Realization of Time-Division Multiplexing Parallax Barrier Using a Lenticular Lens

Hayato Mitomi, Hideki Kakeya

s2020790@s.tsukuba.ac.jp
University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki, 305-8573, Japan
Keywords: 3D; autostereoscopy; backlight; low power consumption

ABSTRACT

In this paper, we propose a time-division multiplexing parallax barrier system using a lenticular lens, which improves light efficiency. The lenticular lens generates a fine striped pattern to be used for the parallax barrier. The basic principle of the proposed method is tested with a prototype system.

1 INTRODUCTION

Parallax barrier is one of the most well-known methods to realize autostereoscopy. However, the conventional parallax barrier systems have limited viewing zones and the image resolution drops because of the barrier structure.

One solution to maintain high image resolution is to use a directional backlight composed of a light guide film and a pair of light sources [1-3], where autostereoscopy is realized by time-division of images on the display panel and the directionality of backlight. The drawback of this method is the fixed viewing zone due to the fixed directionality of backlight. To enlarge the viewing zone, directionality of backlight has to be controlled to follow the motion of the viewer, which requires thick optical systems [4-10].

An easier and more compact way to realize full resolution autostereoscopy is time-division multiplexing parallax barrier [11,12]. The pixels of a stereo pair are divided into two frames by resolution, where one frame shows half of each view and the other frame shows the other half by shifting the phase of the barrier pattern and the image pattern. Since this system requires a pair of LCD (Liquid Crystal Display) panels layered with a short interval, the system can be thin and compact.

In addition, head-tracking technology widens the viewing zone [13-16]. By monitoring the position of the viewer, the image or the barrier pattern is adjusted accordingly to move the viewing zone so that it always follows the position of the viewer and maintains correct stereoscopy.

To ensure a wider viewing zone, Zhang et al. have proposed time-division quadruplexing parallax barrier [17-20] as shown in Fig. 1, where the same image is delivered to two of the four viewpoints, which avoids emergence of crosstalk when each of the viewer's eyes is positioned between the two viewpoints showing the same image.

When the barrier is slanted, the slits can be shifted by subpixel or sub-subpixel unit [21], which enables fine tuning of barrier patterns and reduces crosstalk when the barrier pattern is properly controlled to follow the motion of the viewer. The theory on the viewing zone without crosstalk has already been established [22,23].

Another drawback of parallax barrier is its low luminance. When the aperture ratio is 1/4, the luminance becomes 1/4 of the original image. When time-division multiplexing is applied, the image becomes all the more dark because of the usage of two LCD panels with limited transmittance. Therefore, higher power consumption is needed to maintain the luminance of image.

In this paper, we propose a method to realize time-division multiplexing parallax barrier with higher luminance and low power consumption by use of a lenticular lens to generate a barrier pattern.

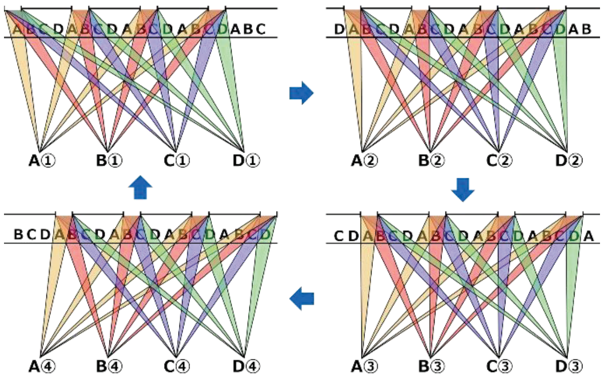

Fig. 1 Time-division quadruplexing parallax barrier.

2 PRINCIPLE

In the proposed system, we use slanted LED light bars arranged side by side as shown in Fig. 2 for the backlight. Here one every four bars are luminous, while the luminous bar is alternated for time-division multiplexing.

The image of the backlight generated by the lenticular lens reproduces the parallax barrier as shown in Fig. 3. In reality, the distance between the backlight and the lens is much larger that the distance between the lens and the parallax barrier.

Let W be the width of LED light bar, D be the distance between the backlight and the lenticular lens, d be the distance between the lenticular lens and the parallax barrier, and w be the slit width of the parallax barrier. Then

$$D : d = W : w \qquad (1)$$

holds because of the similarity of triangle.

Let W_l be the lens pitch of the lenticular lens as shown in Fig. 4. From the similarity of triangles

$$D : (D + d) = W_l : 4w \qquad (2)$$

is derived. If these equations are satisfied, overlap of slits as shown in Fig. 5 does not occur.

