Perceived Depth in Arc 3D Display Can Penetrate into Behind Real Object by Moving Arc 3D Images in Contrast to Non-penetrated Perceived Depth in Stereoscopic Display

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Keywords: HUD, motion parallax, depth perception.

ABSTRACT

Arc 3D display can solve serious difficulty in perceived depth penetration into or behind the real object in stereoscopic image only by moving head or 3D image position. Arc 3D image can be successfully perceived around desired position even in or behind the real object.

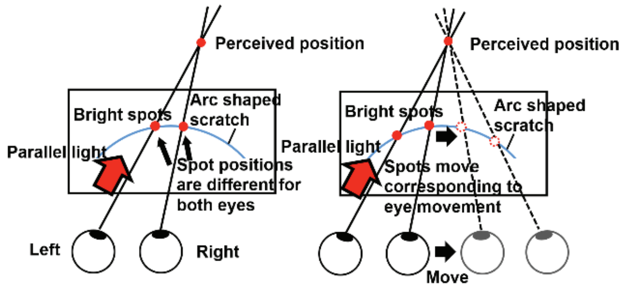
1 INTRODUCTION

In recent years, HUD (Head-Up Display) has been come to use in many cars around windshield or on the bonnet. In the future, if HUD images can perceive at farther positions, for example at a long distance of 10 m, HUD can apply to various situations such as car navigation, danger marking and so on. However, there is a very serious problem for perceiving HUD images at farther positions. This serious problem derives from real cars in front of your car, such as truck, van, etc. Even when you try to display a stereoscopic image at farther positions penetrated into or behind the real cars by controlling various parameters like disparity, stereoscopic images cannot be perceived at far positions but are stuck around real car surface in front of your car. This is considered to be caused by the difference of physiological cues for 3D vision between stereoscopic images and real objects [1]. That is, stereoscopic images satisfy only vergence and binocular disparity. In order to solve this problem, 3D display which satisfies almost all physiological cues for 3D vision is necessary.

One of such a precious 3D display having almost all physiological cues for 3D vision is Arc 3D display. Arc 3D display was firstly reported by Dr. Plummer as the phenomenon of "a virtual image appears in the lower space on a board" [2]. Dr. Daibo also roughly reported 3D display (Arc 3D display) which provide dotted stereoscopic image in space [3]. However, they have not clarified precise characteristics.

We have precisely studied the characteristics in Arc 3D display from theoretical and experimental approaches [4], resulting in important characteristics that Arc 3D display has almost all physiological cues. Figure 1 shows principle of Arc 3D display. The left and right figures show (a) binocular disparity and (b) smooth motion parallax. (a) When arc-shaped scratches are illuminated, each eye with different position perceives one bright spot according to the eye position. This results in binocular disparity. (b) When eye moves horizontally, bright spot position moves continuously according to eye motion, resulting in smooth motion parallax [4].

In this paper, we have estimated perceived depth penetration into or behind real object in Arc 3D display by moving head or 3D display position as compared to that in stereoscopic display.



(a) Binocular disparity (b) Smooth motion parallax
Fig. 1 Principle of Arc 3D display

2 EVALUATION METHOD

2.1 The experimental apparatus for estimating perceived depth in Arc 3D display

Figure 2 shows the experimental apparatus for estimating perceived depth in Arc 3D display. Stimulus image of Arc 3D display was a white dotted line of 100 mm long, whose depth was set to 100 mm, 150 mm or 200 mm behind Arc 3D display substrate. White light was used for illuminating arc-shaped scratches. Real object was a box with white flat surface and depth of 150 mm. Subjects were let memorize Arc 3D image depth by 5 seconds image exposure, and after turning off stimulus, move the reference to memorized perceived position of Arc 3D image for three times. Subject’s head moving condition was stationary or moving to left and right for about 80 mm width with a period of 2 seconds. Moving condition of Arc 3D image and the stereoscopic image was stationary or moving to the left and right for about 40 mm width with a period of 2 seconds.

