Effect of picture quality improvement in integral photography with lens mask

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Abstract

An experiment evaluating our technique for improving the picture quality of integral photography is presented. In integral photography, a lens array or a pinhole array is used. The quality of the lens array depends on the manufacturing method. In some economical manufacturing methods, the focal length of each lens is not always uniform, and the lens array may have spaces between the minute lenses. These factors may cause the image quality to deteriorate. Please include a brief abstract of this paper. Avoid using figures or equations in the abstract.

Introduction

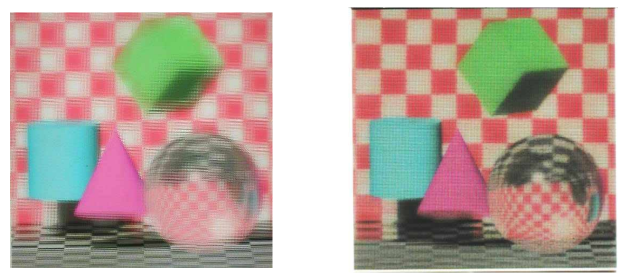
Integral photography is an excellent 3D image display system because 3D images can be seen even if the observer's viewpoint moves up and down or right and left. No special glasses are required. In this method, a central image containing many smaller images observable from multiple viewpoints is projected on a plane by arranging the images obtained through one convex lens or pinhole.

Conventional integral photography technology requires making a metal mold in advance to manufacture a lens array. Therefore, the only way to make integral photography cost effectively was to use a pinhole array. For instance, one method for printing on a transparent seat uses a color printer [1]. However, integral photography has now been made possible and cost affordable with a lens array. The reason is that manufacturing the lens array only requires applying printing technology. The image quality of integral photography has been improved by combining the lens mask including the pinhole with this lens array.

Integral photography that uses lens array with printing technology

The lens array made with printing technology is not made based on a metal mold. Instead, the lens is formed with the surface density by putting a transparent material on a transparent board (or seat). Therefore, the difference in the accuracy of each lens is greater than that of a lens made based on a metal mold. Moreover, the interval between lenses must be maintained for the manufacturing method.

Integral photography that uses this kind of lens array has some problems with image quality. First of all, light that leaks from the space between lenses causes image quality deterioration. Light that reaches the observer through the pinhole or lens must have originated from one particular point. However, a lot of light reaches the observer without passing through the lens or pinhole. Therefore, this light causes the boundary to become unclear, as shown in Figure 1(a). The cause of another decrease in image quality is low accuracy in the lens. Because the difference in the focal length of each lens is considerable, not only the light from a particular point but also light from points around it gets to the observer's eye. In our research, we solved these problems using a lens mask with pinholes whose diameter is less than that of the lens. The mask was arranged in front of the lens array, as shown in Figure 2. Sharp images, like the one in Figure 1(b), can be obtained by using this mask.



(a) Lens without mask (b) Lens with mask

***Figure 1**. Examples of 3D images*

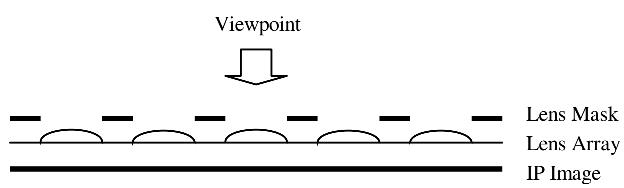


***Figure 2**. Integral photography that uses lens mask*

This lens mask is a transparent sheet on which black ink was painted, except in the lens areas. As a result, the light that leaks from the space between lenses is intercepted, and deterioration in the image quality is suppressed. Moreover, deterioration in the image quality caused by lack of uniformity in the lens focal length can be suppressed because extra light that passes through the fringe area of the lens is shut out. By reducing the diameter of the pinhole, the image becomes clearer, but the brightness of the image decreases. Therefore, the best diameter can be obtained. The diameter of the hole should be large when a high quality lens array with a small focal length error is used. On the other hand, the diameter of the hole should be small when the quality of the lens is not high enough and when the focal length is not uniform.

In integral photography with a lens, the range for binocular vision is decided depending on the characteristics of the lens, in particular, the focal length. The range where binocular vision is possible broadens when a lens with a short focus is used. If a lens array is fabricated using printing technology, making lenses with a short focal length becomes difficult. Getting wide range binocular vision is also more difficult to achieve. However, the binocular vision can be made wide by deliberately arranging the lens nearer than the focal position and by suppressing the deterioration of the image quality with a lens mask whose hole diameter is small.

Experiment

We used the image shown in Figure 3 for an evaluation experiment and examined which position looked to have separate lines. As shown in Figure 4, the center of the disk was 1, and the outside was 10. We then subjectively determined the position where the lines were separate.

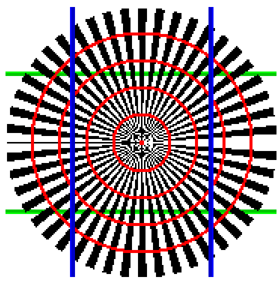


***Figure 3**. Image of disk used in evaluation*

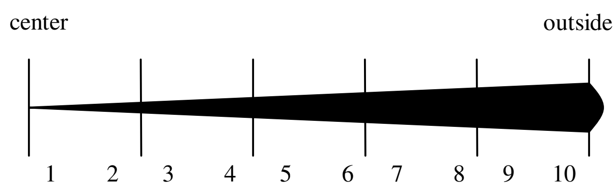


***Figure 4**. Separation value of disk*

Depth is a factor that influences the image quality of the 3D images. The image of the object seen at the front (or rear) of the screen is not sharp. Therefore, we set the virtual disk position for the evaluation in the front (or rear) of the screen. When the image was 20 × 20 cm, the position of the disk for evaluation was front 6 cm of the screen, front 3 cm, rear 3 cm, rear 6 cm and at the same position of the screen. We prepared eight kinds of masks with holes that had diameters that were 100%, 90%, 80%, 70%, 60%, 50%, 40%, and 30% of the element image width and height. We also evaluated a 3D image without a mask for the sake of comparison.