We can reproduce time-division quadruplexing parallax barrier by switching the luminous part of the LED light bars at a high speed as shown in Fig. 6.

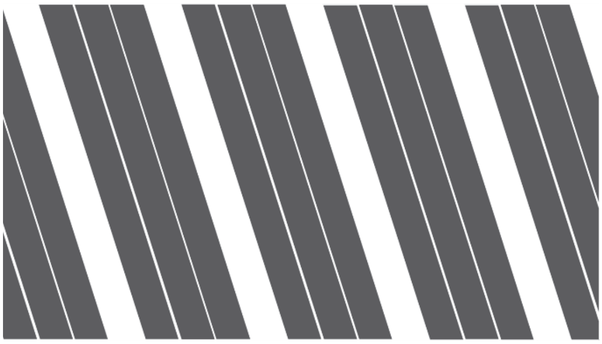

Fig. 2 Arrangement of inclined LED bar light.

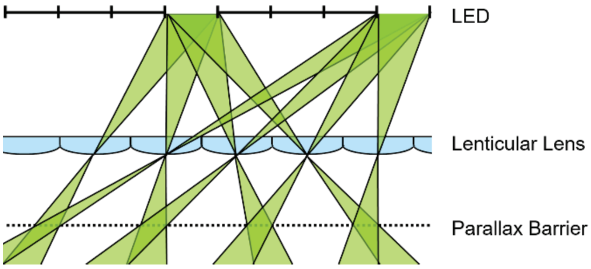

Fig.3 Generation of parallax barrier image with a lenticular lens.

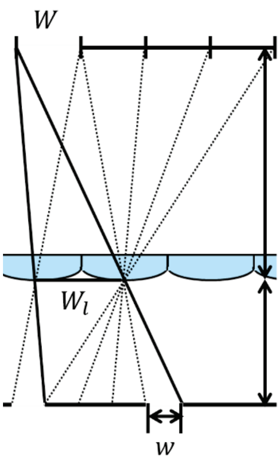

Fig.4 The relations of optical parameters.

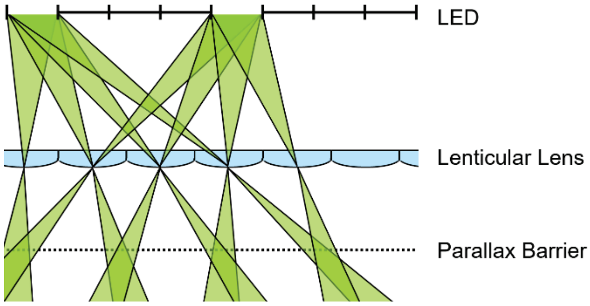

Fig.5 Overlap of slits.

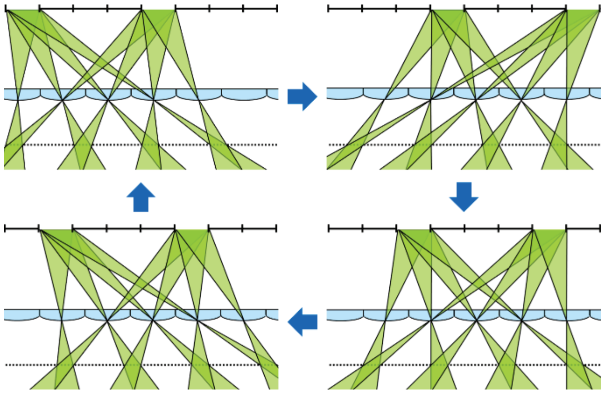

Fig. 6 Time-division quadruplexing parallax barrier with the proposed system.

3 PROTOTYPE

In the previous research, the parallax barrier and the image display panel were both composed of LCD panels with the same pixel pitch. However, the slit width of the parallax barrier is not always the same as that of the LCD panel. In this case the image for different viewpoint are mixed, which causes crosstalk as shown in Fig. 7.

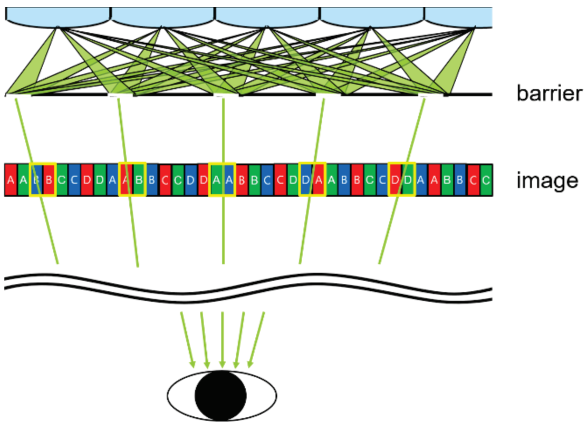

Fig. 7 Crosstalk caused by displacement of pixel pitch.

