Proposal for Light Field Mirage

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ABSTRACT

Mirage, which consists of a pair of parabolic mirrors, is a well-known 360-degree display system. This study explored replacing the parabolic mirrors in Mirage with multiple flat-panel light field displays to realize "Light Field Mirage". Rays emitted from 3D objects are reconstructed for 360-degree viewing. Preliminary experiments were conducted.

1 INTRODUCTION

A 3D display system with 360-degree visibility is expected to be used in the medical and entertainment fields. Such displays are also expected to be used for communication via the Internet.

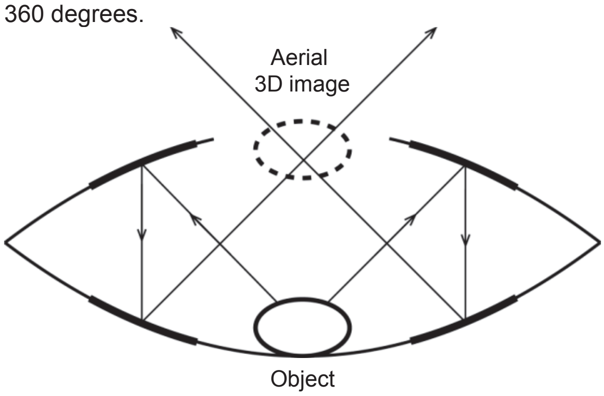
Kitamura et al. proposed a glasses-type 360-degree 3D display system called "illusion hole," that combines a flat-panel two-view 3D display and a hole to allow multiple observers [1]. Miyazaki et al. proposed a glasses-free 360-degree 3D display that consists of a concave mirror, a high-speed spatial light modulator (SLM), and a scanning mirror [2]. Butler et al. proposed a system called "Vermeer" that consists of a pair of parabolic mirrors, a high-speed SLM, and a spinning diffuser [3]. Takaki et al. proposed a system consisting of a rotating screen and multiple high-speed SLMs [4]. Because the latter three are glasses-free systems requiring a scanning mechanism, their display systems are complicated.

We propose Light Field Mirage, which consists of multiple flat-panel light field displays. It uses a simple configuration to produce 360-degree 3D aerial images without glasses. This paper provides preliminary experimental results using one light field display.

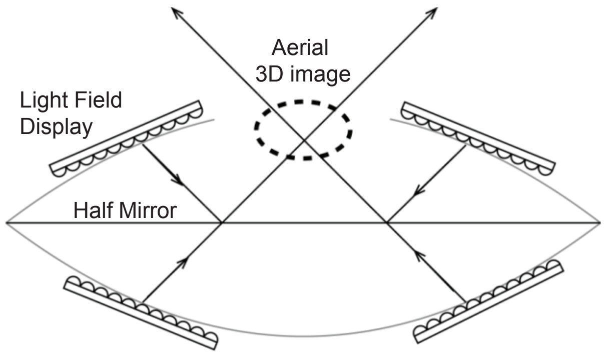
2 CONCEPT OF LIGHT FIELD MIRAGE

Figure 1(a) shows the original Mirage, which consists of a pair of parabolic mirrors. Rays from a 3D object placed on the bottom parabolic mirror are reflected twice by the two mirrors to form a real image at a hole at the top of the upper parabolic mirror. The real image can be observed from 360 degrees by multiple observers.

Figure 1 (b) shows the Light Field Mirage proposed in this study. The two parabolic mirrors of the original Mirage are replaced with multiple flat-panel light field displays, each consisting of a micro-lens array and flat-panel display. Rays from the upper displays are reflected by the half mirror. The light field displays simulate the rays reflected by the parabolic mirrors in the original Mirage system. All light field displays generate 3D images at the hole located at the top of the display system. The reconstructed aerial 3D images can be observed from 360 degrees.



(a) Original Mirage



(b) Light Field Mirage

Fig. 1 Concept of Light Field Mirage

Conventional integral imaging displays generate parallel rays to produce 3D images. This study uses the recently developed integral imaging display technique which generates rays that converge to 3D images [5, 6]. This resolution-priority integral imaging technique can provide higher resolution 3D images, although the depth of field of 3D images is shallower. In the proposed system, the central depth plane (CDP) where the rays converge and high-resolution 3D images are generated is placed at the top hole of the display system.

