Accommodation Response to a Super-Multiview Display Based on Time-Division Multiplexing Parallax Barrier

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ABSTRACT

We have measured the focal accommodation response of viewers to a dense light field generated by time-division sextuplexing parallax barriers. We have confirmed that focal accommodation in front of or behind the display screen is induced as expected.

1 INTRODUCTION

In the conventional stereoscopy, two different images with binocular parallax are shown to each eye, where binocular vergence is induced in front of or behind the screen, while focal accommodation is always adjusted to the screen. This vergence-accommodation conflict often causes eye fatigue of the viewer. Super-multiview displays have been proposed as one of the solutions to this problem [1-4].

Super-multiview displays project multiple light rays to the pupil. When two or more rays are projected onto the retina, focal accommodation is induced to the stereo image so that the image on the retina may not be a double image. To realize a practical super-multiview display, a huge number of views are required to be displayed to cover a wide viewing zone.

To overcome this problem, Takaki et al. have proposed a system to generate light field only around the tracked eye positions [5]. However, the resolution of the presented image decreases because it is based on spatial multiplexing using a lenticular lens. To eliminate resolution degradation, Kakeya et al. have proposed a method that combines time-division parallax barriers and LCD panels where the orders of color filter alignment are reversed [6]. The viewing zone in the depth direction has also been expanded by changing the number of time-division adaptively [7,8].

In the above display, the mechanical focusing effect has already been confirmed with a camera, but it has not been measured whether human focal accommodation is properly induced. In this paper we report the results of experiments to measure the focusing of human eyes to the time-multiplexing super-multiview display.

2 THEORY

One of the causes of eye fatigue peculiar to stereoscopic vision is vergence-accommodation conflict as shown in Fig. 1. When you see things in the real world, focusing and binocular convergence are adjusted to the same depth. However, when you see a stereoscopic image with a conventional 3D display, the convergence is induced to the 3D image away from the screen, while the focus is adjusted to the display screen. This difference of adjustment causes eye strain.

One of the methods to solve this vergence-accommodation conflict is super-multiview display technology. As shown in Fig. 2, super-multiview displays project images for two or more viewpoints onto a single eye. Then, in order to prevent the image from being doubled, the focal point is guided to the intersection of the rays. When the focal accommodation is properly induced, the vergence-accommodation conflict disappears.

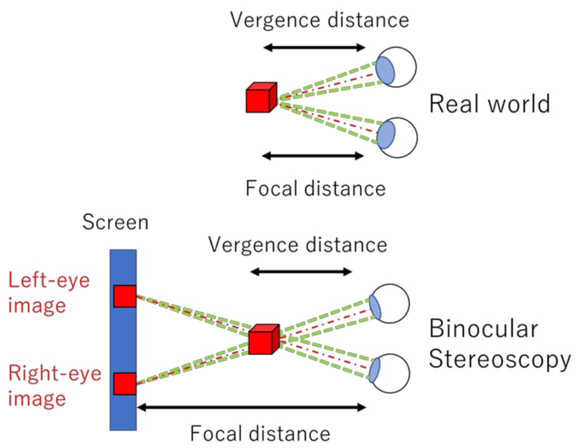

Fig. 1 Vergence-accommodation conflict.

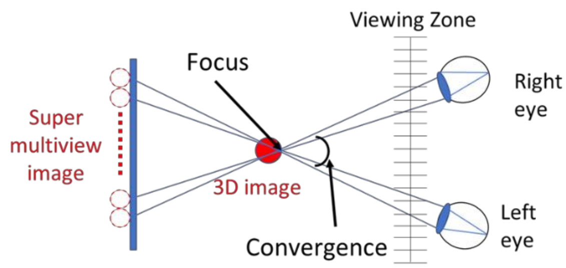

Fig. 2 Principle of Super-multiview display.

To realize a super-multiview display, huge number of images for continuous viewpoints have to be generated. To reduce the number of viewpoints required, Takagi et al. proposed a system that displays multi-viewpoint images only around the eyes using eye-tracking as shown in Fig. 3 [5].

Though this method can reduce the number of required viewpoints, the resolution of the presented image is reduced due to the spatial multiplexing based on lenticular lens optics. To solve this problem, Kakeya et al. proposed a method that combines a time-division parallax barrier and a face-to-face arrangement of LCD panels [6].

