Touchable Holography

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1 Introduction

Mid-air displays which project floating images in free space have been seen in SF movies for several decades [Rakkolainen 2007]. Recently, they are attracting a lot of attention as promising technologies in the field of digital signage and home TV, and many types of holographic displays are proposed and developed. You can see a virtual object as if it is really hovering in front of you. But that amazing experience is broken down the moment you reach for it, because you feel no sensation on your hand.

Our objective is adding tactile feedback to the hovering image in 3D free space. One of the biggest issues is how to provide tactile sensation. Although tactile sensation needs contact with objects by nature, the existence of a stimulator in the work space depresses the appearance of holographic images. Therefore some kind of remote-controllable tactile sensation is needed. That is achieved by our original tactile display [Iwamoto et al. 2008]. The following paper explains the technologies employed for a "Touchable Holography."

2 Principle

2.1 Holographic Display

We use "Holo [Provision 2009]," a holographic display which provides floating images from an LCD by utilizing a concave mirror. The projected images float at 30 cm away from the display surface. A user can get near to the image and try to touch it. Of course, his fingers pass through it with no tactile sensation.

2.2 Tactile Display

"Airborne Ultrasound Tactile Display [Iwamoto et al. 2008]" is a tactile display which provides tactile sensation onto the user's hand. It utilizes the nonlinear phenomenon of ultrasound; acoustic radiation pressure. When an object interrupts the propagation of ultrasound, a pressure field is exerted on the surface of the object. The acoustic radiation pressure P [Pa] is written as

$$P = \alpha E \qquad (1)$$

where E [J/m^3] is the energy density of ultrasound. α [-] is a constant ranging from 1 to 2 depending on the reflection coefficient at the object surface. The acoustic radiation pressure acts in the same direction of the ultrasound propagation. That is, roughly saying, the ultrasound "pushes" the object. Eq.(1) suggests that the spatial distribution of the pressure can be controlled by using wave field synthesis. When the tactile display radiates the ultrasound, the users can feel tactile sensation on their bare hands in free space with no direct contact.

The current version of prototype consists of 324 ultrasound transducers. The resonant frequency is 40 kHz. The phase delays and amplitudes of all the transducers are controlled individually to generate one focal point and move it three-dimensionally. The total output force within the focal region is 1.6 gf. The diameter of the focal point is 20 mm. The prototype produce sufficient vibrations up to 1 kHz.

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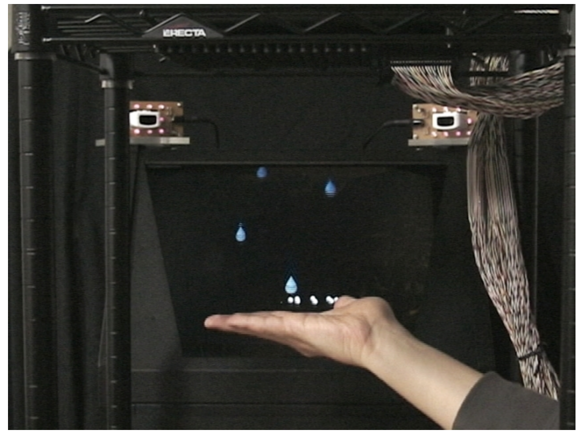

Figure 1: *Developed interaction system. An aerial imaging system, a non-contact tactile display, and a Wiimote-based hand-tracking system are combined. In this figure, the ultrasound is radiated from above and the user feels as if a rain drop hits his palm.*

2.3 Hand Tracking

While camera-based and marker-less hand tracking systems are demonstrated these days, we use Wiimote (Nintendo) which has an infrared (IR) camera for simplicity. A retroreflective marker is attached on the tip of user's middle finger. IR LEDs illuminate the marker and two Wiimotes sense the 3D position of the finger. Owing to this hand-tracking system, the users can handle the floating virtual image with their hands.

3 Application

The developed system can render various virtual objects because not only visual but also tactile sensation is refreshable based on digital data. It is useful for video games, 3D CADs, and so on. Here we show an example of demos. Fig. 1 shows a demo in which rain drops fall from above. When the rain drop hits the user's palm, he feels tactile sensation created by the ultrasound. In another demo, he sees and feels a small virtual creature running on his palm.

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