Viewing Distance Limitation for the Sticking Perceived Depth of Floating Image to Real Object

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Keywords: Floating image, Perceived depth, Viewing distance

ABSTRACT

We propose a new method for easily changing perceived depth of floating image by sticking floating image to a real object. This sticking effect is limited by viewing distance of real object over 1.5 m. When viewing distance is increased to 2.0 m-3.0 m, sticking range of perceived depth is increased to about 0.1 m.

1. INTRODUCTION

There are many techniques for forming spatially floating image, such as one using a half mirror or a lens. Recently, augmented reality (AR) for merging real object and virtual floating image has been proposed with many technologies, in which virtual images can be perceived as if they exist in real space [1]. However, in order to change depth position of the floating image, it is necessary to move the position of the original object. Figure 1 shows an example of the fusion of a real object and a floating image. The floating image is displayed on a large monitor and, by using a half-mirror, floating image appears to be on the stage besides the real object as if it were there. However, the large monitor needs to move in order to move the floating image backward or forwards, resulting in difficulty to apply for many applications.

If it would be possible to move the depth of the floating image more easily without moving the monitor, floating image could be applicable for much more applications, such as AR stages. Nakano [2] reported that floating images by stereoscopic display or arc 3D display are stuck to a real object in the absence of motion parallax. This phenomenon suggests that we might stick even a floating image using half mirror to a real object, although this floating image is not stereoscopic image but an optical 2D image.

In this paper, we propose a new method to change the perceived depth of floating image using a half mirror by sticking a floating image to a real object.

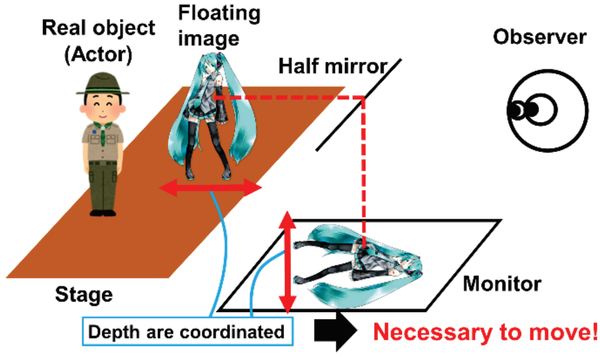


Fig. 1. An example of fusion of real object (Actor) and floating image (CG image) using a half mirror

2. PROPOSED METHOD FOR CHANGING PERCEIVED DEPTH OF FLOATING IMAGES BY STICKING TO REAL OBJECT

We propose a new method to change the perceived depth of the floating image by sticking it to real objects, as shown in Fig. 2. Figure 2(a) shows the optically designed position of the floating image. Since the distance between the monitor and the half-mirror is equal to the distance between the half-mirror and the floating image, an image of monitor is floating in front of a real object. However, when a real object is located near the floating image, floating image is perceived to be stuck to real object as shown in Fig. 2(b). This phenomenon allows the perceived depth change of the floating image using a half mirror without changing the monitor position.

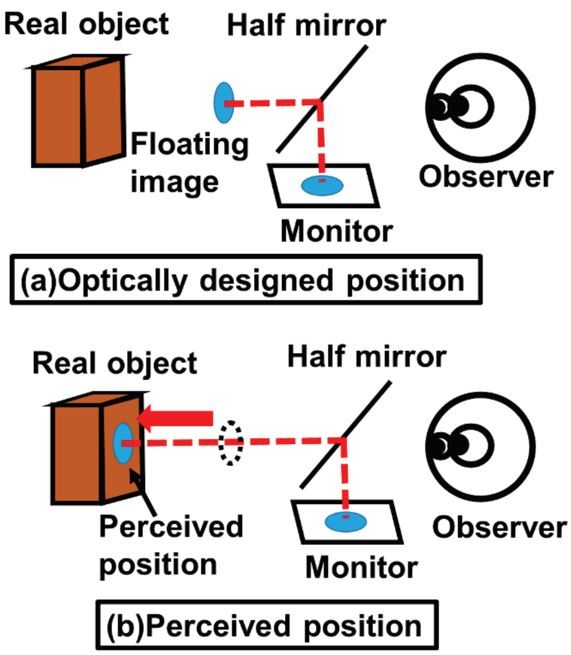


Fig. 2. Our proposed method for moving floating image by sticking a floating image to a real object position

3. EXPERIMENT OF PERCEIVED DEPTH OF FLOATING IMAGE WHEN THE VIEWING DISTANCE IS CHANGED

The experimental system for estimating perceived depths of floating image is shown in Fig. 3. The stimulus of a floating image was an optical virtual image of a white circle displayed on an LCD with a diameter of 5.52 cm by using the half mirror. A brown cardboard of 58 cm height and 42 cm wide was used as a real object. Floating image and real object were overlapped from subject position. The viewing distances to the floating image were 1.5 m, 1.7 m, 2.0 m and 3.0 m. The position of the real object was changed in the depth direction from −200 mm (in front) to 200 mm (behind) relative to optically designed position of the floating image.

