Motorcycle Head-Up Display: Design of Presenting Navigation Information

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***Abstract*—Navigation systems for motorcyclists are gaining attention using state-of-the-art technologies. While it is expected to provide benefits to riders similar to the technologies used for automobiles, the effectiveness of motorcycle head-up and head-mounted displays is not yet well understood. Therefore, this paper presents a human-centered design approach using a prototype of a motorcycle head-up display and an immersive virtual reality simulator. For validation, the motorcycle head-up display was equipped on a commercial motorcycle and tests were conducted in the real-world environment.**

Many navigation systems have been introduced for automobiles, though not for motorcycles. However, the demands of a navigation system dedicated to motorcycles are considered to be high, indicating lack of useful products on the market. Some motorcycle riders use smartphone applications for navigation, however, the riders have difficulties obtaining information while riding. Earlier studies indicate that motorcycle rider's move their viewpoints on the road surface more careful than automobile drivers as a slight obscurity on the road could make the motorcycle unstable.[1]

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Recent studies propose concepts utilizing state-of-the-art technologies such as head-up display (HUD) to provide information near where the riders are considered to be looking. HUDs are effective for automobiles, though it is carefully controlled regarding distraction against the driver.[2]

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The issue of distraction applies to motorcycles, which require studies since the viewpoint movements differ. Many commercial contributions on realizing this technology are an ongoing project, especially by implementing HUD to a helmet.

An attached wearable display device to the head is named as a head-mounted display, which also is known as a helmet-mounted display (HMD) when the display is mounted on a helmet. Use of HMD for augmentation or navigation is known to be effective in fields like outdoor sports.[3] There have been various studies and proposal with HMD for motorcycle application such as police motorcyclist.[4] There transpose been various fundraising campaigns such as Skully AR-1, Nuviz Ride, and Livemap, or major company like BMW also has announced a conceptual motorcycle HUD at CES2016. Commercializing motorcycle HUD is a challenging project due to difficulties with minimizing the HUD to implement inside the helmet, securing the helmet safety, and distributing it at an affordable price. However, research on distraction can be conducted by using simulation environments[1] and prototype of HUDs.

MOTORCYCLE HUD PROTOTYPE AND TESTING ENVIRONMENT

HUD is composed of a projector, lens, and a half-mirror. The rider moves their viewpoint between $-20°$ to $+5°$, vertically.[1] The focal distance can be configured, based on motorcycle riders' eye-tracking data (see Figure 1). The distance configuration is based on the rider's viewpoint movement angle and their eye height (1.55m). Considering the optimal display distance which is not too far or close, the focal distance for navigation information shall be configured in a distance slightly closer than the road surface (4m).

The components for the motorcycle HUD prototype are composed of microelectro mechanical systems (MEMS)-based laser projector, a non-spherical lens, and an ordinary acrylic board with 92.6% transparency for the half-mirror. First, the motorcycle HUD prototype was designed to conduct experimental tests to investigate configurations for presenting navigation information, the half-mirror was designed to cover a broad range of riders' field of view. The HUD was mounted on a motorcycle simulator operated in

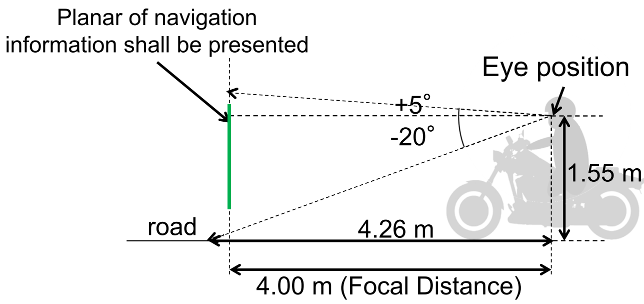

Figure 1. Configuration for focal distance of presenting information.

a testing environment for the human-centered design approach.

An immersive virtual reality environment was utilized for the testing environment. The testing environment is composed of immersive CAVE (see Figure 2),[5] and a motorcycle simulator provides a three-dimensional (3-D) stereo image through 3-D glasses stereo to the rider tracked by the electromagnetic sensor.

CONFIGURATION OF PRESENTING NAVIGATION INFORMATION

There are three configurations necessary to concern for a motorist navigation system.[6] The configurations are described as *when*, *where*, and a *suitable form to their characteristics*, which are rephrased as information presentation *timing*, *position*, and *quantity* for easier understanding. Although *suitable form* sounds as if it includes other parameters than quantity, the *form to suit* their characteristics as the quantity of information is either too much or too little.[6] Hence, considering the *suitable form* as information quantity, the three configurations need comparison for presenting navigation information.

