Improvement of Perceived Depth in Binocular Stereopsis with Different Sizes of Stereoscopic Images by Using Motion Parallax

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ABSTRACT

Instability of perceived depth by binocular disparity due to different stereoscopic-image sizes can be improved by motion parallax. Perceived depth by binocular disparity without motion parallax is degraded as image size difference increased. When motion parallax is contradictory with binocular disparity, perceived depths are widely degraded regardless of image size difference.

1 INTRODUCTION

Various stereoscopic displays, such as one in 3D movies, use mainly horizontal binocular disparity and vergence. When the retinal image sizes of the right and left eyes are usually almost the same in stereoscopic images using binocular disparity, the perceived depth is stable. On the other hand, as shown in Fig. 1, when the left and right retinal-image sizes are different, for example, due to different powers in wearing glasses between the left and right eyes, perceived depth becomes unstable [1].

We previously reported [2] that motion parallax improves the instability of binocular fusion and perceived depth caused by vertical disparity. This suggests that motion parallax also improve the instability of perceived depth by retinal-image size difference, because monocular perceived depth can operate with only a single eye, resulting in no effect by retinal-image size difference. However, there is the possibility of rivalry between binocular disparity and motion parallax if depths can be perceived separately by two depth cues.

In this study, we evaluate effects of motion parallax on perceived depths by binocular disparity with retinal-image size difference in stereoscopic images by comparing perceived depth with or without head/stimulus movement.

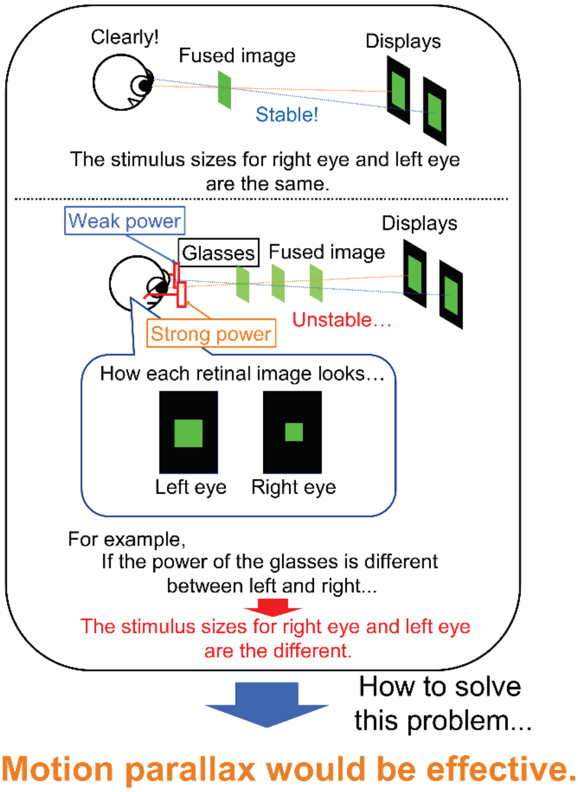

Fig. 1 An example of stereoscopic problem due to stereoscopic image size difference in the left and right eyes

2 HOW TO EVALUATE PERCEIVED DEPTHS IN BINOCULAR STEREOPSIS WITH DIFFERENT SIZES OF STEREOSCOPIC IMAGES BY USING MOTION PARALLAX

2.1 Binocular Disparity and Motion Parallax

As the distance between the left and right human eyes is about 65 mm, there is a slight difference between the retinal images of the right eye and the left eye. This difference is called binocular disparity.

When the head is moved while gazing at a certain distance, objects in front of the gazing point move in a direction opposite to the head movement, and objects behind gazing point move in the same direction in the retinal image. This is called motion parallax.

Binocular disparity and motion parallax are important physiological cues of depth perception.

