# 3D Image Input System for High Resolution Integral Photography

***Hideo Kasuga, Kazuhisa Yanaka, Susumu Sasaki and Yasushi Hoshino****
***Kanagawa Institute of Technology, Atsugi, Kanagawa, Japan***
****Nippon Institute of Technology, Miyashiro, Saitama, Japan***

## Abstract

Integral photography (IP), in which viewers can see 3D images from almost any viewing points without wearing special glasses, is one of the ideal 3D display technologies. Generally an IP image, which is composed of many element images, is captured through a lens array. However, this method is not suited to produce high resolution 3D images, because only small number of picture elements is assigned to each element image. We propose a 3D image input system for high resolution IP. In this system a CCD camera is attached to an XY plotter instead of a pen, and 32 × 32=1024 images are successively captured by the camera as it moves vertically and horizontally. The captured images are processed by our program to compose an IP image. We examined the IP image by using it in our 3D display system, which consists of two transparent films, a transparent board and illumination. The IP image is printed in advance on one of the transparent films by high resolution ink jet printer, and pinholes are printed on the other transparent film. By experiments, it has been confirmed that composite IP images generated by our system reproduce proper 3D images.

## Introduction

Heretofore various approaches to display 3D images have been investigated. Among them, integral photography (IP), which was proposed by Lippmann in 1908, is attractive autostereoscopic system because it projects 3D images to viewers in any direction without special glasses. So, it has been referred to as one of the ideal 3D display techniques. An IP image is composed of many element images in various directions. Generally these images are captured through a lens array with many convex microlenses as shown in Figure 1[1]. Each element image is formed by the light rays which passing through each lens from any direction. In this method, all element images are captured at once, therefore each element image size is restricted. Consequently, it is not suited to produce high resolution 3D images. So as to create high resolution 3D images, a large array of lens and a high resolution capture device are necessary. However, It is not necessarily to capture all element images at once if real time 3D display is not requested.

In this paper, we propose a 3D input system for high resolution IP. In our method, images are captured from a number of camera positions, and thereafter an IP image is computationally composed based on the light ray directions and camera positions.

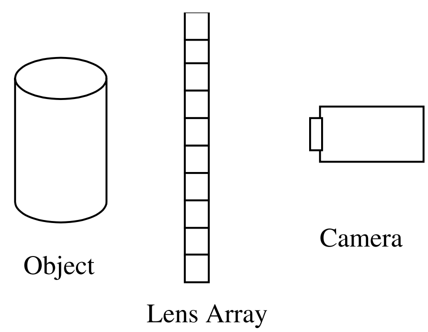


*Figure 1. Conventional IP image Capture System*

## Proposed System

Our 3D display system[2] consists of two transparent sheets, a transparent plate and an illumination. Two transparent sheets are used as shown in Figure 2. The upper transparent sheet, on which a pinhole array is printed, is the substitute of the lens array. Only the grid points of the sheet remain transparent. Other parts of the sheet are covered by black ink so that light does not go through the sheet. On the lower transparent sheet, IP image data are printed. We used a high resolution inkjet printer to print dedicated patterns on the two transparent sheets. By putting a transparent acrylic board between the two transparent sheets, the interval between two sheets is kept constant. By illuminating the sheets from the bottom by a back light, a 3D image can be displayed.

The number of pinholes on the upper sheet is 180 × 180. The number of pixels on the lower sheet that go through a pinhole is 32 × 32. Therefore, the number of pixels printed on the lower sheet is 5760 × 5760.

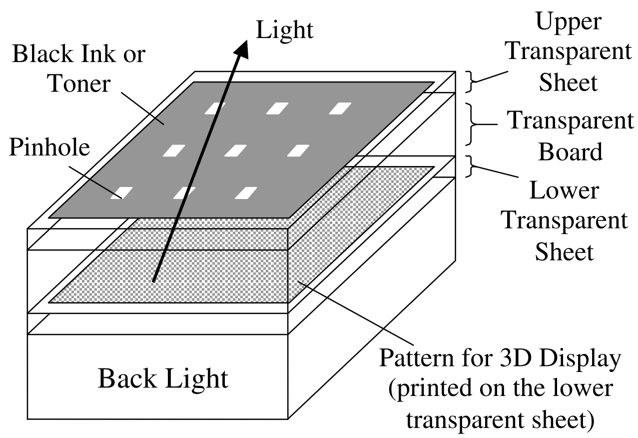


*Figure 2. 3D Display System*

Our 3D image input system consists of a CCD camera and an XY plotter as shown in Figure 3. In this system a CCD camera is attached to an XY plotter instead of a pen, and it can move vertically and horizontally to a position specified by a host computer precisely. By using this camera, images are successively captured by the computer. The camera moves horizontally 32 times and takes a raw of images. This action is repeated 32 times while moving vertically. Therefore the number of captured images is 32 × 32 = 1024. The number of camera positions should be large enough in order to get high quality 3D image. However in this experiment, the number is decided to be 32 × 32.

