3D Image and Real Object Have Differences?

~ Enhancing or Fooling Image Reconstruction in Brain ~

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Keywords: DFD display, Arc 3D display, Continuous motion parallax, Brain complementation, Image reconstruction in brain

ABSTRACT

We review importance of continuous motion parallax and enhancing or fooling of image reconstruction in brain by using continuous motion parallax, occlusion, and brain complementation. Our proposed method for enhancing or fooling of image reconstruction in brain can successfully solve many discrepancies between optically designed and perceived depths.

1 Introduction

What is different between 3D image and real object? We consider that the important difference between 3D image and real object is continuous motion parallax which is satisfied only in a few precious 3D imaging technologies. Our Arc 3D display [1] and Depth-fused 3D (DFD) display [2] are two of such 3D imaging without optical image reconstruction, including Super multi-view 3D display [3] and Visually equivalent light field 3D display [4].

Moreover, by utilizing further 3D factors, such as occlusion, brain complementation, etc., we consider that enhancing or fooling of image reconstructions in brain by using these 3D factors are also important.

In this paper, we review importance of continuous motion parallax and enhancing or fooling image reconstruction in brain.

2 Importance of Continuous Motion Parallax

In physiological factors for 3D vision, binocular disparity and vergence are satisfied by almost 3D displays. Although multi-view 3D displays have coarse movement parallax, continuous movement parallax and accommodation are difficult to satisfy in almost 3D displays. As accommodation has low sensitivity, we consider that continuous motion parallax has an important role for 3D perception like a real object.

In this section, examples of 3D displays with continuous motion parallax and their drastic effects will be reviewed.

2.1 DFD Display

Figure 1 shows principle of DFD display. DFD display is composed of two layered 2D displays with a gap. When front and rear images are overlapped from midpoint of observer eyes and luminance ratio between them are changed, front and rear images are depth-fused to one 3D image and its depth can be changed according to luminance ratio.

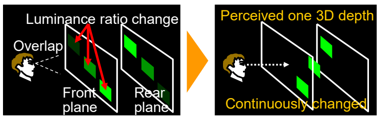


Fig. 1 DFD (Depth-fused 3D) display

Figure 2 shows perceived depths of continuous motion parallax in DFD display. Even at very large front-rear gap of 1600 mm, perceived depths can be successfully changed continuously, resulting in continuous motion parallax in DFD display.

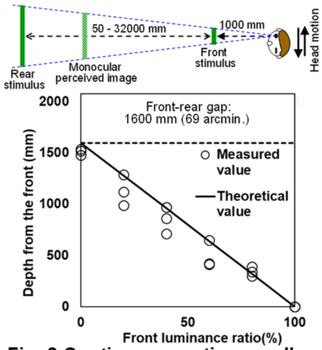


Fig. 2 Continuous motion parallax in DFD display

2.2 Arc 3D Display

Figure 3 shows principle of Arc 3D display [1]. In Arc 3D display composed of arc-shaped scratches, one bright spot appears on arc-shaped scratch according to one eye position by using a single light. (a) Different bright spot positions of both eyes by interocular distance lead to binocular disparity. (b) Automatic and continuous moving of bright spot according to eye movement results in continuous motion parallax.

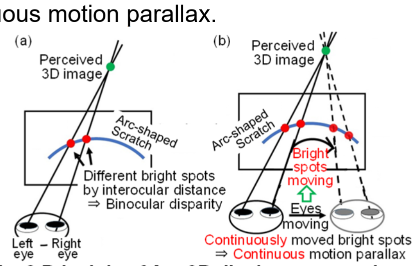


Fig. 3 Principle of Arc 3D display: an arc-shaped scratch corresponds to a pixel of usual display

2.3 Perceived depth robustness for decreasing one-eye visual acuity

Not a few anisometropic people with different visual acuities between both eyes are well known to have difficulty in perceiving depth.

Figure 4 shows difference of perceived depth degradations between stereoscopic and DFD displays. Perceived depth degradations were evaluated by ratio of correct answer in middle depth stimulus between three depth stimuli. Stereoscopic display has large degradation by decreasing one-eye visual acuity to 0.1. On the other hand, little degradation can be achieved in DFD display [5] even at lower visual acuity of one eye around 0.1 because of continuous motion parallax even at fixed head.

