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Research paper



Smartphone-Interlocked Advanced Driver Assistance System Development for Safety

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Abstract

In this paper, we propose new advanced driver assistance system (ADAS) that interfaces with smartphones. The proposed system consists of a heads-up-display (HUD) and a driving information rear display (DIRD), and this configuration outputs information from the ADAS into the front and rear windshields. The HUD and DIRD help drivers operate their vehicles safely. In particular, the HUD and DIRD are constructed by combining navigation information provided by a smart phone and vehicle maintenance information, where vehicle information is provided by the electronic control unit (ECU). Experimental results show that the ADAS can be improved by providing the driver with the necessary safe driving information, and the vehicle can be easily maintained using the information obtained directly from the ECU.

Keywords: *ADAS; HUD; DIRD; Safety*

1. Introduction

Advanced driver assistance system (ADAS) research is attractive as it may produce accident prevention methods. ADAS is a system that helps drivers operate their vehicles safely. Information used in ADAS must reflect the user's requirements and meet compatibility criteria. In addition, information overload should not occur; therefore, the system requires simplified feedback that does not distract the driver. HUDs also help drivers safely operate their vehicles [1]. Conventional ADAS research focuses on coping with imminent situations while driving, but it is not an optimal system for preventing traffic accidents. Furthermore, preventing an adverse traffic incident in advance is more effective for safety.

The information that drivers actually need to prevent accidents is not useful while driving, and drivers find it difficult to synthesize this information instantaneously. In particular, changes in the situation behind the vehicle are unclear to a driver.

In recent years, smart phones that include various sensors have been developed [2]–[4]. Sensor networks that utilize these sensors have also been widely used in intelligent transportation systems, which can provide drivers with new functions that enable safer driving [5]. The conventional sensor application is used to analyze data accumulated through collision experiments as real-time operational data, which is then used to prevent traffic accidents [6]–[8]. As automobile accidents have increased in the United States, existing automakers have added a variety of devices such as airbags, seat belts, and anti-lock braking systems (ABS), etc. to vehicles to ensure safety. These are passive methods for addressing accidents [9]. Today, however, automakers are studying more aggressive and active ways to improve safety such as ADAS, lane departure warning system (LDWS), and collision avoidance system (CAS) [10]–[13]. Because these systems are expensive additional products, it is difficult to include them in low-cost, economical vehicles during production. Older vehicles do not have these systems and are only equipped with the aforementioned passive systems.

In this study, we designed HUD and DIRD systems for ADAS; we combined these systems with a smartphone navigation app and the proposed ADAS control app in the smartphone to provide navigation information to the HUD and DIRD. HUD helps safe driving and DIRD helps prevent accidents by presenting information regarding the preceding vehicle to the driver of the rear vehicle. The ADAS control app is also designed for vehicle maintenance and can utilize information obtained from the vehicle ECU. A test was performed to illustrate how the proposed system works.

2. ADAS

The ADAS consists of the HUD/DIRD control system and light emitting diode (LED) modules, which include an LED controller and an LED display board. The ECU and smartphone are connected wirelessly to the HUD/DIRD system via Bluetooth, as shown in Figure 1.

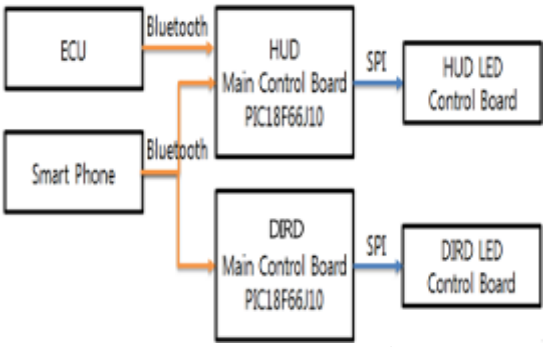


Figure 1: Block diagram of the ADAS.

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HUD/DIRD modules display information as text on the windshield using a high-brightness LED dot matrix panel. The displayed information is delivered wirelessly through Bluetooth from the ADAS control app in the smartphone, which extracts the required text information from the navigation app. The HUD/DIRD system is composed of a master control unit (MCU), memory, and LED display, as shown in Figure 2.

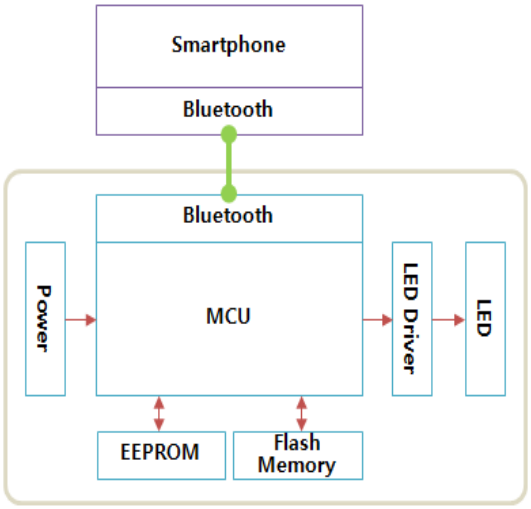


Figure 2: Schematic of the HUD/DIRD system.