To solve this problem, the position of the barrier slits should be shifted periodically as shown in Fig. 8. The period of subpixel shift depends on the distance between the display and the observer.

To confirm the quality of autostereoscopic image obtained by the proposed method, we made a prototype system, where a LCD panel is used in place of an array of LED light bars for simplicity. The optical design of the prototype system is shown in Fig. 9. We used a pair of 24-inch full HD LCD panels. The pixel pitch of these panels was 0.276 mm. The width of the backlight bar was 90 pixels wide. The distance between the front panel and the lenticular lens was 6.5 mm, and the distance between the backlight bars and the lenticular lens was 100 mm. The lens pitch was 0.7 mm, while the radius of the lenslet was 0.5 mm.

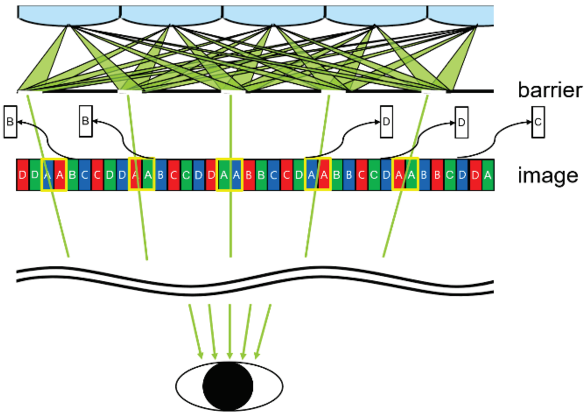

Fig. 8 Correction of slit displacement.

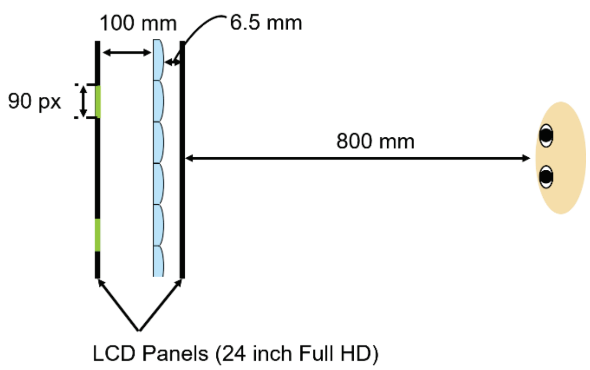

Fig.9 Optical configuration of prototype system.

4 EXPERIMENT AND RESULT

We observed stereoscopic images displayed by the prototype system. In the experiment, the distance between the display and the observing point was 800 mm, while the subpixel shift is applied every 380 subpixels.

First we showed a black image for the right eye and a white image for the left eye. The observed images are shown in Figs. 10 and 11. Though some color noise was observed, the images for the left eye and the right eye were separated as intended.

Next we showed Tsukuba stereo pair, one of the well-known stereo pair images. The observed images are shown in Figs. 12 and 13. As shown in the figures, no distinct crosstalk was observed.

Thus it is confirmed that the proposed method attains full resolution autostereoscopy as expected.

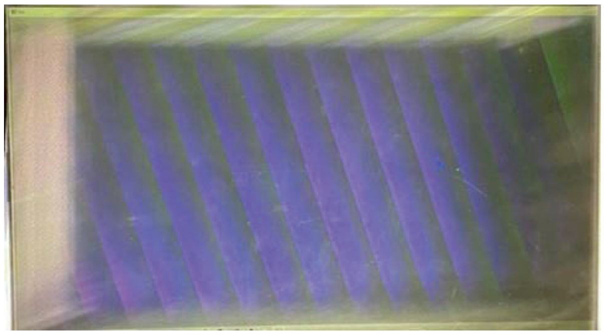

Fig. 10 A black image observed at the right-eye viewpoint.

Fig. 11 A white image observed at the left-eye viewpoint.

Fig.12 Tsukuba stereo pair observed at the right-eye viewpoint.

Fig. 13 Tsukuba stereo pair observed at the left-eye viewpoint.

5 CONCLUSIONS

In this paper, we have proposed a time-division multiplexing parallax barrier system using a lenticular lens. We have confirmed with a prototype system that an autostereoscopic display with little crosstalk is observed. As for future work, we plan to realize a light bar composed of LED to attain low power consumption.

ACKNOWLEDGEMENT

This research is partially supported by the Grant-in-Aid for Scientific Research, JSPS, Japan, Grant number: 17H00750 and is partially supported by JST CREST Grant Number: JPMJCR18A2.

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