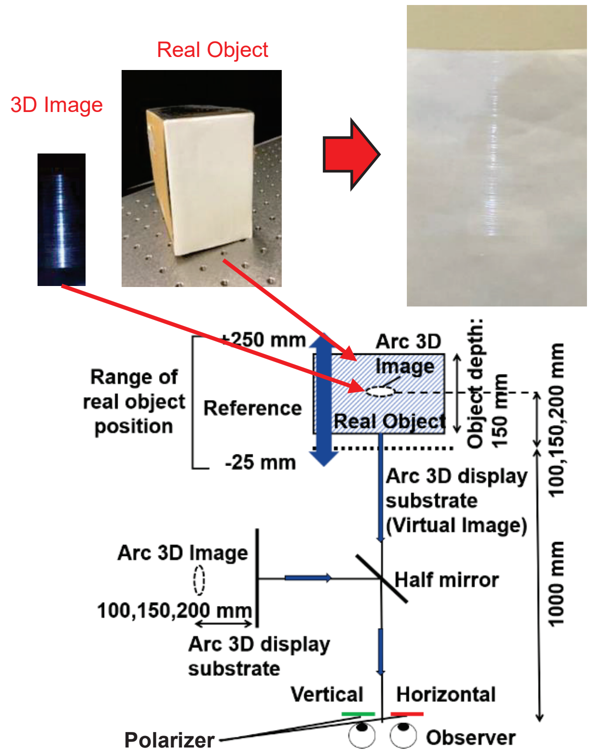


Fig. 2 Experimental set up for estimating perceived depth in Arc 3D display

2.2 The experimental apparatus for estimating perceived depth in stereoscopic display

Figure 3 shows experimental apparatus for estimating perceived depth in stereoscopic display. Stimuli of stereoscopic images were also white lines which were the photographs of stimuli in Fig. 2. Polarization plates were used for separating stimulus images to left and right eyes. Other conditions were the same as those in Arc 3D display shown in Fig. 2.

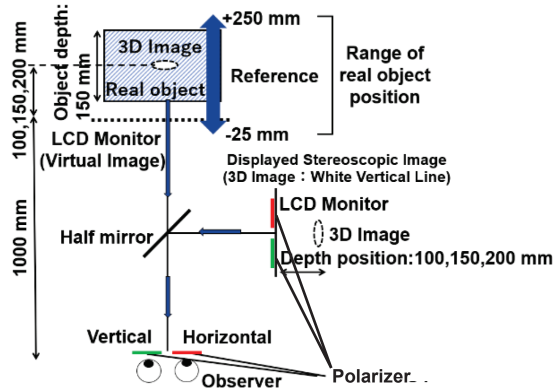
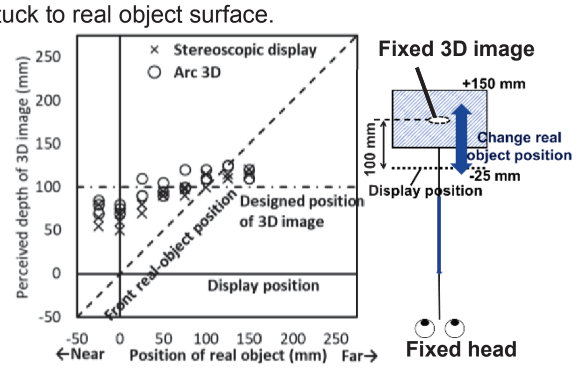


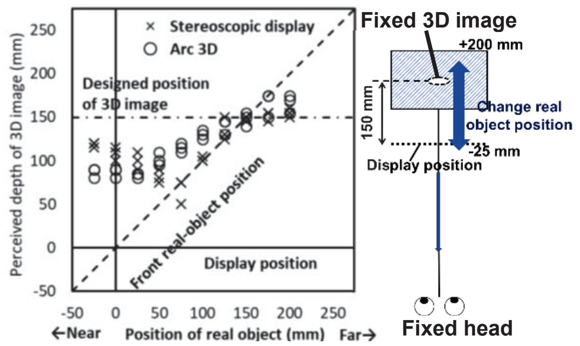
Fig. 3 Experimental set up for estimating perceived depth in stereoscopic display

