Using a Mobile Device Fingerprint Sensor as a Gestural Input Device

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CHI'16 Extended Abstracts, May 7–12, 2016, San Jose, CA, USA.
ACM 978-1-4503-4082-3 /16/05.
http://dx.doi.org/10.1145/2851581.2892419

Abstract
With the spread of mobile device fingerprint sensors, there is an opportunity to allow interaction beyond biometric authentication on the same device. The fingerprint sensor can detect simple gestures, enabling an additional gestural input method. We conducted user research sessions with ten people to understand the usefulness of a fingerprint sensor that also functions as a gestural input device. We identified general user perceptions as well as reactions to specific gestures and interactions. We find that this concept has promise and point to gestures and interactions that can provide a compelling and useful new input method.

Author Keywords
Fingerprint sensor; interaction techniques; one-handed operation; small gestural input device.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces. – Input devices and strategies, Interaction styles

Introduction
As mobile devices proliferate and become repositories for ever increasing amounts of personal data, many people worry about privacy and security. There is a consumer desire for high security while maintaining

convenient and frequent access to a device. As a result, growing numbers of mobile devices include fingerprint sensors. These fingerprint sensors provide a faster, easier unlock method than complex passwords and increased security over swipes or PINs. In order to provide effortless biometric authentication, fingerprint sensors are placed in an easily accessible location, commonly on the front and near the bottom. In this prime location, they are easily accessible in any grip.

Another trend is the advent of larger mobile devices, many of which have displays over 5.5" diagonal. These devices can be difficult to use, especially in one-handed grips which limit thumb reach. One-handed thumb input is so important [6] that devices and operating systems [4] [14] include features to move content closer to a user's natural thumb position. An easily accessible fingerprint sensor makes it possible to support more thumb interactions. Instead of awkwardly stretching their thumb or shifting grips to reach distant items on the touchscreen, users can interact via gestural control on the fingerprint sensor, in easy reach of their thumb.

Fingerprint sensors are primarily used to unlock mobile devices. Once a device is unlocked, the fingerprint sensor is used in very few applications and is otherwise idle. Since the fingerprint sensor is in an easily accessible location and is largely unused outside of unlocking, it is possible for this piece of prime real estate to have some additional usefulness. When the fingerprint sensor is not being used for authentication, its sensing capabilities can be used to detect touches and simple gestures, such as taps and swipes [3], to provide device input that is complimentary or orthogonal to touchscreen interaction.

In this user research study we explore the usefulness of a front-facing fingerprint sensor that also functions as a gestural input device, going beyond biometric authentication. Our goal is to identify user perceptions of fingerprint sensor gestural input, as well as reactions to specific gestures and interactions. We conducted user research sessions with ten people and found that gestural input on a fingerprint sensor is generally well-received.

Related Work

Since a gesture-sensing fingerprint sensor will provide indirect control of the display content, we reviewed products and research on controlling a mobile device with other touch input. The Motorola Backflip of 2010 [1] has a touch input surface on the back of the device for navigating pictures and home screens. Similarly, the Oppo N1 phone [9], has an input area on the back of the device for scrolling, navigation, and taking photos.

Work by Spelmezan et al. [12] uses proximity and pressure sensors to provide gestural control on a button on the side of a device. Ronkainen et al. [11] use an accelerometer to detect taps on the sides of the mobile device, primarily to control a music player and provide shortcuts to a message viewer.

On the front of the device, the HTC Desire Z [15] has an optical trackpad for navigating home screens, item selection, and text cursor navigation. The Blackberry Bold (2011) [13] also uses an optical trackpad for cursor control, selection, and menu access. These solutions all use a dedicated input device. With our solution, the gesture-sensing capabilities of the existing fingerprint sensor can provide similar functionality.

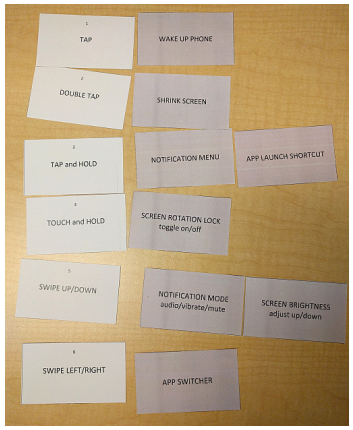

Figure 1: Example of a participant's final card sort, showing mappings between gestures and interactions.