As shown in Fig. 4, perceived depth was measured by matching the reference image position to the perceived position as follows. (1) The subject observed the stimulus with both eyes with fixing his head by using chin rest and memorized perceived depth of the stimulus. The display time of the stimulus was 2 seconds. (2) The subject moved the reference to the memorized perceived depth position after the stimulus was turned off.

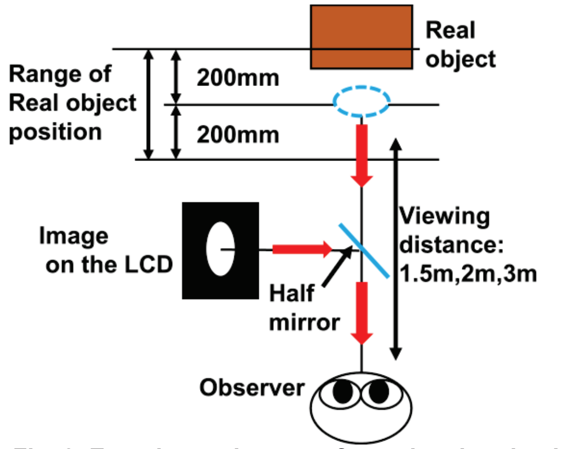


Fig. 3. Experimental system for estimating depth perception of floating image sticking to a real object

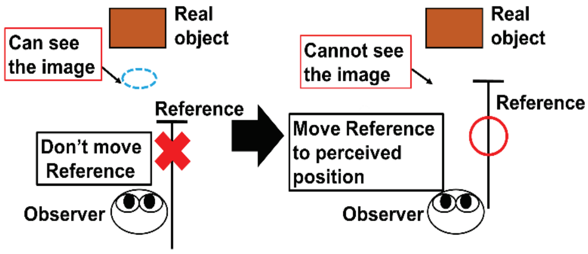


Fig. 4. Perceived depth measurement process using the reference after turning off the stimulus

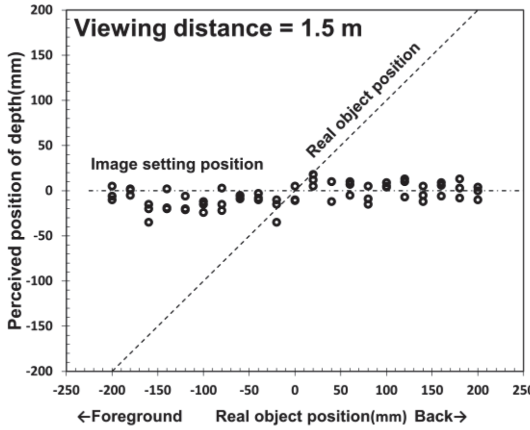
4. STICKING RANGE CHANGE OF A FLOATING IMAGE TO REAL OBJECT BY CHANGING VIEWING DISTANCE

Figure 5 shows perceived depth dependence on real object position change at viewing distances of (a) 1.5 m, (b) 1.7 m, (c) 2.0 m and (d) 3.0 m. At viewing distance of (a) 1.5 m, floating images do not have clear sticking region of perceived depth to the surface of the real object, although some images around zero is difficult to judge. This means that floating image position does not change even when real object position changes, resulting in no sticking range of floating images.

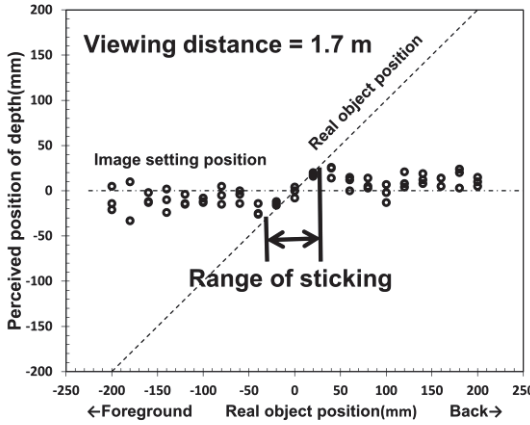
On the other hand, at viewing distances of (b) 1.7 m, (c) 2.0 m and (d) 3.0 m, perceived depths of floating images can be successfully changed by changing real object position in the range of (b) ± 25 mm, (c) ± 45 mm and (d) ± 50 mm. At the viewing distance of (b) 1.7 m, an accurate value of the sticking image within ±25 mm is successfully obtained as compared to 1.5 m. These indicate that the threshold for the sticking of the floating image for the change in viewing distance is around 1.5 m or less than 1.7 m.

