Convertible 3D-2D display by use of integral imaging system with plastic fiber array

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Abstract

A three-dimensional (3D)-two-dimensional (2D) convertible display system using a plastic fiber array is proposed. The proposed system has an advantage of making use of a light source for 3D image from an arbitrary location. The optical efficiency of 3D images in the proposed system is enhanced compared with previous research.

1. Introduction

Three-dimensional (3D) displays are expected to be the next revolution in the history of display. There are various categories in 3D displays; the integral imaging system shows a new way to produce practical 3D display, especially. Integral imaging, which is also called integral photography [1], is able to display full parallax 3D images, express quasi-continuous viewpoints and color images without any special glasses. However integral imaging has some disadvantages that it has limited viewing angle, depth and resolution. To mitigate these problems, some novel integral imaging schemes with enhanced depth and viewing angle were reported recently [2-4]. Furthermore, various techniques utilizing 3D display based on integral imaging have been intensively researched [5-6].

With these approaches, now the 3D-2D convertible integral imaging display system is under great attention [3, 7, 8]. On account of well designed 2D display, many people desire 3D display systems to have 2D display resolutions. However, if we hope to display 3D images, we cannot help sacrificing some quality of 2D images because of the expression of 3D information with limited 2D information. And there are huge quantity of 2D contents compared with 3D contents. Consequently, we need 3D-2D convertible display system for these reasons. And 3D-2D convertible display system will also be a great help in establishing a 3D display system.

Recently, our group reported 3D-2D convertible display system using polymer-dispersed liquid crystal (PDLC) and pinhole array on a polarizer (PAP) [3, 7]. In the case of PDLC, we needed a high voltage to operate with PDLC and occupied a large space for collimating light. The PAP system was quite simple and thin, but it had some shortcomings with brightness.

In this paper, we propose the 3D-2D convertible integral imaging system with plastic fiber array. The proposed system, utilizing a plastic fiber array, has an advantage of making use of a light source for 3D display from an arbitrary location. In addition, we can bend plastic fiber array between backlight unit and point light source at acryl plate. Finally, the brightness of images is increased compared with previous 3D-2D convertible system [7].

2. Principle of proposed method

The basic principle of our system is that each 2D or 3D mode uses different light sources, as shown in Fig. 1. The 3D-2D convertible integral imaging system with plastic fiber array consists of a backlight unit, plastic fiber array, an acryl plate, and a transmission-type display panel just like a spatial light modulator (SLM). In the 2D mode, the backlight unit is on and the surface light source is activated, and we see the 2D images normally. Therefore observers could see the

2D image on the SLM plane because of the surface light coming from the diffused backlight unit through acryl plate. In the 3D mode, the point light source array is generated from the plastic fiber array. In our proposed system we use different light sources for the 2D mode and the 3D mode. The light source for generating point light source array for 3D display can be placed at an arbitrary position since the plastic fiber array is capable of bending freely between the light source for 3D and display panel. The light rays from the light source for 3D image can be easily coupled to the plastic fiber array, and finally will be modulated by the SLM and integrate 3D images with 2D elemental images.

