Aerial 3D/2D Composite Display: Depth-Fused 3D for the Central User and 2D for Surrounding Audiences

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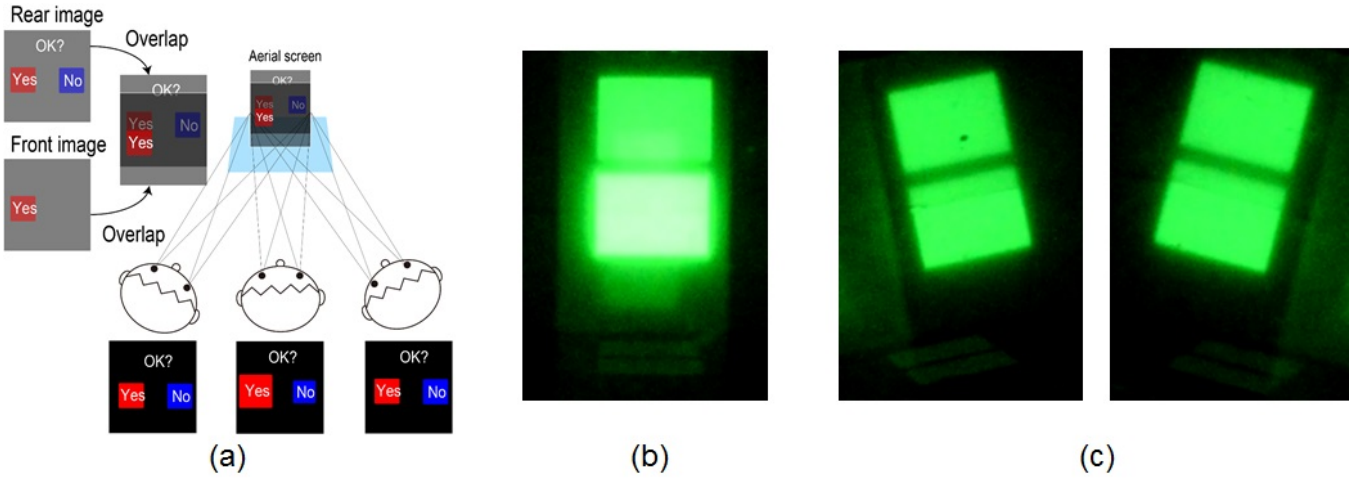

Figure 1: (a) Schematic diagram showing aerial 3D/2D composite display. While the user in the center views depth-fused 3D (DFD) image in the mid-air, only the rear aerial 2D image is visible for the viewers on both sides of the user. The two-layered aerial images are visible only for the central user. (b) Aerial 3D image observed at the center. The luminance of the bottom tile is increased because it is the addition of the front and the rear aerial image. (c) Aerial 2D images observed from the left and the right of the center. The luminance of both tiles are the same because only the rear aerial image is visible from outside the viewing position of the aerial DFD image.

ABSTRACT

This paper proposes a novel optical system to show an aerial 3D image for a user in front of the display and to show its 2D image for the surrounding viewers. Our optics forms two-layered aerial images that are visible in a limited viewing area. Outside the viewing area, only the rear aerial 2D image is visible. The viewing area is controlled by the area of a retro-reflector in AIRR (Aerial Imaging by Retro-Reflection). The center perceives depth in the aerial screen based on DFD (Depth-Fused 3D) display.

CCS CONCEPTS

• **Hardware** → *Displays and imagers*;

KEYWORDS

display, aerial display, 3D

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1 INTRODUCTION

Aerial displays are expected to be the next-generation information screens for vehicles, digital signage, and entertainment. Aerial imaging by retro-reflection (AIRR) [Yamamoto et al. 2014] is one of the aerial display techniques. AIRR can form an aerial image with a wide viewing angle and with a large-size scalability by use of mass-productive optical components. With AIRR, we can view an aerial image in the mid-air without using 3D glasses. The aerial image formed with AIRR becomes 2D when a conventional 2D flat panel display is used for the light-source display. In order to realize

dynamic interaction on the aerial screen, it is important to give a depth cue for the user because there is no physical contact at the aerial screen. In addition, showing a 3D image gives more detailed information to the user. Depth-Fused 3D (DFD) display [Suyama et al. 2004] has been proposed as a 3D display method. DFD can be achieved by two overlapping 2D images without using auxiliary tools such as glasses and features high depth controllability because its perceived depth is linearly depends on the luminance ratio between the two layered images. However, DFD perception occurs only for a limited viewing area. Outside the viewing area, observers perceive two separated images. Thus, one of the layer should be eliminated for the observers who stand outside the viewing area. The purpose of this paper is to propose a novel optical system to from aerial 3D/2D composite screens [Terashima et al. 2017]. In combination of AIRR and DFD display, an aerial 3D image is visible for the central user while an aerial 2D image is shared between surrounding audiences.

