Dual-View Aerial Display by Use of Linear Prism

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ABSTRACT

We propose an optical system for two-view aerial signage over an LED panel. It was confirmed that the crosstalk in the aerial image was reduced by using the linear prism. The aerial signage shows different apparent images depending on the viewing directions.

1 INTRODUCTION

Aerial imaging by retro-reflection (AIRR) has been proposed as a method to form an aerial image for a wide range of viewing angle [1]. AIRR has been utilized in various research fields. For example, research on expressing picture depth [2], research on immersive imaging device [3], and research on secure display [4]. In the conventional method of AIRR, there is one-to-one relationship between an aerial image and a light-source display, but recently, it has been demonstrated that two different aerial images can be generated at different locations from one light source by using slit array and two beam splitters in AIRR [5]. However, the previous design requires a large foot space to install the aerial signage system. To solve this problem, we proposed a novel optical design that forms two different aerial images at two directions from one light source by using a retro-reflective slit array and a beam splitter in AIRR [6]. However, this design succeeded in reduction of the foot space, whereas caused a new problem that crosstalk due to the slit array occurred. This paper proposes a new arrangement that forms aerial images without crosstalk by using the linear prism.

The objectives of this paper are to propose a new arrangement for two-view aerial signage without crosstalk and to confirm our design with a proto-type aerial signage by use of an LED panel. Our proposed optical system can show two different images depending on the viewing directions while using single LED panel and requires just several times of the LED foot space.

2 PRINCIPLE

2.1 Aerial imaging by retro-reflection

The principle of AIRR is shown in Fig. 1. AIRR is composed of three elements: a light source, a retro-reflector, and a beam splitter. Light from the light source goes to the beam splitter and splits in reflected light and transmitted light. The reflected light impinges the retro-reflector and go back to the beam splitter after the retro-reflection. The light splits again on the beam splitter. The transmitted light converges to the position of plane symmetry of the light source regarding the beam splitter.

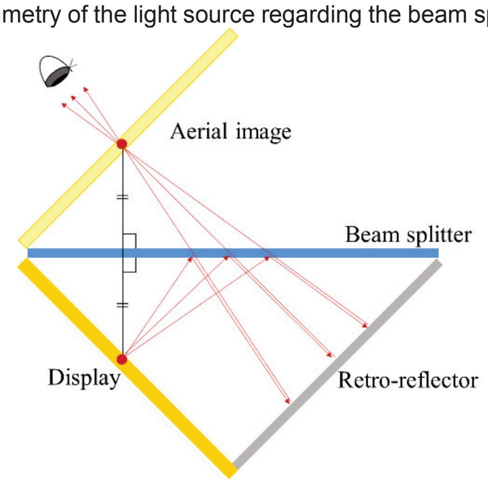

Fig. 1 The principle of AIRR.

2.2 Autostereoscopic LED display by use of a parallax barrier

Our optical design is inspired by a stereoscopic display by use of a parallax barrier [7], which is shown in Fig. 2. Interleaved images are shown on an LED panel and a slit array, called parallax barrier, is placed in front of the LED panel. Different LED pixels are visible through the apertures of the slit array depending on the viewpoint. The left and right viewing positions depend on the slit pitch and the distance between the slit array and the LED panel.

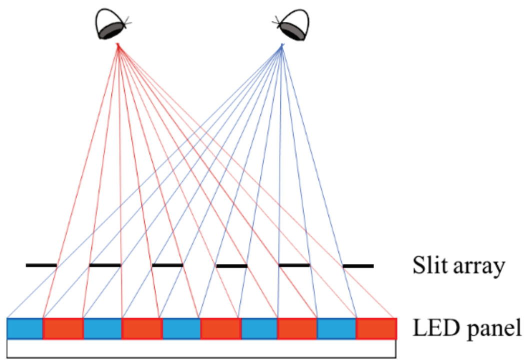

Fig. 2 Autostereoscopic LED display by use of parallax barrier.

2.3 Forming Two-View Aerial Signage Over an LED panel by Use of a Retro-Reflective Slit-Array

Fundamental structure to form two-view aerial signage in front of an LED panel is shown in Fig. 3. The parallax barrier in Fig. 2 is replaced by a retro-reflective slit array, which is a punctuated retro-reflector [8]. The retro-reflective slit array generates two-view directivity. To increase the visibility of aerial images, we made the LED invisible from the front by disposing the polarizer and the reflective polarizer in a cross Nicol arrangement. In this case, the light from the display penetrates polarizer and reflects at the reflective polarizer. The polarization angle of the retro-reflected light is rotated by 90 degrees after penetrating the quarter-wave retarder twice. Therefore, the retroreflected light transmits through the reflective polarizer and converges into the plane symmetric position of the light source regarding the reflective polarizer.