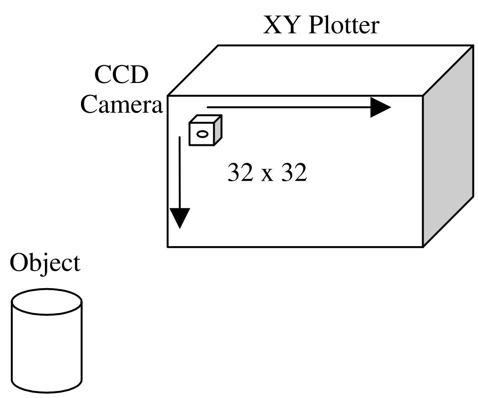


*Figure 3. Input System*

The captured images are processed to compose an IP image. The position relation between an element image and a pinhole are shown in Figure 4. It is necessary to decide the position of a pinhole in virtual because in our input system there is neither a pinhole nor a lens. For this reason, we suppose that the virtual pinhole array exists at particular position in the real 3D space, and calculate each element image as shown in Figure 4. Although the size of the virtual IP image and the virtual pinhole array are not necessarily the same as that of physical sheets, at least it must be proportional to the size of the real sheets in order to get undistorted 3D data. If the size of virtual sheets and physical sheets is different each other, the size of 3D objects displayed by this system is different from that of original 3D objects, although the shapes are preserved. Then the direction of the pinhole from each pixel in an element image is calculated. The value of the pixel is obtained from the image captured by the camera which is in the direction of the pinhole. The procedure of making an IP image is shown as follows.

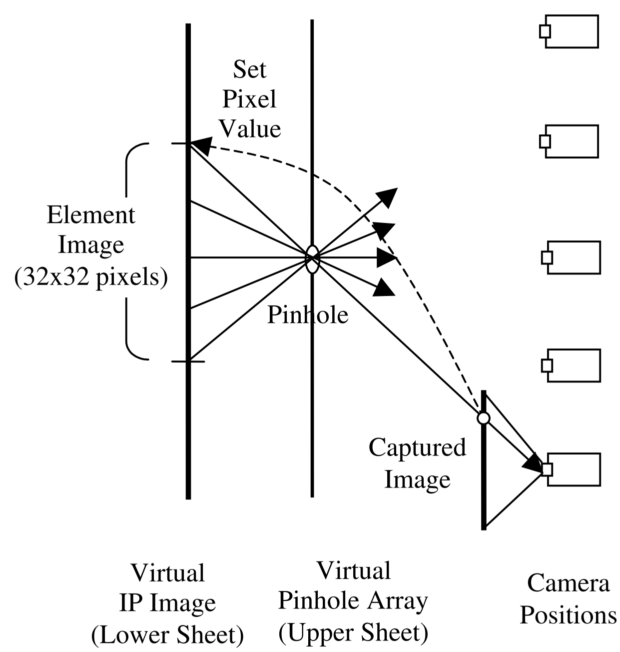


*Figure 4. Position Relation between an Element image and a Virtual Pinhole*

1. Among 32 × 32 camera positions, search a camera position which is the nearest the straight line passing both the pinhole and each pixel in the element image.
2. On the image captured at the camera position mentioned above, find the pixel which is in alignment with the virtual pinhole and the element image pixel, sample the pixel value and set it to the pixel on the element image.

The viewable angle of 3D image that is composed of this system is decided by the viewable angle from the camera and the distance between the camera and the virtual pinhole array as shown in Figure 5. Also, the interval of the upper sheet and the lower sheet, that is the thickness of the transparent board, is decided. The viewable angle becomes wider if the distance to the virtual pinhole array is small. However, minimum distance to the virtual pinhole array exists. The minimum distance is expressed by

$$dist = range/\tan(ang/2) \tag{1}$$

where *dist* is the minimum distance, *range* is the moving range of the camera, and *ang* is the viewable angle from the camera. Also, maximum size of the virtual pinhole array exists. Maximum size of the virtual pinhole array equals the mobile range of the camera. It is necessary to capture images by a camera which has a wide viewable angle so that 3D image can be seen from a wide angle.

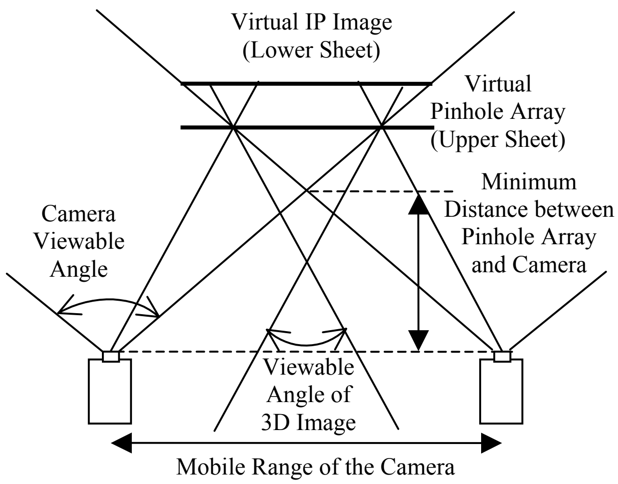


*Figure 5. Relation of the Distance and the Viewable Angle*

## Experiments

Experiment devices are shown as Table 1.

