Glove-Based Sensor Support for Dynamic Tangible Buttons in Spatial Augmented Reality Design Environments

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Abstract

Spatial Augmented Reality has shown promising results to support the industrial design process, this paper explores improvements by incorporating tangible buttons to allow dynamically positioned controls with a wearable glove sensor system for simulating prototype design functionality. We present a system to support the low cost development of an active user interface that is not restricted to the two-dimensional surface of a traditional computer display.

1. Introduction

This paper presents a dynamically configurable physical user interface methodology to support interactive mock-up creation for industrial designers. Our system combines four fundamental technologies to allow designers to explore interactive design concepts. Our novel contribution is the development of an interactive design system employing Spatial Augmented Reality (SAR) for appearance presentation, tangible buttons for enhanced user interface fidelity, vision tracking to capture the placement of user interface controls and our new wearable RFID enhanced glove with fingertip read resolution to support emulated button presses. Our methodology allows designers to *dynamically* refine a design by rearranging the physical components of a user interface. This virtually changes the appearance of the tangible user interface, and emulates user interface functionality. The goal of this method is to allow the designer to instantiate their ideas in a haptically rich form, as early as possible in the design process. Figure 1 shows a non-planar white dome with a blue projected SAR appearance, movable tangible buttons and the wearable RFID glove in use.

Previous research has explored how the use of SAR can be incorporated to support designers developing mock-up prototypes [2]. This paper reports on our investigations in improving the fidelity of the haptics in SAR systems by using wearable RFID technology to combine functional tangible buttons with projected SAR mock-ups. By using unattached individual tangible buttons, the designer maintains the ability to re-configure aspects of the mock-up design but unlike previous implementations they can physically pick up the tangible buttons that compose the user interface and re-configure them until the desirable design is reached. While RFID readers have previously been embedded in gloves [3], the novelty of this glove-based RFID reader is its ability to emulate tangible button presses.

Industrial designers use well known methodologies to guide them through the steps of a successful product design. Augmented reality (AR) allows virtual graphical data to be

Figure 1. RFID glove used with SAR mock-up.

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combined and registered with a physical world view. AR is commonly presented to users with head mounted or hand held displays. These display techniques alone do not provide the users with any haptic feedback. Spatial Augmented Reality [1] is a novel form of AR that uses projectors to change the appearance of everyday objects that provide tactile feedback for a more immersive and stimulating user experience. For example, the WARP [4] system projects onto a foam model to allow designers to try out different material properties and finishes for a design prototype.

2. Dynamic Tangible Button Interactions

This section describes the process a designer would take when developing design prototypes with tangible button interactions. The tangible buttons we present have two basic requirements; haptic feedback and dynamic configuration. They allow the designer to physically move parts of the user interface and re-position them to obtain an optimal layout. The tangible buttons are neutral in color to allow SAR images to be projected onto them. Consider the example of designing a calculator. In this example, the designer would like to compare different button layouts and spacings. A predefined set of colors and textures of the tangible buttons can be altered via an interface to the SAR system. The designer may iteratively change appearances and placements of the tangible buttons. The movement of a tangible button is captured by our computer vision system, and the texture is projected onto the tangible button in the new location.

The functionality of the tangible buttons is supported through an embedded RFID tag in each button and the RFID reader embedded wearable glove with a fingertip wrapped antenna. The user interface of the calculator buttons and display can all be made functional. This approach has made it possible to avoid using traditional electronics embedded in the physical buttons which is a time consuming task and is unique for each design. Instead the RFID tags provide a generic solution and do not require any wires or a power source to be attached to the mock-ups. The tangible buttons are activated by touching the antenna finger on a button, and the RFID reader sends an ID to the simulator application via an event. The simulator application may change the appearance of the tangible buttons, and update a virtual LCD panel on the calculator. This process more closely simulates the interactions required for using the interface and allows the designers to assess functionality and usability aspects. Our system allows the development of new shapes and sizes of tangible buttons with technologies readily available to designers (CAD software, 3D printers, and commercial RFID tags). Currently this is a difficult process with the electronic prototyping systems, such as Phidgets and Pushpins, as that process requires detailed knowledge of electronics.

3. Implementation

This section describes the implementation of our tangible buttons, RFID glove and computer vision system. We employed a SAR system consisting of two NEC NP200 ceiling mounted projectors, one Sony XCD-X710CR camera (with IR filter removed), a workstation computer (AMD Athlon 64 Processor 3200+, 512 MB RAM, Ubuntu 10.10) and a white timber SAR blank as the substrate. We have constructed a custom tangible button with a retro-reflective marker and RFID tag. The 27mm diameter tangible buttons were modeled on a CAD system, and printed using a Dimensions uPrint plus printer. The top surface is fitted with a square 1cm x 1cm retro-reflective marker that is used by the vision system to identify the location of the tangible button. The underside of the tangible button is fitted with a 15mm diameter circular RFID tag allowing each button to be uniquely identified. The RFID system used with the glove is realized using an inductive RFID reader module manufactured by ID Innovations[1], model number ID2. In addition to having a carrier frequency of 125 Khz, the module was also chosen because it has no internal antenna allowing one to be designed for the glove. The antenna should have an inductance of 1.08mH in order to form a resonant circuit at 125 Khz to match the ID2 reader we selected.

4. Conclusion

This paper has presented a novel user interface methodology to be used for product design in a SAR environment. Tangible buttons are leveraged to provide a physical interface that allows the designer and end user to re-configure the layout of the user interface during development. To implement the system, we employ spatial augmented reality for appearance details, vision tracking to capture the physical movement of tangible buttons and a custom fingertip resolution RFID reader to capture tangible button presses.

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