An Adaptive Time-Division Multiplexing Parallax Barrier Allowing Multiple Observers

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ABSTRACT

We propose an autostereoscopic display allowing multiple observers with adaptive time-division multiplexing parallax barrier. To make sure that every observer is in the proper viewing zone to enable stereoscopy, the number of time-division multiplexing is switched in accordance with the distance between the observers.

1 INTRODUCTION

In recent years, with the advances of 3D technologies, medical institutions start to use 3D systems for endoscopic surgery instead of using the previous 2D systems, so that the medical staff can obtain the depth information during the surgery. However, they have to wear special glasses to observe the 3D image. Some staff also complain that they cannot communicate with each other enough without eye-contact. To overcome this problem, we need to develop an autostereoscopic display system which enables multiple users to observe high resolution and high quality 3D image at the same time.

As one of the simplest and the widely acknowledged autostereoscopic method, the conventional parallax barrier has had problems of poor resolution per view and narrow viewing zone.

Time-division multiplexing parallax barrier can deal with the poor resolution issue by involving active barriers [1,2]. By switching the parallax barrier in two frames and changing the display position of the stereo pair image accordingly, it is possible to utilize all the resolution of the panel. Since a refresh rate of 60 Hz or higher is required to present a flicker-free image to the human eye, this method requires a display refreshing at 120 Hz or higher.

To deal with the viewing zone issue, head-tracking technology has been introduced to follow the viewer's motion [3-6]. By detecting the position of the observer's eyes and changing the pattern of the barrier and the displayed image accordingly, the viewing zone is greatly expanded. Furthermore, Zhang et al. proposed time-division quadruplexing parallax barrier, which shows 2 viewpoints in full HD and holds a wider viewing zone for each viewpoint with less crosstalk [7-11]. As shown in Fig. 1, they proposed a 4-view system and used it to show 2-view images. When we apply the stereo pair to the viewpoint A(L), B(L), C(R), D(R), we obtain 4 viewpoints aligned as "LLRR", so that when the left eye is between points A and B, and the right eye is between the points C and D, 3D images without crosstalk are observed.

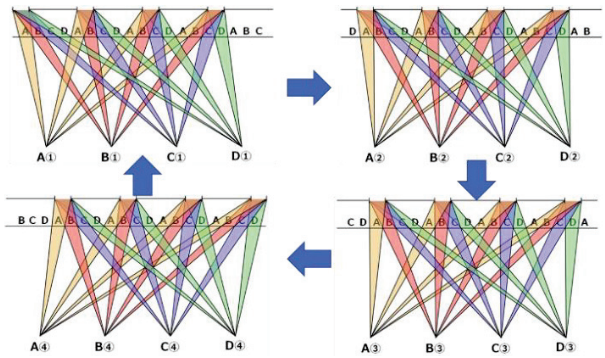

Fig. 1 Time-division quadruplexing parallax barrier.

Based on this system, shift of the slits by subpixel unit has been introduced, which realizes finer control of barrier slits to reduce the crosstalk [12]. Subpixel shift is enabled when the slits are slanted by $\tan^{-1} 1/3$. To reduce the moiré caused by the layered panels without destroying stereoscopy, a lenticular lens that diffuses light only along the inclined slits is inserted as shown in Fig. 2.

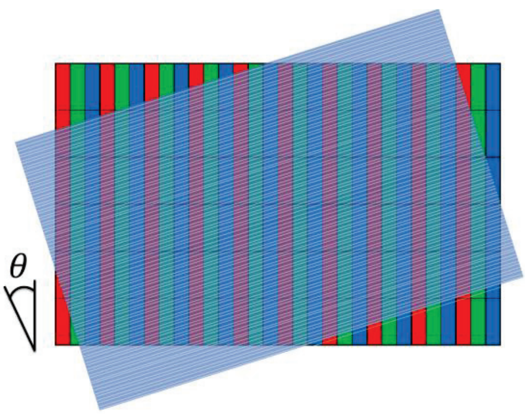

Fig. 2 Inclined directional diffusion.

Further fine shift of slit is realized by a slanted barrier slits whose inclination angle $\tan^{-1} 1/6$ [13]. Here the directional diffuser is set so as to diffuse the light in the same direction as the inclined barrier slits. In this system, the slit moves by 1/2 subpixel in the horizontal direction when the slit is shifted by 1 pixel in the vertical direction.

When the minimum shift unit is half the original size, the viewing zone without crosstalk is expanded due to the fine tuning of barrier pattern. The viewing zone in the depth direction has also been expanded by changing the number of time-division adaptively [14].

Though the expansion of viewing zone for a single viewer has been achieved, the number of viewer has been always limited to one in the autostereoscopic display based on parallax barrier.

In this paper, we propose the first prototype system that enables autostereoscopy by two observers at the same time based on parallax barrier technology. We use the adaptive time-division system to achieve this goal.

2 METHOD

2.1 Basic Principle

When two people observe the stereo image with the conventional system at the same time, one observer can obtain correct stereoscopic viewing, while the other may experience a reverse viewing where the right-eye image and the left-eye image are reversed. Then stereoscopy for one of the two observer is destroyed because the left and the right eyes are in the opposite viewing zone.

