Evaluation of Motion Parallax to Reduce Cardboard Effect when Stimulus of Stereo Images Are Natural Scene

Kosuke Takahashi[1], Haruki Mizushina[1], Shiro Suyama[2], Kenji Yamamoto[1]

[1]{c612236011, mizushina.haruki, kenji.yamamoto}@tokushima-u.ac.jp
Dept. of Optical Science and Technology, Tokushima University, 2-1 Minamijyousanjima, Tokushima, 770-8506, Japan
[2]suyama@opt.utsunomiya-u.ac.jp
Center for Optical Research and Education, Utsunomiya University, Utsunomiya 321-8585, Japan
Keywords: 3D, cardboard effect, motion parallax, binocular disparity, shooting distance

ABSTRACT

Cardboard effect in stereo images can be successfully reduced if the motion parallax is properly given to binocular disparity. We evaluate whether the cardboard effect in can be reduced in natural-scene stereo images by adding motion parallax for four shooting distance.

1 INTRODUCTION

Recently, several 3D technologies are developed and focused on. In the 3D technologies, stereoscopic 3D display is widely used in 3D movies in cinemas, and "Cardboard effect" is known as one of the perceptual distortions in stereoscopic 3D displays [1-3]. The cardboard effect refers to a perceptual phenomenon in which some objects in a stereo image are perceived as flat objects. When the shooting distance of the camera and viewing distance of the stereoscopic display are different, cardboard effect often occurs [4-6].

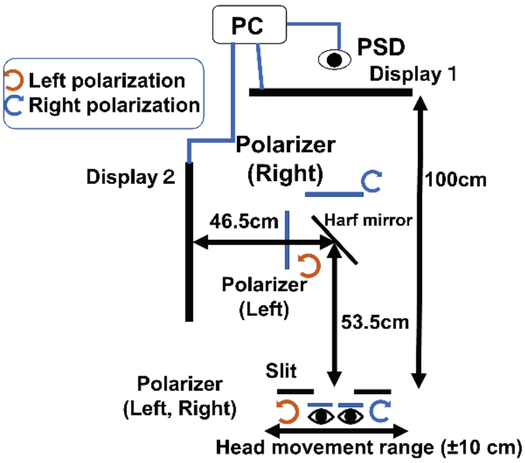
Motion parallax is one of the cues of depth perception [7]. A previous study reported that the addition of motion parallax with head movement to binocular disparity reduces the cardboard effect [8]. However, the effect of shooting distance or focal length of the lens when motion parallax is added to binocular disparity is still unclear. We were curious about the important parameter: shooting distance. Our previous experiments with varying shooting distances showed that the addition of motion parallax helped to reduce the cardboard effect [9]. The cardboard effect was more pronounced as the shooting distance increased, resulting in an improvement with the addition of motion parallax. But the stimulus images in the experiment were unnatural. In the foreground, there was a floating sphere with lots of random dots on the surface that could not exist in natural scene. In the background, an image consisting of a natural river and beautiful cherry blossoms was used. To remove this sort of unnaturalness, the stimulus images are improved to consist of people and a live stage as natural scene in this paper. As well as the previous paper [9], we evaluate whether the cardboard effect can be reduced by addition of motion parallax for four shooting distances in natural-scene stereo images. To get the subjects to answer perceived depth simply and correctly even in such kind of natural scene, we apply our original asking method in this paper.