Moreover, to reduce the crosstalk in the aerial image, we improved the separation of the displayed image by inserting a linear prism in front of an LED panel, as shown in Fig. 4. The structure of linear prism is shown in Fig. 5. By arranging the linear prisms with the hypotenuse in the opposite direction for each LED pixel row, the light rays of the adjacent LED pixel rows can be bent in opposite directions. Where θ is the slope angle of the linear prism, φ is the deflection angle of light rays and n is the refractive index of the linear prism. The formula of the ray bending angle is expressed as follows:

$$\varphi = \sin^{-1}\left\{n \sin\left(\theta - \sin^{-1}\frac{\sin\theta}{n}\right)\right\} \qquad (1)$$

Characteristic curve of the deflection angle of light rays in linear prism is shown in Fig. 6. The deflection angle of light rays increases as the slope angle of the linear prism increases. It is possible to set the position with highest brightness to any position by changing the slope angle of the linear prism.

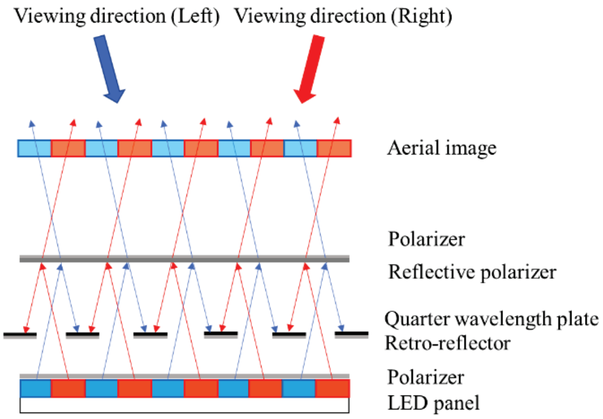

Fig. 3 Fundamental setups to from two-view aerial signage by use of a retro-reflective slit array.

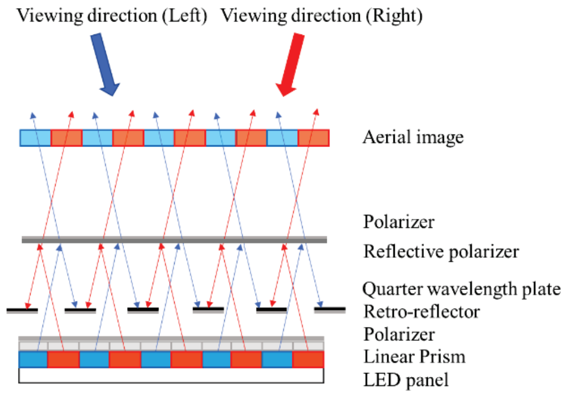

Fig. 4 Improvement of the separation of the displayed image by use of a linear prism.

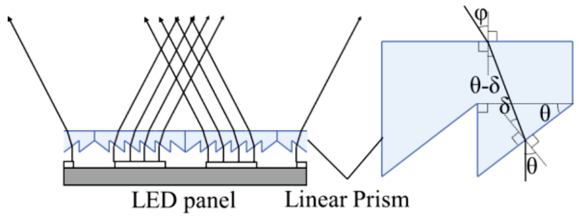

Fig. 5 LED panel covered with linear prism.

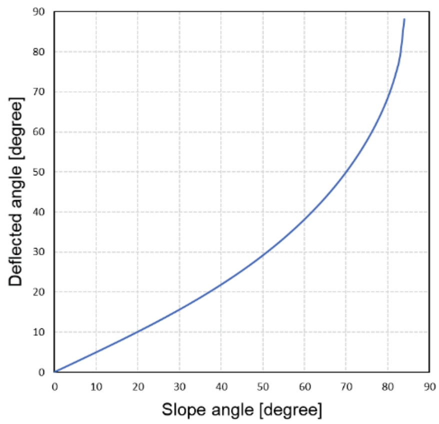

Fig. 6 Characteristic curve of the refraction angle of light rays in linear prism.