2.2 Evaluation Method of Perceived Depths of Stereoscopic Images with Image Size Difference between Left and Right Eyes

Figures 2 and 3 show experimental system and stimulus for estimating perceived depth of stereoscopic images with retinal-image size difference between left and right eyes. Displays were placed at the front and side of the subject and provided the stimuli for the right eye and the left eye. Both displays were observed at the same position from a subject using a half mirror. The distance from the subject to the front display was 1000 mm. The distance from the half mirror to each display was 370 mm. A clockwise or counterclockwise circular polarizer was set on each display. The subject also wore circular polarizer glasses so that the right eye and the left eye could separately observe each stimulus of the right or left eyes, which provided binocular stereopsis. Reference images for depth estimation were displayed above and below the center stimulus. A position sensitive device (PSD) was used for tracking the position of LED light attached to the subject's head to synchronize the stimulus and head movements, which provided motion parallax.

Three squares were displayed vertically on front and side displays as shown in the upper right of Fig. 2. The upper and lower squares were fixed as references images for estimating perceived depth of middle square. The reference size of the stimulus was a square with a side of 58.4 arcmin., and the center stimulus size ratios of left and right stimuli were (i) 0.9:1.1, (ii) 0.8:1.2, and (iii) 0.7:1.3 as shown in Fig. 4. Horizontal disparity was 19.9 arcmin. which corresponded to stereoscopic depth of +100 mm behind the reference images on the display. Stimulus movements for simulating motion parallax corresponded to depths of +100 mm (behind the reference), 0 mm (on the display) or −100 mm (in front of the reference). Stimulus movement of +100 mm and −100 mm depths are called as the "consistent" and "contradictory" directions, respectively.

Figure 5 shows four experimental conditions of head and stimulus movements: (a) conventional stereoscopic display observed with fixed head (perceiving depth by only binocular disparity), (b) moving head and stimulus in consistent direction, (c) conventional stereoscopic display observed with moving head (moving head and fixed stimulus), and (d) moving head and stimulus in contradictory direction.

Perceived depth and binocular fusion were evaluated three times for each of three stimulus size ratios. The perceived depth was measured by the distance between thumb and first finger of the subject. Perceived depth was estimated just before end of displaying stimulus. Both stimulus and reference images were presented for 11 seconds. Subject moved his head horizontally in a 2 seconds cycles.

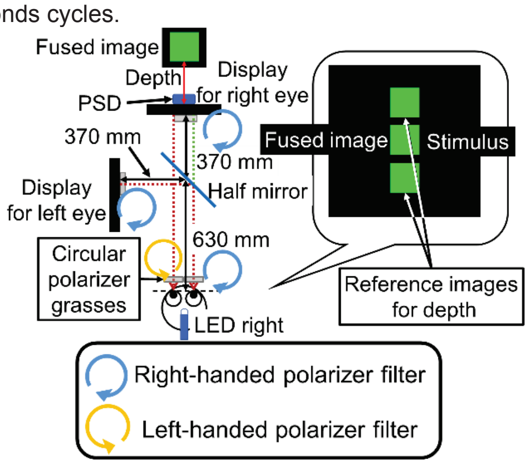

Fig. 2 Experimental system for evaluating perceived depth of stereoscopic images with image size difference

