BeyondTouch: A framework for extending input on commodity smartphones

Cheng Zhang
School of Interactive Computing
Atlanta, GA 30308 USA
chengzhang@gatech.edu

Rosa I. Arriaga
School of Interactive Computing
Atlanta, GA 30308 USA
arriaga@cc.gatech.edu

Gregory D. Abowd
School of Interactive Computing
Atlanta, GA 30308 USA
abowd@gatech.edu

UbiComp'13 Adjunct, Sept 8-12, 2013, Zurich, Switzerland.
ACM 978-1-4503-2139-6/13/09...$15.00.

Abstract
The primary mode of interaction with a smartphone is limited to the front-facing touchscreen and several physical buttons along the sides. This project will extend the input modality of a smartphone with built-in sensors (microphone, gyroscope, and accelerometer etc.). We will firstly introduce the prototype BackTap, adding four distinct tap locations on the back case of a smartphone. The BackTap interaction can be used eyes-free with the phone in a user's pocket, purse, or armband while walking, or holding the phone with two hands. We also present evaluation data that showed users were able to tap four distinct points with 92% to 96% accuracy. Finally, we describe future research plans.

Author Keywords
Acoustic classification; mobile; heuristics; inertial sensors; touch; always-available input;

ACM Classification Keywords
H.5.2. Information Interfaces and Presentation: User interfaces; Input devices and strategies

General Terms
Human Factors; Design; Measurement

Introduction

Currently, the primary mode of interaction with a smartphone is limited to the front-facing touchscreen and a small number of physical buttons along the sides. However, contemporary smartphones are equipped with an increasing number of sensors, specifically accelerometers, gyroscopes and microphones, which can be exploited to support a wider variety of software-detected input events without any further change to the devices themselves. Interactions based on these built-in sensors have only scratched the surface of the potential they offer. Traditionally, these sensors are used separately, based on the purpose for which each was designed. We have developed the BackTap prototype. This project takes advantages of existing sensors to provide more input possibilities, e.g., detecting the positions of tapings on the back of the phone.

We first review related work on extended input through sensing on mobile devices. Then we describe the BackTap prototype. In the last part, we discuss our future plan for this project.

Related Work

We review related work for interactions on the back of a mobile device, tapping interactions, and the use of built-in sensors on commodity phones.

Several researchers have experimented with shifting mobile interaction away from the touchscreen to the side and back of the device, as a means to eliminate occlusion. Behind Touch and BlindSight place a 12-key pad on the backside of a mobile phone [11, 7]. HybridTouch and Gummi allow users to scroll by performing drag gestures on a touch pad mounted on the backside of a mobile device, mainly with the non-dominant hand [12, 10]. LucidTouch used a camera pointed at the back case of a device to further explore two- handed interactions on the back [13].

Tapping is one subset of gestures available for interaction with a mobile phone. TapInput built a prototype with additional sensor and found that the tap gesture was the preferred of six gestures compared in a user study [8]. Hinckley et al. designed an application to recognize the user's tap gesture on the two top corners of a phone through inertial sensors[4]. ForceTap utilizes the accelerometer to distinguish a strong tap from a gentle tap on the touchscreen [3]. Whack Gestures [6] enabled the user to interact with the phone by striking its case forcefully with the palm or heel of the hand. PocketTouch enables capacitive touch-based gesture control and text input on a mobile device through fabric enclosing the device (e.g., a pocket or bag) [9].

One trade-off with many of the approaches presented so far is that they require additional sensing to be attached to the mobile phone. Recently, Hinckley et al. explored techniques using only inertial sensors and touch input for hand-held devices, providing touch-enhanced motion and motion-enhanced touch gestures [5]. GripSense is a system that leverages mobile device touchscreens and only their built-in inertial sensors and vibration motor to infer hand postures [1]. TapSense detects which part of the finger is being used to tap on the screen by analyzing the different sounds [2]. In our project, we extend the interactions using only commodity sensors (i.e. microphones, accelerometer, gyroscope etc.) that are embedded in the phone.

a. In-pocket Interaction

b. Two-hand Interaction

Figure 1. BackTap interactions under two usage conditions: (a) in- pocket and (b) two-hand.

BackTap Prototype

BackTap is a prototype on a smartphone that allows the user to tap on each of the back four corners: top-left, top-right, bottom-left, and bottom-right. It was implemented on a Samsung Galaxy S3 running Android 4.0.4. Our software detects tap events by analyzing data from three built-in sensors: the microphone, accelerometer, and gyroscope. We applied heuristic techniques to identify the characteristic signature of taps on each of the four corners of the back case. The BackTap interaction may be used while the phone is in a pocket (see Figures 1a) or while holding it with two hands (see Figure 1b). These interactions suggest a number of compelling applications. Two examples that leverage eyes-free interactions and pre-defined taps are a music player where 1 tap equals "on" and two equals "pause." The other is a sequence of taps that trigger an in-pocket text-reply (e.g., two taps sends a "busy can't text" message). A third example is a game application that uses all four positions (see Figure 1b) and can avoid screen occlusion.

