

# Forming Multiple Aerial 3D Images by Use of Infinity Mirror, AIRR, and DS3D Display

**Kazunari Chiba<sup>1</sup>, Daiki Nishimura<sup>1</sup>, Masayuki Shinohara<sup>3</sup>,  
and Hirotsugu Yamamoto<sup>1,2</sup>**

<sup>1</sup>Utsunomiya Univ., 7-1-2 Yoto, Utsunomiya City, Tochigi 321-0904, Japan,

<sup>2</sup>JST ACCEL, 7-1-2 Yoto, Utsunomiya City, Tochigi 321-0904, Japan,

<sup>3</sup>OMRON Corp., Shiokoji-dori Horikawa-higashiiru, Shimogyo-ku, Kyoto 600-8530, Japan

Keywords: aerial image, 3D, AIRR, retro-reflector

## ABSTRACT

This paper proposes a new way of aerial display application based on infinity mirror, AIRR (Aerial Imaging by Retro-Reflection) and DS3D (Directional Scattering 3D) display. Our proposed method can form multiple aerial 3D images in a compact display setups.

## 1 INTRODUCTION

Currently, various technologies for forming images in the mid-air have been proposed. One of them is aerial imaging by retro-reflection (AIRR) [1], which features a wide viewing angle and a large-size scalability. This paper proposes an application of AIRR to form multiple aerial 3D images with a compact display system. Our proposed system consists of infinity mirror that forms a multiple virtual images of the light source with a faced mirror structure, AIRR, and a directional scattering 3D (DS3D) display. DS3D display forms a 3D image by illuminating a transparent plate structure with an LED light and features a thin structure.

## 2 PRINCIPLE

### 2.1 AIRR (Aerial Imaging by Retro-Reflection)

We use the aerial imaging by retro-reflection (AIRR) [1] as a method of forming aerial image. AIRR features a low cost, a wide viewing angle, a large-size scalability. Furthermore, the aerial image formed with AIRR is visible without 3D glasses. There is no special hardware at the aerial image position.

The fundamental structure of AIRR is shown Fig. 1. AIRR consists of three elements: a light source, a beam splitter, and a retro-reflector. Light from the light source goes to the beam splitter and splits in transmitted and reflected light. The reflected light heads for the retro-reflector. The retro-reflected 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. 2 shows an example of aerial image observed on a screen. By moving the screen back and forth, the aerial image is clearly visible at the aerial image position.

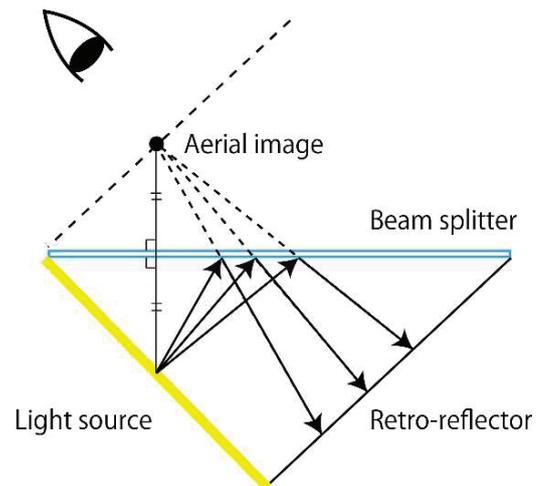


Fig. 1 Principle of AIRR.



Fig. 2 Aerial image formed with AIRR.

### 2.2 Infinity mirror

The principle of infinity mirror is shown Fig. 3. The light source is located between a mirror and a half mirror. The virtual images are indicated by (a), (b) and (c) in the figure. Image (a) is the virtual image formed by the mirror directly reflecting the light of the light source. Image (b) is formed by the mirror reflecting the light once reflecting by the half mirror. Image (c) is formed by reflecting the light beam forming (a) again by the half mirror and reflecting it again by the mirror. Similarly, multiple reflections on a mirror and a half mirror form multiple virtual images from one light source. Fig. 4 shows multiple virtual images on the mirror.

