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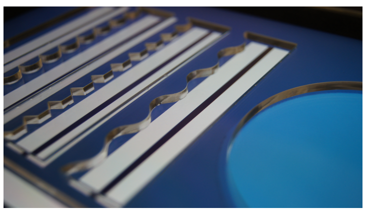

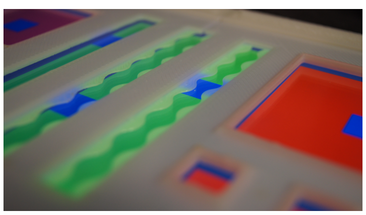

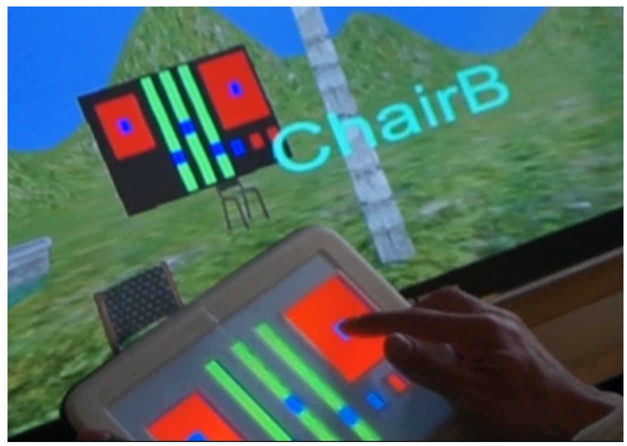

Abstract

With the current widespread interest in head mounted displays, we perceived a need for devices that support expressive and adaptive interaction in a low-cost, eyes-free manner. Leveraging rapid prototyping techniques for fabrication, we have designed and manufactured a variety of panels that can be overlaid on multi-touch tablets and smartphones. The panels are coupled with an app running on the multi-touch device that exchanges commands and state information over a wireless network with the virtual reality application. Sculpted features of the panels provide tactile disambiguation of control widgets and an onscreen heads-up display provides interaction state information. A variety of interaction mappings can be provided through software to support several classes of interaction techniques in virtual environments. We foresee additional uses for applications where eyes-free use and adaptable interaction interfaces can be beneficial.

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Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; H.5.2 [Information Interfaces and Presentation]: User Interfaces—Input devices and strategies

1 Introduction

Due to a new generation of low cost head mounted displays, there is widespread and renewed interest in the development of immersive games and compelling virtual reality experiences. As versatile and expressive interaction devices are an important part of creating engaging virtual experiences, we have developed a set of panels that can be overlaid on multi-touch tablets and similar devices to aid user interaction when a user is immersed in a fully occlusive head mounted display. These panels add passive tactile feedback to the feature-less touch surfaces, allowing users to discriminate and locate different controls without the need to look at the panel. Since interaction schemes are easily remapped, and since panels are easily removed and replaced, resultant interfaces are highly adaptable to the needs of the user and the virtual reality application.

The interaction panels can provide a number of basic user interface widgets including one dimensional sliders, dials, and two dimensional touch pads. These can be mapped to a variety of interaction techniques for immersive environments. For example, a two dimensional touch pad can be used to perform ray cast selection of virtual objects. Toggle buttons can be used to specify if scale, position, or orientation properties should be manipulated. Three sliders can be used to adjust the three dimensions of the selected property.

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2 Related Work

A variety of researchers and developers have incorporated interactive surfaces into immersive virtual reality. Many of these have utilized inert surfaces and added tracking of the surface and a corresponding interaction tool, like a stylus or hand. This is often referred to as a "pen and tablet" metaphor. Lindeman et. al discussed how such tracked surfaces could improve the user performance through tactile and haptic feedback, and the physical constraint of the surface, which can steady a user's movement [7]. This class of "pen and tablet" metaphors have been used in the design and demonstration of interaction techniques for creating 3D models for zoological design [1], architectural design [2], and mixed reality automotive design [4]. A set of advanced design variations on this metaphor were developed by Szalavar and Gervautz as a "Personal Interaction Panel" [9] and developed further by Schmalstieg [8].

Another class of interactive surfaces involves active touch interface devices, like smartphones and tablets, in a basically unmodified form. A pen based computer provided a 2D interface in the Mobile Augmented Reality System [3]. Finger Walking in Place (FWIP) is an travel technique in which finger movements simulating walking are recognized on a multi-touch smartphone and produce viewpoint movement in a virtual environment [5, 6].

Our interaction panels differ from both classes of interaction surfaces. Since we are using devices with active touch interface surfaces, we do not need to incorporate additional tracking. This avoids the expense and configuration effort required to employ a tracking system. Moreover, the economies of scale that pertain to high volume smartphone and tablet manufacturing also help to make active devices cost-effective in comparison to inert surfaces employing consumer level tracking solutions, which can be less cost effective and often provide less accurate touch interaction. An additional differentiator is our modification of the active touch devices with several tactile features to aid in eye-free interaction.

