SLAP Widgets: Bridging the Gap Between Virtual and Physical Controls on Tabletops

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Abstract
We present **S**ilicone i**L**luminated **A**ctive **P**eripherals (SLAP), a system of tangible, transparent widgets for use on vision-based multi-touch tabletops. SLAP Widgets are cast from silicone or made of acrylic and include sliders, knobs, keyboards, and keypads. They add tactile feedback to multi-touch tables and can be dynamically relabeled with rear projection. They are inexpensive, battery-free, and untethered widgets combining the flexibility of virtual objects with tangible affordances of physical objects. Our demonstration shows how SLAP Widgets can augment input on multi-touch tabletops with modest infrastructure costs.

Keywords
Tangible user interfaces, transparent widgets, dynamic relabeling, tabletop interaction, multi-touch, toolkit

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces: Input Devices and Strategies

Introduction
Beginning with the first computer interfaces, physical input devices have a long tradition in Human-Computer Interaction. Thanks to their haptic nature, users can operate them in an eyes-free fashion and maintain

visual attention elsewhere. Graphical user interfaces, on the other hand, have the advantage of being easily positioned right at the locus of the user's attention, and dynamically configured to match a specific task.

With the widespread interest in multi-touch interfaces, some shortcomings of on-screen controls have begun to show. For example, typing on a projected soft keyboard is difficult due to the lack of tactile feedback and it also requires visual attention. But returning to physical inputs is not always an option since they are often far away from the locus of activities or occlude contents when placed on a table. On-screen buttons and scrollbars also lack tactile feedback, making it hard to operate them fluidly, and physical counterparts are not readily available.

SLAP Widgets are transparent tangibles made from flexible silicone and acrylic. As input devices, they combine the advantages of physical and virtual on-screen widgets. They provide haptic experiences with tactile feedback and support fluid and eyes-free operation. At the same time, thanks to their transparency and rear projection, they support dynamic software-controlled labeling and graphics within the devices as well as around them. SLAP Widgets are also very simple hardware devices requiring minimal additional infrastructure. Their pure mechanical construction does not require any electronics or tethering chords. When made from silicone, they are very durable, physically flexible and can literally be tossed around and "slapped" onto a table. Many can be placed on a table and simultaneously operated. Combined with their low cost, they are ideal for researching and prototyping interfaces.

Related work

With the increasing interaction on flat surfaces without tactile feedback, research has focused more and more on compensating the missing tactile qualities. SenseSurface[1] recently introduced physical controls, like knobs, to the desktop environment. Magnets are used to stick these controls onto the display, and internal sensors broadcast the manipulation data via Bluetooth. However, the controls of SenseSurface are opaque and cannot be relabeled dynamically.

Audiopad [7] combines knob-based controller "pucks" with multidimensional tracking using RFID tags. Each puck has two tags for determining their angular orientation as well as position. Audiopad uses multiple pucks for selection and confirmation, not allowing single-handed operation. Furthermore, Audiopad pucks do not have a physical axis of rotation and their position may drift while rotated.

VoodooSketch [1] supports the extension of interactive surfaces by physically plugging widgets into a palette or drawing them. Yet this approach lacks the ability to label widgets on the fly. Furthermore, voodoo tangibles require electrical power and are more complicated and costly.

reacTable [5] implements low-cost widgets in a musician's interface. It uses optical fiducials for tracking the position and orientation of tokens on a table. Although software could be implemented for different purposes, the reacTable tokens do not offer more manipulation possibilities than positioning and turning, thus constraining the interaction. Another

[1] http://girtonlabs.googlepages.com/sensesurface

drawback is that the fiducials are opaque and occlude the graphics underneath the token. Therefore, custom labels can only be projected around the token.

DataTiles [8] introduce the idea of relabeling through the use of transparent acrylic tiles. Although DataTiles mix graphical and physical interfaces, they do not fully explore the affordances of physical controls of the real world. Whereas DataTiles use engraved grooves in combination with a pen to manipulate data, they do not provide tactile feeling of real-world controls. Furthermore, DataTiles have to be placed at a specific grid on the display, constraining the tabletop interaction.