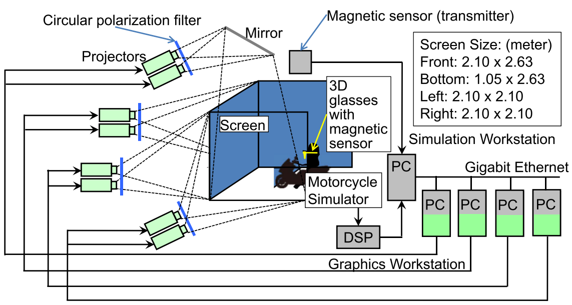

Figure 2. Overall structure of the immersive cave motorcycle simulator.

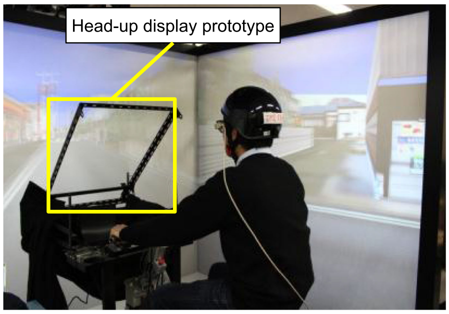

Figure 3. HUD prototype equipped on the immersive cave motorcycle simulator for testing.

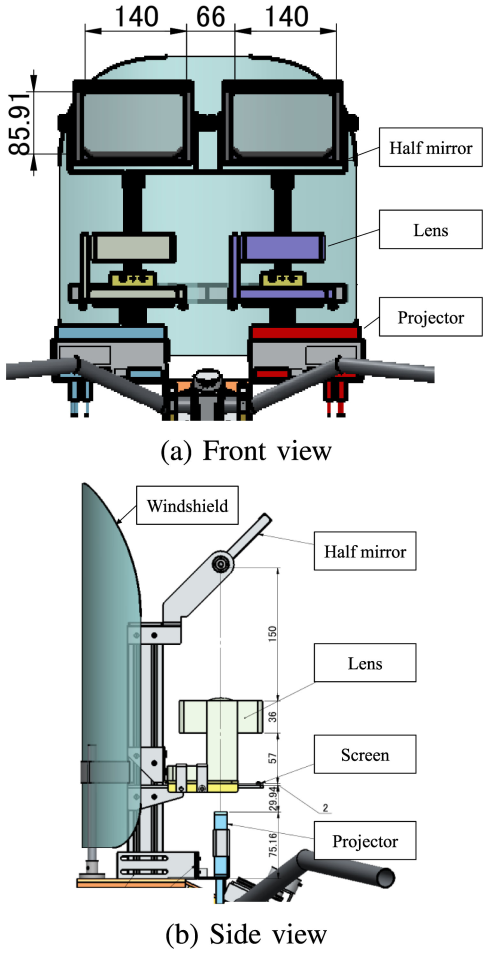

Figure 5. Structural view of the HUD prototype configured to show on the lower left and lower right positions indicated in Figure 4. (a) Front view. (b) Side view.

Study Using the Immersive CAVE Motorcycle Simulator

An eye-tracking sensor (nac, EMR-9) was utilized to evaluate the viewpoint movement for the three configurations.[1] Tests were conducted using the motorcycle HUD prototype to clarify the configurations of information presentation timing, position, and quantity. Each experiment had 10 participants, all male in their 20s to 50s. The experiment was conducted inside the immersive CAVE motorcycle simulator for safety and ethical purposes (see Figure 3).

For information presentation timing, in a condition of riding a motorcycle at a maximum of 30 km/h, 55m prior to the upcoming crossroad was the optimal timing. For information presentation position, the position 5° lower, 5° to the left and right relative to the road vanishing point were the fastest positions the rider could understand the information (see Figure 4). For information presentation quantity, considerations from and the presenting information quantity shall be no more than five letters of Hiragana. The HUD prototype was then optimized after the tests for configuration of the position to present navigation information (see Figure 5).

