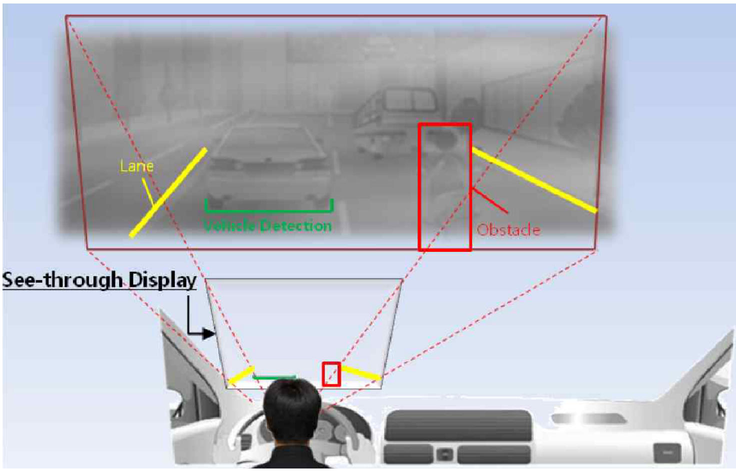


Fig. 1. System overview (unseen situations under unfavorable weather conditions)

2.2 Description of the Sub-module

Vehicle Position Estimation Module. This module estimates the 3D location of the vehicle using a GPS and an IMU. It then utilizes a 3D map DB from the 3D map extraction sub-module. We use a modified Kalman filter to increase the rate of correct information provided [6].

3D Object Recognition Module. This module detects ground-plane based obstacles from an input stereo image, and thereafter classifies the detected obstacles into pedestrians or cars using an HOG (Histogram of Oriented Gradients) based SVM (Support Vector Machine) [7,8], and provides their distances during daytime conditions. Otherwise, during the nighttime, it tracks obstacles out of visual range using a fusion between night-vision and radar technologies. This module then conducts a preprocessing procedure, such as edge detection and noise elimination, from the input image sequence.

Driver-view Tracking Module. This model detects the driver's head location, estimates the driver's gaze, and thereafter calculates the driver's viewpoint using a camera equipped on the display housing device. For this module, it is assumed that the driver's eyes are aimed in the same direction as their head.

Registration Module. This module matches the 3D objects generated according to the driver's perspective. To do so, this module receives 3D data integrated from the output of each module, which are transformed into coordinates of the real world as viewed by the driver.

Projection and Display Module. This module displays safety-warning and useful traffic information to the driver using a see-through HUD with an interactive design.

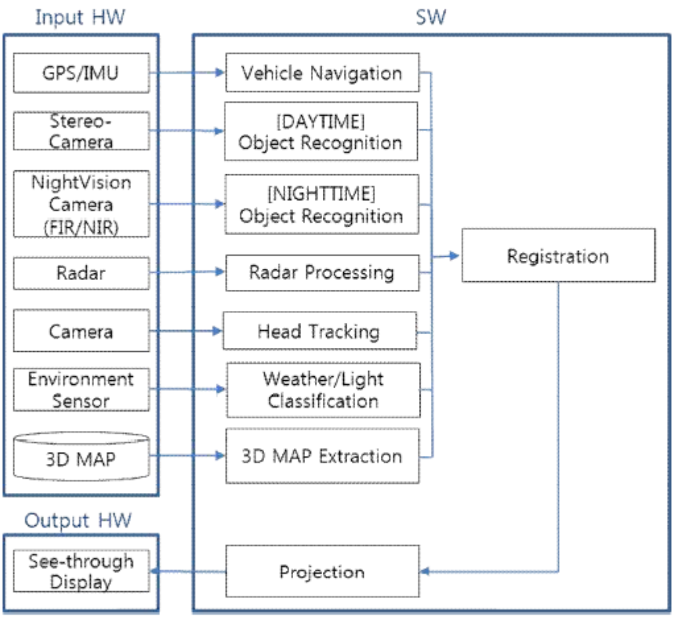


Fig. 2. System flowchart

3 Comparative Experimental Design of an Efficient Information Representation Method for the Proposed AR-HUD System

Experimental Design. We designed two objective experiments for the driving performance and cognitive usability, and one subjective assessment for driving satisfaction. The first experiment was conducted to determine the effects on the driving performance and cognitive usability, and was implemented using a high-fidelity driving simulator. The second experiment was conducted to find the effects on the driver's cognitive reaction when various types of information are provided. The subjective satisfaction of each driver was measured using a psychology-based traffic questionnaire.

Driving Simulator and Peripherals. A 3DOF motion-based, high-fidelity driving simulator was used in the experiment. The simulator provides force feedback and a rich 3D audio environment. Three channel displays for the front, left, and right screens provide a 130 deg. x 40 deg. full-scale field of view. The fully textured graphics were generated using SCANNeRTM software, which delivers a 60 Hz frame rate at a 1024*768 resolution. The software can simulate various kinds of traffic scenarios such as the motion of nearby vehicles and pedestrians, and changes in traffic signals. Various kinds of vehicle data including the location, motion, velocity, acceleration, RPM, braking, and steering were collected by vehicle sensors at a rate of 50 Hz. A face LAB4.6TM eye-tracking system was installed on the dashboard of the simulation vehicle to track the driver's head and eye movements. Figure 3 shows the experimental environment used.

