RePro3D: Full-parallax 3D Display using Retro-reflective Projection Technology

Takumi Yoshida, Sho Kamuro, Kouta Minamizawa, Hideaki Nii, and Susumu Tachi
The University of Tokyo[*]
Keio University[†]

Figure 1: *The 3D object that is projected onto the retro-reflective screen can be seen from a number of viewpoints with motion parallax, and the user can operate this object using his/her hands.*

1 Introduction

Motion parallax is important to recognize the depth of a 3D image. In recent years, many 3D display methods that enable parallax images to be seen with the naked eye have been developed. In addition, there has been an increase in research to design interfaces that enable humans to intuitively interact with and operate 3D objects using their hands. However, realizing 3D object interaction as if the user is actually touching the object in the real world is quite difficult. One of the reasons for this is that the screen shape in conventional methods is restricted to a flat panel. In addition, it is difficult to achieve a balance between displaying the 3D image and sensing the user input. Therefore, we propose a novel full-parallax 3D display system that is suitable for interactive 3D applications. We call this system RePro3D. Our approach is based on a retro-reflective projection technology[Inami et al. 2000]. A number of images from a projector array are projected onto the retro-reflective screen. When a user looks at the screen through a half mirror, he or she, without the use of glasses, can view a 3D image that has motion parallax. We can choose the screen shape depending on the application. Image correction according to the screen shape is not required. Consequently, we can design a touch-sensitive soft screen, a complexly curved screen, or a screen with an automatically moving surface. RePro3D has a sensor function to recognize the user input. Some interactive features, such as operation of 3D objects, can be achieved by using it.

2 Method

When images from a number of projectors are projected onto a retro-reflector, there is a strong reflection of light in the direction of each projection lens. Using a half mirror, a same number of viewpoints are made at symmetrical points to the half mirror. By arranging many projectors in a matrix, a 3D image can be seen from multiple viewpoints. In order to show smooth motion parallax, the density of the projector array must be sufficiently high. Preliminary experimental results show that the distance between two adjacent projectors should be lesser than 1.5 cm. Commercially available projector arrays do not have adjacent projectors at such small distances because of the resulting increase in size and cost. Therefore, we have developed a high-density projector array by arranging a number of projection lenses in a matrix on a high-luminance LCD. Figure 2 shows the optical system of RePro3D. The system consists of a number of lenses, an LCD, a half mirror, and a retro-reflector as a screen. Lenses are located at an appropriate shift from the image area on the LCD so that the projection areas due to each projection lens may overlap. Shield plates are placed between the lenses to prevent light for other viewpoints from entering the lens. RePro3D can produce vertical and horizontal motion parallax; however, it cannot produce motion parallax in the front-back direction. We use an infrared camera as a sensor to recognize the user input. Infrared rays are emitted onto the screen through the half mirror near the camera, and the camera captures the reflected rays. Because the retro-reflector causes an intense reflection of the rays, a clear distinction is possible between the screen and other objects such as the user's hands.

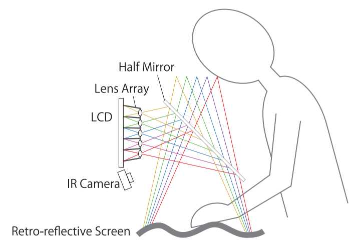

Figure 2: *Optical system configuration of RePro3D.*

3 Prototype Implementation Results

We have developed a prototype of our proposed system. The luminance of the high-luminance LCD is 1000 $\mathrm{cd/m^2}$. This area has 40 viewpoints, each with a size of 120 $\times$ 70 mm. The image resolution of each viewpoint was 60 $\times$ 60 pixels. We used an IEEE-1394 camera with a resolution of 640 $\times$ 480 pixels for sensing the user input. Figure 1 shows the results of displaying 3D objects using the prototype system. Distortionless parallax images were displayed on a curved surface from 40 viewpoints. Users were able to intuitively operate the 3D object by moving their hands. We plan to develop devices that have higher resolution and to create interactive applications for demonstration of these devices.

References

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[*]e-mail: {takumi_yoshida, sho_kamuro}@ipc.i.u-tokyo.ac.jp
[†]e-mail: {kouta, nii, tachi}@tachilab.org

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