3 PERCEIVED DEPTH CHANGE OF 3D IMAGE IN ARC 3D DISPLAY AND STEREOSCOPIC DISPLAY BY CHANGING REAL OBJECT POSITION

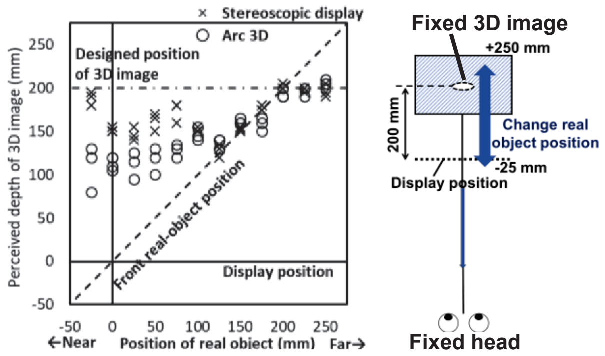
Figures 4, 5 and 6 show perceived depth change in Arc 3D image and stereoscopic image by changing real object position at image depths of (a) 100 mm (b) 150 mm and (c) 200 mm. Figure 4 shows perceived depth change when fixing head and 3D image positions, that is, all is stationary. Perceived depths in Arc 3D display and stereoscopic display are changed along depth change of real object. As 3D image position increases, those degradations get worse and deviations are increased. This indicates that both Arc 3D image and stereoscopic image with stationary head and 3D image are almost stuck to real object surface.



(a) 3D image position: 100 mm



(b) 3D image position: 150 mm

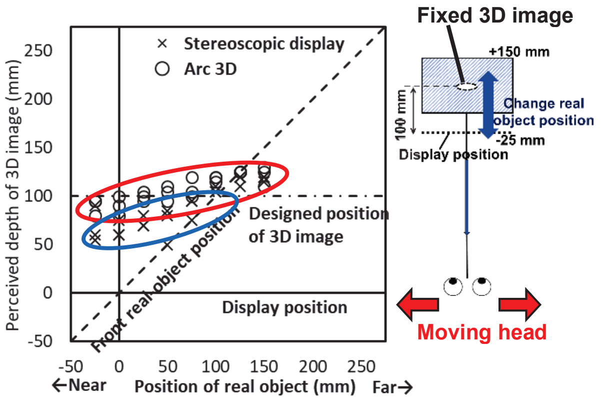


(c) 3D image position: 200 mm

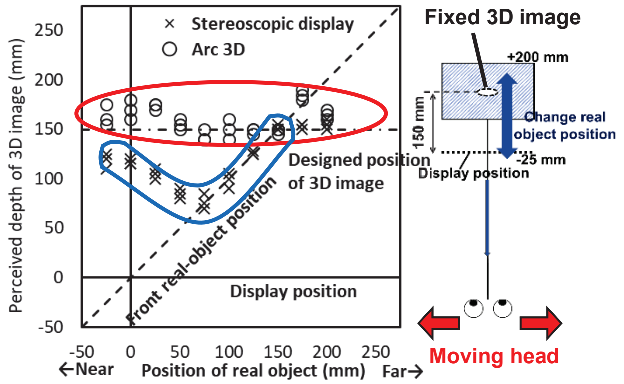
Fig. 4 Perceived depth change of 3D image in Arc 3D display and stereoscopic display by changing real object position when fixing head and 3D image positions

Figure 5 shows perceived depth change in Arc 3D display and stereoscopic display by changing real object position when moving head and fixing 3D image. Stereoscopic image positions have tendencies of stuck position change according to real object positions. In Fig. 5(a), at all designed positions of 3D images, stereoscopic image without motion parallax has the same stuck tendency as stationary case in Fig. 4. In Fig. 5(b) and (c), when distance between front real object position and designed position of 3D image is large, perceived depths gradually approach around designed position of 3D image. This is because of difficulty in gazing both of them.

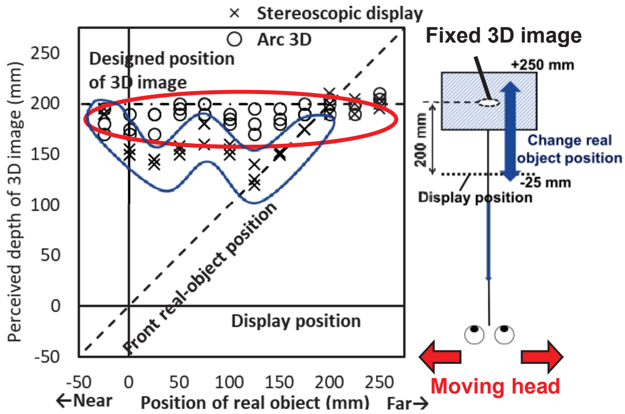
On the other hand, perceived depths in Arc 3D images keep around designed positions of 3D images, even when real object positions are widely changed. Thus, only by moving head position, Arc 3D images with smooth motion parallax can improved their perceived depths to around designed 3D image depths penetrated into real object at all designed positions of 3D images.