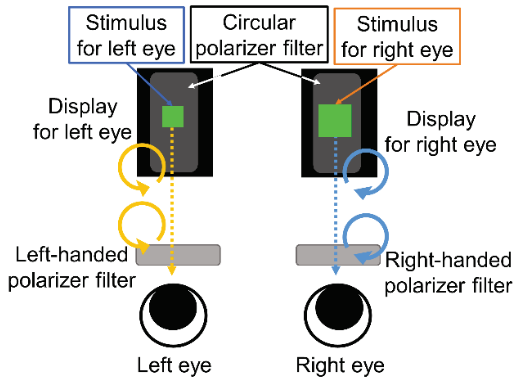

Fig. 3 Binocular stereopsis method using circular polarizer filters

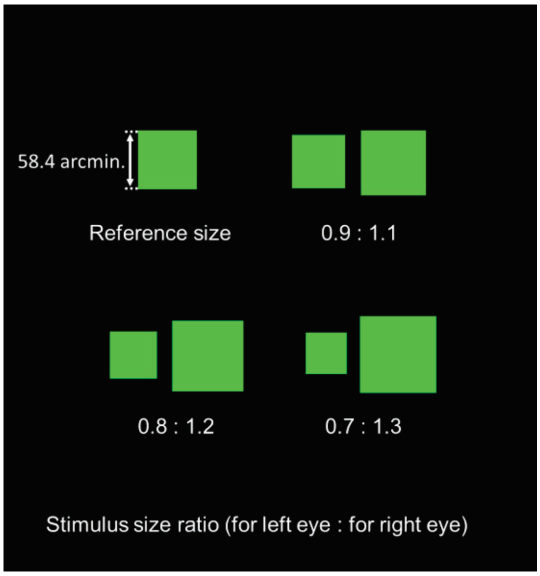

Fig. 4 Stimulus size differences between left and right eyes

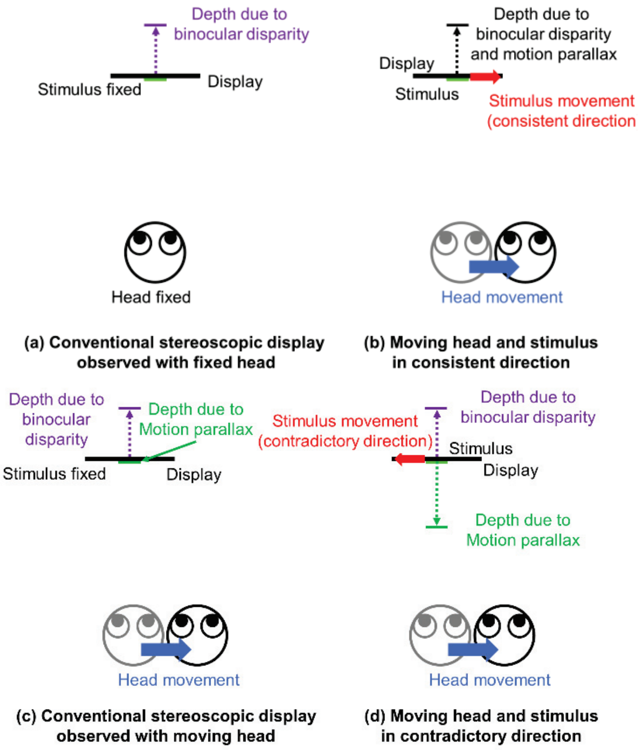

Fig. 5 Four experimental conditions of head and stimulus movements

3 EFFECTS OF MOTION PARALLAX ON PERCEIVED DEPTHS OF STEREOSCOPIC IMAGE WITH IMAGE SIZE DIFFERENCE

Dependence of perceived depth on head movement and/or stimulus movement are shown in Fig. 6. In the condition (a) conventional stereoscopic display observed with fixed head provides the depth only by binocular disparity without motion parallax. When the stimulus size difference is as small as 0.9:1.1, perceived depth is almost the same as the designed depth of +100 mm with some deviations. However, as the stimulus size difference increases, perceived depths are degraded towards the display position.

On the other hand, in the condition of (b) moving head and stimuli in the consistent direction, perceived depth is the same as the designed depth of +100 mm with small deviation. Moreover, perceived depth degradations are small enough as the image size difference increases.

In both conditions of (c) conventional stereoscopic display observed with moving head and (d) moving head and stimuli in the contradictory directions, perceived depths are widely degraded towards the display position, and have unstable and large deviations regardless of the image-size differences, resulting in difficulty to perceive the depths. As designed depths by motion parallax are set to (c) the display position (0 mm) and (d) depth of −100 mm, perceived depths by binocular fusion are considered to be pulled down towards these designed depths by motion parallax.