Tap	Land, quickly lift
Double Tap	Land, quickly lift, land, quickly lift
Tap and Hold	Land, quickly lift, land, hold until activation
Touch and Hold	Land, hold until activation
Swipe Up/Down	Land, move vertical, lift
Swipe Left/Right	Land, move horizontal, lift

Table 1: Gesture definitions for the six proposed fingerprint sensor gestures.

Since gestural input on the fingerprint sensor may alleviate some problems with one-handed thumb interaction, we also review work in this field. Karlson and Bederson [5] propose a solution using pre-selection states and drag gestures to access targets. Work by Yu et al. [16] uses gestures, menus and a cursor to reach distant targets. Rekimoto [10] uses accelerometers as an input method to control the device, while Chang et al. [2] use accelerometers to move interaction areas within thumb reach. In contrast to Karlson et al. and Yu et al., we are not proposing that the fingerprint sensor be used as a cursor-like navigation device. Instead, we propose a solution using the existing fingerprint sensor for gestural input to access specific functions that might otherwise be difficult to reach.

On newer Apple iPhones, a double tap on the fingerprint sensor shifts display content to the bottom of the phone to improve one-handed thumb interaction [4]. Our study investigates a similar feature while also studying a broader set of gestures and interactions.

User Research

Participants

Ten participants (5 male) between the ages of 22 and 55 were recruited among colleagues who are unfamiliar with this project. All participants had experience with touchscreen smartphones and most had used smartphone fingerprint sensors. Of the ten participants, six were iPhone users while four used Android phones.

Interview Method

We held semi-structured user research interviews with each participant. Interviews lasted about 30 minutes and had three parts: phone use and interactions, card sorting exercise, and rating gestures.

Initially, participants were asked about their phone use and desired new interactions. Following the interview, participants did a card sort [8] and think aloud task, accompanied by Wizard-of-Oz [7] style demos to clarify gestures and interactions. Participants were given cards representing six gestures (Table 1), which were chosen for this study based on an earlier gesture analysis. An additional set of cards represented eight interactions (Table 2), which were developed from brainstorming and analysis of mobile device interactions.

Participants were asked to group or match the cards to form gesture-interaction pairs. They did not have to use every gesture or interaction card. They were asked to "think aloud" about their preferences and reasons for pairing a gesture to a particular interaction.

Additionally, Wizard-of-Oz style demos of gestural input on the fingerprint sensor area were provided so participants could try gestures and interactions first-hand. The demos were built in an HTML/Javascript page which was displayed on a Samsung Galaxy S6 smartphone. To achieve the Wizard-of-Oz effect, a Bluetooth keyboard was paired to the smartphone. The moderator entered keypress shortcuts to control display content on the smartphone. This allowed participants to experience gestural control on the fingerprint sensor.

Finally, participants were asked to provide ratings and verbal comments about each gesture. Participants rated each gesture on four 5-point Likert scales for understanding, ease of use, comfort, and general like or dislike of the gesture.

Application launch shortcut	Directly launch a pre-selected application
Notification pull-down menu	Show menu w/ notifications, configuration options
Wake up device	Wake up the device and turn on the display
Shrink screen	Resize content for one-handed thumb use
Adjust screen brightness	Adjust the brightness of the display up or down
Screen rotation lock toggle	Turn screen rotation lock off or on
Notification mode toggle	Change notification mode: mute, vibrate, or sound
Application switcher	Show active applications so users can switch apps

Table 2: The eight proposed interactions that participants were asked to comment on and map to the gestures in Table 1.

Analysis
All participant comments were hand-recorded for later analysis. Photographs were taken at the end of the card sorting activity to capture each person's final mapping (Figure 1). Rating data was collected on a worksheet.

All comments were transcribed and coded to aid in analysis. First, we assessed the general level of understanding or confusion in participant comments and questions. Beyond this, comments were coded for the participant's overall reaction to each concept. Finally, we analyzed comments for each gesture or interaction, looking for areas of consensus or conflict across users, as well as specific insights or concerns.

