Resolution Improvement for Light Field Display Using Near Virtual-Image Mode

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ABSTRACT

We have previously the near virtual-image mode for a flat-panel type light field display to increase a viewing zone and light efficiency. This study improves the near virtual-image mode to increase a resolution of 3D images. The prototype display was constructed to verify the proposed technique.

1 Introduction

The light field displays [1-3] reconstruct rays emitted from three-dimensional (3D) objects and viewers can observe 3D image without wearing 3D glasses. The flat-panel type light field display [4] has the simplest and the thinnest form factor among other types of configurations for light field displays, such as, the projector array type [5], and multi-layer type [6]. However, the conventional flat-panel type has the drawbacks of a narrow viewing zone, low light efficiency, and low resolution.

The conventional flat-panel systems combine a high-resolution flat-panel display with a lens array or an aperture array. The lens-array system has a high light efficiency and a small viewing zone, and the aperture-array system has a large viewing zone and a low light efficiency. We have proposed a new flat-panel system which employs both lens and aperture arrays [7]. The proposed system is based on the near virtual-image mode and has a larger viewing zone than the lens-array system and a higher light efficiency than the aperture-array system.

In this study, we propose a technique to increase the resolution of the light field display using the near virtual-image mode.

2 Theory

The previously proposed light field display using the near virtual-image mode is shown in Figure. 1. The gap between the flat-panel display and the lens array is made smaller than the focal length of the lens array to increase the viewing zone. In this case, virtual images of pixels of the flat-panel display are produced behind the lens array. For the efficient increasement of the viewing zone, the gap should be reduced sufficiently. Thus, the virtual pixel images are produced near the flat-panel display and the magnification of the virtual images is not high and several virtual pixels images are observed through each lens of the lens array. The aperture width of the aperture array is made equal to the width of the virtual pixel images to allow the observation of a single virtual pixel image through each lens of the lens array in order to reduce the crosstalk between rays proceeding in the different directions. The aperture array reduces the effects of the aberrations of the lens array.

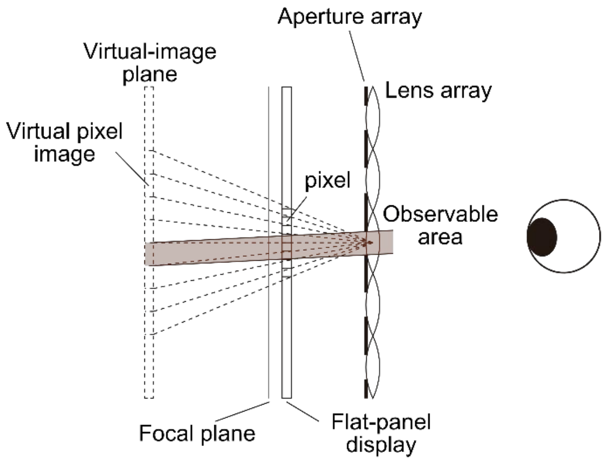


Fig. 1 Flat-panel light field display using near virtual-image mode.

The technique to increase the resolution proposed in this study is illustrated in Fig. 2. The gap between the flat-panel display and the lens array is further reduced to lower the magnification of the virtual images so that the number of virtual pixel images correspond to each lens is increased. Then, the width of the apertures of the aperture array is widened to allow plural pixel images to be observed through each lens. Consequently, the resolution of 3D images increases. With the proposed resolution improvement technique, because the divergence of rays from the lens array becomes larger compared to the previous near virtual-image mode, the considerations are required about the relationship between image blur and resolution.

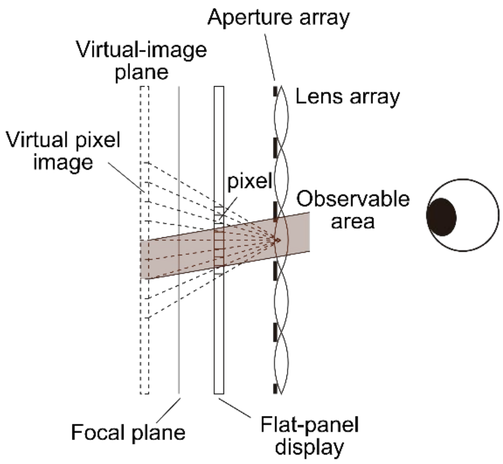


Fig. 2 Improvement of resolution for flat-panel light field display using near virtual-image mode.

