PERCs Demo: Persistently Trackable Tangibles on Capacitive Multi-Touch Displays

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ITS'14, November 15– 18, 2015, Funchal, Portugal
ACM 978-1-4503-3899-8/15/11.
DOI: http://dx.doi.org/10.1145/2817721.2823474

Abstract
Tangible objects on capacitive multi-touch surfaces are usually only detected while the user is touching them. When the user lets go of such a tangible, the system cannot distinguish whether the user just released the tangible, or picked it up and removed it from the surface. In this demo we demonstrate PERCs [2], persistent capacitive tangibles that 'know' whether they are currently on a capacitive touch surface or not. This is achieved by adding a small field sensor to the tangible to detect the touch screen's own, weak electromagnetic touch detection probing signal. In this demo we present two applications that make use of PERC tangibles – An air hockey like game for two players and a single person arcade game.

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

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

Introduction
Tangible objects in combination with multi-touch surfaces have been shown to be useful in a large variety of application scenarios. The haptic experience and tactile feedback

provided by tangibles guides user input and allows for fast eyes-free interaction [4]. However, using them on modern capacitive touch screens is problematic.

Capacitive touch screens detect touches by creating an electric field above their surface. When an object with high capacitance, such as a human finger, comes close to the surface, this electric field changes. The touch screen measures this change and reports a touch. Tangibles on touch screens, such as Capstones [1] or TUIC [5], normally use electrically conductive material on their bottom and sides, so that a user touching them increases their capacitance enough to register as a touch. However, this means that for the tangible to be detected, the user has to continue touching it. As soon as the user releases the tangible, the capacitance drops, and the system fails to detect the tangible—even if it remains on the surface. This makes it impossible to distinguish whether a tangible has been picked up and removed from the touch screen, or whether the user has just let go of the tangible, leaving it on the touch screen.

PUCs [3] addressed this issue by introducing tangibles that ground themselves through currently inactive sensor electrodes of the capacitive touch screen. However, most touch screens have adaptive filtering mechanisms that remove touches that have been stationary for too long.

PERC tangibles [2] extended the PUCs concept by adding a sensor into the tangibles that detects the signal emitted by the capacitive touch screen's electric probing field. This enables the tangible to determine whether it is currently placed on a capacitive touch surface or not, even when its touches are being filtered out by the touch system. That status is communicated from the PERC tangible to the system via Bluetooth; the communication channel also assigns a unique ID to each tangible independent of its touch pattern, solving the identification problem with PUCs.

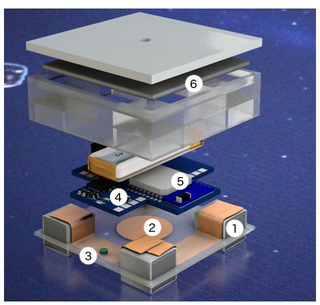

Figure 1: The six main components of a PERC tangible: (1) marker pattern, (2) field sensor, (3) light sensor, (4) micro controller, (5) Bluetooth element, and (6) lead plate.

In this demo we present two applications that make use of PERCs tangibles [2]. Since PERCs are fast and reliable, users can use tangibles on a capacitive screen just as if they were using their fingers. The additional haptic experience and tactile feedback allow for fast and eyes-free interaction, where typical finger gestures would not suffice.

PERCs

A PERC tangible consists of three main components: A PUCs marker pattern, the field sensor, and a light sensor (Fig. 1). In addition to these main components each PERC also includes a microcontroller, a Bluetooth 4.0 chip, a battery, and a small lead plate on top of the tangible to increase the tangible's weight.

Marker Pattern

The marker pattern consists of three 8x8 mm pads connected via conductive copper foil (Figure 1.1). Each pad creates a touch point that is detected by the capacitive touch screen. For the pads, we use a soft conductive weave that is usually used as EMS shielding[1]. This has the benefit that the pads do not create any scratches on the touch surface and that they remain in good contact with the surface.

Field Sensor

The field sensor is the part of a PERC tangible that actively determines if the tangible is placed on a touch surface at any given time or not. For this purpose, an antenna at the bottom of the tangible picks up the signature of the electric field above the surface, which is created by every capacitive touch screen, shown in Figure 2. The PERC field sensor consists of this antenna, a comparator integrated circuit that

[1] www.we-online.com

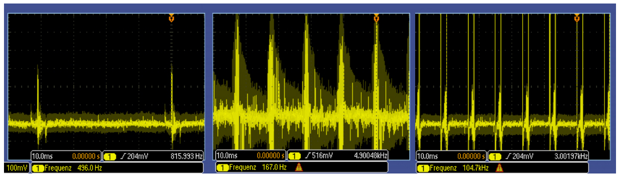

Figure 2: Touch detection signals by (left to right) iPad 4, 3M screen, and Microsoft 55" capacitive screen

detects peaks above a certain voltage threshold, and a microcontroller to trigger a timeout if the next peak was not detected within a specific period of time, determined by the touch screen's pulse frequency. In our current implementation, the threshold of the field sensor is set to detect the capacitive touch screen if the distance between the touch surface and the tangible falls below 1 mm.

