ARForce

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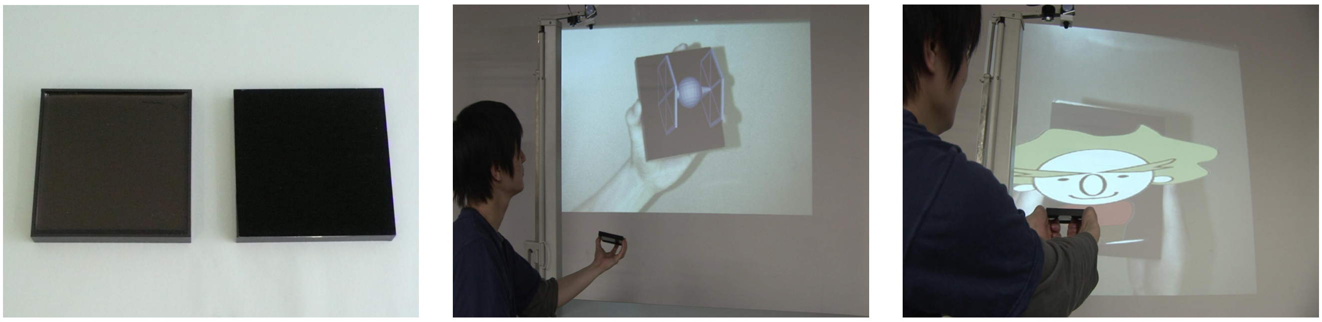

Figure 1: *Conceptual Image.*

1 Introduction

In recent years, the usage of augmented reality (AR) systems has become common. AR achieves the combination of real-world and computer-generated data. ARTookKit[Kato and Billinghurst 1999] is one of the prominent examples of an AR system; it measures the 3D positions and IDs of physical markers and combines computer-generated graphics with real video images. Users can move or rotate the virtual graphics by relocating the physical markers; however, it is impossible to touch or manipulate the virtual graphics directly using the users' fingers.

The objective of this research is to manipulate virtual graphics using fingers, for example, touching, pushing, twisting, pinching, and expanding the virtual graphics in midair. To achieve our objective, we require an interface that has the following three features. First, the interface must usable in midair. Second, it must recognize multiple simultaneous touch points. Third, it must measure both the magnitude and direction of force applied using fingers.

Therefore, the aim of our study to develop a wireless interface that measures the distribution of force vectors applied by fingers, in order to construct AR environments in which users can manipulate virtual graphics by the use of natural finger motions. To achieve this aim, we propose a novel marker-based interface termed "ARForce." This interface can detect the distribution of force vectors on its surface as well as its 3D position, rotation, and ID by using a vision-based approach. ARForce enables users to observe overlaid virtual images and control them using fingers. In the future, we intend to measure information precisely and control virtual objects in the same manner as real objects. As a result, we will develop a novel computer-human interface that accepts a highly natural input.

2 Background and Related Work

In the field of Computer Human Interaction, various types of interactive systems have been proposed that allow users to manipulate virtual images using fingers or hands of users. CyberGlove[Immersion] and Soap[Baudisch et al. 2006] are representative researches of the finger pointing device that works in midair.

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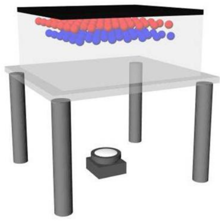

Figure 2: *Simplified diagram of GelForce.*

Figure 3: *ForceTile.*

Rekimoto et al. have also proposed a hand-held pointing device that use tilt as the input method[Rekimoto 1996].

On the other hand, in a field of Augmented Reality, there are a lot of researches that combine the virtual data to real world. In this field, many systems utilized 2D marker[qrc] to measure IDs and positions[Kakehi et al. 2007; Woods et al. 2003]. By using a vision-based marker recognition method, we can detect the position, rotation and ID of object easily in real-time. In addition to these input, some systems tried to recognize richer information about users' input. Active CyberCode[Ayatsuka and Rekimoto 2006] allows a user to give commands by putting his/her finger on a printed button beside the code. EnhancedDesk[Koike et al. 2000] recognizes not only 2D markers but also gestures of the user. The Haptic Hand[Kohli and Whitton 2005] uses special device in addition to 2D marker, and allows user to touch virtual objects.

Toward these systems, we propose a novel tangible interface "ARForce" that works as a 3D marker and pointing device. This interface allows user to manipulate the virtual images using not only 3D position and ID but also the distribution of force vectors without using electric devices. Furthermore, note that the markers on our interface are invisible for users unlike many of other marker-based system.