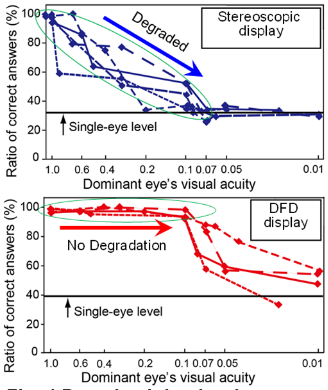


Fig. 4 Perceived depth robustness for decreasing one visual acuity of one eye in DFD display

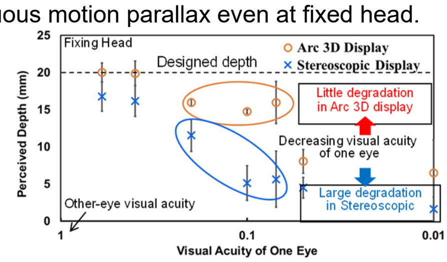


Fig. 5 Little depth degradation in Arc 3D display by decreasing one-eye visual acuity

Figure 5 shows little degradation of perceived depth in Arc 3D display. Also in Arc 3D display, little degradation of perceived depths can be achieved [6] even at lower visual acuity of one eye under 0.1 because of continuous motion parallax even at fixed head.

Thus, continuous motion parallax is considered to have important role for perceiving depth like a real object.

3 Enhancing image reconstruction in brain

Even when optical or physical configuration is correctly designed and set up, perceived depths are sometimes widely different from designed positions. For example, floating images by use of optical lens are frequently perceived around lens position, not at designed depths. This section describes the examples of discrepancy between designed and perceived depths, and solutions by enhancing image reconstruction in brain by using continuous motion parallax.

3.1 Sticking problem of floating images to real object surface

Figure 6 shows sticking examples of floating image to a real object. When real object, such as large truck, is in front of your car, floating image designed at faraway cannot be perceived at far depth penetrated into real object, but is stuck at near real object surface (rear surface in truck) like left illustration.

Right graph shows this discrepancy between designed and perceived depths. When observer head is fixed, floating images both by stereoscopic and Arc 3D displays are stuck to positions of real image at large range of depths. This is a severe problem for applying 3D display to navigation in various fields.

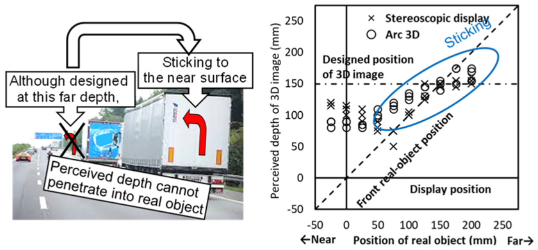


Fig. 6 Floating image sticking to real object surface

3.2 Solution of sticking floating image to real object surface by using continuous motion parallax

Figure 7 shows solutions for sticking 3D image to real object surfaces. Solutions are to utilize continuous motion parallax. (a) By moving observer head, perceived depths in Arc 3D display can successfully penetrate into or behind real object, although stereoscopic images remain stuck to real object surface. (b) By moving 3D images, perceived depths in Arc 3D display can also successfully penetrate into or behind real object, in contrast to stereoscopic images stuck to real object surface [7]. These are because Arc 3D display has continuous motion parallax and stereoscopic display has not motion parallax.

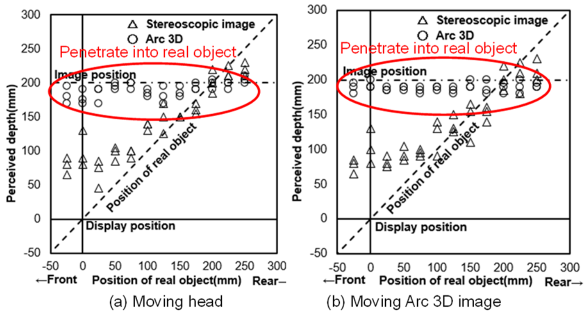


Fig. 7 Arc 3D image penetration into real object by moving (a) head and/or (b) Arc 3D image

Thus, continuous motion parallax can improve floating image sticking to real object surface by enhancing image reconstruction in brain.

4 Fooling image reconstruction in brain

Besides above enhancing image reconstruction in brain by continuous motion parallax, we reported that several important visual factors, such as occlusions, brain complementation, etc., improve 3D image perception. This section describes the examples of fooling image reconstruction in brain by using occlusion and brain complementation besides continuous motion parallax.