System design

A multi-touch table provides the infrastructure for sensing physical SLAP Widgets (knobs, sliders, keyboards, and keypads) as well as displaying the virtual objects (e.g., movies, images, text fields) they modify. Widgets are transparent and utilize the rear projection display of the table to dynamically present labels and graphics around and beneath them. Associations between physical widgets and virtual objects are created and removed using synchronous tapping while halos indicate their status. These associations determine the labeling and graphics of the widgets. For example, a slider labeled "brightness" may have "0" and "255" at its extremes with gradations between black and white spanning its range of articulation.

Multi-touch Table

Our table uses a combination of infrared technologies to sense surface pressures and near surface reflections using a single camera and computer vision software. A

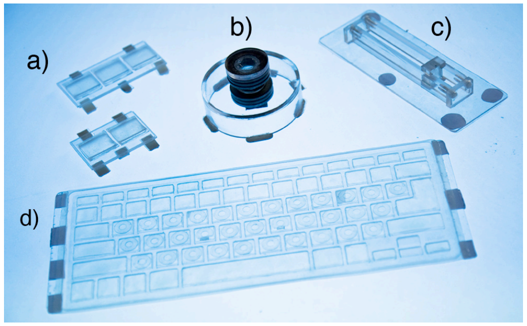

Figure 1. The SLAP widget set. a) Keypads with two and three buttons. b) Knob. c) Slider. d) Keyboard.

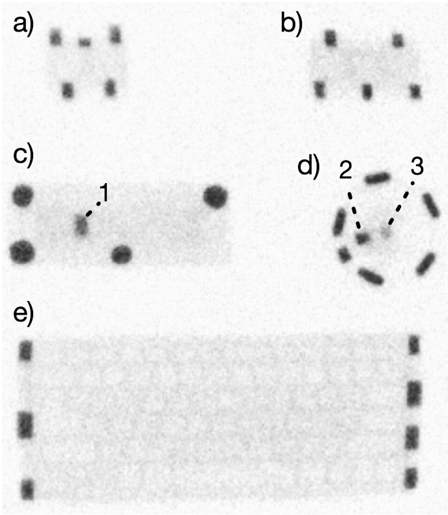

Figure 2. Footprints of SLAP widgets (image has been inverted for better perception). a-b) Keypad with two and three buttons. c) Slider with sliding knob (1). d) Knob with angle indicator (2) and push indicator underneath the rotation axis (3). e) Keyboard.

rear projection displays graphics onto the matte touch surface without parallax errors. A silicone film between this projection/touch surface and the acrylic panel translates surface pressures to optical radiation by frustrating the total internal reflection (FTIR) as popularized by [2]. The very low surface pressures of lightweight widgets are difficult to detect reliably by FTIR alone. Hence, additional infrared LEDs are placed inside the table providing Diffuse Illumination (DI) as described in [6]. They are used to spot reflective materials that are added to the widgets. DI is also used to sense articulating parts (knob and slider) not in contact with the surface. DI's ability to sense slightly contacting and non-contacting objects is complemented by FTIR's ability to sense surface contact pressures.

Widgets

All widgets are constructed from transparent acrylic and silicone enabling the projected graphics to shine through (see Figure 1). As shown in Figure 2, reflective markers of foam and paper create uniquely identifying "footprints". Reflective materials were also fastened to moving parts to track their position.

KEYBOARD

The SLAP Keyboard is a modified iSkin[2] silicone keyboard cover. Cemented onto each key is a transparent 0.01" PVC keycap providing rigidity for improved tactile feedback. Two rigid strips of transparent acrylic are glued on the edges of the keyboard to provide structural stability and reflective portions for an identifiable footprint. Fingertip forces are conveyed directly through the keys onto the multi-touch surface triggering FTIR, detected as blobs in particular key regions, and interpreted as keystrokes. Keycap labels or graphics are dynamically displayed under the SLAP keyboard.

KEYPAD

A keypad's base is rigid and only the actual buttons are made of silicone. Its keys are much larger, 20mm x 15mm. Two and three button variations have been fabricated and aggregates can be created by fastening multiple units together. As with the keyboard, fingertip forces are directly conveyed and labels/graphics are dynamically displayed.

