Exploring the combination of optical components suitable for the large device to form aerial image by AIRR

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ABSTRACT

This paper reports comparative study of optical components to form life-scale aerial image formed with AIRR (aerial imaging by retro-reflection). We assembled four life-size aerial devices that surrounds a user. We found that locating prism-type retro-reflector above the light source and the beam splitter gives brightness and high contrast.

1 INTRODUCTION

The aerial display, which has been expressed as a symbol of the future in science fiction movies, has become a reality in recent years. It is beginning to be used in digital signage, the user interface of equipment and so on. In these applications, the use of aerial display on various scales from table-top to life-size is expected. Previously, our laboratory has proposed various devices based on aerial imaging by retro-reflection (AIRR) [1]. AIRR consists of three elements: a light source, a beam splitter, and a retro-reflector. The beam splitter does not require special processing, and any transparent material with the transmission and the reflection can be adopted. The retro-reflector can be easily enlarged by using roll or tiled materials. For these reasons, it seems that AIRR is more suitable for making a large imaging device, compared to other aerial imaging technologies. However, most of the devices previously proposed are table-top sized, and there are many unclear points about the aerial images obtained when these are scaled up. In this study, we made four types of large-scale devices by combining principles and materials used in our previous studies (two types of principles, two types of light sources, two types of beam splitters, and two types of retro-reflector), and compared the aerial images they formed.

2 PRICIPLE

We adopted two principles to form aerial images. One is wall-type [2], and the other is see-through type [3].

2.1 Wall-type device

Wall-type device locates light source, beam splitter and retro-reflector as described in Fig. 1. Part of the light emitted from the light source is reflected by the beam splitter and heads toward the retro-reflector. On the retro-reflector, the light is reflected to the direction it comes, and heads toward the beam splitter. Part of the light passes through the beam splitter, which leads to the forming aerial image. When Observers see the aerial image, the background of the image is always covered with the retro-reflector and the beam splitter.

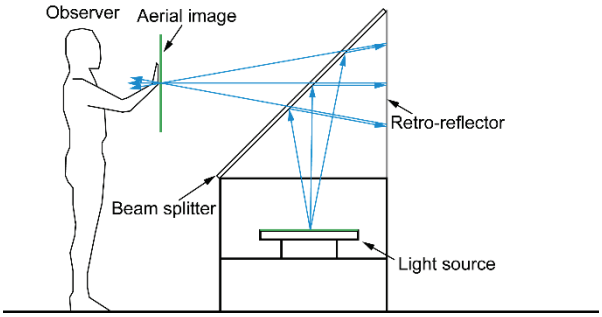

Fig. 1 Diagram of wall-type device
The way of light emitted from the light source is shown as blue arrows.

2.2 See-through device

See-through device locates light source, beam splitter and retro-reflector as described in Fig. 2. Part of the light emitted from the light source passes through the beam splitter and heads toward the retro-reflector. On the retro-reflector, the light is reflected and heads toward the beam splitter. The light is partly reflected by the beam splitter, which leads to the forming of aerial image. Observer can see the aerial image and the background of the device at the same time through the beam splitter.

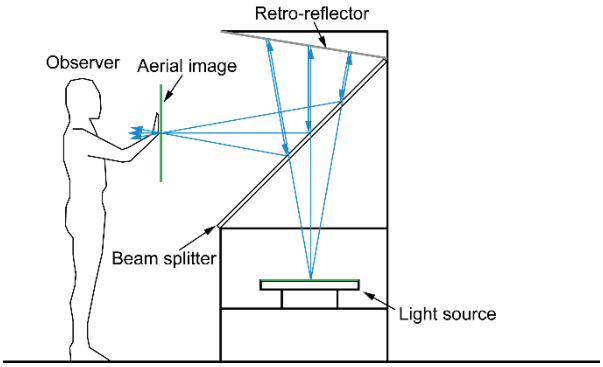

Fig. 2 Diagram of see-through device
The way of light emitted from the light source is shown as blue arrows.

3 MATERIALS

We prepared two type of retro-reflector: beads type and prism type. Beads type is flexible and gives wider viewing angle, whereas prism type has higher reflectance [4]. As the light source, high luminance LED panels (6mm and 2.5mm pitch) and LCD (PN-A601, Sharp Corporation, Japan) were used. For beam splitter, polyvinyl chloride sheet (PVC sheet, thickness: 0.1mm) and acrylic board (thickness: 5mm) were adopted.

By using these principles and materials, we made 4 large devices named A, B, C and D. Table 1 explains their component and assembled size.

Table 1 Combination of principles and materials used in each assembled device (Device A, B, C and D).
LED* and LED** indicate that their pitch is 6mm and 2.5mm, respectively.

	A	B	C	D
Principle	Wall-type		See-through	
Retro-reflector	Beads	Prism		
Light Source	LED*	LCD	LED**	LED**
Beam Splitter	PVC sheet			Acrylic
Width (mm)	2350	2200	2000	2000
Depth (mm)	1590	1400	1000	1000
Height (mm)	2950	2000	1800	1800

On the light source, a yellow square (300mm×300mm) is projected as a test image. The formed aerial image are photographed by Nikon D7500 (F6.3, 1/60 shutter speed and ISO 10000). The luminance of light sources and aerial images were measured by BM-9A (TOPCON TECHNOHOUSE CORPORATION, Japan).

4 RESULTS

Fig. 3 shows the aerial images formed by assembled devices. The luminance of light sources and aerial images, and calculated efficiency of light utilization on these devices are shown in Table 2.

5 DISCUSSION

Among these four devices, Device D formed the clearest aerial image and showed the highest efficiency of light utilization. However, its aspect ratio was different from that of a test image projected on the light source, because the beam splitter was bent by its own weight. In Device A and B, the area around the aerial image was also bright. These devices adopted wall-type principles. This is probably because the light source is close to the retro-reflector in these cases.

From results of this study, we propose that the see-through principle, the prism-type retro-reflector and high luminance LED panels are suitable to the life-size device forming aerial image. In the case of using the PVC sheet as beam splitter, a formed aerial image is less distorted, but it will be necessary to improve the brightness of the image. Otherwise, in the case of using the acrylic board as beam splitter, the bright and clear aerial image is formed, but the future work is necessary to remove the distortion of the image.

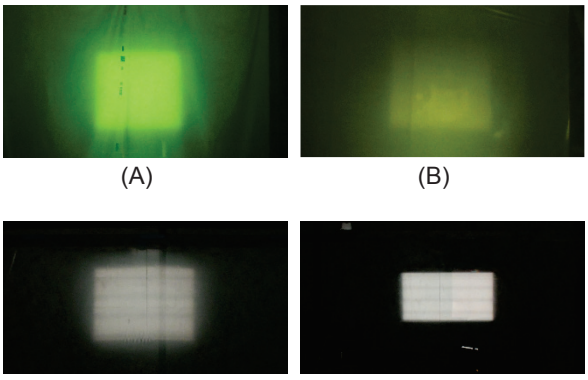

Fig. 3 Aerial images formed by assembled devices.
Panel characters indicate the name of Device.

Table 2 Luminance of light sources and aerial images of each assembled device.

	A	B	C	D
Light source (cd/m^2)	458	740	226	226
Aerial image (cd/m^2)	8.50	5.58	4.59	6.77
Efficiency (%)	1.85	0.75	2.02	2.99

6 CONCLUSIONS

From the results of combining principles and materials used in our previous studies based on AIRR, we propose that the see-through principle and the prism-type retro-reflector is suitable to the life-size device Regarding the beam splitter, we found that there are different points to be solved between PVC sheets and acrylic board.

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