Aerial 3D Display using a Symmetrical Mirror Structure

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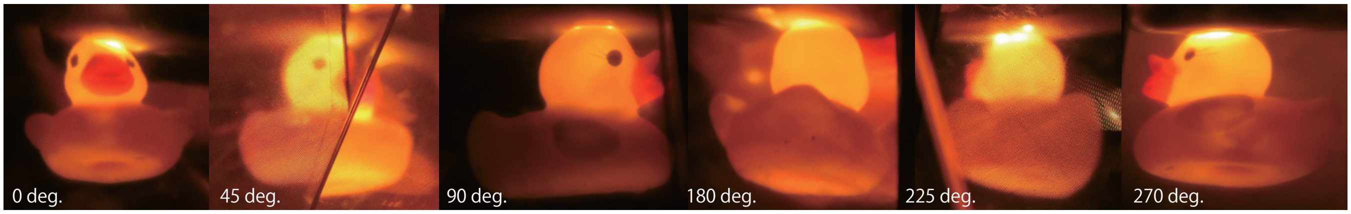

Figure 1: All-around view of a stereoscopic aerial image using our proposed system.

ABSTRACT

In the present study, we propose a new wide-viewing-angle aerial imaging display that can display aerial three-dimensional images to the surroundings. Aerial imaging has a strong visual impact, and significant efforts have been made to realize aerial imaging. In recent years, attention has been drawn to optical elements that realize retroreflective transmission, which makes it possible to easily project such images into the air. However, the viewing angle of the aerial image is narrow, and it is difficult for multiple people to simultaneously observe aerial images or to observe aerial images from all angles. Therefore, in the present study, by symmetrically arranging the mirrors at the end of the retroreflective optical transfer system, the maximum viewing angle of the aerial image is enlarged and observation from the entire circumference becomes possible.

CCS CONCEPTS

• **Human-centered computing** → *Mixed / augmented reality*; *Displays and imagers*;

KEYWORDS

aerial imaging, all-around view, micro-mirror array plate, symmetric mirror, stray light

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1 INTRODUCTION

In science fiction movies and animation, aerial-image-projection apparatuses make it possible to display various images in mid-air. A great deal of research has been carried out to realize the presentation of such mid-air images. Recently, a special optical element called a retroreflective optical transfer system has attracted a great deal of attention. This optical system can clearly display images floating in mid-air by placing a liquid crystal display (LCD), for example, under the system.

However, aerial images produced using this retroreflective optical transfer system have a narrow observable range. Moreover, if the observer moves significantly from the front, the image will not be visible. Therefore, it is impossible for multiple people to observe an aerial image at the same time, and there is a significant restriction on the observation direction. Although some researches have tried to extend this limitation[Kajita et al. 2016; Yamamoto et al. 2015], the viewing angle of them is only slightly enlarged in the vertical direction. Moreover, the magnitude of the viewing-angle enlargement has not been discussed in detail.

2 PROPOSED METHOD

In the present study, we propose an aerial imaging display that can be observed by multiple people from the entire circumference using simple mirrors and a retroreflective optical transfer system. In the proposed system, a micro-mirror lens array plate (MMAP) is used as a retroreflective optical transfer system. An important element of this proposal is an optical system which realizes magnification of the maximum viewing angle by reflecting light that is not incident on the MMAP with the mirror and supplementing the missing light of the aerial image. The structure of the optical system is shown in Figure 2.

The optical system has a structure in which mirrors are arranged so that the light source side and the aerial image side are symmetric with respect to the MMAP. We refer to this as a symmetric mirror structure. The blue viewing area (normal viewable angle) shown in Figure 2 is the observable area of the aerial image created using only the MMAP. In addition, by installing mirrors so as to sandwich the light source, the light rays which did not originally enter the MMAP are reflected by the mirror and are incident on the mirror. These light rays are folded back by the mirror installed on the aerial image side, and its maximum viewing angle is enlarged while maintaining continuity with the original aerial image. The tilt angle of the mirrors is effective to reduce the number of reflections of light rays at the mirror, which degrades the quality of the aerial image. As a result, the viewing angle is realized as in the case in which the infinite MMAP is arranged for the light source, and the maximum viewing angle reaches 180°. The enlarged angles are shown as red regions of Figure 2.