In the implementation of ARForce, we adopt the method of our previous project "Gelforce[Kamiyama et al. 2005; Sato et al. 2007]" to measure a distribution of force vectors. Its sensor consists of a transparent elastic body and two layers of colored markers within

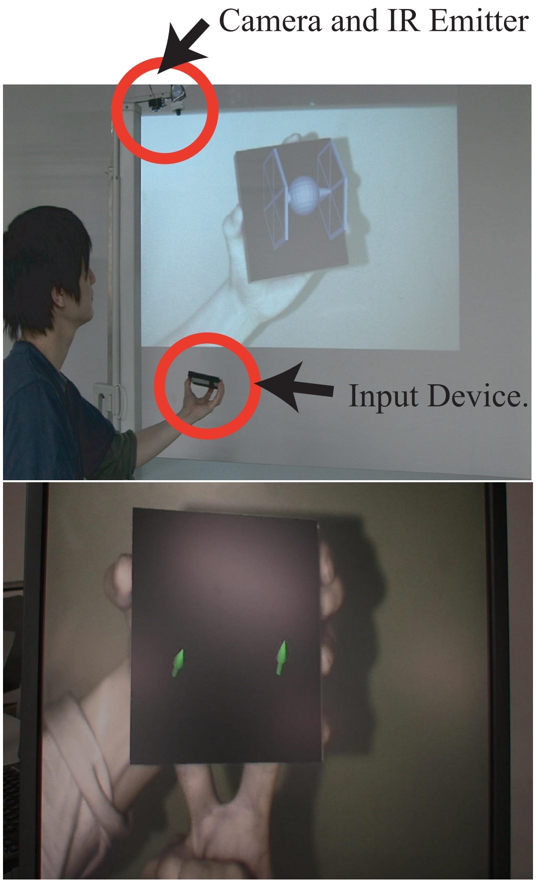

Figure 4: *(Top) Appearance of proposed system. (Bottom) Captured image and force vectors. The green arrows show the force vectors applied by the user.*

the body (Fig. 2). When a force is applied to the body's surface, we optically measure the internal strain of the body through the movement of the markers. Finally, force vectors are calculated from the strain by an elastic theory. Recently, we have also developed a tangible interface named ForceTile[Kakehi et al. 2008](Fig. 3) using the method of GelForce. However, there is a clear difference that ForceTile is designed only for tabletop display, and ARForce can be used in 3D space.

3 System Overview

Fig. 4 (top) shows the appearance of the ARForce system. A user controls the tile-shaped interface and applies force to the bottom of the interface with his/her fingers. A camera placed above the user captures the image of the interface using infrared (IR) light. Using a computer vision technique and the elastic theory, we can measure the 3D positions and IDs of interfaces and the distribution of force vectors in real time. Fig. 4 (bottom) shows the measured force vectors and captured image. The green arrows show the force vectors applied using fingers.

3.1 Hardware

Input Device Fig. 5 shows the structure of the proposed tile-shaped interface. The outer body of the interface is enclosed in an acrylic case. The inside of the interface contains a transparent elastic body. When the user applies force to the interface, both

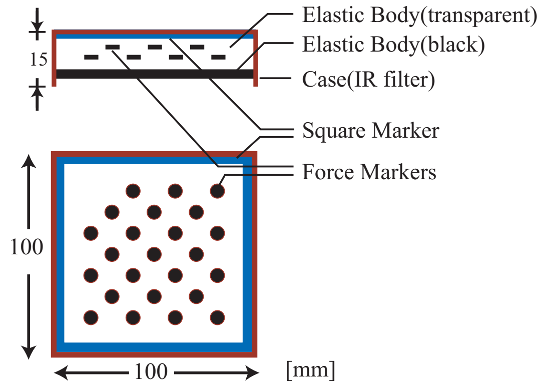

Figure 5: *Structure of proposed interface.*

the transparent and black elastic bodies are deformed and the force markers that are placed in the transparent elastic body are moved. In order to capture the 3D position of the interface, a square marker is attached to the acrylic case. Each interface has different patterns of force markers, which enables ID discrimination. The force markers and square marker are composed of retroreflective materials.

The acrylic case acts as an IR filter that blocks the visible light spectrum and transmits IR rays. Therefore, the interface appears black, and it is impossible to observe the inside of the interface with the naked eye.

Camera Because many CCD cameras have optical filters that block IR rays, it is impossible to capture the force markers using such cameras. Therefore, we remove the filter from our camera. An IR emitter is placed near the camera because the force markers and the square marker are composed of retroreflective materials. Fig. 6 shows the captured image of the interface.

