PUCs Demo: Detecting Transparent, Passive Untouched Capacitive Widgets

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Figure 1: PUC widgets on an iPad: a transparent Bridge PUC (left) and a Ring PUC (center). The clip to permanently ground a touch point and override the iPad's adaptive filter can be seen on the right.

Abstract
Capacitive multi-touch displays are designed to detect touches from fingers that often change the location. This is quite the opposite of our goal: detect passive objects placed on them. In fact, these systems usually contain filters to actively reject such inactive input data. We present a technical analysis of this problem and introduce Passive Untouched Capacitive Widgets (PUCs). Unlike previous approaches, PUCs do not require power, they can be made entirely transparent, and they do not require internal electrical or software modifications. Most importantly they are detected reliably even when no user is touching them.

Author Keywords
Tangible user interfaces; transparent widgets; passive widgets; tabletop interaction; capacitive multi-touch

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces Input Devices and Strategies

Introduction
Most modern multi-touch devices use capacitive technology to detect users touch input. Tangible widgets for such systems where introduced by Rekimoto in 2002 [4]. Other systems such as the CapWidgets [3] and Capstones [2] extend this first approach. However, all these widgets have one common drawback: they rely on the human body capacitance to be detect by the touch screen. This means they can only be detected if a user touches them. This leads to several problems: it is not possible for the system to distinguish whether the object has been lifted form the screen, or the user is no longer touching the widget. Furthermore, if a widget is moved without being touched, for example, by flicking the widget, this movement cannot be detected by the touch screen as well.

In this demonstration we present *Passive Untouched Capacitive Widgets (PUCs)*—simple physical widgets the can be detected by an unmodified capacitive touch screen without being touched by a user. We will explain how these PUC widgets are detected by the screen. Furthermore, we show how the can be made totally transparent.

Capacitive Touch Displays
Capacitive touch displays detect a touch point by sensing a grounded electrical conductor, such as a human finger, that is close to the display [1]. To be able to detect this conductor a display consists of a set of row electrodes and a set of column electrodes. Electrodes in one of these sets act as transmitters (Tx) while the electrodes in the other set act as receivers (Rx). If a signal is applied to one Tx electrode, at each intersection between this Tx electrode and each Rx electrodes, a capacitive coupling is established. We refer to these intersections as active. The coupling is measured by each Rx electrode. By activating only one Tx electrode at any time the system is able to measure the capacitance of each intersection individually.

If a grounded conductor such as a finger comes close to one of the intersections, the coupling between both electrodes at this intersection is disturbed such that the measured capacitance for this intersection is reduced. With this method the display controller is able to determine the shape and center of the contact point, by using interpolation between multiple intersection.

With this technique a capacitive display is able to detect very small changes in the capacitiance of each intersection. However, this signal is noisy and would lead, without filtering to a large set of false positive touch detections. Therefore, nearly all commercially available capacitive displays use a set of filters that only detect a human finger very close to the surfaces as a touch point.

PUCs
We found out that a widget has to fulfill basically two requirements to be detected as a touch point by a capacitive touch display: (1) It has to reduce the capacitance of the intersection in the same way as a human finger would. (2) The shape of the contact point has to be elliptical with a size similar to a fingertip.

Alternatively to already proposed widget for capacitive touch displays [4, 2] PUC widgets accomplish both requirements without a user touching them. Through there specific setup they ground themselves by electrically connecting multiple active and inactive intersections. While the active intersection is scanned, the inactive intersection serves as ground. This grounding is strong enough to disturb the capacitive coupling at the active intersection enough such that the system detects the contact point of a widget as a touch.

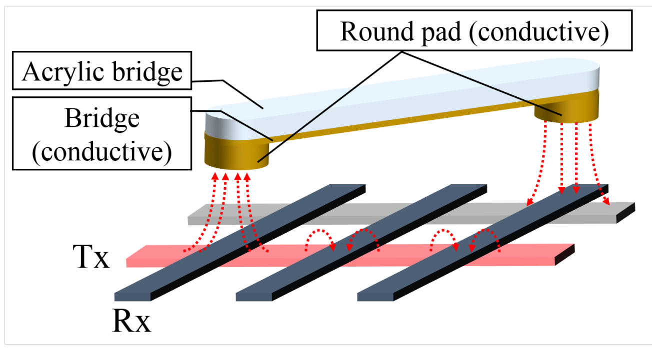

Figure 2: Basic concept of a Bridge marker. Red connections indicate capacitive coupling between marker and electrodes.

There are different options ways to create PUC widgets, one basic version is shown in Figure 2. It consists of two round *pads* that fulfill the second requirement, and a conductive "Bridge" that connect both *pads*. The conductive parts can be for example made of copper (cheap) or *indium tin oxide* (ITO) foil, which is more expensive but totally transparent as can be seen in Figure 1 .

We will now show how we trick the capacitive system to react to the passive widgets. We "short-circuit" the Tx and Rx electrodes with our bridge: When a Tx electrode under one pad is currently active and the Tx electrodes under the other pad is inactive (at ground level), this second pad has a capacitive coupling to ground. This ground coupling is sufficient to reduce the $Tx - Rx$ intersection capacitance under the first pad to below the threshold for touch detection. Similarly, when the Tx electrodes are active under the second pad (when the touch screen scanning algorithm reaches that area), the Tx electrodes under the first pad will no longer be active, and thus coupled to ground. This lets the Bridge PUC generate one touch event for each of the two pads, without the aid of external grounding. However, if both pads are aligned with one Tx or Rx electrode both pads will not be coupled to electrical ground. In fact instead of decreasing the capacitance of the active intersection, the capacitance is increased by creating a strong coupling between Tx and Rx. This means, the system does not recognize a touch at all.

Thus, instead of the bridge layout we suggest a "Ring" widget (shown in Figure 1). This widgets also has a set of pads, but they are connected with a ring-shaped conductive material that hovers above the surface. Since the capacitive field reaches out of the display the hovering conductive material also creates a capacitive coupling to the inactive intersection under it. This setup ensures that parts of the widget are not aligned to a single Tx or Rx electrode, independent of the widget orientation.

Both the "Bridge" and the "Ring" are only two very simple widget geometries that could be used as widget marker for any kind of widget. Furthermore, any other structure would be also possible if the distance between the pads is large enough that the display does not merge both pads to a single touch pad and the widget is large enough to connected multiple active and inactive intersections. Both of the values depending on the capacitive display on which the widget should be placed. In our experiments we found out that for mostly all Apple devices the distance between two pads should be 1.5 cm and a "Ring" widget should have at least a diameter of 2.5 cm.

Demonstration Experience

In this demonstration we will show a large variety of different PUCs and show how they can be build and how they can be used in different scenarios. The vistors will be able to experience each of the presented PUCs on a iPad and on a 27" Pereceptive Pixel display.

Conclusion

In this demonstration proposed *PUCs*, tangible widgets for capacitive multi-touch screens that (a) are *passive* and require no batteries; (b) can be detected even when *untouched*; (c) can be completely *transparent*; and (d) work with *unmodified* off-the-shelf multi-touch screens. Our contributions also include (e) the new approach of grounding a widget via a second pad or hovering conductive material plane.

Acknowledgments

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