For the supporting ADAS, which displays information such as vehicle operation and various guide instructions acquired from the navigation app on the HUD and DIRD, the developed software was divided into three areas as follows:

- ✓ Drive information management
- ✓ Car management
- ✓ HUD/DIRD management

Drive information management and car management are explained in this section, and HUD/DIRD is described in the next section.

2.1 Drive Information Management (DIM)

The DIM delivers navigation and various guidance information to the HUD/DIRD and is composed of modules that handle the functions listed below.

- HUD/DIRD connection process
- Receiving navigation and guidance information and data conversion for HUD/DIRD
- Transfer display (output) data to HUD/DIRD

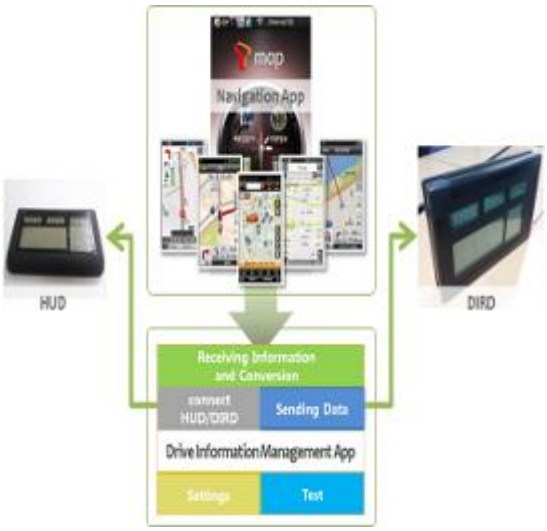


Figure 3: Functions within the DIM module.

Navigation and guidance information data obtained via Messenger are rearranged for the HUD/DIRD, and this information is converted into image data to be displayed to the driver. Image data is '1 color bitmap' type and will be converted to horizontally reverse the direction for the HUD, as shown in Figure 4. The image data is transferred normally to the DIRD.

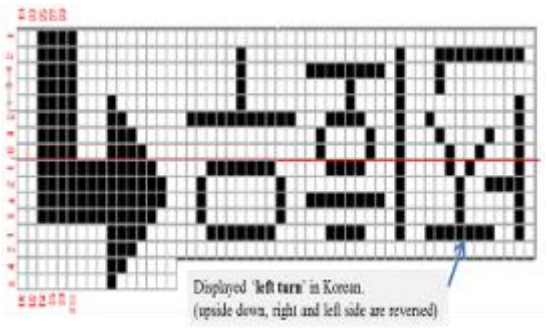


Figure 4: One color bitmap.

2.2 Car Management (CM)

The CM app includes the modules shown in Figure 5. This app allows the driver to easily monitor car information transmitted from the ECU to the smartphone app. The CM app also includes a function to manage the parts replacement cycle, which facilitates timely car maintenance.



Figure 5: Functions within the CM app.

The main screen in the CM app will initialize Bluetooth and connect to the ECU.



Figure 6: Bluetooth connection within the CM app.

Vehicle status menu

The Vehicle status menu displays information received from the ECU.

Data is only available when connected.
After requesting fault information from the ECU, the CM app receives data from the ECU and displays the faulty data with orange color and normal data with blue color on the screen.
At present, data for five parameters (engine oil, coolant, batteries, oxygen sensor, and knock sensor) are available.
If the vehicle status menu is turned off, the main screen in the CM app returns to the vehicle status/ management menu.



Figure 7: Fault examples in the vehicle status menu.

Vehicle management menu

The Vehicle management menu presents information necessary to manage vehicle maintenance.

The screen displays the item, recommended distance between overhauls, real distance traveled since the last overhaul, and a completion button.
This information allows the driver to easily determine when to perform the next overhaul of each item. The overhaul distance can be reset by pressing the completion button.

Figure 8 shows an example of an engine oil change notice in the vehicle management menu. The distance is changed from 10,000 km to 20,000 km because the engine oil is changed every 10,000 km. The app notices that the next engine oil change should be performed when the odometer reaches 20,000 km.

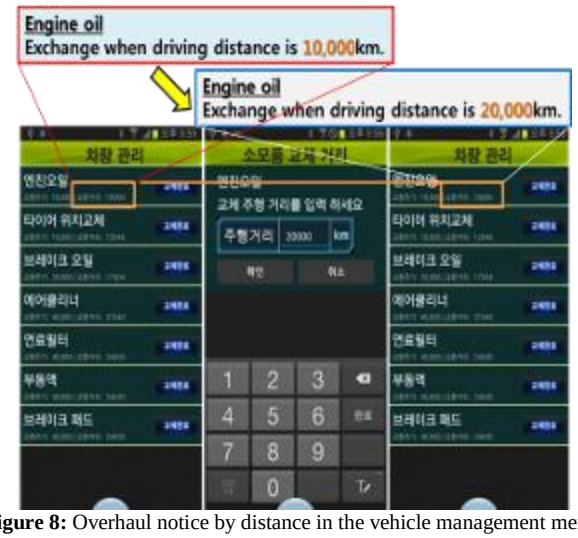
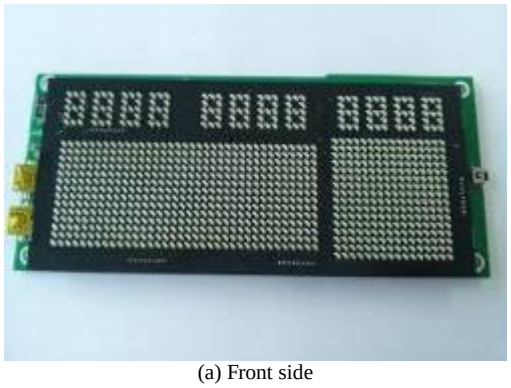