3 PROTOTYPE

The proposed technique places multiple light field displays at the top and bottom to generate 3D images produced at the hole away from the display screen. In this study, one light field display was constructed to verify the production of high-resolution 3D images at the hole position.

Image formation by the resolution-priority integral imaging system is illustrated in Fig. 2. Elemental images displayed on a flat-panel screen are projected in the CDP by the corresponding micro-lenses. The distance between the lens array and the flat-panel display is made longer than the focal length of the micro-lenses to locate a CDP at a finite distance.

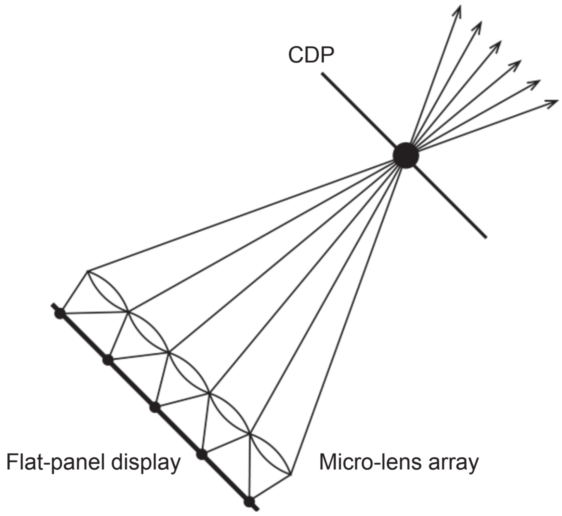


Fig. 2 Image formation by resolution-priority integral imaging method

Figure 3 depicts the experimental system. The inclined angle of the light field display was set to 45°. Table 1 shows the specifications of the micro-lens array and the liquid-crystal display (LCD) used to build the experimental system. The lens array was arranged as a hexagonal array with 58×37 micro-lenses. The lens pitch was 1.98 mm and the focal length was 10.0 mm. The resolution of the flat-panel display was 2,560×1,440. An acrylic plate 15.8 mm thick was sandwiched between the micro-lens array and the LCD panel. The distance between the lens array and the CDP was 108 mm. The diameter of the elemental images corresponded to 38.9 pixels. The resolution of the 3D images was 153×112, which was larger than the number of micro-lenses because resolution was prioritized. The viewing distance was 600 mm. The viewing zone angle was 10.7°, and the width of the viewing area was 113 mm at the viewing distance. Figure 4 is a photograph of the constructed light field display unit.

Figure 5 shows photographs of the produced areal 3D image. This image had smooth motion parallax. As shown in Fig. 5, the resolution of the 3D image appeared to be higher than the number of micro-lenses.

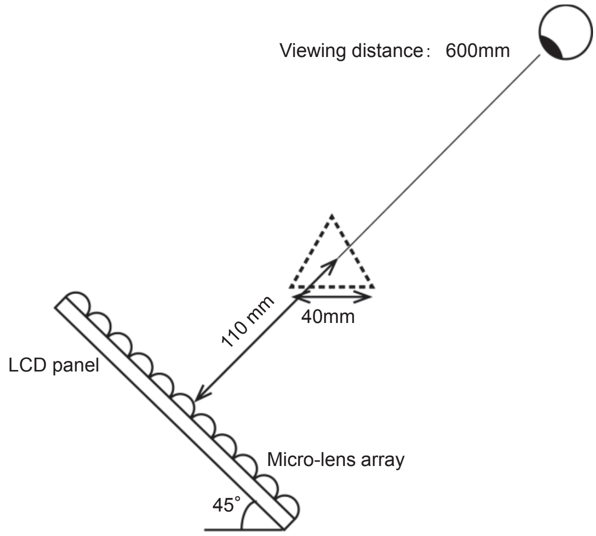


Fig. 3 Experiment using one display unit

Table 1 Devices used for experiment

Micro-lens array	
Model	NTKJ FE10
Lens pitch	1.98 mm
Focal length	10 mm
Size	100 × 100 mm
Thickness	2.06 mm
LCD panel	
Model	Sharp LS060R1SX01
Size	6 in.
Resolution	2,560 × 1,440 (RGB)
Pixel pitch	51.75 μm
Display area	132.48 × 74.52 mm

