Rapid Prototyping of Customizable Physical User Interfaces by Means of Infrared Modulation

ABSTRACT

Rapid prototyping of physical user interfaces (PUIs) can be useful for designers if the "look and feel" of a device and interaction with the system come together early in the design process. While most professional designers use computers to accomplish this, do-it-yourself designers still build prototypes by hand. Toolkits including Phidgets, iStuff, and Calder can be used to assist these designers, but if a new part is added, a delay is induced because the toolkit implementation needs to include the new part. As a result, the designer has to use the provided parts thus constricting creativity. We developed a system that extends BOXES (Building Objects for eXploring Executable Sketches) to allow for newly built customizable discrete (e.g. button, switch) and continuous (e.g. knob, slider) inputs to interact in a wireless manner. In order to evaluate the ease of creativity, a qualitative user study was conducted on a media player environment.

Author Keywords

Rapid prototyping of physical user interfaces, customizable tools

ACM Classification Keywords

H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces. – Prototyping.

INTRODUCTION

In order to rapidly prototype and build physical user interfaces (PUIs); designers want to develop the "look and feel", or form, of a device and interaction with the system simultaneously [2]. The reason for this is so the design process is more fluid, faster, and allows for more iteration [12]. While most professional designers use computers to accomplish this, do-it-yourself designers still build prototypes by hand. These designers can make more practical designs keeping both form and interaction in mind. The ability to use their own input devices enables them to envision their design and expand their creativity as they are prototyping. As a result, the design process of PUI is more efficient and robust when keeping form and interaction together because they can rapidly prototype more creative ideas at a low cost.

However, there is no current support that allows form and interaction to remain together throughout the entire design process. Building Objects for eXploring Executable Sketches (BOXES) [12] currently provides rapid prototyping of PUIs in the very early design stages. This is followed by the use of toolkits for a more sophisticated design, but not to the point where the designer is manufacturing their own parts. There are many toolkits that assist in the design process including Phidgets [9], iStuff [4], widget tapping [8], Switcharoo [2], Calder [13], and Lego Interface Toolkit [3]. One issue with these toolkits is if a new part is added, a delay is induced because the toolkit implementation needs to include the new part. As a result, the designer has to use the provided parts thus constricting creativity. This limits designers to a certain group of premade devices, which isn't the goal when they are still trying to brainstorm endless options.

In this paper, we seek to bridge the gap between form and interaction in the earlier stages of design. We developed a system that extends upon BOXES, designed to link discrete inputs with a software application early in the design process using household items such as cardboard, thumbtacks, foil, and tape via serial communication. We added to BOXES by enabling wireless devices which can be discrete (e.g., button, switch) or continuous (e.g., knob, slider) devices and are customizable. In addition, we have created an easily customizable slider by cutting out shapes of paper painted with wire glue and using paper clips to determine the position of the slider. Designers can construct particular devices they wish to use, and specify this to BOXES so they test both form and interaction without inner working knowledge of the devices themselves. This helps the designer prototype until they want to manufacture the parts.

One way to simulate interaction of customized input devices is by using infrared (IR) light emitting diodes (LEDs). They can be placed on customized parts and can be simulated using infrared modulation. IR modulation consists of turning on and off an IR LED repeatedly to create a binary message which is then decoded by the system. The IR LEDs can portably attach to discrete and continuous devices, and are read by an IR receiver. BOXES is configured to decipher various IR messages in order to determine the status of discrete and continuous devices. For example, if the designer wanted to add a slider, the IR receiver would read in the IR message and BOXES would decode that the particular slider was active.

The rest of this paper is organized as follows: First, there will be a discussion of the system. This will be followed by experimentation and methodology of the qualitative study. The evaluation of the system and discussion will then be addressed. In closing, the conclusion and future work will be presented.

RELATED WORK (.5 PAGES)

Toolkits

Previous toolkits have sought to make the lives of a designer easier when prototyping a new device. Most toolkits provide the ability to work with 3D forms [3, 9, 2, 8, 4, 13, 5]. In order to increase convenience, some toolkits allowed designers to use household supplies in their designs such as the Lego Interface Toolkit and BOXES [3, 12]. The Lego Interface Toolkit used Lego blocks to build an interface, while BOXES provided materials such as cardboard, foil, thumbtacks, and tape. Although there are kits that work with a wired connection [3, 9, 8, 4, 13], in order to get the prototyped device to have a form closer to the finished product, work has been done with wireless devices instead [2, 13].