Whenever the field sensor detects the presence of a capacitive touch surface, the tangible sends a *set* event via BLE to the system. The system correlates this message temporally to newly appearing touches in order to link the UUID to the tangible's position. Until the tangible recognizes the absence of the electric field and sends a corresponding *lift* event, the system considers it as being on the table even if its touches are filtered out.

Unfortunately, there are still two situations in which the field sensor alone does not suffice to detect a PERC tangible reliably: In situations where two tangibles are placed at the same time and in situations where not all markers are detected by the system.

Light Sensor
To resolve these ambiguities, we added a light sensor underneath the tangible. The light sensor allows to ping stationary tangibles in uncertain situations.

When two tangibles send a *set* event a very short time frame, the system first pings each tangible individually with a bright dot at the position of the light sensor. If a tangible detects this change, it notifies the system via BLE about the change and the ambiguity is resolved.

If the system detects only two touch points and a *set* event is received, the position and orientation of the tangible can only be detected up to a 180° ambiguity. Since the light sensor is placed with an offset from the center, this yields two possible positions of the light sensor. The system now pings these positions as before, and if the light sensor detects the change the orientation is clear.

Other Components and Power Cconsumption
Within each PERC we use a MSP430G2553 microcontroller, a BLE112 Bluetooth module, a TEMD6200FX01 light sensor, and a Renata LIPO battery (3.7 V, 175 mAh).

Since PERCs use active components, we have to deal with battery lifetime. The 175 mAh battery in our PERCs typically yields about 60 hours of continuous use and could be easily recharged via conductive power transfer. If a tangibles battery is low, the system can inform the user via visual feedback on the screen and the user can exchange the tangible with a new one.

Demo experience
In our demo we will present two different usage scenarios for PERCs on a 27" perceptive pixel display.

The first application is an air hockey inspired application where two users play against each other (Fig. 3). The mallets are PERC tangibles, the puck, borders, and goals are displayed on the screen. Each player holds one of the PERC mallets and tries to score a goal against the other player. This scenario demonstrates PERC tangibles in fast abrupt

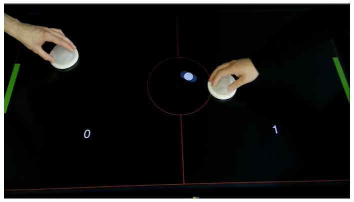

Figure 3: An interactive airhockey game in which PERC tangibles are used as mallets

Figure 4: A space-invader game in which PERC tangibles are used as space ships.

movement. Since PERC tangibles make use of the PUCs marker concept, the digital representation of the mallet reacts as fast as the typical touch detection. Most of the time users will touch the mallet, but since PUCs markers are independent of users touching them, pushing the mallet and letting it go at the same time is also possible.

The second application is a space-invader like break out shooter game. As shown in Figure 4, the user gets up to three space ships and has to move them correctly to shoot at incoming enemy space ships. The incoming space ships have different colors and only the correspondingly colored player ship can hit an enemy ship. To force users into moving the space ships even more, space ships mix their colors if they are placed close to each other. There will be enemies who can only be defeated by combining the player ships the correct way.

The players ship will be represented by three tangibles. Since the player ship automatically shoot, one ship can be put aside while the others are operated. This scenario shows a more stationary use of PERC tangibles – the player's space ships constantly shoot at enemy ships as long as they remain on the surface. Even if the touch screen filters out the stationary tangible, the field sensor will inform the system about the tangible still being in place on the surface.

These examples are not the only applications where PERCs can be used. PERC tangibles are not limited in size or shape and since each tangible has a unique Bluetooth UUID, a theoretically unlimited amount of tangibles could be connected to the system. As demonstrated in our applications, PERCs work as fast moving tangibles as well as slow or static tangibles. PERCs also work on a variety of commercially available touch screens. With only very small adjustments we managed to use PERCs on a Microsoft 55" display, on a Perceptive Pixel 27" display, and the iPad.

Acknowledgments
This work was funded in part by the German B-IT Foundation and by the Norwegian Research Council through the MACS project (project number 217788).

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