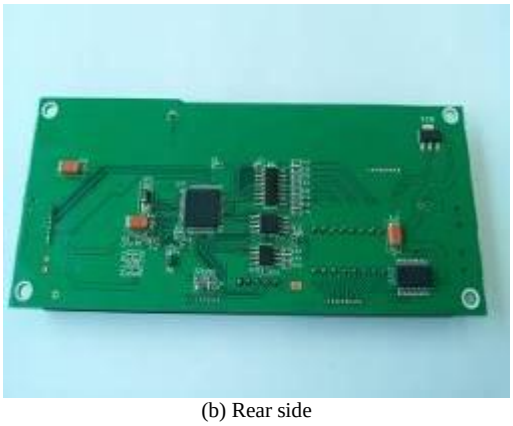
Figure 8: Overhaul notice by distance in the vehicle management menu.

3. Test and Validation

The developed HUD module is shown in Figure 9.



(a) Front side



(b) Rear side

Figure 9: HUD device.

The HUD/DIRD management app transmits the required navigation and guidance information to the driver. This information is transmitted as a horizontally reversed image to the HUD module, which results in normal display to the driver, as shown in Figure 10.

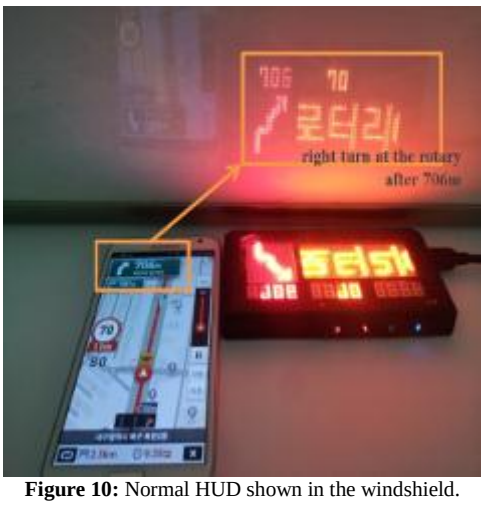


Figure 10: Normal HUD shown in the windshield.

The HUD screen is divided into 5 regions in order to display distance, speed limit, vehicle speed, text guidance, and graphical guidance, as shown in Figure 11. Distance shows the real distance to the destination, speed limit is the maximum legal speed at the current position, and vehicle speed is the current driving speed of the vehicle. Text and graphical guidance is actual information required to drive the vehicle to the destination.

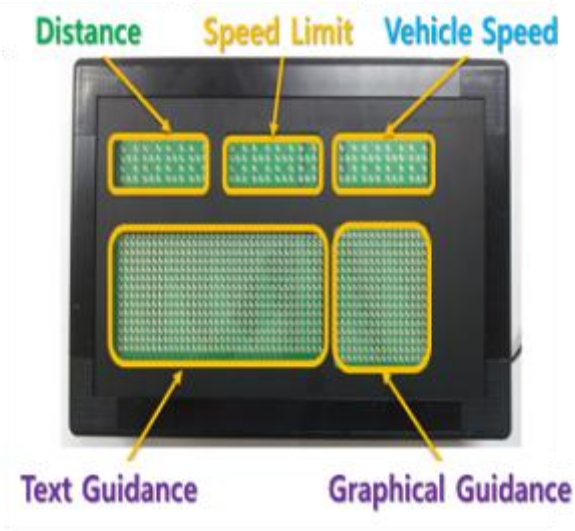


Figure 11: Five regions in the HUD.

The DIRD module is actually the same as the HUD module; the only difference is that the HUD/DIRD management app delivers the image in the normal view as shown in Figure 11, rather than in a horizontally reversed view. The five regions in the DIRD module are the same as those in the HUD module.



Figure 12: DIRD module.

4. Conclusion

In this study, as a piece of advanced safety vehicle (ASV) technology, we developed an HUD/DIRD system that displays navigation, guidance information, and vehicle status on the front and rear windshields. Information is obtained from a smartphone and is made suitable for use with the HUD/DIRD. The HUD presents information to drivers in the front windshield, which minimizes driver distraction and assists in safe driving. The DIRD presents information in the rear windshield, which delivers information regarding the front vehicle to the driver of the rear vehicle. The DIRD enables the rear vehicle to be operated in an adequately defensive and forward-looking manner, which is part of a smart and safe driving system for traffic accident prevention.

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