The brightness of the 3D image is proportional to the area of the hole. Table 1 shows the area of the holes (These are equal to the brightness of the images) in relation to the diameter of the hole of the masks. The area shown in the table shows the aperture rate, which is 1 without the mask. The aperture rate is given by the following expression.

$$\alpha = \frac{\pi}{4} d^2 \tag{1}$$

Where α shows the aperture rate, and d shows the ratio of the diameter to the size of the element image.

Table 1. Relationship between area and diameter

Diameter	Area (aperture ratio)
100%	0.79
90%	0.64
80%	0.50
70%	0.38
60%	0.28
50%	0.20
40%	0.13
30%	0.07

Table 2 shows the experiment results. From Figures 5 to 9 are graphs showing results in the table.

Table 2. Experimental results

	+6 cm	+3 cm	0 cm	-3 cm	-6 cm
None	5	5	3	4	5
100%	5	5	3	4	5
90%	5	4	3	4	5
80%	5	4	3	4	5
70%	4	4	3	3	5
60%	4	3	3	3	4
50%	4	3	3	3	4
40%	4	3	3	3	4
30%	4	3	3	3	4

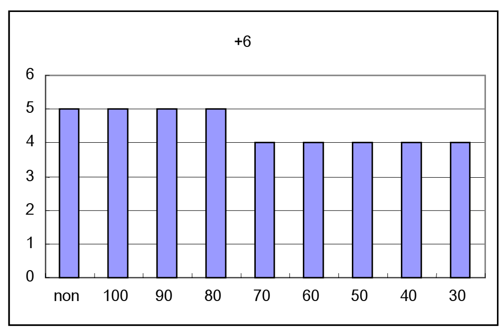


***Figure 5**. Results of +6 cm in position of the disk*

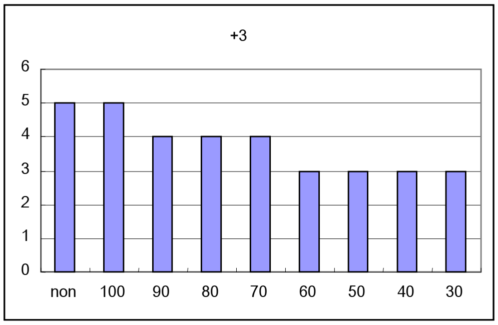


Figure 6. *Result of +3 cm in position of the disk*

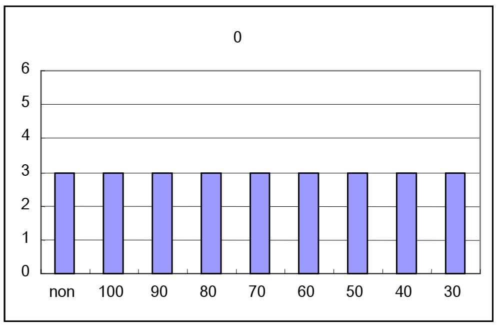


Figure 7. *Result of 0 cm in position of the disk*

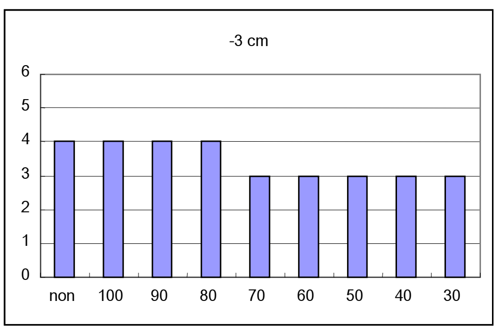


Figure 8. *Result of -3 cm in position of the disk*

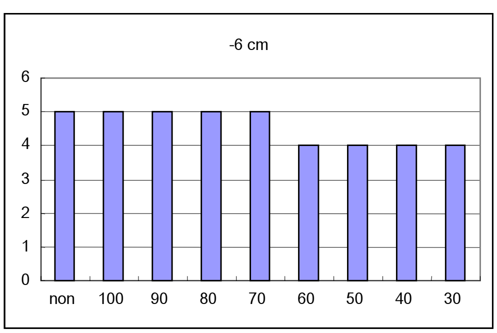


Figure 9. *Result of -6 cm in position of the disk*

The results of the experiment indicated that the appropriate diameter for the hole is from about 60 to 80%. When the diameter of the hole is large, improving the image quality produces a significant effect. However, when the diameter of the hole is less than 50%, no noticeable effect is evident. In addition, the image darkens.

Conclusion

Experiments demonstrated that the 3D image quality of integral photography for obtaining three-dimensional images was high when a lens array was used together with a pinhole mask. Moreover, the appropriate diameter of the hole in the mask was determined. The accuracy of the lens was not much of a problem, and the enough effect was sufficient, even with inexpensive lenses. Therefore, our proposed method is effective for generating high quality 3D images at low cost.

References

[1] Susumu Sasaki et al., 3D Display System Using High Resolution Transparent Printer Output, Proc. IS&T's NIP 18, pg. 807. (2002).

Author Biography

Hideo Kasuga received his BE, ME, and Dr. Eng. degrees from Shinshu University in 1995, 1997, and 2000. He worked at this university as a research associate for several months, and subsequently moved to the Kanagawa Institute of Technology, Japan, in 2000. He is currently a lecturer at the institute. His main research field is image processing.