Wide Viewing Angle 3D Aerial Display using Micro-Mirror Array Plates and Aerially-coupled 3D Light Sources

Naoki Hashimoto
naoki@hashimoto.lab.uec.ac.jp
The University of Electro-Communications

Kota Murofushi
murofushi@hashimoto.lab.uec.ac.jp
The University of Electro-Communications

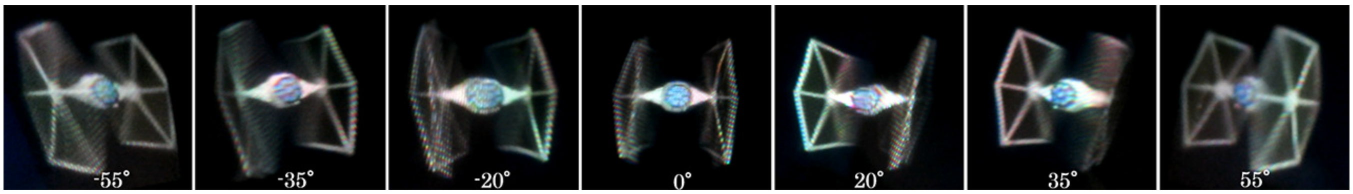

Figure 1: Aerial 3D images presented at a wide viewing angle.

ABSTRACT

In this study, we propose a method to produce a simple 3D aerial image display with a wide viewing angle. In recent years, research on aerial imagery has been actively evolving. However, in order to create a 3D aerial image with a wide viewing angle, complex and large-scale devices are still required. In the present study, the visual field of a retro-transmissive optical system is widened by a symmetric mirror structure that also enables multiple 3D images to be seamlessly coupled midair to form a wide viewing angle 3D display. As a result, a viewing angle approximately three times that of the conventional system is realized using only simple optical systems.

CCS CONCEPTS

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

KEYWORDS

3D aerial imaging, micro-mirror array plate, symmetrical mirror structure, lenticular lens

ACM Reference Format:
Naoki Hashimoto and Kota Murofushi. 2020. Wide Viewing Angle 3D Aerial Display using Micro-Mirror Array Plates and Aerially-coupled 3D Light Sources. In *Special Interest Group on Computer Graphics and Interactive Techniques Conference Posters (SIGGRAPH '20 Posters), August 17, 2020.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3388770.3407396

1 INTRODUCTION

3D images floating in the air have long appeared in science fiction movies and the like, and have attracted the attention of many people as an effect that is associated with a new era of futuristic technology. In recent years, retro-transmission optical systems that can easily produce aerial images, such as the Micro-Mirror Array Plates (MMAPs) [Otsubo 2014], have become widespread. This optical system can form an aerial image from a light source at a plane-symmetric position, and can greatly simplify the complicated optical system that was required in the past. However, the viewing angle of this aerial image is narrow, and in order to produce a 3D aerial image, a light source, that is, a stereoscopic display, with a similarly wide viewing angle is required. It is still difficult to achieve the expansion of both viewing angles at the same time. In the present study, the viewing angle of the aerial image produced by MMAPs is expanded by a simple mirror structure. At the same time, by aerially coupling multiple images on the existing stereoscopic display using the mirror structure, 3D aerial images with a wide viewing angle are realized.

2 EXPANSION OF OPTICAL SYSTEM

A symmetric mirror structure[Hashimoto and Hamamoto 2018] is adopted as a method to expand the viewing angle of MMAPs. As shown in Figure 2, this structure is composed of mirrors arranged symmetrically on both the light source side and the aerial image side. In this figure, the mirrors are arranged in parallel for simplicity although they can be set at an angle for more effective functioning. It is important to note that the MMAPs only produce an aerial image of the light incident on the MMAPs itself. Any light that does not enter the MMAPs cannot be observed as an aerial image, and consequently, the corresponding viewing angle is lost. To address this problem, the symmetric mirror structure reflects a portion of the non-incident light into the MMAPs, thus expanding the viewing angle of the aerial image.