The time-division parallax barrier is a technique to increase the number of viewpoints in autostereoscopic displays without spatial resolution loss [9-14]. Fig. 4 shows an example of the time-division quadruplexing parallax barrier. Images for different viewpoints are displayed on pixels A, B, C and D by switching between 4 barrier patterns and display patterns at a high speed.

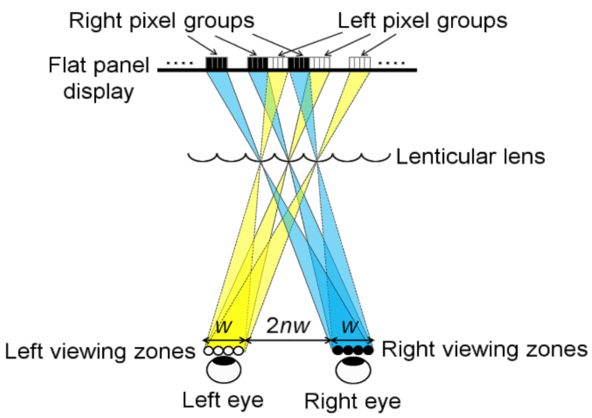

Fig. 3 Super-multiview display with head-tracking [5].

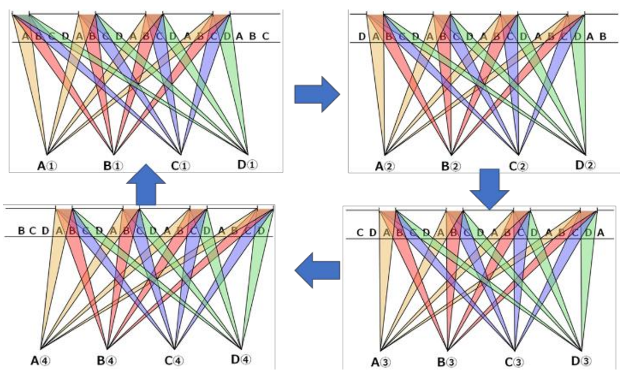

Fig. 4 Time-division quadruplexing parallax barrier.

In the time-division parallax barrier, the number of viewpoints increases as the number of time divisions increases, while the frame rate drops accordingly. For example, when time-division sextuplexing parallax barrier display is applied on a 180 Hz LCD panel, 30 Hz interlace image is realized. If a larger number of time-division is applied, the flicker stands out. One way to further increase the number of viewpoints without flickering is to assign different light rays to each color. By placing the display panel to face each other, the order of the color filters is reversed and the light rays of three RGB colors have different directivities. Thus the number of viewpoints is tripled. As a result, 18 images with horizontal parallax can be displayed when combined with time-division sextuplexing parallax barrier.

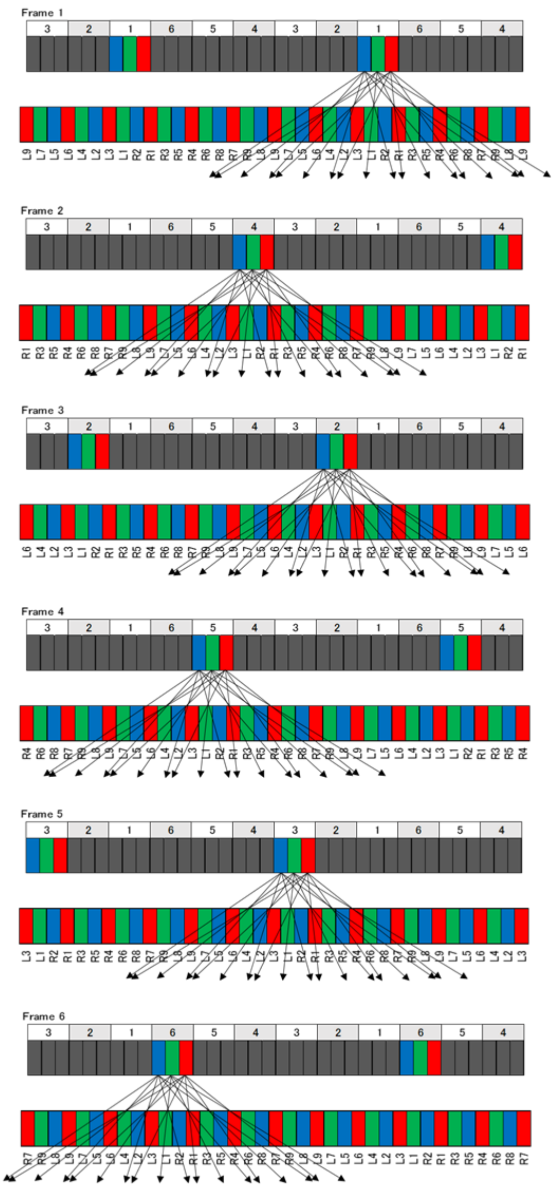

Fig. 5 Principle of super-multiview system with sextuplexing time-division parallax barrier [6].