4.1 Aggressive use of floating image sticking for virtual moving of floating image depth

There are many techniques for forming spatially floating image, such as one using a half mirror or a lens [8] as shown in Fig. 8. Such augmented-reality method can provides the fusion of a real object and a floating image. However, in the real stage, the large monitor needs to move in order to move the floating image backward or forwards, resulting in difficulty to apply for many applications.

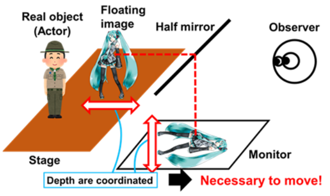
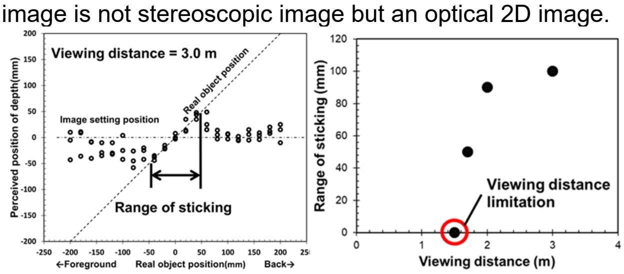


Fig. 8 Problem in floating 3D image using a half mirror

If it would be possible to move the perceived depth of the floating image more easily without moving the monitor, floating image could be applicable for much more applications. In previous section 3.1, floating images by stereoscopic display or arc 3D display are stuck to a real object in the absence of motion parallax [7]. This phenomenon suggests that we might stick even floating image using half mirror to real object, although this floating image is not stereoscopic image but an optical 2D image.



(a) Floating image moving by sticking (b) Sticking range increasing

Fig. 9 Aggressive use of floating image sticking for moving floating image depth

Figure 9 shows perceived depth dependence of floating image on real object position change. In left graph at viewing distances of 3.0 m, perceived depths of floating images can be successfully changed by changing real object position in the range of ± 50 mm. Deviations are different between the sticking region and other region. This indicates that mechanisms for depth perceptions are considered to be different between sticking region and other region.

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

Thus, sticking of floating image to real object can successfully achieve floating-image depth motion.

4.2 Pseudo perceived depth in several side-by-side 2D displays by using occlusion effects

For on-line communications, conventional 3D displays are expensive and have problems that special equipment, such as 3D glasses, parallax barrier or lenticular lens, etc. is needed and that stereo-blind people cannot enjoy 3D perception. If depth perception can be obtained only by pictorial cues, such as occlusion effect, even stereo-blind people can also enjoy 3D perception.

We have proposed a new simple pseudo 3D display [9] utilizing occlusion effect by frames and/or gap in two side-by-side 2D displays with moving stimuli across the displays. Figure 10 shows our proposed method using occlusion effect. In our proposed pseudo 3D display, two 2D displays are arranged side by side with frames (bezel), gap, horizontal bend and vertical inclination. Moreover, horizontally moving stimuli are displayed across two displays behind their frames and/or gap. This results in pseudo-depth perception behind the frames and/or gap by occlusion effect.

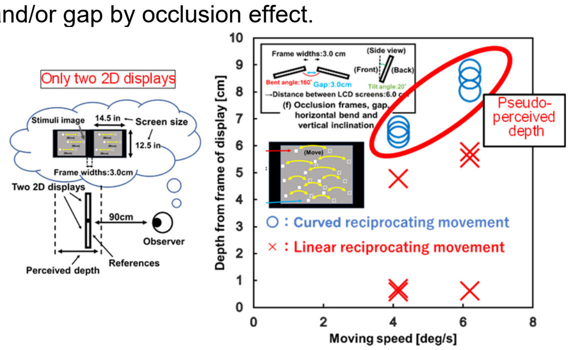


Fig. 10 Pseudo-perceived depth by using fame, gap and curved reciprocating movement

In right graph, pseudo-perceived depths can be successfully increased to 7-9 cm at curved reciprocating stimuli by using frame, gap and display bend and inclination, although linear reciprocating stimuli have perceived depths of 5-6 cm. Moreover, curved reciprocating stimuli does not have zero perceived depths around 2D display surface.

Thus, our simple pseudo 3D display utilizing occlusion effect only by using two side-by-side 2D displays can successfully provide pseudo-perceived depths.