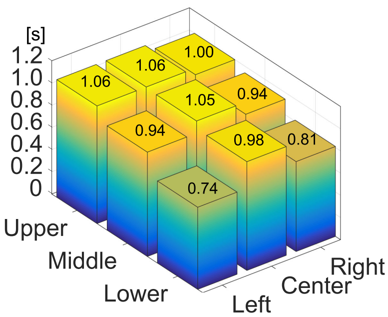

Figure 4. Experiments indicate that the lower left and lower right positions were the fastest duration for the rider to understand the navigation information (details of experimental conditions and data analysis is available[1]).

Actual Vehicle Testing of Motorcycle HUD Outdoors

Based on the results of configurations of presenting navigation information, the motorcycle HUD was mounted on an actual vehicle for further testing. A front view of the motorcycle HUD equipped on to an actual scooter type motorcycle is in Figure 6. The HUD has two half-mirrors positioned at the same view angle with the lower left and right regarding previous work.[1] For the HUD projector, it has been

Figure 6. Front view photo of the HUD equipped on to the testing vehicle.

replaced to a different MEMS-based laser projector.

While the testing vehicle is a commercial vehicle capable of riding on public roads, further actual vehicle testings were conducted on non-public roads (private roads), for safety and ethical concerns. Figure 7 shows the riding course used for the actual vehicle testing to test if the configurations based on the virtual reality environment were effective in an outdoor environment. Experiment was configured to show navigation information to go straight, turn left, or turn right at a location 40m prior from the target turn points. The rider did six trial runs of navigation information presented to turn left, for two times per turn point. Experiment conducted against one male in the 30s resulted the rider was 100% successful understanding the presented navigation information.

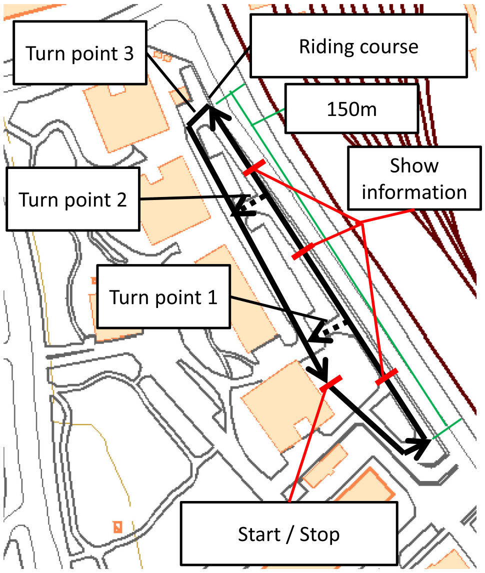

Figure 7. Riding course for testing the HUD.

DISCUSSIONS

A human-centered approach to realize the motorcycle HUD prototype has been successfully configured with three important parameters: presenting navigation information timing, position, and quantity. Experimental test results using actual vehicles in the real world indicated that the HUDs can be utilized on motorcycle effectively for presenting navigation information. However, it is to be noted that there is a possible bias since most riders are aware of the upcoming technology, riders are favorable to the HUD in the first place. Therefore, evaluation and analysis were performed mainly on objective eye-tracking data, although it cannot deny the possibility of favor against the technology affecting viewpoint movements.

In general, favoring affects human's attention and information processing behavior.[7] HMD was rated more attractive over a head-down display in terms of attractiveness and qualitative feedback.[8] Hence, while the implementation has been successful, extra caution is necessary to consider that providing information while driving is generally a distraction. Many studies on distraction have been done for automobiles, which already have regulations and guidelines.[9] Regarding the different characteristic of viewpoint movement, current regulations and guidelines may not be the perfect guide to follow, although it is mandatory.

While traditional regulation and guidelines are updated, most of the constraints were made assuming the display to be a conventional liquid crystal display. When using a HUD, new configuration parameters like the focal distance, and display position becomes necessary to take into consideration. Other parameters like luminance and brightness affects the visibility, which needs to be understood well. For example, raising the brightness of the information contributes to better visibility, but the driver feels bothersome with high luminance HUDs while driving.[10] Presenting icons or symbols are effective and less bothersome, which is considered easy to understand.[11]

CONCLUSION

This paper discussed design of the motorcycle HUD for navigation information presentation. A human-centered design approach was adapted since the motorcycle rider's viewpoint movement is known to move in a characterful way. A virtual reality environment was utilized for a safe testing environment with a motorcycle simulator. The testing of the motorcycle HUD prototype in the real environment using a scooter type motorcycle clearly demonstrated its effectiveness.

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