3 EXPERIMENTS

In the super-multiview stereoscopic display described above, the focal effect has been confirmed only by camera photographing, not by human subjects. Here we conduct an experiment to measure the human focal accommodation with the time-division multiplexing super-multiview display. In the experiment, parallax images of 18 viewpoints were displayed in the horizontal direction by the sextuplexing time-division display. To measure the human focal accommodation response, we used an auto refractometer (WAM-5500). Fig. 6 and Fig.

7 show the viewing area for the experimental conditions. The distance between the two panels was 30 mm, and the distance between the panel and the observer was about 460 mm. The viewing area width per viewpoint was about 1.4 mm and the viewing area width per eye was 1.4 × 9 = 12.6 mm.

Super-multiview images were displayed 70 mm in front of and 100 mm behind the display screen. One eye of the observer was shielded. At first, a stereoscopic image was displayed in front of the display, and after 15 seconds, it was displayed behind. Accommodation response was measured while three kinds of images (asterisk, thin cone, Landolt ring) were displayed to 6 subjects, all male in their twenties. When the Landolt ring was shown, the subjects were asked to answer the directions of opening while the ring changed after each answer. A schematic of the experiment is shown in Fig. 8.

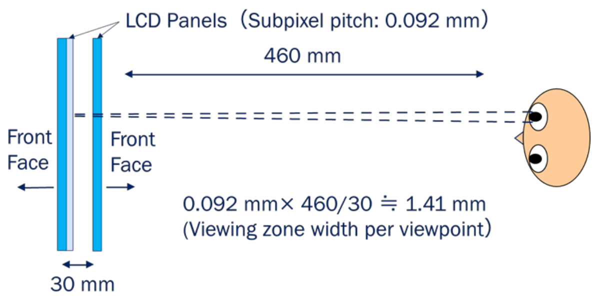

Fig. 6 Viewing range width of one viewpoint.

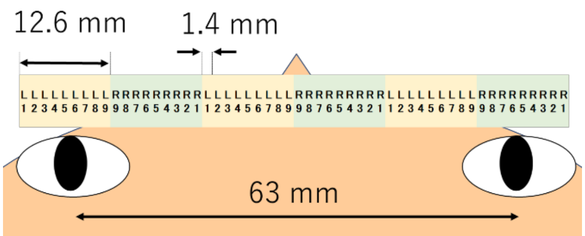

Fig. 7 Viewing zone of the experimental.

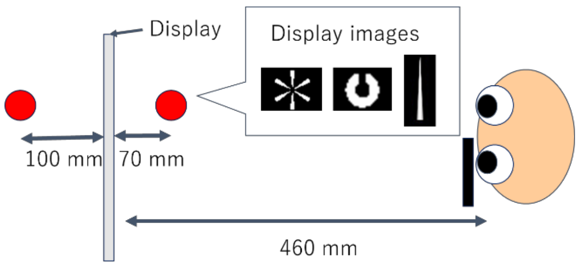

Fig. 8 Experiment schematic.

4 RESULT

The results for 6 subjects are shown in Figs. 9-14. Although the response depends on the subjects and the kind of image to be displayed, some results indicate that the absolute value of diopter decreases after around 15 seconds, when the depth of the super-multiview image changes. One possible reason of the unstable result is the parallax only in the horizontal direction.

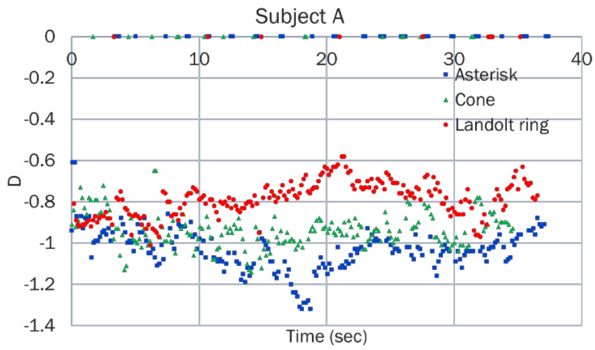

Fig. 9 Result of Subject A.

