On-wheel Finger Gesture Control for In-vehicle Systems on Central Consoles

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Abstract
To reduce visual and biomechanical distractions when drivers interact with in-vehicle systems of the central console, we propose a new driver interface approach that integrates on-wheel gesture control and head-up display. We then verify its effectiveness based on experiments. In the proposed method, the most frequently used switches for the audio and air conditioner, located on the central console, are selected and displayed on the menu of a head-up display. The driver can use this display to turn the switches on/off, using a specific number of fingers while keeping both hands on the steering wheel. We compare the effectiveness of the traditional interface with that of the new interface based on objective measurements and subjective evaluations of the behaviors of the vehicle and driver. The results show that there are fewer visual and biomechanical distractions when drivers interact with the new in-vehicle interface compared with the traditional interface.

Author Keywords
Driver distraction; driving simulator; eye tracking; gesture interface; head-up display; human-vehicle interaction.

ACM Classification Keywords
H.1.2. User/Machine Systems, H.5.2. User Interface, H.5.3. Group and Organization Interfaces

Introduction
Driving is a complex task, one that is sufficient to command a person's full attention. Performing other activities simultaneously would therefore lead to a

major decline in driving performance. According to the NHTSA traffic accident database, 25–30% of all traffic accidents and 78% of collision accidents that occur in the US are caused by driver distractions [1, 2]. The actual vehicle driver data show that when drivers take their eyes off the road for more than 2 s, the probability of an accident increases, while performing a complex task increases the collision risk by a factor of three [3]. About 50% of accidents due to driver distractions are caused by the use of smart phones and in-vehicle infotainment systems, such as navigation systems [1, 3]. Tasks that require the direct use of the hand while driving, such as touching a screen or pushing buttons on the central console, are major factors in traffic accidents [4].

In this study, we propose a new interface method based on on-wheel finger gestures and a head-up display (HUD) to minimize the driver's visual and biomechanical distractions as they manipulate audio and air conditioning systems via the central console. This approach, without a touch device, improves upon the previous on-wheel gestures [5, 6] by allowing hands to remain on the wheel, maximizing the advantages by combining an HUD for information display. To verify that the new interface reduces distractions, an experiment was performed based on Ref. [7], using a driving simulator, and the results were compared with the performance of the traditional interface.

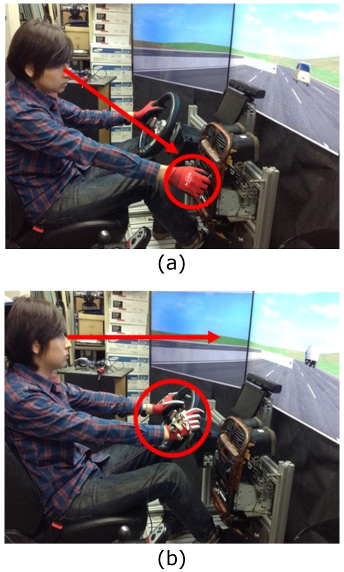


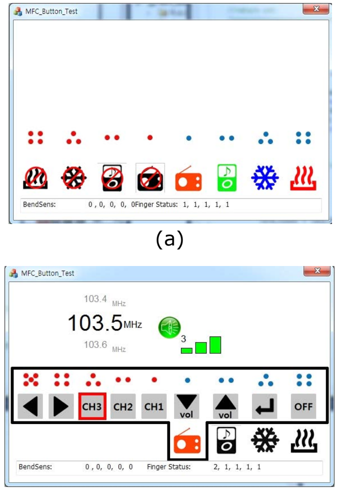
Figure 1: Visual direction and hand positions during device control via the central console: (a) Traditional interface, (b) New interface using on-wheel gesture and HUD.

User Interface Design

Visual distraction occurs when the driver's vision shifts to the central console (located to the lower right of the steering wheel) in order to execute tactile control of the audio and air conditioning systems, as shown in Figure 1(a). In addition, biomechanical distraction occurs when the driver's hand moves away from the steering wheel. To address these problems, we developed a new form of gesture control where the fingers are allowed to move while the hands remain on the steering wheel, as shown in Figure 1(b). We have also designed a new interface that displays the device control menu on an HUD to minimize visual distractions.

In this study, we refer to the spreading and closing of the fingers while the hands remain on the steering wheel as "on-wheel finger gestures," or simply as "on-wheel gestures." The number of spread fingers can be determined using a pattern recognition technique based on computer vision. The on-wheel gestures can operate a specific switch according to the number of fingers spread, while the hands remain on the steering wheel. In our study, gestures were used to select menus on the HUD, but we did not distinguish which fingers were spread. On-wheel gestures facilitate immediate response to dangers because both hands remain on the steering wheel. Moreover, the finger that is spread does not need to be a specific finger, which avoids problems arising from differences in cultural norms regarding which fingers are spread.

