Depth Perception for Virtual Object Displayed in Optical See-Through HMD

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***Abstract*— This paper presents depth perception for virtual objects displayed with an optical see-through type head-mounted display (HMD) when there is a real object in front of it. In the real world, we cannot see the object behind another object. However, in augmented reality using an optical see-through type HMD, it is seen overlapping the object in front of it. We researched depth perception for a virtual object for this case. Perception of the depth of a virtual object in such a situation is very important to enable development of a technique of interaction with a virtual object. From the subjective test performed, we found that human vision could perceive the depth of a virtual object for the above case although there were significant differences between individuals, especially in short distances from the user.**

Keywords- HMD; optical see-through; virtual object; depth perception.

I. INTRODUCTION

Research into augmented reality (AR), in which virtual objects in a real world assist our activities, has recently become popular. ARs that enable users to interact with a virtual object are attracting attention [1][2]. In many studies on AR, a head-mounted display (HMD) has been used. There are two types of HMD; video see-through and optical see-through. The former does not show the real world directly to the user, but shows it captured by the camera, and virtual objects are rendered in the captured image by image processing. On the other hand, when using an optical see-through type, a user can see the real world directly and virtual objects are superimposed in the real world; therefore, user can see their actual hands directly. This is very important when a user interacts with a virtual object using their hands because it is natural for users interacting with virtual objects directly with their actual hands instead of using virtual hand. From this point of view, the optical see-through type HMD is more suitable. However, a problem with this type occurs in that when a virtual object is superimposed behind a real world object, it becomes translucent instead of being naturally obscured. This unnaturalness may affect a user's depth perception of the virtual object. It is important to accurately obtain the depth of a virtual object that a user perceives for natural interaction. In this study, we evaluated the effect of the semi-transparency of virtual objects on depth perception.

II. DEPTH PERCEPTION FOR INTERACTION

Figure 1 outlines the importance of the system acquiring perceived depth for users. If the depth obtained by the system and that perceived by the user are different as shown in Figure 1, the system cannot react with the virtual object when the user sees that his or her hand touched it. This prevents smooth interaction between user's hand and virtual object.

Figure 2 outlines the problem of the optical see-through type HMD. Figure 2 (a) shows that from the side, the virtual object is located farther than the user's hand as the user reaches towards it. Figure 2 (b) shows the view from a user's point of view and the subsequent problem of the optical see-through type HMD. In the real world, when an object is positioned behind another object, it cannot be seen due to occlusion by the front object. However, the virtual object is seen in a translucent state although it is located farther than the user's hand.

The main factor for the depth perception of an object at a short distance in human vision is binocular disparity; however, occlusion is also used as a cue of the depth. In the

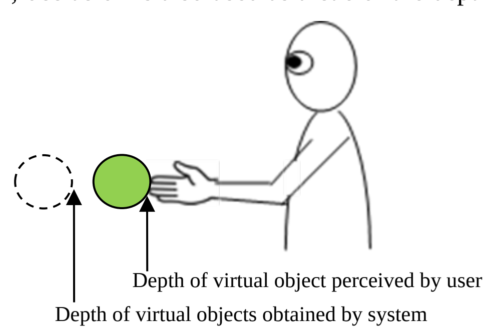

Figure 1. Interaction with virtual object using actual hand.

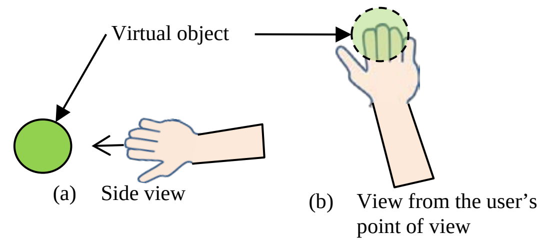

Figure 2. Problem of optical see-through type HMD.

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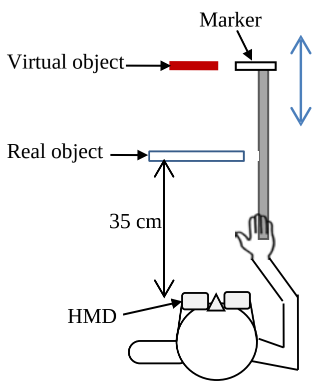

Figure 3. Layout in the subjective test.

real world, the depth perceived from binocular disparity and occlusion is almost the same, however, in the case shown in Figure 2, these two depths contradict each other. Binocular disparity is expected to be the dominant factor of depth perception; however, the absence of full occlusion by a hand has a possibility of affecting depth perception. In this study, we conducted a subjective test about the depth perception for the case shown in Figure 2.

III. Subjective Test

Figure 3 shows the layout of the subjective test. We used an HMD with two 1280×720 pixel OLED displays for both eyes, which provides the equivalent of an 80 inch display 5 m ahead by magnifying optics.

Virtual objects were square white patterns. The pattern size was 11 cm on the virtual screen 5 m ahead, therefore if it is seen, for example, 1 m ahead; it will be perceived as a square of about 2 cm in size. We set the brightness of the pattern to a grayscale value of 127, of which the maximum is 255. The virtual object is displayed within a distance range of 40 to 80 cm, which is the range where people can manipulate things directly with their own hands. A real object that is white was placed 35 cm from the observer's eye position. Although the virtual object is located behind it, it overlaps the real object.

Five subjects, all with normal eyesight and could see stereoscopically, moved a thin plate-shaped marker using their right hand and stopped it at a position just beside the virtual object to indicate the depth of the virtual object perceived by the subject. For reference, we conducted the same test without the real object.

IV. Results and Discussion

Figure 4 shows the results of the subjective test. In both cases where there was an actual object or not, the perceived depth of the virtual object increased as the depth set based on binocular disparity increased. However, the differences of data between subjects were significant in the case where there was an actual object, particularly at a short distance. This is considered to be due to the instability of the depth perception of the virtual object due to the existence of the real object. Furthermore, the reason that this difference increases at a short distance seems to be due to the large binocular disparity at a short distance.

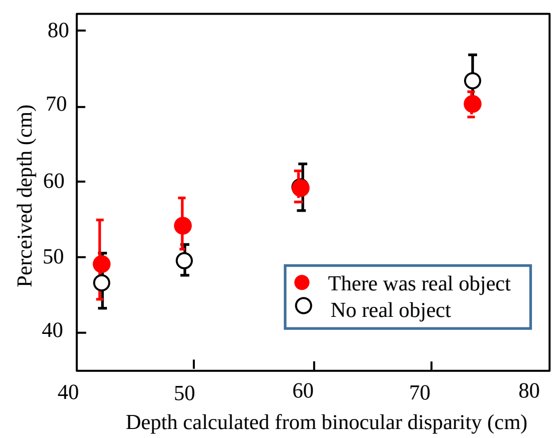

Figure 4. Result of subjective test

The result in this study shows that some technique that reduces the influence of the real object for this purpose is needed.

V. Conclusion and Future Work

We researched depth perception for virtual objects displayed in an optical see-through type HMD when there is a real object in front of the virtual object. We clarified from the subjective test that perceived depth of the virtual object changed depending on binocular disparity. However, the depth perception in human vision became varied under the influence of real objects existing in front of it, and the difference between individuals was significant.

In the future, we need to reduce the influence of the real object. To achieve this, we will try to develop a technique that can display only a part of the virtual object that is not obscured by a real object. This will improve the depth perception of a virtual object because it is the same in the real world.

Acknowledgement

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