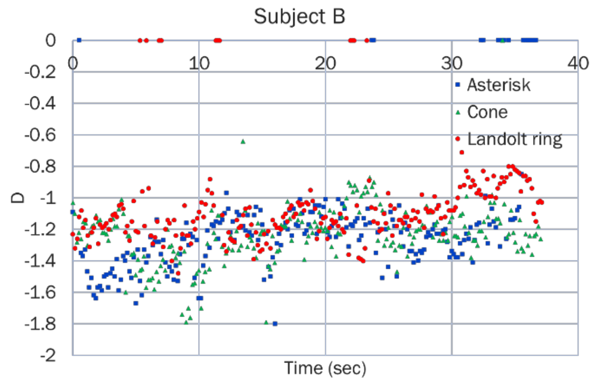

Fig. 10 Result of Subject B.

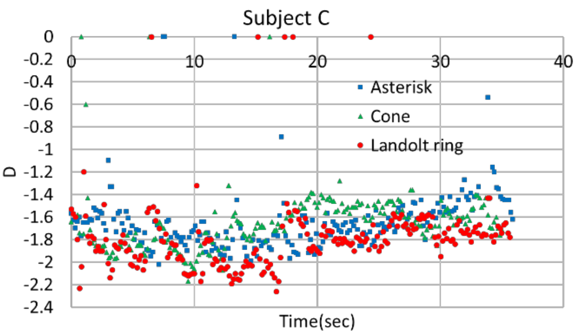

Fig. 11 Result of Subject C.

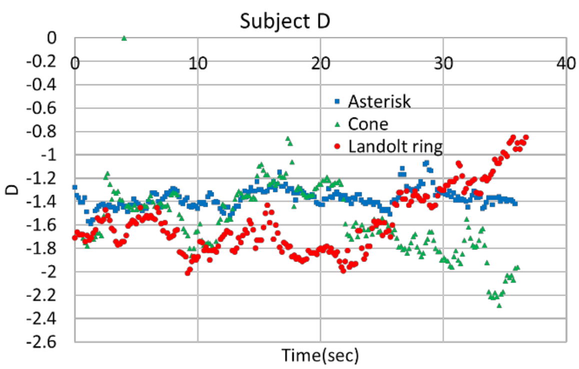

Fig. 12 Result of Subject D.

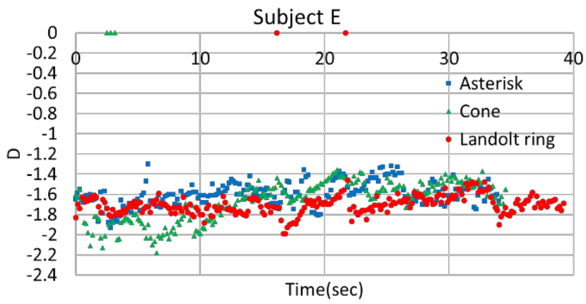

Fig. 13 Result of Subject E.

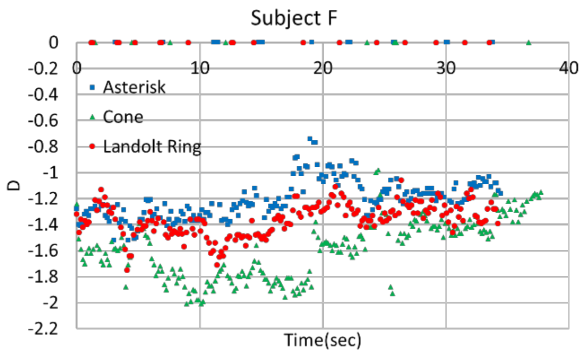

Fig. 14 Result of Subject F.

5 CONCLUSIONS

In this paper, we have confirmed the effect of super-multiview display using time-division parallax barrier on human focal accommodation. From the experimental results, we have found that it has some effect to induce human focusing, although the effect is dependent on individuals and the kinds of images to be displayed.

ACKNOWLEDGEMENT

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