The range of sticking is larger at the viewing distance of (c) 2.0 m than that at (b) 1.7 m. As sticking range of the floating image at the viewing distance of 3.0 m is about ± 50 mm, and the ranges of the sticking range of the floating image to the real object have the saturation tendency over 2 m.

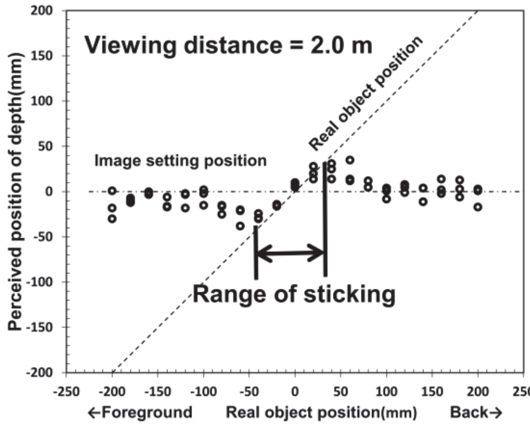
Deviations are different between the sticking region and other region at the viewing distances of 1.7 m, 2.0 m and 3.0 m. This indicates that mechanisms for depth perceptions are considered to be different between them.



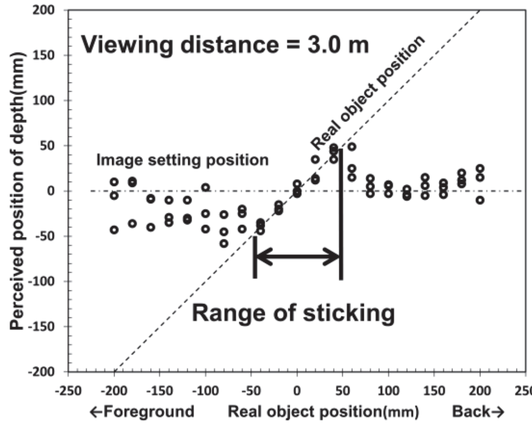
(a)Viewing distance = 1.5 m



(b)Viewing distance = 1.7 m



(c)Viewing distance = 2.0 m



(d)Viewing distance = 3.0 m

Fig. 5. Sticking characteristics of floating image at various viewing distances

5. DISCUSSION ABOUT VIEWING DISTANCE DEPENDENCE

The depth resolutions of binocular disparity at 1.5 m, 1.7 m, 2.0 m and 3.0 m are approximately 3 mm, 4 mm, 6 mm and 12 mm. The depth resolutions of vergence at 1.5 m, 1.7 m, 2.0 m and 3.0 m are approximately 100 mm, 170 mm, 220 mm and 430 mm. The sticking depths (0 mm, 50 mm, 90 mm and 100 mm) of the floating images are much larger than resolutions of binocular disparity and less than resolution of vergence. Moreover, deviations are as small as about 5 mm at sticking regions but as large as about 50 mm at other regions. These indicate that perceived depths as sticking regions are due to different mechanism from that at other regions.

Figure 6 shows the relationship between viewing distance and sticking range. The sticking ranges change significantly between 1.5 m, 1.7 m and 2.0 m, but have a saturation tendency between 2.0 m and 3.0 m. As the sticking range of the floating image to the real object dramatically increases in the range from 1.5 m to 1.7 m, the threshold of sticking about viewing distance is considered to be around 1.5 m.

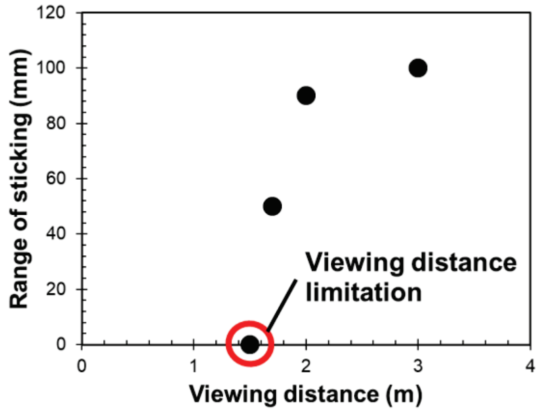


Fig. 6. Sticking range dependence of floating image on viewing distances

6. CONCLUSION

We propose a new method to change the perceived depth of the floating image by sticking to real objects.

The perceived position of a floating image can be successfully moved using a real object at appropriate viewing distances. At a viewing distance of 1.5 m, the perceived position of the floating image cannot be shifted even using real objects. At a viewing distance of 1.7 m or more, the perceived position of the floating image can be successfully changed, and the range of the sticking of the floating image to the real object can be enlarged as the viewing distance is increased.

Thus, we can successfully move the floating image by sticking to a real image without moving the monitor or so.

ACKNOWLEDGMENT

This work was supported by JSPS KAKENHI Grant Number JP19H04155,JP20K21817.

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