2 TWO-LAYERED AERIAL DISPLAY

Fig. 2 shows the optical system to form two-layered images in the mid-air. Light from Light source 1 is reflected by the beam splitter and reaches Retro reflector 1. The retro-reflected light transmits through the beam splitter and forms Aerial image 1. Regarding Aerial image 2, light emitted from Light source 2 is reflected by the half mirror and reaches Retro reflector 2. The retro-reflected light transmits through the half mirror, is reflected by the beam splitter, and forms Aerial image 2 above Aerial image 1. Aerial image 1 and Aerial image 2 are overlapped. The gap between the two aerial images is adjusted with the distance of Aerial image 2 from the half mirror. Note that the aerial image position is the plane-symmetrical position of the light source with respect to the beam splitter. Fig. 3 illustrates a fundamental DFD display hardware and perceived depth. The DFD display is composed of a front image and a rear image. When the front and the rear images are overlapped from the viewing position, the two images are perceived as one depth-fused image. The perceived depth is proportional to the luminance ratio between the two images.

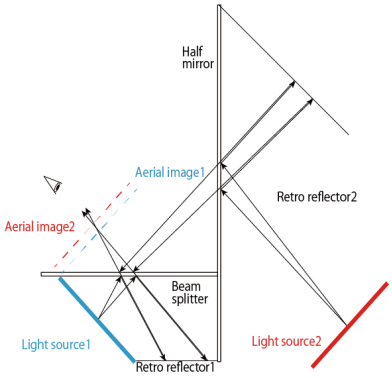

Figure 2: Optical system for two-layered aerial display.

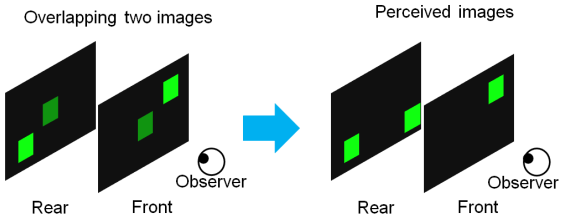

Figure 3: Displayed images for DFD display (left) and perceived depths in the DFD display (right).

3 OUR 3D/2D COMPOSITE AERIAL DISPLAY

The aerial image formed with AIRR is visible where the retro reflector is visible. Our proposed optical system is shown in Fig. 4. Aerial image 1 performs a wide viewing area because Retro reflector 1 has the width more than three-times as wide as Light source 1. On the other hand, the viewing area for Aerial image 2 is limited because the size of Retro reflector 2 is similar to the size of Light source 2. Therefore, when the viewing position is shifted to a left or a right from the center, Aerial image 2 is invisible. Experimental results are shown in Fig. 1 (b) and (c). When the aerial 3D/2D screen is viewed in front of the screen at the center, luminance-addition is conducted because of the overlapping of the aerial images. When the aerial 3D/2D screen is viewed from a left or a right by 30 degrees from the center, only the rear aerial image, that is, only Aerial image 1 is visible. The two green tiles have the same luminance, as shown in Fig. 1 (c).

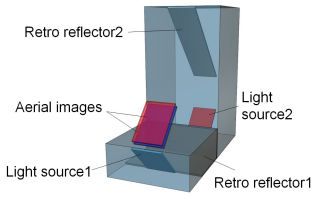

Figure 4: Optics to form aerial 3D/2D composite screen.

4 CONCLUSION AND FUTURE WORK

We have succeeded in forming an aerial 3D/2D composite screen by combining AIRR and DFD. By performing the viewing area control, the separated image problem in the DFD display was solved. Future work is to show surrounding audiences also a 3D image that the central user observes.

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