3 EXPERIMENTS

We have developed a preliminary prototype for experimental confirmation of our design. A 6-mm pitch 32 × 32 LED panel is used for the light source. linear prisms with the hypotenuse are arranged in the opposite direction for each 6 mm pitch. The slope angle of the linear prism (θ) is 45 degrees and the refractive index of the linear prism (n) is 1.49. The geometrically derived deflection angle of light rays (φ) according to Eq. (1) is 22 degrees. The retro-reflective slit array, shown in Fig. 7, is fabricated to have a pitch twice as the pitch of the source LED panel. The displayed image on the LED panel is composed of two images that are divided into horizontal rows in every two rows and alternately interleaved in an image. The interleaved displayed image used for experiments is shown Fig. 8.

Fig. 7 Retro-reflective slit array.

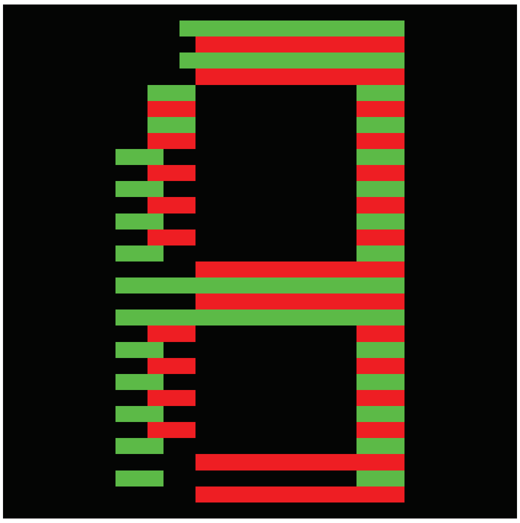

Fig. 8 An interleaved image shown on the light-source LED panel.

Retro-reflective slit array and linear prism separated the interleaved images into two images. The observation results of focusing the aerial image with a moving screen are shown in Fig. 9. The aerial image is clearly formed at the focusing distance. The image is blurred when the screen is out of focusing distance. Note that the screen observation does not maintain the directivity of the two-view aerial signage. Aerial images formed with the fundamental setups (Fig. 3) are shown in Fig. 10 and Fig. 11. Aerial images formed with the improved setups (Fig. 4) are shown in Fig. 12 and Fig. 13. From viewpoint A, a green A was visible on the aerial signage. From viewpoint B, a red B was visible on the same aerial signage. In the improved setup (Fig. 4), we have confirmed that the crosstalk in the aerial image was reduced.

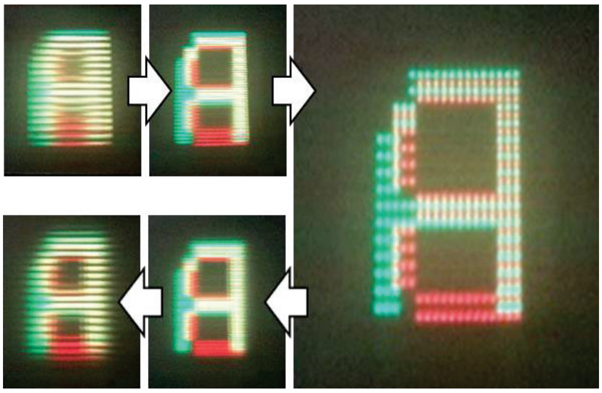

Fig. 9 Screen observation results of the formed aerial signage.

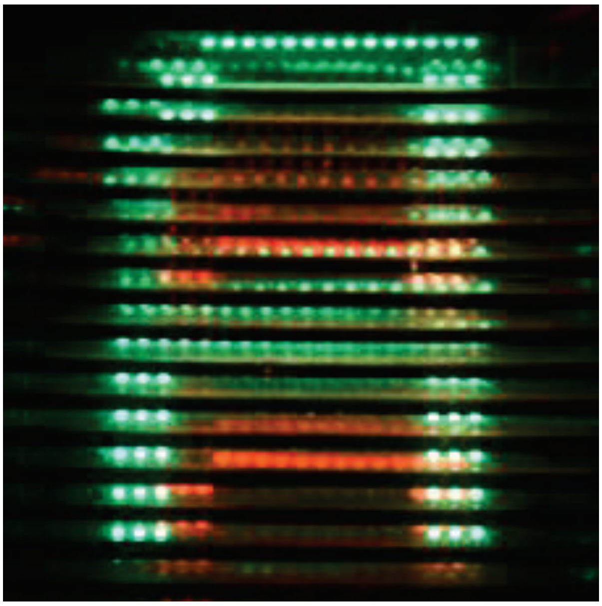

Fig. 10 Viewed aerial image from the viewpoint A.