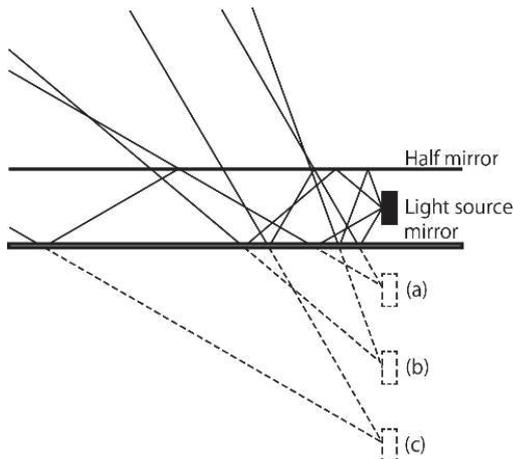


Fig. 3 Principle of infinity mirror.

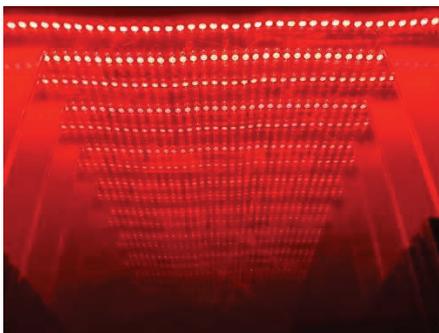


Fig. 4 Multiple virtual images formed by infinity mirror.

### 2.3 DS3D (Directional Scattering 3D) Display

One of the typical realizations of DS3D display is arc 3D display. The principle of arc 3D display is shown in Fig. 5. Arc 3D display utilizes scratches on the arc and light scattering characteristics. When the light source illuminates an arc-shaped scratch, illumination light is scattered on the narrow arc scratches on the board. Two specific bright point can be observed on the scratch. There are many arcs so that bright spots compose a pattern. Due to the difference of viewpoint between lateral eyes, the positions of the bright spots are different between both eyes. Thus, when an eye position is moved, the bright spot moves accordingly.

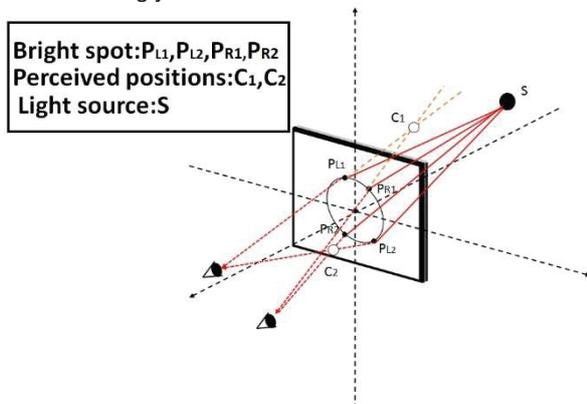


Fig. 5 Principle of Arc 3D display.

### 2.4 Infinity mirror with AIRR

Fig. 6 shows a method of forming multiple aerial images by use of infinity mirror and oblique retro-reflector. A mirror and a half mirror are placed in parallel. A light source is located between these mirrors. Since the reflectance of retro-reflector is higher near normal incidence [3], the retro-reflector is placed obliquely.

Multiple reflections between the mirror and the half mirror are performed. After the retro-reflection, the light reflected on the half mirror converges in the mid-air. In addition, light rays transmitted through the half mirror before retro-reflection also converges to aerial images. Example of multiple aerial image is shown Fig. 7. Aerial images were clearly visible.

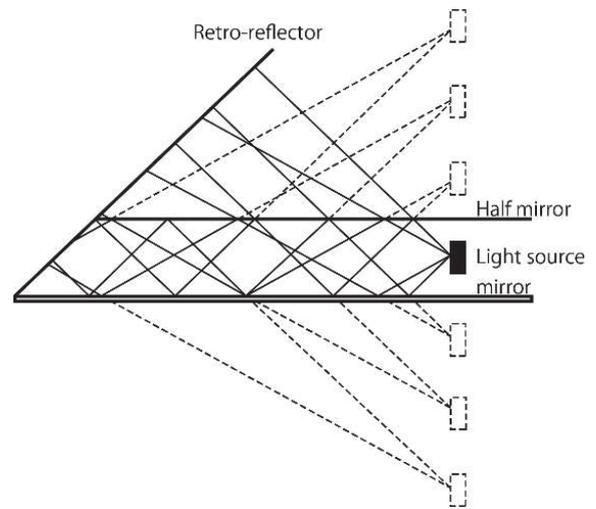


Fig. 6 Infinity mirror with AIRR.