Implementation

Our approach consists of two phases of tap event detection: 1) segmentation, where we determine that a tap occurred; and 2) classification, where we determine the location of the tap on the back case of the phone. In BackTap, we detect taps from a combination of data that comes from the built-in accelerometer, gyroscope, and microphone. The reason we used the microphone was to solve the sensitivity problem caused by only using motion sensors in our first prototype. Meanwhile, the data from inertial sensors can help reduce the environment noise received by microphones.

Evaluation

We conducted the evaluation with 11 participants over a two-day period. The participants tested our system under three conditions: 1) in-pocket and stationary; 2) in-pocket and walking; and 3) two-hands. The results showed that the participants completed a total of 3300 taps; they were able to perform the BackTap interactions with an accuracy that ranged from 92% to 97%. We also have preliminary data that shows that the prototype worked very well in noisy environments (on the street and in buses).

Future Work

BackTap is the first step of a research plan. We believe that there is a potentially large set of interactions based on similar technology. Below are a number of studies we plan to carry out.

Generalization on multiple phones

BackTap, was prototyped on a Samsung Galaxy S3. In the next iteration, we will port the project to other phones that include a microphone, gyroscope, and accelerometer.

Utilize machine learning methods

The heuristic method we used in BackTap makes the implementation light-weight and does not require any training before using it. However, it also limits the abilities of detecting more interactions. Therefore, we plan to use machine learning methods in the next version.

In-depth use of microphones and other sensors

Many new smartphones have multiple microphones inside at different positions. The loudness levels of the sound received by multiple microphones should differ (unless their distances to the audio source is the same). We can use this phenomenon and the frequency of the sound as additional features for the detection of other interactions. We can also adopt other common built-in sensors (e.g. light sensors, proximity sensor, magnetic sensor, camera, etc.) to support more interactions with high precision.

Explore more interactions and applications

BackTap is only the first step, to the potential input language supported by this technology. There are two major categories of potential input languages: direct touch and indirect touch. One hand tap gestures and more input events (tap, release, tap-release, double tap etc.) are just a couple of the direct touch interaction we will develop. Indirect touch interactions include and around-phone interactions may also allow the user to interact with a phone without touching it.

Conclusions

In this paper, we described BackTap a project that uses built-in sensors on commodity phones to extend the possible number of interactions. We also presented a set of results and a plan for future research.

Biographical Sketch

Cheng Zhang is a Ph.D. student in computer science, advised by Dr.Gregory Abowd and Dr. Rosa Arriaga at Georgia Institute of Technology. He entered the program in Aug. 2012 and expects to graduate in 2017.

References

[1] Goel, M., Wobbrock, J., and Patel, S. GripSense: using built-in sensors to detect hand posture and pressure on commodity mobile phones. *Proc. UIST '12*, ACM Press(2012)

[2] Harrison, C., Schwarz, J., and Hudson, S. E. TapSense: enhancing finger interaction on touch surfaces. *Proc. UIST '11*, ACM Press(2011)

[3] Heo, S., and Lee, G. Forcetap: extending the input vocabulary of mobile touch screens by adding tap gestures. *Proc. MobileHCI '11*, ACM Press(2011)

[4] Hinckley, K., and Horvitz, E. Toward more sensitive mobile phones. *Proc. UIST '01*, ACM Press(2001)

[5] Hinckley, K., and Song, H. Sensor synaesthesia: touch in motion, and motion in touch. *Proc. CHI '11*, ACM Press (2011)

[6] Hudson, S. E., Harrison, C., Harrison, B. L., and LaMarca, A. Whack gestures: inexact and inattentive interaction with mobile devices. *Proc. TEI '10*, ACM Press (2010)

[7] Li, K. A. Blindsight: eyes-free access to mobile phones. Proc. CHI '08 (2008), 1389—1398.

[8] Ronkainen, S., Hkkil, J., Kaleva, S., Colley, A., and Linjama, J. Tap input as an embedded interaction method for mobile devices. *Proc. TEI '07*, ACM (2007)

[9] Saponas, T. S., Harrison, C., and Benko, H. PocketTouch: through-fabric capacitive touch input. *Proc, UIST '11*, ACM (2011)

[10] Schwesig, C., Poupyrev, I., and Mori, E. Gummi: a bendable computer. *Proc. CHI '04*, ACM Press(2004)

[11] Shigeo, H., Isshin, M., and Kiyoshi, T. Behind touch: A text input method for mobile phone by the back and tactile sense interface. *Information Processing Society of Japan, Interaction 2003*.

[12] Sugimoto, M., and Hiroki, K. HybridTouch: an intuitive manipulation technique for PDAs using their front and rear surfaces. *Proc. MobileHCI '06*, ACM Press(2006)

[13] Wigdor, D., Forlines, C., Baudisch, P., Barnwell, J., and Shen, C. Lucid touch: a see-through mobile device. *Proc. UIST '07*, ACM Press(2007)