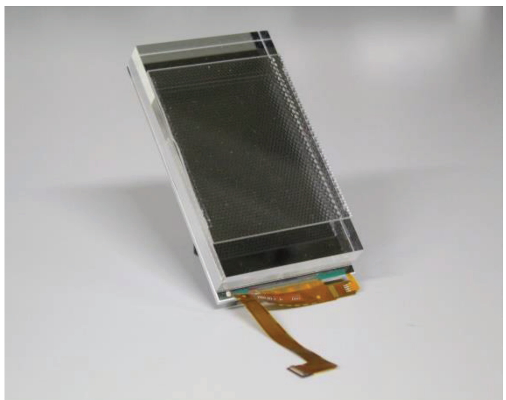


Fig. 4 Constructed light field display unit

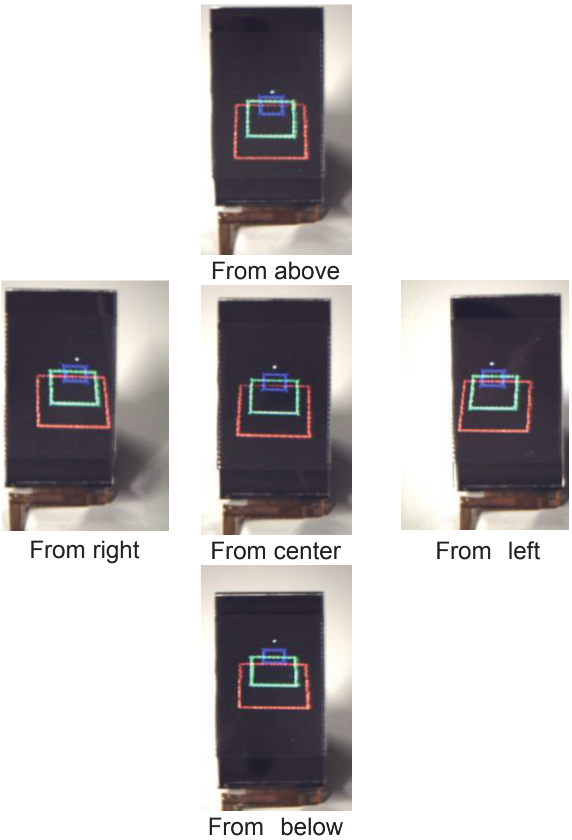


Fig. 5 Aerial image generated by constructed light field display unit

4 DISCUSSION

The experimental setup produced sharp 3D images. Here, the depth of field of the 3D images is calculated based on Ref. 4. As shown in Fig. 6, when the lens pitch is L_p, the image distance is d, and the image diameter is D_i, the depth D_f of the image is expressed by the following equation.

$$D_f = 2D_i \frac{d}{L_p}$$

D_f of the experimental system was 57 mm, which was comparable to the 3D image size.

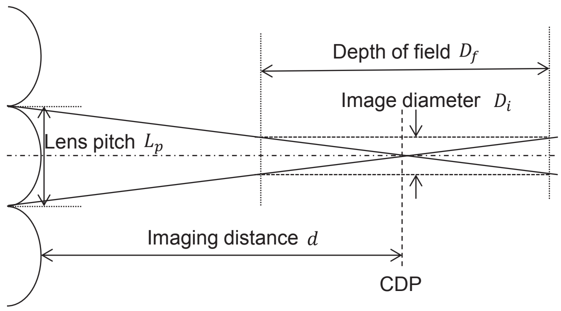


Fig. 6 Depth of field of resolution-priority integral imaging

5 CONCLUSIONS

We proposed Light Field Mirage, which has a simple structure and allows multiple users to observe aerial 3D images from 360 degrees. One light field display unit based on the resolution-priority integral imaging was constructed and the generation of high-resolution 3D images away from the display screen was confirmed. In the future, we will construct a complete Light Field Mirage prototype.

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