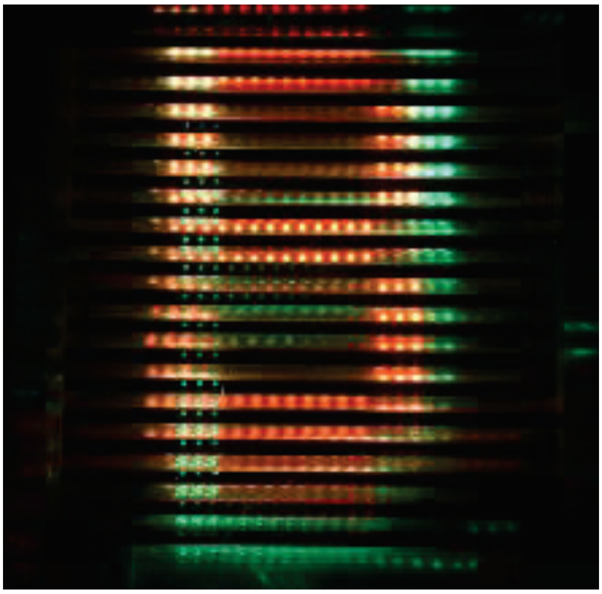

Fig. 11 Viewed aerial image from the viewpoint B.

4 CONCLUSION

We have proposed an optical system for two-view aerial signage without crosstalk over an LED panel. The new arrangement by using the linear prism improve the separation of the displayed image and reduce the crosstalk in the aerial image. Since the formed aerial screen in front of an LED panel shows different information depending on the viewing direction, two opposing people can see different aerial images from a single aerial display system. Showing aerial signage right in front of an LED panel reduces the foot space, which is suitable for the installation of a large-scale aerial display for advertisement and exhibitions.

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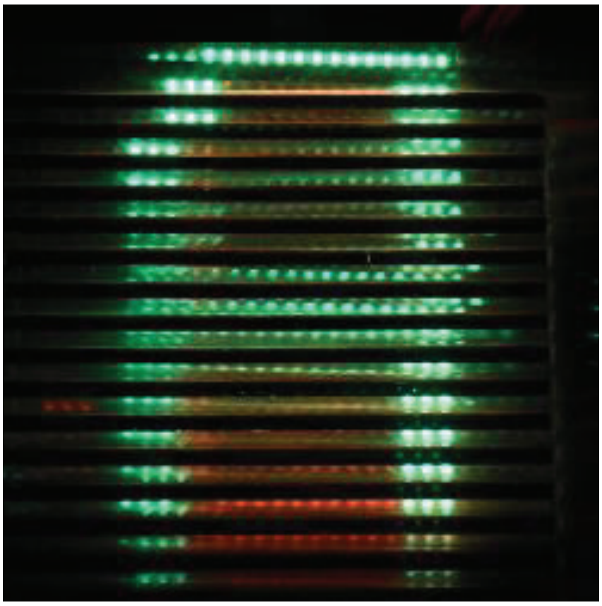

Fig. 12 Viewed aerial image from viewpoint A.

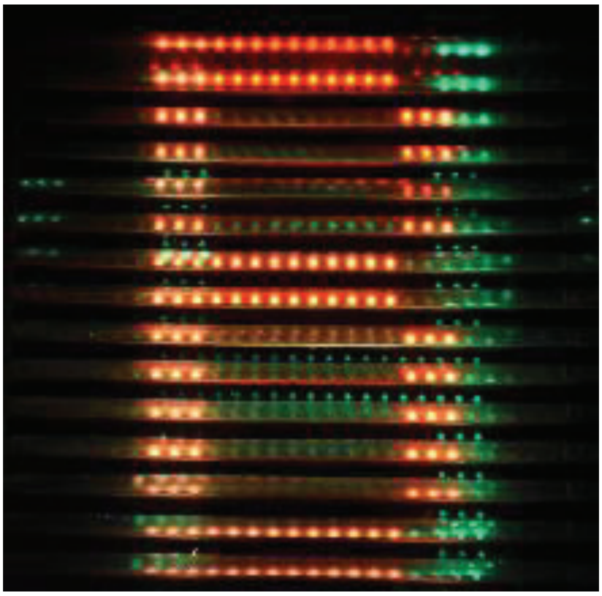

Fig. 13 Viewed aerial image from viewpoint B.

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