3 Prototype system

The light field display was constructed based on the proposed method, which had only horizontal parallax to prioritize the resolution of 3D images. A lenticular lens was used as the lens array, and a slit array was used as the aperture array.

The liquid-crystal display with a resolution of 7,680×4,320 and a screen size of 31.5 in. was used as the flat-panel display. The lenticular lens had a focal length of 0.936 mm and a lens pitch of 0.71 mm. The lenticular lens was slanted to valance the horizontal and vertical resolutions of 3D images [8]. The resolution of 3D images before the resolution improvement was 983×720.

The slit pitch of the slit array was set to 0.71 mm, which was equal to the lens pitch of the slanted lenticular lens. In this experiment, the display was designed so that two virtual images of color subpixel are observed through each slit to double the horizontal resolution of 3D images. The magnification of virtual images was 6.9 and the width of the virtual subpixel images was 0.21 mm. Thus, the width of the slits was 0.42 mm.

Figure 3 shows the constructed display system.

4 Experimental results

First, the formation of the virtual subpixel images was confirmed. Figure 4 shows the image observed through lenses of the prototype system. Since the prototype light field display had only horizontal parallax, the subpixels were magnified only in the horizontal direction. Because the lenticular lens was slanted, the subpixels were magnified in the direction slanted to the horizontal axis. The number of virtual subpixels observed through each slit was 2.0.

Fig. 3 Constructed prototype display.

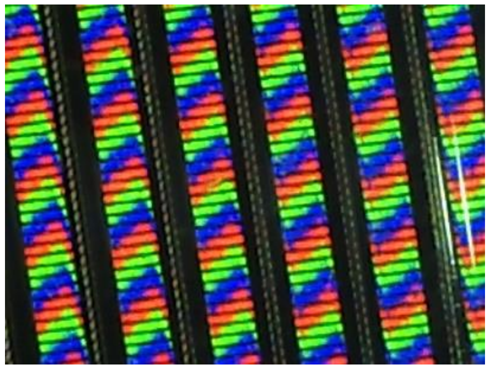
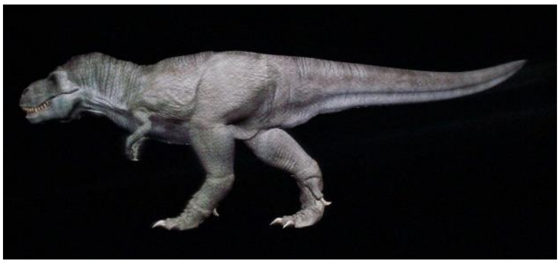


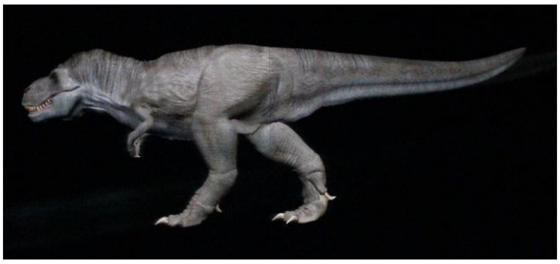
Fig. 4 Magnified image observed through lens array.

The 3D image produced by the prototype system is shown in Fig. 5(a). For comparison, the 3D images produced by the previous near virtual-image light field display is shown in Fig. 5(b). Enlarged images are also shown in Figs. 5(c) and 5(d). The improvement of resolution by the proposed technique was verified.

The measured viewing zone angle of the prototype system was 46°. This angle was larger than 44° of the previous near virtual-image light field display. This is the result of the reduction of the gap between the flat-panel display and the lens array. The measured brightness of the prototype system was 109 cd/m^2.

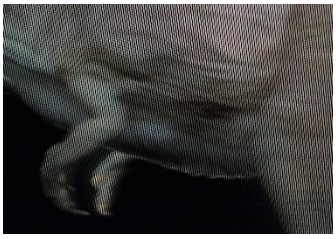


(a)



(b)

(c)



(d)

Fig. 5. Three-dimensional images produced by (a) proposed technique, (b) conventional near virtual-image mode, (c) and (d) are enlarged images of (a) and (b).

5 Summary

This study proposed the technique to improve the resolution of the light field display using the near virtual-image. The improvement of the resolution was experimentally validated.

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