(a) 3D image position: 100 mm



(b) 3D image position: 150 mm

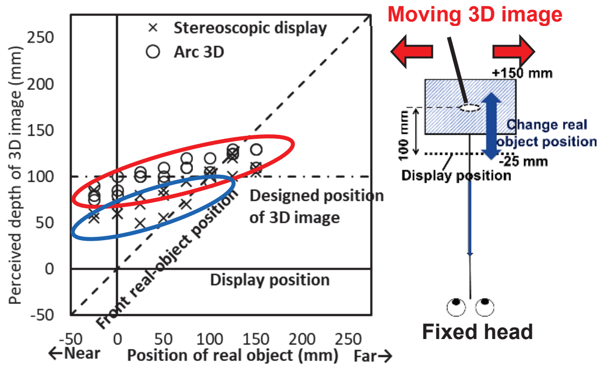


(c) 3D image position: 200 mm

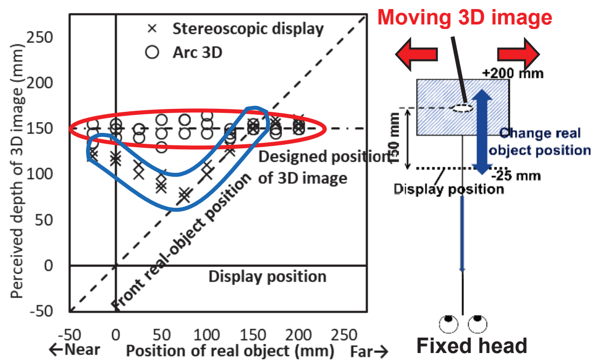
Fig. 5 Perceived depth change of 3D image in Arc 3D display and stereoscopic display by changing real object position when moving head and fixing 3D image

Figure 6 shows perceived depth change in Arc 3D display and stereoscopic display by changing real object position when moving 3D image and fixing head. Perceived depth dependences are almost the same as those when moving head. In Fig. 6(a) at all designed positions of 3D images, stereoscopic image without motion parallax has the same tendency as stationary case in Fig. 4. In Fig. 6(b) and (c), when distance between front real object position and designed position of 3D image is large, perceived depths gradually approach around designed position of 3D image. This is because of difficulty in gazing both of them.

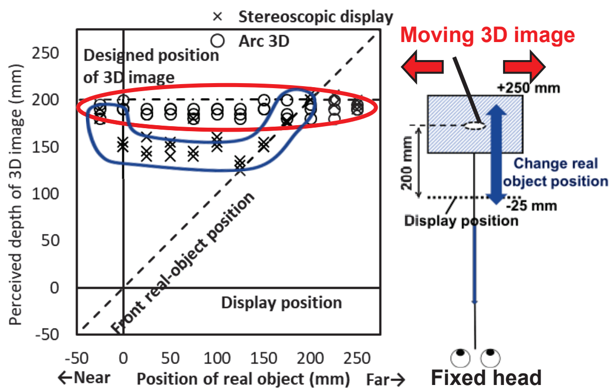
On the other hand, perceived depths in Arc 3D images keep around designed positions of 3D images, even when real object positions are widely changed. Thus, only by moving 3D image position, Arc 3D images with smooth motion parallax can improved their perceived depths to around designed 3D image depths penetrated into real object at all designed positions of 3D images.



(a) 3D image position: 100 mm



(b) 3D image position: 150 mm



(c) 3D image position: 200 mm

Fig. 6 Perceived depth change of 3D image in Arc 3D display and stereoscopic display by changing real object position when moving 3D image and fixing head

4 CONCLUSION

We have clarified that Arc 3D image with smooth motion parallax can successfully penetrate into or behind real object by moving head or Arc 3D image, in contrast to non-penetration in stereoscopic image even when moving head or its image.

We clarified that stereoscopic image without motion parallax has difficulty in penetrating into or behind a real object by comparing depth perception in various conditions. On the other hand, Arc 3D image can penetrate into behind real object.

Thus, Arc 3D display with smooth motion parallax is more applicable for HUD in car or so on.

ACKNOWLEDGMENT

This study was supported by JSPS KAKENHI Grant and Hoso Bunka Foundation.

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