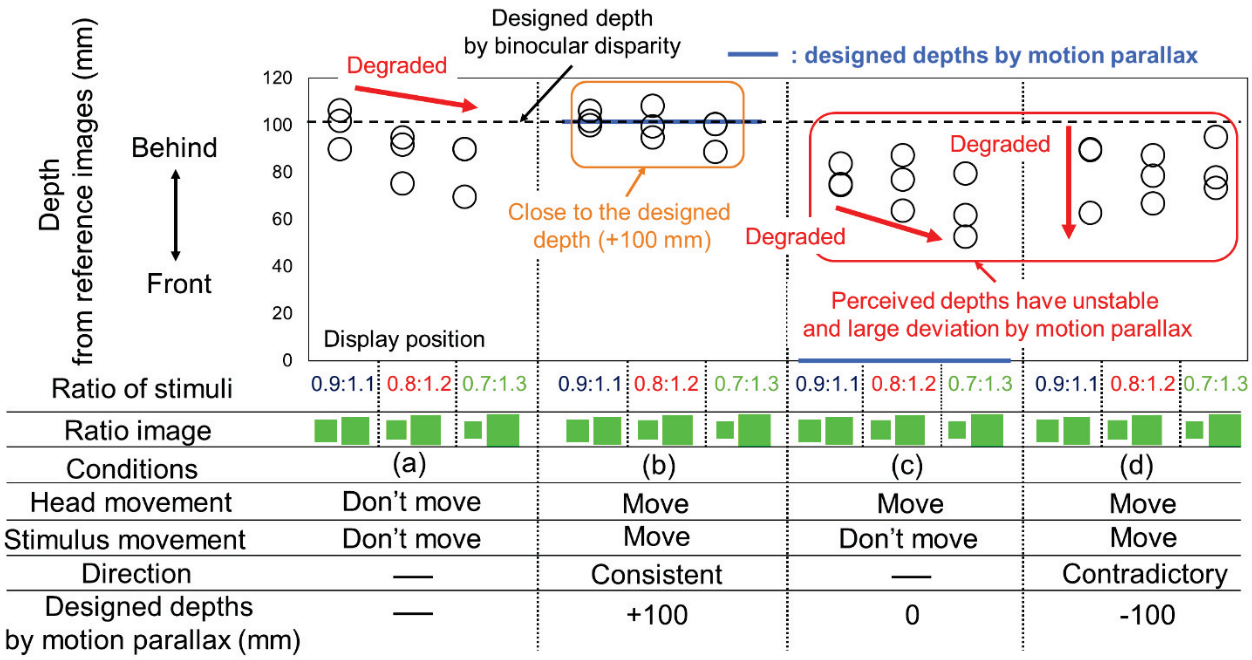

Fig. 6 Effects of motion parallax on perceived depths of stereoscopic image with image size difference

4 CONCLUSIONS

We evaluate effects of motion parallax on perceived depth by binocular disparity with image size differences between left and right eyes by comparing perceived depths with or without head/stimulus movement.

When the depths are perceived only by binocular disparity without motion parallax at fixing head and stimulus, perceived depths are degraded towards the display position as the stimulus size difference increases.

On the other hand, when motion parallax is added in consistent with binocular disparity by moving head and stimuli in the consistent direction, perceived depth is the same as the designed depth with small deviations regardless of image size differences.

In the contrary, when motion parallax and binocular disparity have different designed depths, perceived depth is widely degraded towards the display position and have large deviations. These results indicate that motion parallax give huge effect to perceived depth by binocular disparity with image size difference.

Thus, perceived depth by binocular disparity with image size differences between left and right eyes is successfully improved by motion parallax.

ACKNOWLEDGMENT

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REFERENCES

[1] J. Ong, W.S. Burley Jr., “Effect of Induced Anisometropia on Depth Perception,” Optometry and Vision Science, Vol. 49, No. 4, pp. 333-335 (1972).

[2] Y. Fukuta, H. Mizushina, S. Suyama, “Effects of Motion Parallax on Perceived Depth and Binocular Fusion in Binocular Stereopsis with Vertical Disparity,” IMID, 02_09_1642 (2020).