The central console in a vehicle contains various switches for the audio and air conditioning systems. In the present study, 15 participants were asked to identify the switches that they used most frequently. The results showed that the ON/OFF switches for the air conditioning (cooler and heater) and audio systems (radio and MP3 player), as well as the blower, volume, and thermostat setting switches, were used most frequently. Therefore, we applied on-wheel gesture control to these switches in the present study. All the



(a)

(b)

Figure 2: HUD graphic user interface: (a) Initial menu, (b) Radio control.

switches on the central console can be operated by an on-wheel gesture system, because the proposed gesture controls function as hot keys for the selected switches.

In this study, both hands were used, and the on-wheel gestures distinguished between the left and right hands. Thus, a graphic interface was developed and displayed on the HUD, as shown in Figure 2. The initial screen shows the arrangement of the ON/OFF switches for the radio, MP3, air conditioner (A/C), and heater, as shown in Figure 2(a). The switches that turn on these devices are shown on the right and the switches that turn them off are shown on the left. The Braille dots above each switch represent the number of fingers that need to be spread. The red color indicates the left hand and the blue color is the right hand. After selecting a device from the initial menu, the user is directed to the submenu of the device's switch to control the selected device. Figure 2(b) shows the radio's detailed control menu.

In general, a gesture is captured as an image by a camera, which is then recognized by a pattern recognition process. The aim of this study was not gesture recognition itself; thus, a data glove was used to capture the finger movements instead of computer vision technology. The on-wheel gestures were captured using an Essential Reality P5 Gaming Glove [8]. In this study, the glove was disassembled and its components were attached to a cotton glove, which allowed the glove to be worn easily and the recognition rate of finger bending was increased, as shown in Figure 3.

Figure 3: Essential Reality P5 Gaming Glove: Customized right- and left-hand gloves.

In general, HUDs are projected onto the windshield and focused at distances further than the windshield to allow the driver to view the display with little or no refocusing and without looking away from the scene in front. In this study, a First FS-I09BS10-inchmonitor was used as the HUD, which was located in front of the steering wheel, as shown in Figure 4.

Figure 4: HUD-installed driving simulator.

Road Environment Modeling

UC-win/Road [9] is a 3D urban visualization and transport modeling software system, which was used to construct the road environment. The road used in the experimental environment is 11.55 km in length.. It is a motorway section with six lanes (three lanes in each direction), extending from the Seongsan Ramp, an urban expressway in Seoul, Korea, as shown in Figure 10.

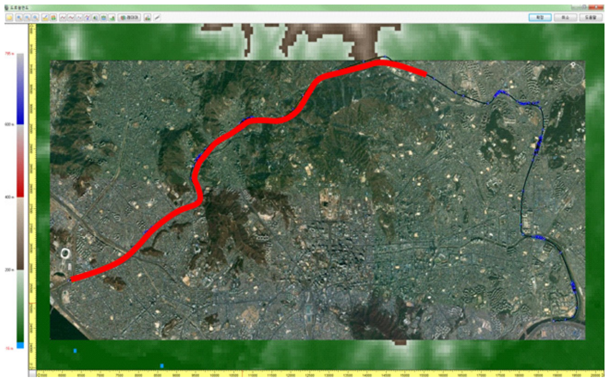


Figure 5: Road environment configuration: Satellite image showing the road.

Experimental Procedure

Before the experiment commenced, the subjects were informed about the study and gave their written consent to participate in the experiment. They practiced driving in the simulator to familiarize themselves with the simulator environment. They also practiced on-wheel gesture control, as well as the traditional push button and rotary switch controls. To minimize the effects of practicing in specific experimental conditions, the subjects were divided into two groups, each of which accessed the two interfaces in the experiment in a different order. The 15 subjects were divided into two groups of eight and seven subjects, respectively. The first group of eight subjects participated in the experiment that used the traditional interface first, whereas the second group of seven subjects used the new interface first. A task in a given scenario was completed within about 15 min, using each interface. After the experiment, the subject was required to complete a questionnaire about the experiment. The experiment lasted about 3 h for each subject.