2 EXPERIMENTAL SYSTEM FOR REDUCING CARDBOARD EFFECT

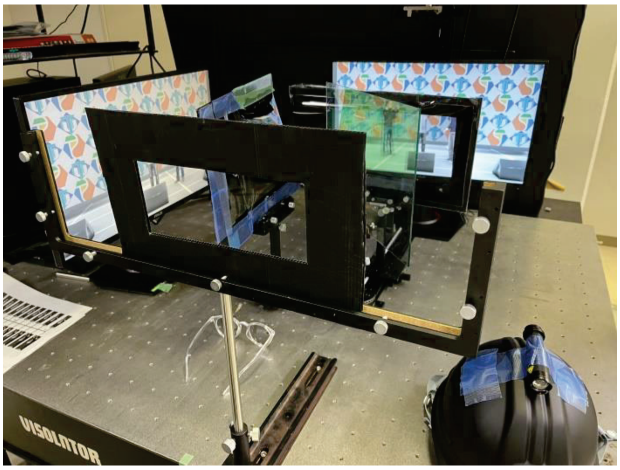
2.1 EXPERIMENTAL SETUP

Fig. 1(a) shows the experimental system as stereoscopic display with head tracking. The right eye receives only the image shown on the display 1 for the right eye. This is because the display for the right eye has a circular polarizer that makes the light right circularly polarized and the right eye wears glasses that transmit only right circularly polarized light. Similarly, the left eye receives only the image displayed on the display 2 for the left eye using left circular polarization. The viewing distance of the subject was 100 cm. Fig.1(b) shows actual experimental apparatus.

For the addition of motion parallax, we used a helmet with infrared flashlight, as shown in Fig. 1(c), and PSD (Position Sensitive Detector). The PSD detected the location of infrared light which was attached on the helmet; the PSD detected the position of subject's head (Fig.1(a)). After that, the stimulus image was updated depending on the position of the detected subject's head, which generated motion parallax. Each time the head moves 1.33 cm horizontally, one image is switched.



(a) Experimental system



(b) Actual experimental apparatus

(c) Helmet with infrared flashlight

Fig.1 Experimental apparatas

The stimulus was created by CG software [10] and consisted of a background image and three men in front as shown in Fig. 2. We used that the background and figures data are distributed online [11, 12]. Fig. 3 shows a schematic of the rendering setup. The target positions of camera (the position where the camera is always facing) was set to the center of the man wearing the cap in the middle. As shown in Fig.3, the horizontal camera movement ranges were ±40 cm, ±80 cm, ±160 cm and ±240 cm. This corresponds to the range of motion of the camera for shooting distance of 4 m, 8 m, 16 m, and 24 m, respectively. when the subject moves head horizontally ±10 cm from a viewing distance of 100 cm. As stereoscopic images, scenes taken from a horizontal distance of 6.5 cm, which is the same as the distance between the eyes, were presented to the right and left eyes, respectively.

Fig. 2 Experimental stimulus composition

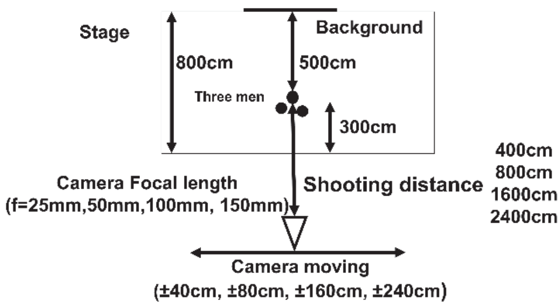


Fig. 3 Rendering system

2.2 EXPERIMENTAL CONDITIONS

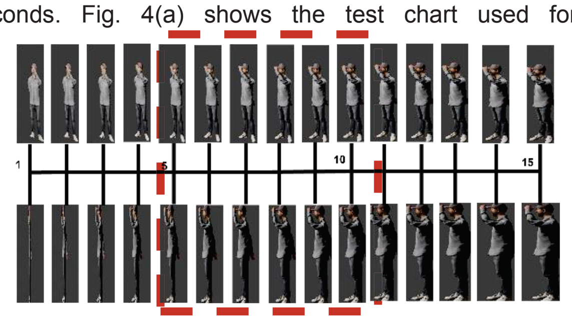
The shooting distance was the distance from the man in the center wearing cap to the camera. There were four kinds of shooting distances, 4 m, 8 m, 16 m, and 24 m which corresponded to focal lengths of 25 mm, 50 mm, 100 mm, and 150 mm, respectively. Increasing the focal length along with the shooting distance results in a constant size of the man on the display under all shooting distance conditions.

