Perceptual Surfaces: Towards a Human and Object Sensitive Interactive Display

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ABSTRACT

This paper reports on our initial results of realizing a computer augmented wall called the *HoloWall* and *HoloTable*. Using an infrared camera located behind the wall, this system allows a user to interact with this computerized wall using fingers, hands, their body, or even a physical object such as a document folder.

Introduction

We are investigating how the future of architectures will be enhanced by computer technologies. Our project is motivated by Ubiquitous Computing [7], Augmented Interactions [6], and other related research on computer augmented environments [8]. We are particularly interested in the role of *surfaces* (e.g., walls, floors, table tops) in a physical environment. For example, walls act as our display medium. We regularly exchange information on walls through calendars, posters, signs, notices, or bulletin boards. It is difficult to imagine offices, museums or homes without walls. Thus it should be worthwhile to research how computer augmented walls will support our daily activities. We consider computerized walls as not just a large display panel. Walls must be aware of the physical environment. Since computer walls could be installed anywhere in a building, unlike whiteboard-sized computers, it is also desirable to allow interaction without the need of any special pointing devices.

In such an environment, sensory perception (e.g., inputs from a camera) plays an important role because people do not always bring a device to control the environment. In this short paper, we present our approach to realize "perceptual surfaces" by introducing a combination of a camera and infrared illumination located behind the surfaces.

Design of HoloWall and HoloTable

The HoloWall is a wall-sized computer display that allows users to interact without special pointing devices. The display part consists of a glass wall with rear-projection sheet behind it. A video projector behind the wall displays images on the wall.

We also have developed a table-version of HoloWall called the *HoloTable* A table-top of the HoloTable is a perceptual display surface and is aware of hand-movement as well as objects on the table.

For both configurations, inputs are recognized in an interesting way. This is done with infrared (IR) lights (we use an array of IR light-emitting diodes (LEDs)) and a video camera with an IR filter (an optical filter that blocks light less below 840 nm) installed behind the wall (Figure 1).

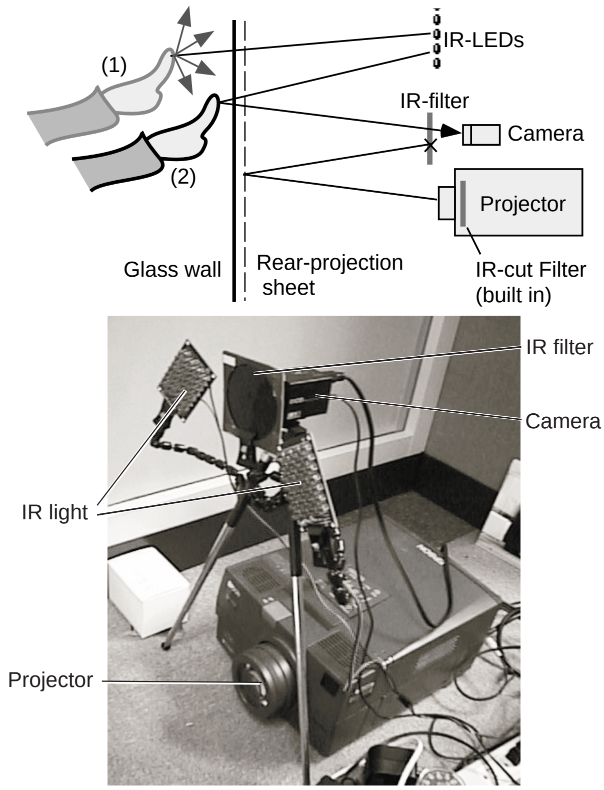

Figure 1: Configuration of the HoloWall

The camera captures the images on the back surface of the wall, which is illuminated by the IR lights. Note that the LCD projector (an EPSON ELP-5000) has a built-in IR-cut filter so that the camera is not affected by the projector's light.

Since the rear-projection panel is semi-opaque and diffusive, the user's shape or any other objects in front of the screen are invisible to the camera (Figure 1 (1)). However, when a user moves a finger close enough to the screen (between 0 cm to 30 cm, depending on the threshold value of the recognition software), it reflects IR light and thus becomes visible to the camera (Figure 1 (2)).

Figure 2: HoloWall in action

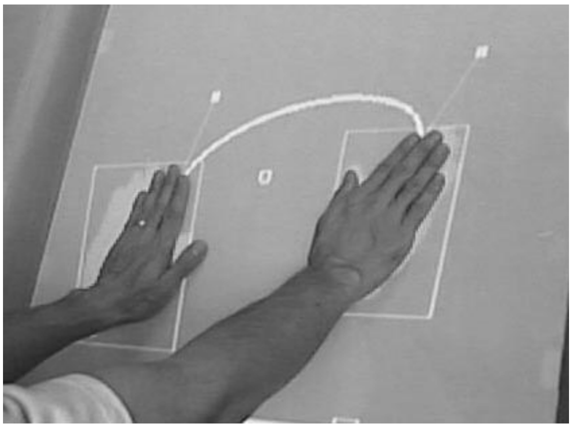

Figure 3: A simple two-handed interface: a user simultaneously manipulates two control points (and directions) on a Bezeir curve

With a simple image processing technique such as frame subtraction, the finger shape can easily be separated from the background. By controlling the threshold value, it is also possible to detect a human body when he/she approaches the screen. In the same way, any physical objects that reflect IR light are detectable. We tested VCR tapes, paper, and document folders, and all were clearly separated from the background (Figure 2, right). We also attached a 2D-barcode to the surface of an object to make it identifiable. When a user puts an object (such as a document folder) with a 2D-barcode on the wall, the system can detect its ID as well as its position. This feature makes it possible to implement an object-sensitive interface.