Experimental Results

First, the following data were measured based on objective measurements: the task completion rate, time for device control, the vehicle’s speed and lane-keeping rates, and the head and eye movements related to driver distraction. Next, a questionnaire survey was conducted to obtain subjective evaluations of the two types of interfaces by 15 subjects. The questionnaire asked the subjects to evaluate each of the interfaces in terms of the levels of difficulty in terms of driving and secondary task performance, as well as their ability to keep their eyes on the road during task execution while driving. As shown in Figures 6, 7, 8 and 9 the results showed that the new interface reduced visual and biomechanical distractions for drivers compared with the traditional interface. The experimental results demonstrated that the new interface reduced the visual and biomechanical distractions associated with locating and controlling devices compared with the traditional interface. The new interface is therefore considered to be beneficial for safe driving.

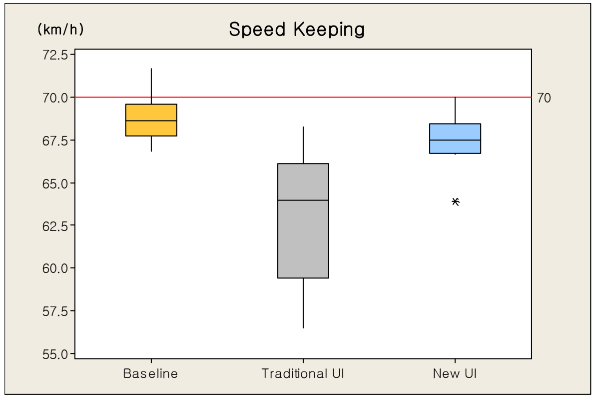


Figure 6: Primary task performance: Speed keeping.

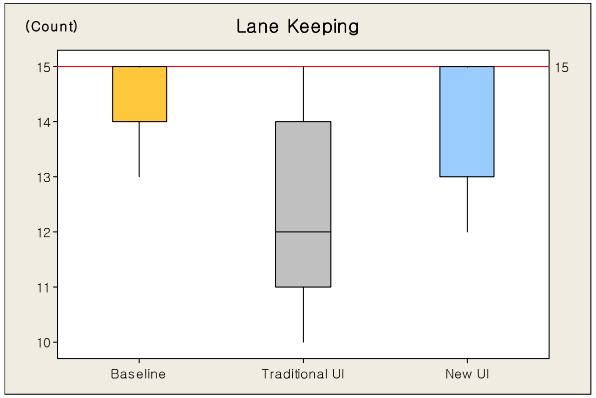


Figure 7: Primary task performance: Lane keeping.

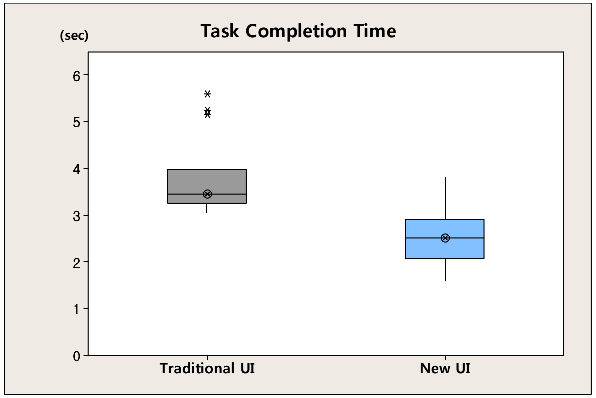


Figure 8: Secondary task performance: Secondary task completion time.

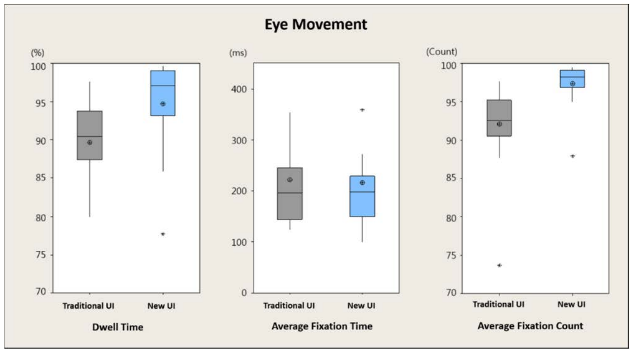


Figure 9: Eye movements

Conclusions

In this study, we developed a user interface based on on-wheel gesture control and an HUD, which is expected to minimize visual and biomechanical distractions when drivers control the audio and A/C systems on the central console. Using quantitative, objective measurements and qualitative, subjective evaluations, we compared the proposed system with the traditional interface that uses tactile control and a head-down display. The results showed that the new interface reduced visual and biomechanical distractions for drivers compared with the traditional interface. Future studies will compare driver performance when using on-wheel buttons with performance when using the proposed on-wheel finger gestures.

Acknowledgments

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