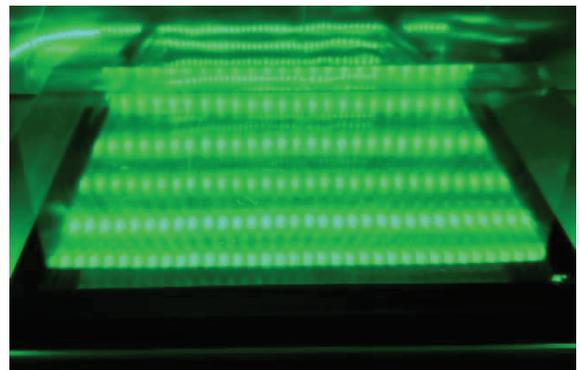
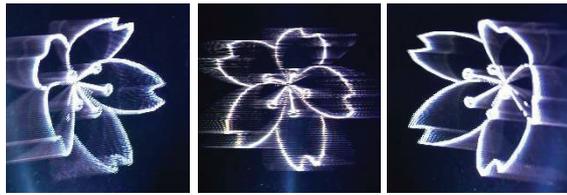


Fig. 7 Multiple aerial images formed by infinity mirror with AIRR.

### 3 MULTIPLE AERIAL 3D IMAGE FORMING IN COMBINATION OF DS3D DISPLAY, INFINITY MIRROR, AND AIRR

We propose a new optical system that combines infinity mirror, DS3D display and AIRR. Viewed results of a DS3D display are shown Fig. 8. The DS3D display has a wide viewing angle about 90 degrees left and right.



Left front right  
Fig. 8 Observations of a DS3D display.

Our proposed method is shown Fig. 9 and Fig. 10. The aerial image of the 3D image on the DS3D display is formed with AIRR. By placing DS3D display between a mirror and a half mirror, the 3D image of the DS3D display is multiply formed in the air.

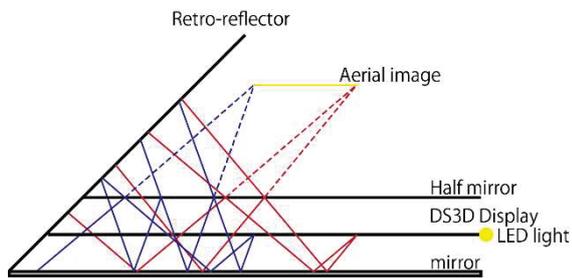


Fig. 9 Principle of our method.

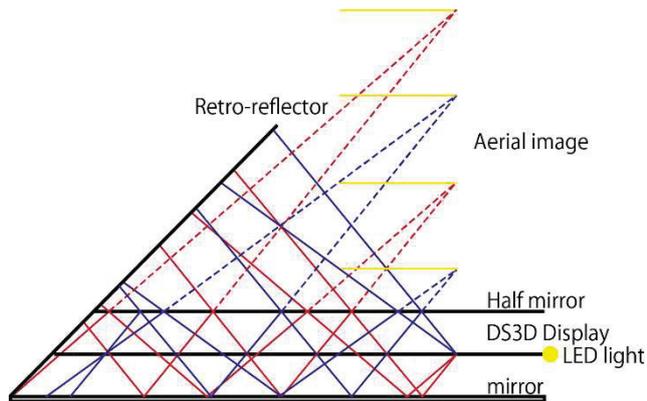


Fig. 10 Multiple aerial images with DS3D display.

#### 4 RESULTS

Multiple aerial image of pattern of DS3D display is shown Fig. 11. We can see the multiple aerial images of a flower. Fig. 12 shows a multiple virtual images, which were viewed over the mirror from different directions.

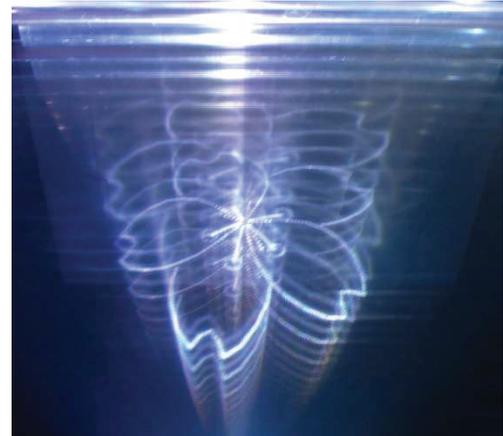


Fig. 11 Multiple aerial images formed by our proposed optical system.



Left



Above



Right

Fig. 12 Virtual images under the mirror.

## 5 CONCLUSION

We have succeeded in forming multiple aerial 3D images by using AIRR, infinity mirror and DS3D display.

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