The symmetric mirrors placed on the light source side generate virtual images A and B on the left and right sides of the light source. The light from these virtual images is then projected into the air at the symmetrical position by the MMAPs, and the aerial images A and B are generated. Next, the light that generates the aerial images A and B is reflected back by the symmetric mirrors on the aerial image side, and an image is formed at the position of the aerial

SIGGRAPH '20 Posters, August 17, 2020, Virtual Event, USA

ACM ISBN 978-1-4503-7973-1/20/08.
https://doi.org/10.1145/3388770.3407396

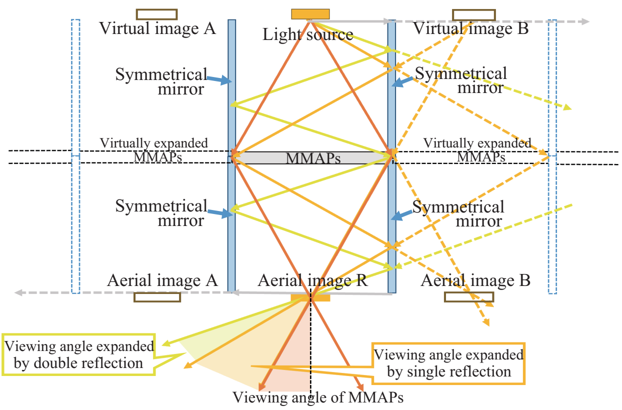

Figure 2: Viewing angle expansion by symmetrical mirror structure.

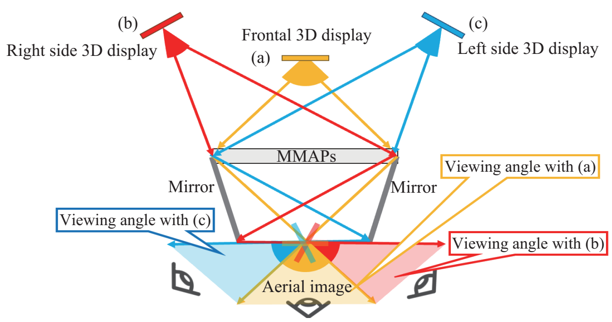

Figure 3: Aerial coupling of 3D light sources.

image R. At this time, the viewing angles of the aerial images A and B are similarly reflected back and added to the viewing angle of the aerial image R. Thus, the viewing angle of the aerial image R is expanded up to about 180 degrees.

3 EXPANSION OF 3D LIGHT SOURCE

Next, in order to create a light source capable of producing stereoscopic images over a wide viewing angle, we examine the use of multiple simple stereoscopic displays. Each display shares the viewing angle of a target object and displays a part of its 3D shape. The combination of these parts enables stereoscopic presentation to a wide viewing area.

The symmetric mirror structure is used as a method of arranging multiple stereoscopic displays at the same spatial location which shares a central axis to smoothly combine the images on each display. As shown in Figure 2, in the symmetric mirror structure, a light source and two virtual images are combined into one aerial image. Therefore, by replacing the light source and the virtual images with stereoscopic displays, it is possible to combine three stereoscopic images and produce a single aerial image with a wide viewing angle. Figure 3 shows a combination of the multiple displays and the symmetric mirror structure.

In this figure, the mirror structure on the light source side is removed. Additionally, the mirrors on the aerial image side are

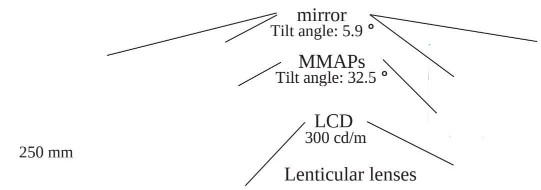

Figure 4: Overview of the implemented system.

arranged in a non-parallel fashion to reduce the number of light reflections and to suppress attenuation.

4 IMPLEMENTATION

Figure 4 shows an actual implementation of the proposed method. To avoid overcomplicating the system, three lenticular lenses (40 lpi) were attached to a FullHD-LCD to create three stereoscopic displays. The effective viewing angle of each lenticular lens at Figure 4 is about 41 degrees. By coupling the displays according to the proposed method, it is possible to cover a total viewing angle of about 123 degrees.

The MMAPs were placed at an angle to the display to prevent being fed light from the light source directly. The angle of the mirrors and the distance between the light source and the MMAPs were set as shown in Figure 4 in order to make full use of the viewing angle of the stereoscopic displays and to minimize stray light.

The results of the proposed system are shown in Figure 1. The viewing angle was about 123 degrees, which is three times that of the original lenticular display. In addition, this system can be implemented with easily available materials and without using complicated optical elements. In future studies, we will investigate a method for further expansion of the viewing angle as well as expansion in the vertical direction.

ACKNOWLEDGMENTS

This work was supported by JSPS KAKENHI Grant Number JP19H04152.

REFERENCES

Naoki Hashimoto and Kyosuke Hamamoto. 2018. Aerial 3D Display using a Symmetrical Mirror Structure. In *SIGGRAPH 2018 Posters*. 31.

Makoto Otsubo. 2014. Optical imaging apparatus and optical imaging method using the same. U.S. Patent No. 8,702,252. Washington, DC: U.S. Patent and Trademark Office.