3 Hardware Design

We developed the panel hardware for ease of fabrication with modern rapid prototyping techniques, utilizing either 3D printing or laser cutting. Our first prototypes were made of clear acrylic sheets and shaped with a computer controlled laser cutter. Later prototypes focused on 3D printing of ABS plastic, allowing various depth features to be added.

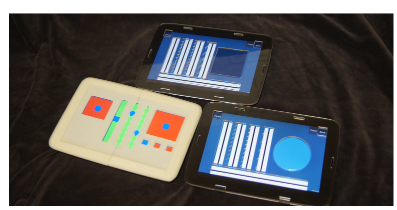

Figure 1: Examples of Some Basic Widget Types in Laser Cut and 3D Printed Interaction Panels.

We have implemented a number of basic widget types. These include horizontal and vertical finger width slits as one dimensional sliders, fingertip sized square holes as toggle buttons, larger round

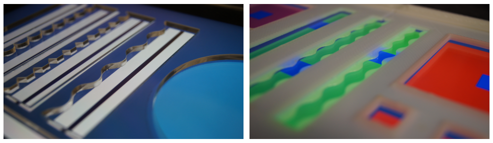

Figure 2: Close Up Views of Ridges, Scalloping, and Other Tactile Feedback Features.

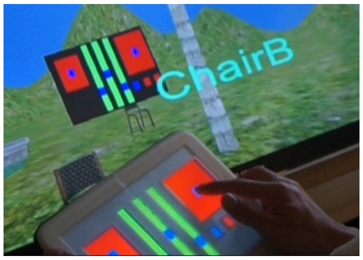

Figure 3: Heads-up Display Showing Interaction Panel State.

holes as dials, and larger square holes as two dimensional touch pads. Examples can be seen in Figure 1.

To provide tactile feedback to help users locate and discriminate controls, we have developed a number of design features, such as scalloped edges and ridges (see Figure 2 for some examples). A more complete list of possible features include: 1) Ridges that surround controls, allowing users to use shape and size to identify a control. 2) Uniquely scalloped edges, of various shapes and scales, which may be beveled, and can act as detents for 1D sliders. 3) Thin washboard or grid textures, which can lie at the bottom of a 1D or 2D control, but are too thin to interfere with touch sensing. 4) Dots, ridges, grooves, and textures, which can be varied in size, direction, and density and associated with particular controls. 5) “Tactile labeling” using Braille, letter shapes, or symbols.

4 Software Design

We implemented software to support the interaction panels as mobile apps running on an Android Nexus 10 tablet. Since we used the Unity game engine for our apps, these can easily be ported to other platforms and operating systems.

4.1 Positioning Widgets

When an interaction panel is placed over the tablet, the software should know where widgets are placed on the panel. This will allow the software to attribute user interactions to the correct widget and send interaction events and states. To handle ad hoc creation of widget layouts for any new panel, we have implemented a widget drawing scheme. Users place the tablet app into widget drawing mode, and place the panel over the tablet. Tracing widget shapes in the panel creates widgets of the appropriate type. Horizonal or vertical strokes create sliders. Single touches create buttons. Circular strokes create dials and square strokes create 2D touch pads.

4.2 Widget Behavior

We implemented a few examples of widget behavior that aid in eyes-free use. A heads-up display is shown to the user in the virtual environment with sliders to depict the current value of each widget (see Figure 3). Touch behavior of widgets can also be altered to improve eyes-free use. The value of the control is only altered when a fingertip encounters the slider. This prevents accidental touches from altering values. Users can run their fingertips across a widget to find and adjust the slider value. Implementations of “phantom fingers” in the HUD can be used to show current locations of fingertips.

4.3 Network Communication

We have created two different network communication implementations. One is a general purpose implementation that uses the Open Sound Control (OSC) network messaging standard used in electronic musical instrument communication. Since libraries for the OSC standard exist for many languages and platforms, this makes it easy for different applications to connect to the interaction panels. A simple messaging protocol is used, which sends low level interaction events. Since many virtual reality applications, and our tablet app, are all written using the Unity game engine, we created a second implementation that leveraged Unity features for networked gaming. This allowed us to complete development and testing more quickly, at the expense of interoperability.

5 Conclusion

The interaction panel could also be useful in systems where the user’s vision is not occluded, but where the user’s attention and visual focus is primarily engaged in another task. This could include control of home and building automation systems. Another use of the interaction panel would be in large display environments for scientific and information visualization. Data scientists could readily utilize customizable handheld controls that could be operated without pulling visual focus away from a complex 3D visualization.

The interaction panel concept and our prototype implementations demonstrate the viability of fabricating custom control panels upon a multi-touch interaction substrate provided by a tablet or smartphone. This allows virtual reality developers to provide an expressive set of controls with tactile feedback that can be operated while users are immersed in a head mounted display. Since interaction panel hardware can be rapidly fabricated, there is the opportunity to develop user interactions in a new way. Interaction hardware and software can both rapidly evolve together.

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