3.2 Software

This system calculates the distribution of force vectors using the same method as that of GelForce. GelForce captures the displacement of force markers, which is caused by the force applied by the user. However, in our proposed system, the positions of the force markers depend not only on the force vectors but also on the position of the device. Therefore, we use an algorithm comprising the following steps.

1. Search for the square marker in the captured image and rec-

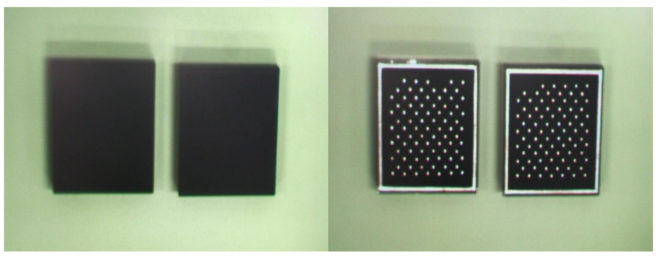

Figure 6: *(left) Camera image without IR light. (right) Camera image under IR light. The inside of the interface is invisible to the naked eye. However, the use of the camera and IR light enables us to capture the view inside the interface. Each interface has different dot patterns, which enables ID detection.*

ognize the ID from the pattern of the force markers.

2. Calculate the 3D position of the interface by measuring the corner position of the square marker in the picture coordinate system.
3. Measure the relative displacement of the force markers, which is caused by the force applied by the user's finger.
4. Calculate the force vectors using the same method as that of GelForce.

4 Apprications.

To demonstrate these functions mentioned above, we have already implemented several prototype applications as followings.

Virtual Objects Viewer In this application, we use ARForce as a virtual object viewer to demonstrate the recognition of finger gestures. This application involves the overlay of virtual images on the live image like ARToolKit. Furthermore, when user expands or twists the input surface of the device, the virtual images are deformed according to the gestures. For example, when the user expands the surface strongly, the graphics enlarge at high speed. Fig. 7 shows snapshots of this application.

Figure 7: *Application of Virtual Objects Viewer.*

Movie Player Fig. 8 shows snapshots of the movie player. In this application, users can control the time parameter of the movies displayed on the interface with their twisting gestures. When the user twists it in a clockwise direction, the movie plays in forward direction; and in a counterclockwise, the movie is rewound. In addition, the playback speed changes according to the twisting speed.

Shooting Game We have also implemented an entertainment application for multiple users. Fig. 9 shows snapshots of the shooting game. Users can operate virtual spaceship using the interface. The position and tilt of the spaceship corresponds to the interface's position and posture. In addition, users can shoot beams by pushing the input surface of the ARForce interface. The direction of the beam changes according to the direction of force applied by the user.

Figure 8: *Movie Player.*

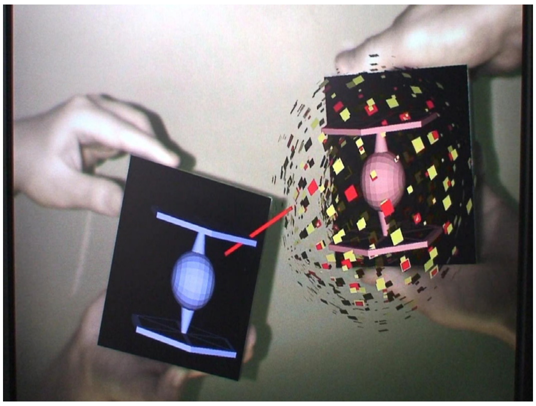

Figure 9: *Shooting Game.*

4.1 Experience for Attendees.

In the site of SIGGRAPH Asia 2008, we will demonstrate the applications mentioned above. We are going to use some cameras and multiple interfaces. Because ARForce discriminates IDs, multiple attendees can join the interactions at one time. In addition, we plan to install projectors or monitors to show the virtual images to the attendees.

5 Conclusion and Future Works

In this paper, we have proposed a novel marker-based interface that can measure not only the 3D positions and IDs of markers but also the distribution of the magnitude and direction of force applied onto it. Using this interface, users can manipulate virtual graphics which are combined to the real-world scene with natural finger motions.

In the future, we have following plans: First, we will keep improving the method and algorithm to measure more precise force vectors. For example, we plan to utilize cameras with high resolution or wide dynamic ranges. Secondly, we will implement a series of new AR applications including games, simulations, media art, and scientific visualizations. Thirdly, we will extend the variety of the interface so that they vary in shape, size, and material.

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