In the proposed method, we control the width of viewing zone in accordance with the distance between the two observers to maintain stereoscopy simultaneously as shown in Fig. 3. Here the widths of the areas where only the left eye image and the right eye image are observed are denoted as ΔL and ΔR respectively. Also the interval between these areas is denoted as ΔEye.

The simplest way to change the width of viewing zone is to change the number of time-division [14]. If we use the optimum number of time-division to place the left and the right eyes of the two observers in the correct viewing zone, stereoscopy is maintained for the two observers.

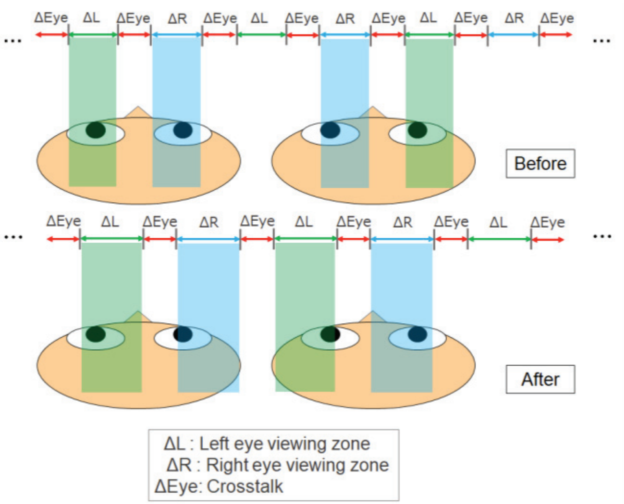

Fig. 3 Changing the width of viewing zone to keep proper stereoscopy

2.2 Fraction Time Division

To keep proper interval of viewing zone in accordance with the distance between two observers, various number of time-division should be chosen to adjust the width of viewing zone. To attain this, we can use fractional number of time-division in place of integer time-division [15].

For example, to realize 10/3 time-division parallax barrier, we move the slit in 1 pixel within 10 patterns as shown in Fig. 3 and display the stereo pair image as shown in Fig. 4. Then the width of viewing zone will be 5/6 times of the that in quadruplexing. In the same way, we can also realize 14/3 and 16/3 time-division parallax barrier.

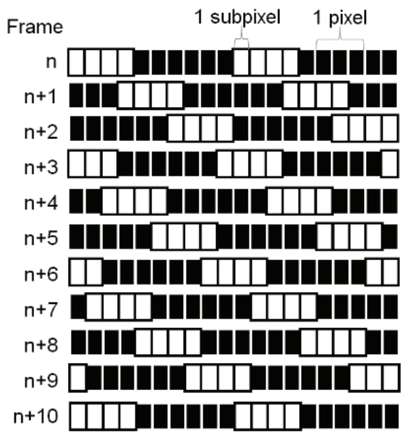

Fig. 4 10/3 Time division parallax barrier slit moving

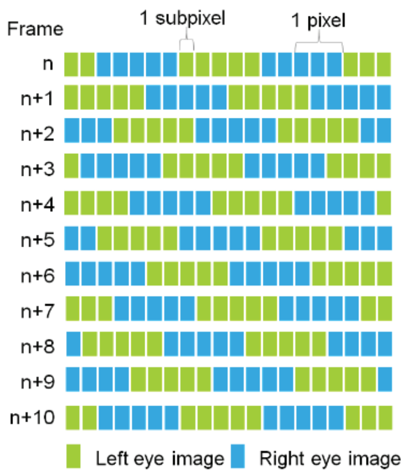

Fig. 5 10/3 Time division parallax barrier image display

2.3 Adaptive Time-Division Multiplexing

Here let the number of time division be t and let the width of single viewing unit ($\Delta L + \Delta R + 2\Delta Eye$) for that time division be l_t. When the distance between the centers of two viewers is d, we choose the number of time division t so that d/l_t may be closest to an integer.

As shown in Fig. 6, the distance *d* between observers must satisfy

$$nl_t - \Delta d < d < nl_t + \Delta d \qquad (1)$$

to ensure that the two observers can observe the proper stereoscopic image, where $\Delta d = \Delta L = \Delta R$.

At every frame, we track the eyes' position of each observer and calculate the distance between them. We select the best number of time division for that distance and apply it to the display system. We also move the slit horizontally to fit the positions of the viewers.

We have confirmed this method with a prototype dime-division multiplexing system and stereoscopy is maintained for two observers simultaneously as expected.

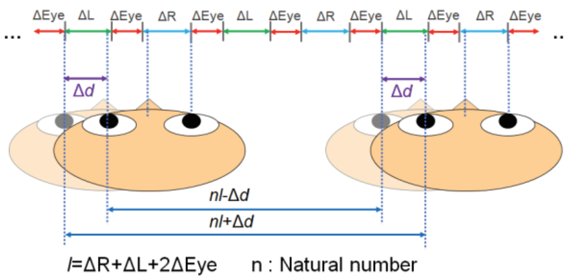

Fig. 6 Prerequisite for stereoscopy

3 CONCLUSION

In this paper, we have proposed an adaptive time-division multiplexing parallax barrier method that allows two observers to view the stereo image at the same time. We have confirmed its validity with a prototype system. The future work is to measure and reduce the crosstalk level so that multiple observers can observe a stereoscopic image comfortably. The viewing zone with little crosstalk is expected to be expanded by using more kinds of time-division.

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