4.3 Space blending method for fixing face gazing angle only by using two mirrors

In hybrid meeting of on-site and on-line participants over a few people that have become mainstream in today's COVID-19 situation, there is a problem that on-site listeners are difficult to know whom on-line speaker is talking to [10]. In order to solve this problem practically, we propose a pseudo face-orientation fixed display of on-line participant by space blending of floating 2D face images only using two mirrors with bend and inclination, everywhere on-site participants are positioned.

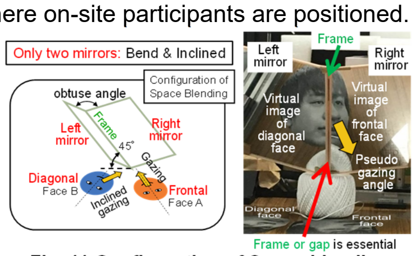


Fig. 11 Configuration of Space blending of two face orientations using two mirrors

Figure 11 shows configuration and an example photograph of our simple and pseudo face-orientation fixed display. Two mirrors combined at obtuse angle are inclined at 45 degrees above frontal and diagonal face images as shown in right photograph and left illustration.

Figure 12 shows principle of our space blending of two face orientations. 45-degree inclined and obtuse-angle combined mirrors as show in Fig. 11 provides two vertically standing and crossed optical virtual images of frontal and diagonal face images behind two mirrors. This illustration also indicates that ratio of these two crossed and vertically standing virtual images is automatically changed according to observer position change. This leads to automatic angle change between pseudo gazing direction and observer position. This automatic angle change results in fixing pseudo gazing direction of on-line participant everywhere on-site participants are positioned.

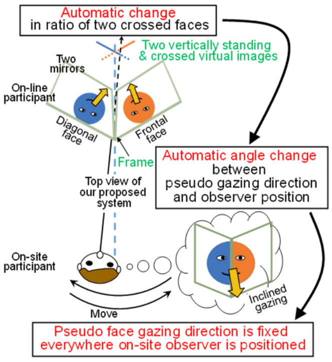


Fig. 12 Principle of Space blending for fixing pseudo gazing direction of on-line participant

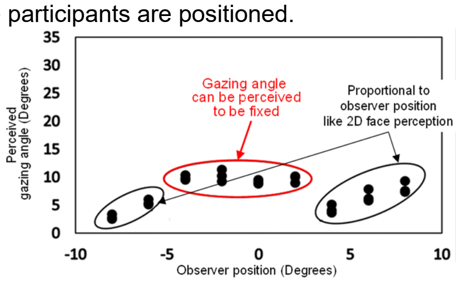


Fig. 13 Perceived gazing direction dependence on observer position by space blending of two face orientations

Figure 13 shows perceived gazing direction dependence of on-line participant on on-site observer position by using our space blending of two face orientations. Outside observer positions of －5 ～ +3 degrees, perceived gazing angle is linearly increased as observer position increases. These linear increases of gazing angle dependences are the same as that of 2D face. 2D face orientation is well known to follow observer position. On the other hand, at observer positions from −5 to +3 degrees, perceived gazing angles remain almost constant, resulting in fixed face orientation of on-line participant everywhere on-site observer are positioned.

Thus, fixed gazing direction of on-site participant can be successfully achieved by using our space blending of two face orientations.

5 Summary

Continuous motion parallax plays an important role in reconstructing 3D image because of enhancing image reconstruction in brain. It is also possible to enhance or fool image reconstruction in brain by using occlusion and brain complementation.

DFD display and Arc 3D display with continuous motion parallax have perceived depth robustness for decreasing one-eye visual acuity or anisometropia.

By moving head and/or 3D image, perceived depth in Arc 3D display can penetrate into or behind real object surface.

Perceived depth of floating image by use of half mirror can be moved without moving original display by using sticking effect to real object movement.

Moving 2D images across two side-by-side 2D displays with frame, gap and display bend and inclination can provide pseudo perceived depths by using occlusion effect.

Space blending of two face orientations by using only two mirrors can achieve fixed pseudo gazing direction of on-line participant everywhere on-site participants are positioned.

Thus, we have proposed and developed our methods for enhancing or fooling image reconstruction in brain by using continuous motion parallax, occlusion effect and brain complementation.

Acknowledgement

This study was supported by JSPS KAKENHI Grant Numbers JP19H04155, JP20K11919, JP20K21817, JP20H05702.

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