The goal of our approach is to support rapid prototyping of PUIs which have a 3D form that fits closer to what the do-it-yourself designer is imagining. Unlike toolkits, the do-it-yourself designers are able to provide their own easily accessible and changeable inputs that they created. This is justified in Plywood Punk, where they say that designers should not be constrained to objects from a kit of parts [14]. Since wireless toolkits allow designs to be more realistic, we also have input devices interact with the computer via wireless communication, and be powered by a portable battery so there are no extra wires that need to be attached to the computer or power supply. There is a casing that will make the battery easily replaceable and allow for prolonged usage so it will not impede on the designer's work. Overall, the prototypes will have both higher fluidity (rapid prototyping) and fidelity (closer to desired form).

BOXES

BOXES [12] was designed to link a physical device with its application early in the design process. This emphasizes the ability to see form and interaction at the same time. This allowed for quicker iterations to improve the physical device. This can be used on existing software applications or someone's own developed software. The do-it-yourself designer can accomplish this by using common household items to create an early stage remote to interact with the computer via usb serial cable. The buttons provided could control clicking and keyboard events in software programs. The buttons work with capacitive touch sensors, where the capacitance was caused by the space between thumbtack and foil.

BOXES UPDATED

The new system is an improvement from BOXES in two ways; wireless communication and the ability to customize continuous input devices using household items. For example, a remote control using buttons to select start and stop, and slider control could be built. The key is that the buttons and slider could be made to multiple shapes and sizes in a short amount of time while deciding which would work best for the remote. Being able to add customized devices allows for more creativity when designing a PUI. The piece that contains the input device is the sender. The receiver decodes the wireless messages and completes corresponding actions on the computer using BOXES software. A more detailed explanation of the sender and receiver follows.

Sender

As Figure 1 illustrates, the sender consists of an ATMega328p board, IR LED, and a 3 volt battery. These components are put into a single board and are attached to various input devices. The microcontroller was programmed using the Arduino platform [1]. In order to conserve power, the IR message status of each device is only sent every 500ms. While idle the board completely powers down. The IR led sends a modulated IR signal to transmit information to the receiver piece.

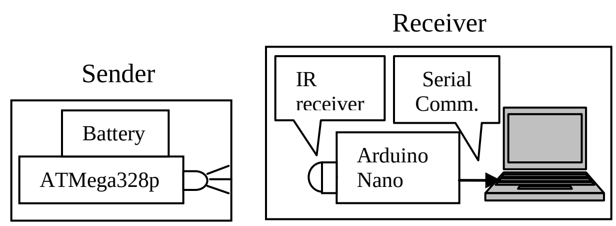

Figure 1. This shows the top level diagram of system.

Receiver

On the right side of Figure 1 is the receiver. The receiver contains an IR receiver, Arduino Nano board, and BOXES. The IR signal is received using the IR receiver and then sent serially to BOXES. BOXES will detect two different types of inputs. The two messages are discrete (id, on or off) and continuous (id, current position). The on or off position of a discrete input device is used to trigger computer events such as clicking or typing. As seen in

Figure 2 below, the user can select a cutting, or screenshot, of the desktop to determine where the mouse will click upon an event.

The other type of device, not included in the original work

Figure 2. The screenshot of cutting has the selection on the volume adjuster.

of BOXES, was continuous input. The current position of continuous device can be used for scrolling, dragging, or moving the mouse and clicking. In order to have the physical slider work with the computer, the two end points of the slider and the portion of the computer screen that they want to be used need to be mapped together. First the

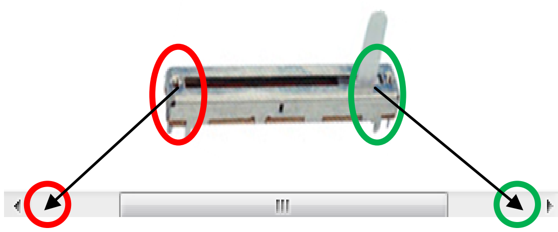

Figure 3. Physical Slider mapped to Digital Slider.

user moves the slider to each end and BOXES will log the two positions. Then the user clicks on each end of the computer screen that they want to map the slider positions to. As the continuous device is moved, so is the position of the mouse on the screen. The user can opt to drag the mouse or move and click the mouse. A pictorial representation is shown in Figure 3 to represent the mapping between a physical and digital slider.

EXPERIMENT/METHODOLOGY (.5 PAGES)

A small user study was run with about 10 – 12 participants over the age of 18. They will be using the system to complete a design task in which they created a physical user interface for a media player application. The study will be a think aloud study.

CONCLUSION AND FUTURE WORK

As of right now, the implementation of the project is nearly done. I plan to complete the finalizing touches to the project, and run the user study at my home institution. I am currently in the process of getting IRB approval for my study. Afterwards, I plan on submitting a short paper to a conference in the next year.

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