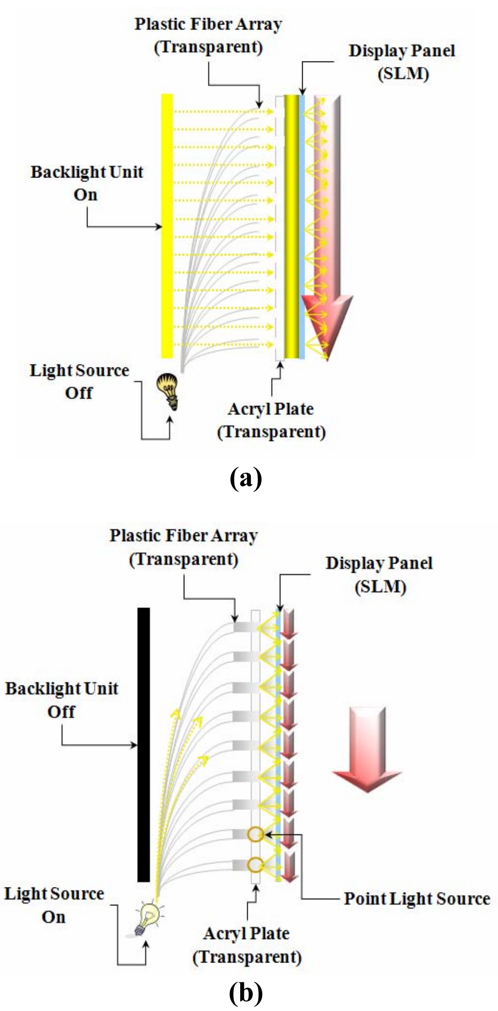


Fig. 1. Concept of the proposed method (a) 2D mode and (b) 3D mode

3. Experiment

We verified our proposed system experimentally. The experimental setup is shown in Fig. 2. As a transmission-type display panel, we used an SLM that had a 0.036 mm pixel pitch in the horizontal and vertical directions with 37 × 28 mm^2 active area. To arrange point light source array with plastic fiber array, the acryl plate is fabricated by using a drilling machine and is composed of 40 × 40 apertures, each of which has a size of 0.2788 mm as shown in Fig. 3. We manually inserted fibers into the holes in the acryl plate. Since the size of the cross sectional areas of plastic fibers have slight variation, it is fixed side by side to the acryl plate with instant adhesive. The light source which is used for plastic fiber array is a high intensity illuminator by Fiber-Lite Corporation (MI-150) which can control brightness.

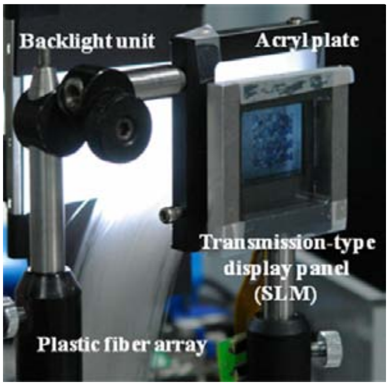


Fig. 2. Experimental setup

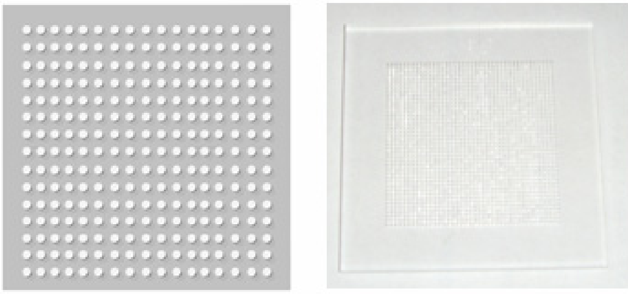


Fig. 3. Acryl plate (Left: schematic, Right: real view)

4. Results and discussion

In the 2D mode, a lotus flower is displayed on the SLM and captured by the CCD camera. The 2D images are displayed with full resolution (1024 × 768) and therefore have good image qualities. Figure 4 shows the observed image when the system acts in 2D mode by turning on the backlight unit and turning off the point light source generated by plastic fiber array. At this time, we can observe the 2D image with full resolution within the viewing angle for the SLM. There are some defects due to different sizes of the cores of plastic fibers. And the instant adhesive material is stuck at the end of the plastic fiber arrays so that we can recognize blurring of the images because of the manual process. However this process could improve with manipulation with mechanical process and uniform plastic optical fiber.

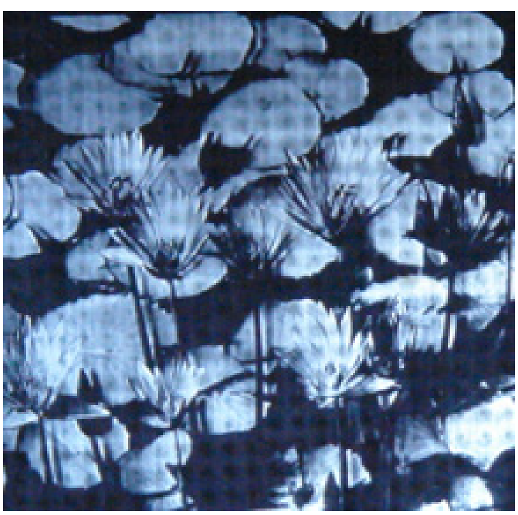
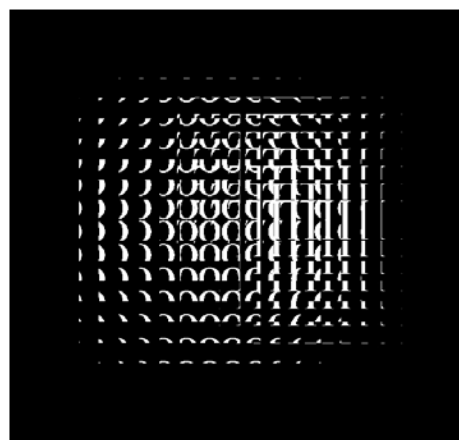