Applications

The HoloWall can be a simple alternative to touch-sensitive panels, because large (wall-sized) touch panels are very difficult to construct and thus are quite expensive.

However, the potential of the HoloWall is not limited to touch panels. Since the HoloWall can detect two or more hands (or fingers) simultaneously, several multi-hand interfaces should be feasible.

Figure 3 shows a simple two-handed application running on HoloWall. In this example, hand positions are tracked by

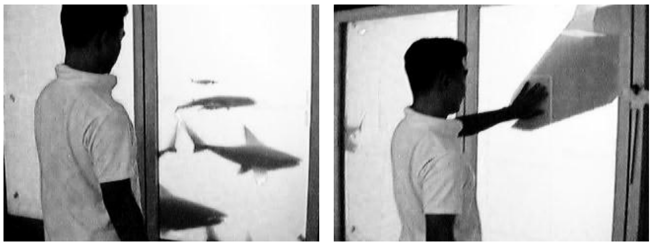

Figure 4: A virtual aquarium reacts to a visitor

using the following method. An incoming video image is first subtracted from the reference image (an image taken when no proximal objects in front of the wall), and binarized by using the predetermined threshold value. Then the system finds connected-regions and selects a hand region among them based on its square area. Since the user's body shape is invisible from the camera, this simple method works well for tracking hand positions. Finally, the gravity center of the recognized hand region and its direction based on the second-order moment are used to control the Bezier curve.

Figure 5: A Map browser on a curtain: When a user touches a map projected on a curtain with one or two hands and moves hands in the same direction, the map moves according to the hand movement. A user can also expand or shrink the map by controlling the distance between two hands.

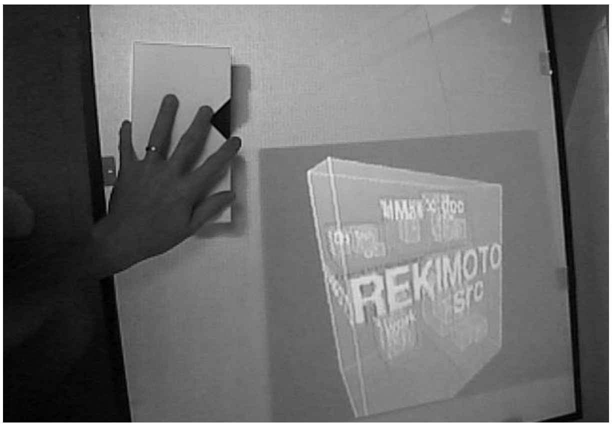

Figure 6: HoloWall shows information of an attached physical object

Furthermore, by measuring the location and the distance of the user's body from the screen, we can design a user interface that is aware of the user's movements. For example, the system would show a 3D virtual aquarium on the wall and when a user walks toward a specific area of the wall, fish in the virtual aquarium swim towards the user (Figure 4).

The material of rear projection panels used in the HoloWall system is not limited to glass. Alternatives include cloth, plastics, and vinyl sheet. Shape is also not limited to flat. For example, the image can be projected on a plastic hemisphere. These features allow an interactive artist to create esthetically interesting interactive environments. Figure 5 shows a body sized two handed map browser which was demonstrated at the NTT InterCommunication Center. In this installation, a large cloth sheet (*interactive curtain*) is used as a screen, and visitors can interact with the computer infomration by touching and pushing the curtain.

Finally, it is also possible to implement a wall that is sensitive to physical objects such as document folders or video tapes (Figure 6). In this example, a 2D matrix code printed behind the object is recognized by the HoloWall camera, and an image related to the object is projected.

Related work

Our approach is quite different from other "gesture-based" systems. Aiming at general perception of human's 3D movement, many traditional gesture-based systems suffer from their unrobustness. Especially, it is difficult and often computationally expensive to distinguish hand shapes from the background (e.g., user's body). The HoloWall approach avoids this problem by introducing a semi-transparent surface.

Our method also has many advantages over traditional touch panels. The HoloWall can detect two or more objects simultaneously, and can also detect human bodies or physical objects other than fingers.

The LiveBoard [1] is a pen sensitive projection display designed as a computerized white board. Unlike the HoloWall, it requires a special IR emitting pen for interaction.

VIDEOPLACE [4] is an artistic installation using a video camera that lets a visitor interact with the environment using his/her body. ALIVE [5] is also a vision-based interactive environments. The visitor manipulates computer objects by means of their own silhouette, so the interaction is indirect as compared to the HoloWall. All these systems do not allow interactions between physical objects and the computer.

The HoloWall / HoloTable architecture is also quite suitable to implement ''Graspable UIs'' [2], and ''Tangible UIs'' [3] where a user controls computer objects by attaching physical ''bricks'' or ''phicons'' on it. Based on the HoloWall architecture, many daily things such as business cards, memo-pads, or paper cups can be used as bricks, instead of using special physical devices.

Summary

We have proposed a new way to realize a computer augmented wall by using a camera and infrared filters. The prototype system, called the HoloWall, proves the feasibility of our idea and demonstrates its potential. We are now developing complete applications featuring multi-hand and object-aware interactions.

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