

Display Specifications Study for Head-Up Display from a Driving Simulator

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Recently, a new Head-Up Display (HUD) which has a more inclined virtual image along the road surface (inclined HUD) has been proposed. The inclined HUD can display navigation information, such as a virtual arrow laid upon the road surface so that drivers can intuitively understand the driving route. In addition, the inclined HUD can display vehicle information, such as speed, as if it were displayed on the vertical virtual image to the road surface. However, the inclined HUD appears as if the shape of the virtual image was deformed due to the motion parallax caused by the driver's head movement or the binocular parallax. In this study, we used the mixed reality (MR) goggles and the driving simulator including the virtual reality (VR) goggles to evaluate the conditions under which the shape of the vehicle information and the entire virtual image were acceptable or not; even when they were deformed by the driver's head motion.

In order to conduct this experiment, it was necessary to select an indicator of deformation as the variable. We selected the differences of the convergence angle that occurs between the upper edge and the lower edge (parallax angle) of the zone where vehicle information is displayed as the variable. The parallax angle is in proportion to the degree of deformation.

Table 1 shows specifications of inclined HUDs used in the experiments. The upper part of the virtual image was the zone where the navigation information was displayed. The lower part of the virtual image was the zone where the vehicle information was displayed. Eight parallax angles were used as experimental conditions by fixing the virtual image distance (VID) of the upper edge of the virtual image (UVID) and varying the VID of the lower edge of the virtual image (LVID). The vertical field of view (VFOV), the horizontal field of view (HFOV), and the look down angle (LDA) were fixed. These inclined HUDs were generated by the MR goggles and the VR goggles. The impression about deformation of the inclined HUD is considered to change depending on the driver's tasks. Therefore, experiments were conducted in the static experiment without the driving tasks and the driving simulator experiment with the driving tasks. Each inclined HUD was displayed in ascending and descending order in each experiment, and 10 participants responded from the following perspectives:

- Whether the information in the vehicle information zone is recognized to be displayed on the vertical virtual image to the road surface or not
- Whether the deformation of information on the entire virtual image is acceptable if it occurs on the actual product or not

Fig. 1 shows the results. The acceptable rate was calculated as the percentage of all the responses that were recognizable or acceptable for each perspective. The acceptable condition of the deformation was defined as the threshold value of the parallax angle at which the acceptable rate was 0.8 or more. The threshold was calculated by linear completion. In the static experiment, the acceptable condition of the vehicle information zone was 0.15 degrees, the acceptable condition of the entire virtual image was 0.16 degrees. There were no big differences between each result. Each result tended to reduce the acceptable rate with an increase of the parallax angle. In the driving simulator experiment, the acceptable condition of the vehicle information zone was 0.20 degrees, the acceptable condition of the entire virtual image was 0.16 degrees. Each result tended to reduce the acceptable rate with an increase of the parallax angle as with the static experiment. The strictest acceptable condition, that is, the smallest parallax angle in the result was 0.15 degrees. As a result, the specification of the vehicle information zone was defined as the parallax angle of 0.15 degrees or less.

Table 1 Specifications of the inclined HUDs

Condition	Parallax angle (deg.)	LVID (mm)	UVID (mm)	HFOV (deg.)	VFOV (deg.)	LDA (deg.)
1	0.04	6000	8000	7	3	5
2	0.07	5000				
3	0.12	4000				
4	0.15	3500				
5	0.20	3000				
6	0.26	2500				
7	0.31	2200				
8	0.35	2000				

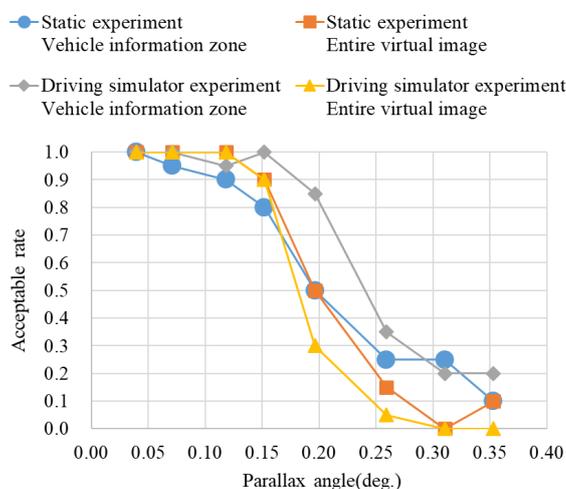


Fig. 1 Results of the static and the driving simulator experiments