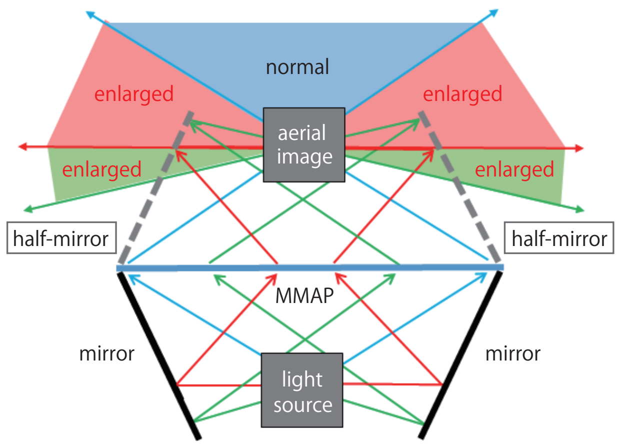

Figure 2: Basic principle of the symmetric mirror structure.

An ideal aerial image is not like a floating plane in the air, but rather exists with a 3D shape like that of the actual objects portrayed. Therefore, in the present study, a symmetric mirror optical system is expanded to correspond to a 3D-shaped light source. This can be easily realized by changing the mirror on the aerial image side to a half-mirror. Final enlarged angles are shown as green and red regions of Figure 2.

3 IMPLEMENTATION

In the present study, we evaluate the effect of the viewing-angle expansion using prototypes of the proposed optical system. The ASKA3D-Plate manufactured by ASKANET was used as an MMAP, and acrylic mirrors were used for the mirror and the half-mirror of the symmetric mirror structure. As a 3D-shaped light source, a soft vinyl toy duck (height: approximately 5 cm) illuminated from the inside was used.

A prototype capable of displaying an image around the entire circumference while avoiding stray light and the shielding problem was developed using an all-around-type optical system with ellipsoid mirrors. Figure 3 shows the actual implementation of the prototype. In order to realize a viewing angle of 360° with respect to the stereoscopic image, an MMAP arranged parallel to the ground was surrounded by a symmetric mirror, and the MMAP was designed to be observed through the mirror from the periphery. Observing the indirect MMAP, we obtained the optimum MMAP effect and devised an arrangement and angle of each mirror so as to avoid the shielding problem due to stray light and the light source itself to the degree possible. However, in actual implementation, the ellipsoid mirror was approximated by combining multiple planar mirrors. This ellipsoid mirror was designed by limiting the total number of viewpoints in the horizontal direction to 12 at 30° intervals and one in the vertical direction. This is to prevent the viewpoint from moving to near 45°, where stray light occurs when observing each mirror.

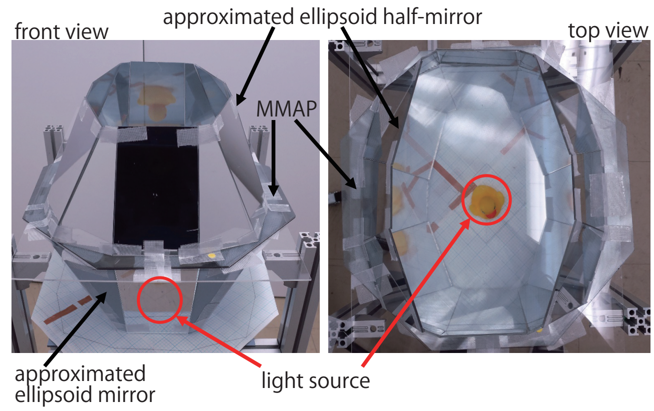

Figure 3: Prototype all-around aerial 3D display

Figure 1 shows the state of observing the aerial image from different angles in the prototype. Based on this figure, observation of the aerial image from around 360° is confirmed to be possible. Moreover, even when moving the observation viewpoint, the aerial image and the stray light can be confirmed to overlap each other so that the aerial image does not become invisible. Since the accuracy of the prototype was insufficient, displacement of the image occurs at the joint of the flat mirrors, but this problem is solved by replacing the flat mirrors with an ideal curved mirror or more precisely approximated plane mirrors.

4 CONCLUSION AND FUTURE RESEARCH

In the preset study, we proposed a new optical system that makes it possible to observe 3D aerial images from all directions. In the future, we will realize a highly accurate ellipsoidal mirror in order to improve the image quality during observation from all angles. On the other hand, as a constraint of this approach, the depth was confirmed to be reversed. This phenomenon is caused by the imaging principle of the MMAP and becomes remarkable as the light source becomes larger. In order to solve this problem, it is necessary to duplicate the MMAP or introduce another new optical system to correct the depth.

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