Implementation of a Tabletop 3D Display Based on Light Field Reproduction

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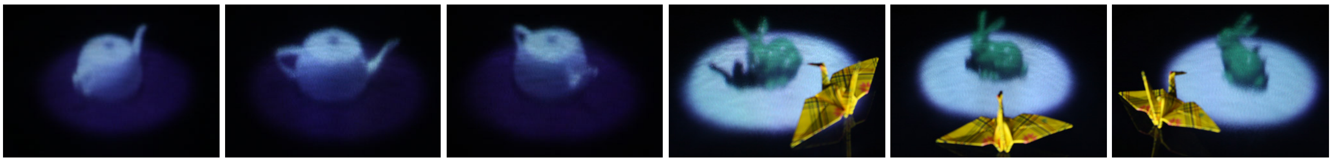

Figure 1: *Photos of produced 3D images shot from three different angles (Utah teapot and Stanford bunny with real paper crane)*

1 Introduction

A tabletop is a useful shared space for diverse collaborative tasks. If the tabletop is considered to be interface, then expression through visual sensation, especially 3D images, is an important way to engage the principal human sense. Many 3D displays that can be observed from any direction have been proposed in recent years. However, some techniques force to wear special glasses and restrict the positions from which 3D images can be viewed [Kitamura et al. 2001]. Other glasses-free 3D displays employ obstructive apparatus on the table [Jones et al. 2007].

In this paper, we propose a novel glasses-free 3D display based on the concept of light field reproduction. We then implement a prototype that is designed to overcome the stated limitations and preserve natural interaction for tabletop tasks.

2 Our Approach

We propose a method of reproducing a light field of a certain volume on the table and creating a ring-shaped viewing area around the table. It employs a special optical device as a screen and an array of projectors. The screen is shaped as a cylinder or cone and features a special optical function for the incoming rays: it diffuses in the direction of the edge line of the shape and passes straight in the direction of the circumference. The projector array projects appropriate individual images onto a side surface of the screen from different directions. Each pixel of the images forms numerous rays passing through each projection center and the projected point of the pixel. These directional rays and the characteristic of the screen reproduce the light field according to the following principle.

On a vertical plane, a ray enters the screen and spreads out at a certain angle. One of the diffused lights of the ray goes straight to the eye of the viewer. On a horizontal plane, the directions of rays produced from the series of projection centers are not changed after they pass the screen. A bunch of rays coming from different projectors are concentrated and form an integrated image on the retina. In other words, when a certain point on the screen is viewed from different horizontal directions, the point is observed with different color and luminosity. This means multiple viewers can obtain individual stereoscopic images from any position around the table.

3 Implementation

We have studied methods to create the conical-screens and examined the directional optical characteristics [Yoshida et al. 2010]. In this work, we describe an approach to implementing the 3D display

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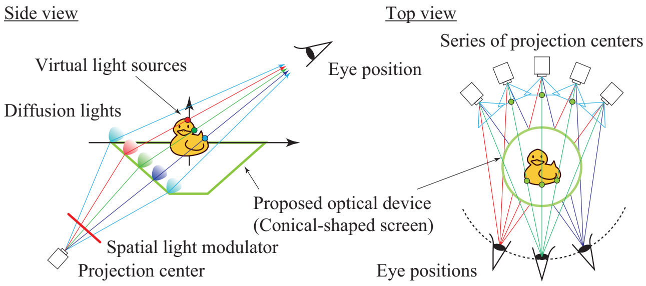

Figure 2: *Configuration of a prototype to reproduce a light field*

by employing optical devices, including a conical device and a new cylindrical-shaped screen that has wider diffusion power than its predecessors.

We assembled the projection units of 96 micro LCD projectors (VGA of 8 lumens) and installed them in a circular manner at a pitch of 14.6 mm and a projection distance of 870 mm. To compute the color and luminosity of each image's pixel, we employed a ray tracing algorithm based on the geometric optics of Figure 2.

Figure 1 shows trial 3D images in several configurations. As a result, this prototype covered one third of the ideal viewing area of 360°. The image quality was a trade-off between the diffusion power of the screen and the pitch of the projectors. Currently, we are improving quality by analyzing those parameters in detail.

This novel 3D display floats virtual objects on a flat tabletop surface like a centerpiece. Multiple viewers can observe the 3D from all around the table without the use of 3D glasses. Our entire 3D imaging mechanism is installed underneath the table, and it does not employ any noisy or easily broken driving parts. It keeps the tabletop area clear and does not disturb collaborative work and natural communications.

References

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