Dependent Variables. During the experiments, vehicle data, eye-tracking data, and video data were collected. The vehicle data were collected from the simulator and include the velocity, steering-wheel angle, accelerator and brake angle, and vehicle position and motion. Eye-tracking data include the head position and orientation, gaze orientation, gazing region, fixation time, and PERCLOSE. For verification of the data, video images from the camera were recorded.

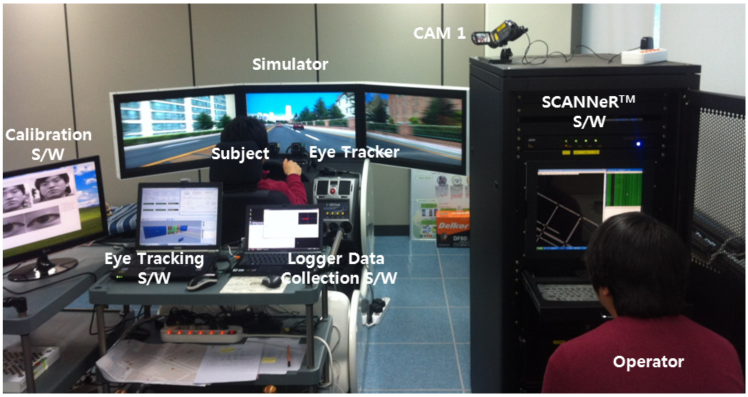


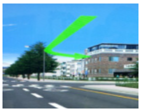
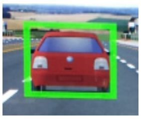
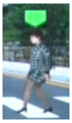
Fig. 3. Experimental Environment

Scenario and Procedure. Each of the thirty participants drove the in-vehicle simulator from start to destination for each information type provided in the AR-HUD system, the order of which was counter balanced. During the experiment, the subjects were encouraged to adhere to the following guidelines: observe the traffic signals, maintain the speed limit indicated by the road signs, and avoid collisions with other vehicles or pedestrians. The driving route for the experiment was planned based on a real road in a 3D graphic scene database. We designed a total of fifty events for four types of routes. Table 1 describes the information type and representation of the designed events.

Subjective Assessment. Using multiple-choice questionnaires and RSME (Rating Scale Mental Effort) [9], the subjective satisfaction and preference for the information provided, and the cognitive workload were measured.

Experimental Method for the Comparative Analysis. The representation of each type of information was determined based on the information attributes, driving situation, and driver characteristics. These predefined representations were divided into non-representations and 3D visualization, and were analyzed using a pairwise comparison between the two. Figure 4 shows the A-route, which is one of the four routes used. In figure 4, E and the number listed next to it are an event and its sequential occurrence, respectively. The route used in the experiments is built using a 3D map. This route includes both an 80 km/h roadway and a footpath. S and F are the starting and final driving points, respectively. To perform each event, all participants drove down the same path several different times. The arrow and number next to each event represent the driving orientation and driving order. Events with the same color share the same event type. Thus, E4, E9, E10, and E15 are the same event type, i.e., pedestrian warning information. In figure 4, the driving starting point is E1, and route A finishes at E16.

Table 1. Information Type and Representation of the Designed Events[1]

Information Type	Event No. (Route Type)	Representation	Attribute
Route	E1 (A-route)	only audio	Default
	E12 (A-route)		3D Visualization (short upper arrow)
Vehicle	E2 (A-route)		3D Visualization (rectangle)
	E5 (A-route)	Non-representation	Default
Pedestrian	E4 (C-route)	Non-representation	Default
	E5 (C-route)		3D Visualization (arrow at head position)
Lane Change	E5 (B-route)		3D Visualization (under arrow)
	E8 (B-route)	Non-representation	Default
POI (Point of Interest)	E3 (A-route)	Non-representation	Default
	E4 (A-route)		3D Visualization (rectangle)
.Traffic Sign	E6 (B-route)	Non-representation	Default
	E6.5 (B-route)		3D Visualization (rectangle)

[1] We described the events of the representative comparison-pairs for the representation according to the information type.

Fig. 4. Experimental Scenario

4 Conclusions and Future Directions

To provide traffic information to drivers using an efficient method, we defined an information representation by considering both the driving situation and the drivers themselves. To prove the suitability of the representation, we also described the experimental design. The results of this experiment will support the effectiveness and validity of the AR-HUD system in the future as an effective representation method based on driver characteristics under complex roads or unseen environments such as those occurring during unfavorable weather conditions. For this, we will further analyze three different methods according to the experimental design described in this paper. The first method is a paired t-test, which compares the differences between non-representation and 3D visualization. The next method is a graph analysis to determine the average distribution of the 30 subjects. Finally, a subjective preference and cognitive load will be measured through questionnaires.

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