Subjects observed the stereoscopic images with both eyes while either moving their heads left and right horizontally in 2-second cycles within the range of ±10 cm or keeping their heads still. In the former case, motion parallax was presented by switching image for every 1.33 cm movement of the head position. When the head was stationary, the still image was presented when the subject's head was in the center. Also, a slit was placed in front of the subject to limit the width of the head movement.

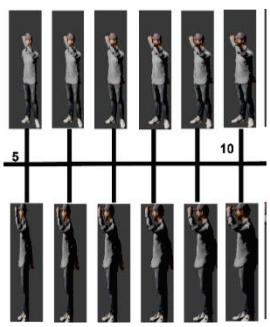
2.3 EXPERIMENTAL PROCEDURE

In our previous experiment, the images were consisted of a background image and a sphere in front of the image, so subjects were asked to answer the perceived diameter of the sphere. In this experiment, the evaluation method had to be changed because the images presented in front were of people, so we could not ask the subjects to answer the diameter of the images. Therefore, the subjects were then asked to answer the question by providing several examples of the thickness of the man they perceived so that they could easily answer the perceived thickness of the man.

In each trial, subjects reported perceived thickness of the man wearing cap after presenting the stimulus for 10 seconds. Fig. 4(a) shows the test chart used for



(a) Overall image of test chart



(b) Enlarged image from 5 to 10

Fig. 4 Test chart used to answer the perceived thickness by the subject

evaluation. Subjects answered the perceived thickness of the man wearing cap by scale value with reference to the evaluation image. In Fig.4(a), the reference image has 15 levels from scale 1 to scale 15. Scale 1 is the thinnest and scale 15 is the thickest. The case where the subject can correctly perceive the thickness corresponds to scale 10, but the subject did not know it. The top images were taken from an angle and the bottom images were taken from right beside.Fig.4(b) is an enlarged version of Fig.4(a).

3 RESULTS

Fig. 5 to Fig.8 show the scale for perceived thickness of the man wearing cap for four subjects. Some of other subjects were less likely to experience the cardboard effect, perhaps due to psychological factors. Therefore, since the purpose of this experiment was to see if the cardboard effect could be reduced by the addition of motion parallax, we limited the number of subjects to those for whom the cardboard effect occurred. The red circle indicates the move (with motion parallax) condition, the blue cross indicates the static (without motion parallax) condition, respectively. The horizontal axis denotes shooting distance, and the vertical axis denotes the scale value of perceived thickness indicated by the subject.

The cardboard effect occurs when the perceived thickness of the man is close to five or less. In Fig.5 to Fig.8, subjects perceived the scale to be near five without motion parallax. On the other hands, the red circle (with motion parallax) are scattered around the scale 9 or 10. Also, we performed a two-way repeated-measures ANOVA [13] on the shooting distance and presence/absence of motion parallax and found a significant main effect of presence/absence of motion parallax for each subjects, $F(1,2) = 20.133$, $p < 0.05$ (subject 1 in Fig.5), $F(1,2) = 158.678$, $p < 0.01$ (subject 2 in Fig.6), $F(1,2) = 75.919$, $p < 0.05$ (subject 3 in Fig.7), $F(1,2) = 2451.571$, $p < 0.001$ (subject 4 in Fig.8).

The reason for this value being near scale 5 instead of around scale 1 could be that subjects psychologically feel that men are thicker because the man scale 1 looks unnatural. The previous experiment showed that the addition of motion parallax reduced the cardboard effect, although the image was unnatural. On the other hand, in the present experiment, even if the stimulus was changed to a natural scene, the cardboard effect was reduced by motion parallax. These results indicate that motion parallax plays a significant role in reducing the cardboard effect.