Figure 6 shows our input device. The XY plotter is connected to a PC with a serial port (RS-232C). The image from the CCD camera is captured by PC with video capture board. The IP image composed of images captured by our input system is printed on a transparent OHP sheet with an inkjet printer. The resolution of the IP image is 720 dpi, so the size of the image is 203.2 × 203.2 mm.

Figure 7 is a photograph of 3D image made by this system. This is a photograph from one direction. However, by changing the viewpoint, images that are from different direction can be seen.

**Table 1. Experiment Devices**

| | |
|---|---|
| **CCD Camera** | MTV-54K0N<br>Picture Element 542(H)×496(V)<br>Dimension 32(W)×32(D)×32(H)mm |
| **XY Plotter** | Graphtec MP5300<br>Dimension<br>670(W)×449(D)×130(H)mm |
| **Inkjet Color Printer** | EPSON PM-970C<br>Max Resolution 2880×2880dpi |
| **Transparent Sheet** | A4 OHP Sheet for Inkjet Printers (210×297mm) |
| **Transparent Board** | Acrylic Board(Thickness 5mm) |
| **Backlight** | Fuji Film Color Illuminator |

The distance from the camera to objects is one of the most important factors. Setting an appropriate distance from the camera to objects is necessary. To capture large objects, the range of movement of the camera must be large. It is left for further study to establish methods to decide optimum parameters.

*Figure 6. Input Device*

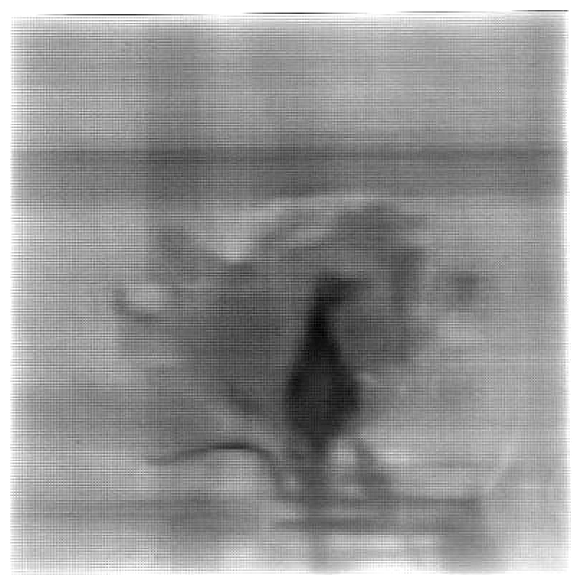

*Figure 7. Photograph of 3D image made by this system*

## Conclusion

A new 3D image input system for integral photography has been proposed, in which a CCD camera which is attached to an XY plotter instead of a pen, and 32 × 32=1024 images are successively captured by the camera as it moves vertically and horizontally. The captured images are processed by our program to compose an IP image by our algorithm. Then the IP image is printed on a transparent sheet and observed through the other sheet on which pinhole array was printed. Because the IP images are generated without lens array, high resolution IP images can be generated by our system. As the number of images captured by the camera increases, the quality of IP images rises. It is desirable that the number of camera positions is large enough in order to catch the most appropriate light ray from each pinhole.

## References


1. Fumio Okano, "Real-time pickup method for a three-dimentional image based on integral photography", *Appl. Opt.*, 36, 1598 (1997).
2. Susumu Sasaki et al., "3D Display System Using High Resolution Transparent Printer Output", *Proc. IS&T's NIP 18*, pg. 807. (2002).


## Biographies

**Hideo Kasuga** is a research associate of Kanagawa Institute of Technology, Japan. He gained BE, ME and Dr.Eng. degrees from Shinshu University in 1995, 1997, and 2000 respectively. He worked at the university as a research associate for months, and he moved to Kanagawa Institute of Technology in 2000. His main research field is image processing.

**Kazuhisa Yanaka** is a professor of Kanagawa Institute of Technology, Japan. He gained BE, ME and Dr.Eng. degrees from the University of Tokyo, in 1977, 1979, and 1982 respectively. He joined Electrical Communication Laboratories of NTT in 1982 and developed videotex terminals, teleconferencing systems, and image coding algorithms. He moved to Kanagawa Institute of Technology in 1997.

**Susumu Sasaki** gained his BE and ME degrees in information technology from Kanagawa Institute of Technology, Japan, in 2001 and 2003 respectively. As his postgraduate research, he studied 3D display system. He joined Japan Technical Software Corporation in 2003.

**Yasushi Hoshino** is a professor of Nippon Institute of Technology, Japan. He gained BE, ME and Dr.Eng. degrees from the University of Tokyo, in 1970, 1972, and 1984 respectively. After he gained ME degree, he joined Electrical Communication Laboratories of NTT and developed LED printers, laser printers, and ion flow printers. He moved to Nippon Institute of Technology in 1994. He published more than 20 papers, including several papers in IS&T's journal. He attended almost all NIP conferences.