KNOB

An acrylic knob rotates on a clear acrylic base. The knob is vertically spring loaded and can be pressed as a button. An internal reflector arm orbits the axis and indicates an angular position to the camera. A reflector centered on the axis communicates the pushbutton function and reflectors on the base provide information on its position and orientation.

SLIDER

Just as the knob, the slider is made entirely of acrylic. Two engraved rails guide the linear motion of the sliding knob (see Figure 1). Reflective material cemented on the edges provides a footprint indicating location and orientation of the base. Reflective material placed on the slider knob indicates its linear position.

Pairing

When initially placed on a surface, a widget displays a wafting blue halo indicating that its footprint is successfully sensed but the widget is lacking an

[2] http://www.iskin.com/

association. Connections between widgets and virtual objects are requested with synchronous double tapping of both a virtual object and a widget's halo. If a virtual object is not found, or if it refuses the association, a red halo flashing around the widget indicates a problem. A green halo indicates a successful association, graphics and labels displayed in and around the widget are updated, and it is ready for use.

If removed from the surface, a widget's association is restored when returned. They can be removed when not in use, and collaborators can toss controls back and forth without loss of configuration. Associations are removed by repeating the synchronous double tapping gesture, or by associating it with a different virtual object. Multiple widgets may be associated to a single virtual object. However, currently a widget may not be associated to multiple virtual objects.

Symmetrical Bimanual Synchronous Tapping is a novel approach to declare associations between objects. In contrast to Hinckley [3], our method does not depend on the objects' spatial proximity to each other.

USER INTERFACE

Keyboard

The SLAP keyboard alleviates the problem of missing tactile feedback of virtual keyboards and leverages capabilities of multi-touch technology. The user can place the keyboard anywhere on the surface, pair it with a virtual object, and begin to enter text as if using a traditional keyboard. Furthermore, the layout of the SLAP Keyboard can be dynamically altered. For example, when a user presses the "<CTRL>" (control) modifier key, icons displayed under the keys reveal their shortcuts; "<CTRL>+C" for copy, "<CTRL>+V" for paste, etc.

Keypad

Buttons are a basic interface. Many applications have a small set of frequently used controls such as play, pause, page-down, and zoom-in/out. SLAP Keypads provide simple controls, require less table space than keyboards, and can be aggregated. Their larger keys are visible from a distance or can accommodate more complex graphics.

By pairing a keypad with an application controller, shortcuts to frequently used functions can be provided for all objects in the application, e.g. cut/copy/paste as known from the Xerox Star [4].

Knob

Knobs are also very basic interfaces frequently found in software mimicking traditional physical controls such as audio volume and video shuttle knobs. Although such virtual knobs leverage familiarity with physical knobs, they lack tangible qualities.

Our knobs provide two modes of operation: *property menu* and *relative browser*. When associated with an object with multiple properties, a circular menu of its properties is displayed. The knob is rotated to select a property and pressed to modify it. The current value of the property is displayed underneath and is changed by turning the knob. A second push confirms the new value and returns to its circular menu of properties to modify. When associated with a video, the knob can be used for frame-by-frame navigation.

Slider

Unlike the knob, sliders are absolute controls and have physical limits on their ranges. The existing position of a slider replaces rather than modifies existing parameter values. Thus, it can be used to distribute or transfer values between parameters with a series of quick un-pairing and pairing. Like a knob, property values are projected directly below the slider for compact representation.

The slider can be used for any interaction where an absolute value needs to be set. It could be used as a physical timeline for fast navigation in a video object, or just like an analog slider for setting volumes in an audio context.

Conclusion

Physical and virtual widgets each have their respective advantages: virtual widgets can be relabeled dynamically and physical widgets provide natural tactile feedback. We introduced SLAP Widgets to tabletop interactions to combine advantages of both. They are made of transparent acrylic and silicone, allowing relabeling with rear projection while providing tactile feedback. An existing FTIR multi-touch infrastructure is utilized and extended with DI for a low cost approach to exploring tangible tabletop interactions. Synchronous tapping is presented as a method of establishing associations between virtual and physical objects. Parameter selection and differences between absolute and relative controls are demonstrated.

Acknowledgments

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