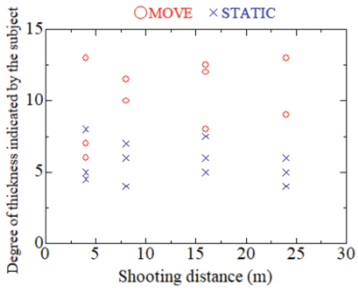


Fig. 5 Perceived thickness with and without motion parallax (Subject1)

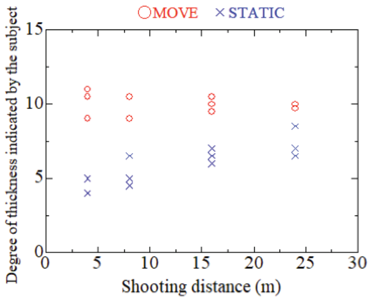


Fig. 6 Perceived thickness with and without motion parallax (Subject2)

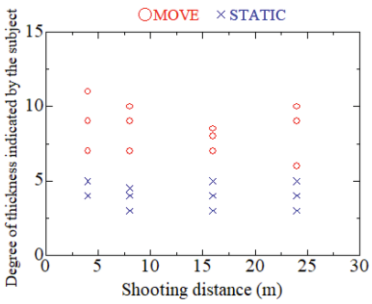


Fig. 7 Perceived thickness with and without motion parallax (Subject 3)

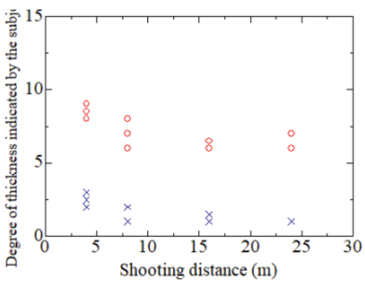


Fig.8 Perceived thickness with and without motion parallax (Subject 4)

4 CONCLUSIONS

We proposed a method of reducing cardboard effect in the stereo images, which is applicable to various shooting distances by adding motion parallax. Perceived thicknesses of the man tend to appropriately perceived thickness of the man with motion parallax. In future, we will examine whether the cardboard effect occurs due to the positional relationship of objects and reduction effect due to changes in motion parallax.

Acknowledgements

This study was supported by JSPS KAKENHI Grant Numbers JP19H04155, JP20K11919, JP20K21817, JP20H05702 and JP22H005353.

References

[1] S.Herman, "Principles of Binocular 3D Displays with Applications to Television," SMPTEJ.80, 539(6), (1971).

[2] H. Shigemasu, S. Shindate, and T. Sato, "The mechanism of "cardboard cut-out phenomenon"," VRSJ, Vol. 10, No. 2, pp.249-256, (2005, in Japanese).

[3] H.Yamanoue, M.Okui, F.Okano, and I. Yuyama, "Geometrical Analysis of Puppet Theater and Cardboard Effect in Stereoscopic Images," JSIMS 56(4), 575(8), (2002, in Japanese).

[4] J. M. Foley, "Binocular distance perception," Psychological Review, Vol. 87, No. 5, pp. 411-434, (1980).

[5] I. P. Howard and B. J. Rogers, "Binocular Vision and Stereopsis," Oxford University Press (1995).

[6] H. Yamanoue, M. Okui and I. Yuyama, "A Study on the Relationship Between Shooting Conditions and Cardboard Effect of Stereoscopic Images," IEEE Trans. Circuits Syst. Video Technol., Vol. 10, No. 3, 411-416, (2000).

[7] B. Rogers and M. Graham, "Motion Parallax as an Independent Cue for Depth Perception," Perception, Vol. 8, pp. 125-134, (1979).

[8] H. Nate, K. Susami, and T. Hatada, "Reduction in Cardboard Effect by Motion Parallax," Journal of ITE, Vol.56, No. 6, pp. 1015-1019 (2002, in Japanese).

[9] K. Takahashi, H. MIzushina, S. Suyama, and K. Yamamoto, "Effect of Motion Parallax and Shooting Distance for Reducing Cardboard Effect in Stereo Images," IMID, (2022, to be published)

[10] https://www.blender.org/

[11] https://tar.booth.pm/items/3304011

[12] https://www.turbosquid.com/ja/3d-models/3d-rigged-photorealistic-rendering-model-1413846

[13] R. A. Fisher, "The use of multiple measurements in taxonomic problems," Annals of Eugenics, Vol. 7, pp. 179-188, (1936).