Fig. 4. The 2D image (a lotus flower)

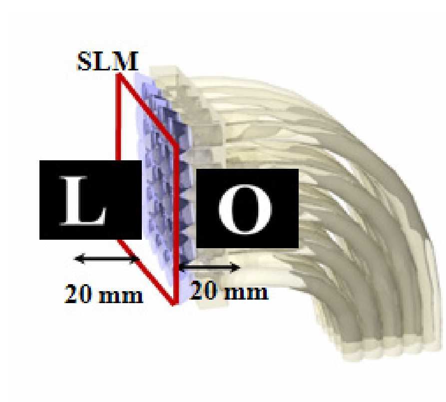
Figure 5 shows elemental image using our experiment and schematic of experiment. In the 3D mode, the image of two letters 'L' and 'O' are formed at 20 mm in front of and behind the point light source array which was implemented by plastic fiber array, respectively as shown in Fig. 5(b). In order to increase the optical efficiency, we use the plastic optical fiber. It is easy to couple the plastic fiber array, and the core's cross sectional area (98% of overall cross sectional area of plastic fiber) occupies almost the entire area of plastic fiber compared to other optical fiber. Therefore, the optical efficiency of 3D images will be enhanced. Figure 6 shows the experimental result observed from different viewing directions.

5. Summary

In this paper, we proposed the 3D integral imaging system by use of plastic optical fiber array. The proposed system for 3D integral imaging has an advantage of making use of a light source from an arbitrary location. Since the plastic fiber array for 3D images is easily bendable, the point light sources are formed freely with the plastic fiber array regardless of optical path. The 3D-2D convertibility has been verified experimentally. In the proposed system, the optical efficiency of 3D images is enhanced.



(a)



(b)

Fig. 5. (a) Elemental image, (b) Schematic of experiment

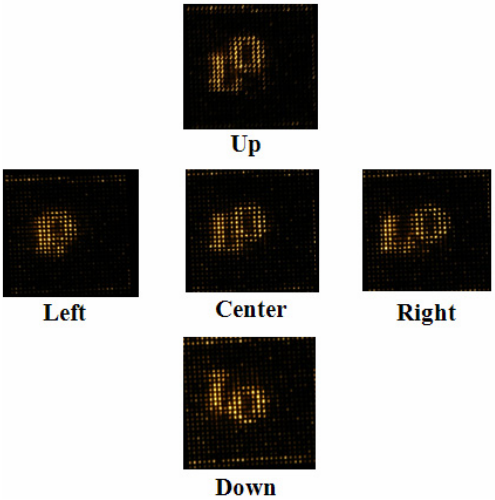


Fig. 6. The 3D images observed from different viewing directions

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References

1. G. Lippmann, Comptes-Rendus, Acad. Sci. **146**, pp. 446-451 (1908)
2. H. Liao, T. Dohi, and M. Iwahara, Optics Express, **15**, pp. 4814-4822 (2007)
3. J.-H. Park, H.-R. Kim, Y. Kim, J. Kim, J. Hong, S.-D. Lee, and B. Lee, Optics Letters, **29**, pp. 2734-2736 (2004)
4. Y. Kim, J.-H. Park, S.-W. Min, S. Jung, H. Choi, and B. Lee, Applied Optics, **44**, pp. 546-552 (2005)
5. S. Jung, S. A. Shestak, K. Cha, T. Kim, J.-P. Koo, and S. Kim, Stereoscopic Displays and Virtual Reality Systems XII, Proceedings of SPIE, USA, **5664**, pp. 340-348 (2005)
6. J. Arai, H. Kawai, and F. Okano, Applied Optics, **45**, pp. 9066-9078 (2006)
7. H. Choi, S.-W. Cho, J. Kim, and B. Lee, Optics Express, **14**, pp. 5183-5190 (2006)
8. S.-W. Cho, J.-H. Park, Y. Kim, H. Choi, J. Kim, and B. Lee, Optics Letters, **31**, pp. 2852-2854 (2006)