Interactive Holographic Display System Using Motion Sensor

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Keywords: Holography, three-dimensional display, computer-generated hologram.

ABSTRACT

We present the real-time three-dimensional display system based on electronic holography. The system uses a motion sensor to detect the finger gesture and the motion of the observer. By switching hologram patterns according to the gesture and motion, we realize the interactive holographic display system.

1 INTRODUCTION

Holography [1] can record and reconstruct wavefront of light. The wavefront is recorded as the hologram using interference of light. The wavefront recorded in the hologram is reconstructed using diffraction of light. The hologram can be calculated by simulating the behavior of light on computer. It is called as the computer-generated hologram (CGH) [2]. Electronic holography [3,4], which uses the spatial-light modulator (SLM) to display hologram patterns, mainly uses CGHs. Then, electronic holography enables to reconstruct three-dimensional (3D) moving pictures by switching CGHs. Because the computational amount of CGHs is too huge to realize real time processing, many algorithms to accelerate CGH calculation have been proposed [5-12]. In this paper, we demonstrate the real-time 3D display system capable of interactive reconstruction of 3D images based on electronic holography using the motion sensor.

2 CONSTRUCTED SYSTEM

2.1 System Overview

In this work, we constructed the real-time holographic display system that can draw 3D images in air with the index fingertip of the observer as the interactive reconstruction system. The constructed system consists of three parts: input, calculation, and output parts. First, in the input system, the position of the index fingertip of the observer is detected by the motion sensor. Secondly, in the calculation part, the CGH is calculated based on the position of the index fingertip. Finally, the calculated CGH is displayed on the SLM, and the point image is reconstructed in air. By repeating the series of the processing, we can draw 3D images in air in real time.

2.2 CGH calculation

We consider a point-light source is placed at the same position as the index fingertip to be detected by the motion sensor. Its coordinates at the N-th detection are expressed by (x_N, y_N, z_N). Then, the complex amplitude distribution, which is formed by the light emitted from (x_n, y_n, z_n), is given by

$$u_N(x, y) = \frac{1}{r}\exp\left(i\frac{2\pi}{\lambda}r\right), \tag{1}$$

$$r = \sqrt{(x - x'_N)^2 + (y - y'_N)^2 + (z'_N)^2}, \tag{2}$$

$$x'_N = x_n + x_{offset}, \tag{3}$$

$$y'_N = y_n + y_{offset}, \tag{4}$$

$$z'_N = z_n + z_{offset}. \tag{5}$$

Here, (x, y) indicate the xy coordinates on the CGH plane. i and λ denote the imaginary unit and the wavelength of the light, respectively. Because the origin of (x_n, y_n, z_n), which depends on the motion sensor to be used, is different from (x, y), we apply the offset values of x_{offset}, y_{offset}, and z_{offset} to reconstruct the point image of (x_n, y_n, z_n) appropriately. Then, the CGH pattern at the N-th detection can be expressed by

$$h_N(x, y) = \arg[U_N(x, y)], \tag{6}$$

$$U_N(x, y) = \sum_{n=1}^{N} u_N(x, y), \tag{7}$$

where the operator $\arg[C]$ indicates the argument of the complex number C. We used the kinoform as the phase-modulation-type CGH.

3 RESULTS

Fig. 1 shows the schematic diagram of the experimental setup for the constructed system. We used Leap Motion (Leap Motion Inc.) as the motion sensor [13] to detect the position of the index fingertip of the observer. Using the coordinate of the detected position, the CGH is calculated by the host PC. The calculated CGH data is output to the SLM to display the CGH, and the holographic image is projected in air.

The laser beam is collimated by the beam expander, and illuminates the SLM through the half mirror. The wavelength of the light is 532 nm. We use the phase-modulation-type SLM with the resolution of 1920×1080 pixels. The pixel pitch of the SLM is 8 μm. We set the digital camera at 50 cm away from the SLM. For simplicity to demonstrate the constructed system, the 3D images are project at the place which is different from the position of the index fingertip to be detected. We captured the video of the 3D images by the digital

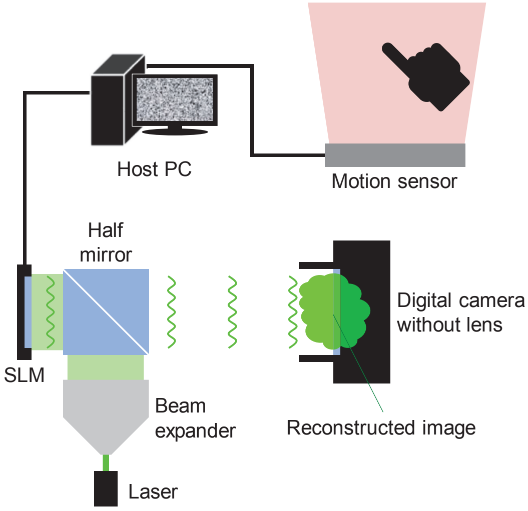

Fig. 1 Optical setup for electronic holography.

camera without lens.

Fig. 2 shows the holographic images extracted from the captured video. In Fig. 2, the bright square-shape image at the center of each picture indicate the 0th-order diffraction light. We can see the point images are drawn in air by the system. Because each point image is focused or blurred according to the position of the index finger to be detected, we can also confirm the 3D images are projected in air by the system.

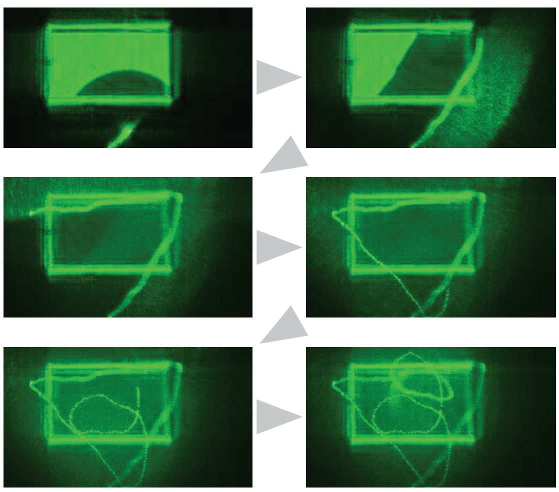

Fig. 2 Holographic images captured by digital camera without lens.

4 CONCLUSIONS

We demonstrated the interactive holographic display system using the motion sensor. By the system, aerial drawing of holographic images with the index fingertip was realized in real time. This work will be expected to contribute holographic cross-reality display system in future.

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