Results

The results of this study aim to answer three major questions that motivated our research:

1. How do people feel about gestural input on a fingerprint sensor?
2. What gestures do people like or dislike on a fingerprint sensor?
3. What interactions do people want to access using gestures on a fingerprint sensor?

How do people feel about gestural input on a fingerprint sensor?
Of the ten participants in the study, nine had positive reactions to fingerprint sensor gestural input. These participants independently generated many ideas and reacted enthusiastically to the proposed gestures and interactions. The participant who was not interested in fingerprint sensor gestural input commented that they only use their phone for calls, email, and pictures and are not interested in more features.

Participants had some concerns about gestural input on the fingerprint sensor. Nearly every participant worried about accidental activations of gestures. As a result, participants were cautious about how they assigned interactions to gestures, avoiding anything that would be disruptive if unintentionally activated. Participants also worried about discoverability, wondering how they would find the feature and learn to use it. Finally, participants wanted to avoid redundancy with existing input methods, such as physical buttons, soft buttons, and the quick access menu.

What gestures do people like or dislike on a fingerprint sensor?
Initially, participants preferred tapping and swiping on the fingerprint sensor. However, as participants did the card sorting exercise and tried gestures, their preferences changed. Participants realized that tap was prone to accidental activations. They worried about inadvertently tapping the fingerprint sensor while changing grips or idly interacting with their device. Participant ratings are shown in Figure 2, and their comments are summarized below.

Tap: Tap is viewed as comfortable and easy but too likely to produce unintended activations.

Double Tap: Double tap is perceived as comfortable and easy and much less likely to be unintended than tap.

Tap and Hold: This gesture is confusing for nearly every participant. Several people say it feels awkward and they feel like they are doing something wrong.

Touch and Hold: Some participants are confused by Touch and Hold, but upon clarification like the gesture's

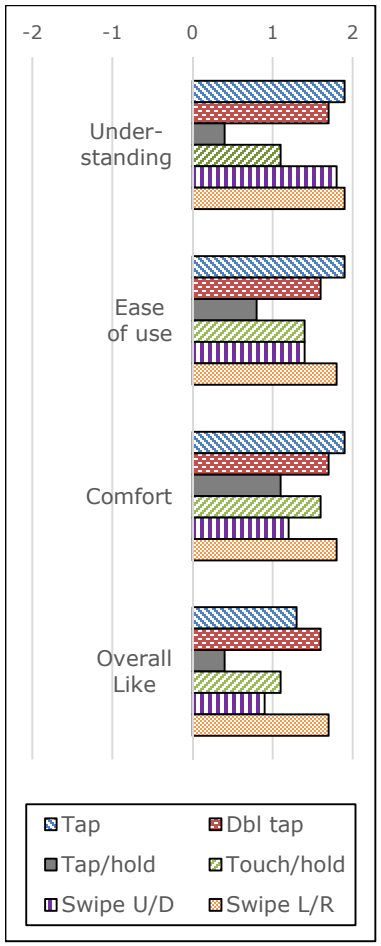

Figure 2: Participants' average ratings for the six proposed gestures.

simplicity. However, several people say they like to rest their finger on the fingerprint sensor button, which would cause inadvertent activations.

Swipe Up/Down: Participants understand and like this gesture. However, for the reference device, a Samsung Galaxy S6, the button is only 5mm tall which makes vertical swiping less comfortable. Also, several people notice that they are inadvertently activating on-screen items during swiping, which is problematic.

Swipe Left/Right: Participants understand and like this gesture. With the 15mm wide area, users can comfortably swipe left and right. However, some people notice that wide swipes cause unintended activations of the soft buttons on either side of the fingerprint button, which might require gesture filtering if implemented.

In brief, there were a few promising gesture candidates. While *Tap* is seen as prone to accidental activations, *Double Tap* provides an easy gesture with more robustness. This mirrors the result in Ronkainen et al. [11], where single taps were eliminated from the study due to high false activations, and only double taps were used. *Swipe Left/Right* is well suited to our reference device (due to the wide rectangular form-factor), but *Swipe Up/Down* could also be effective on a square or round fingerprint sensor of sufficient size.

What interactions do people want to access using gestures on a fingerprint sensor?

USER-GENERATED INTERACTION IDEAS

Before introducing the concept of fingerprint sensing, participants were asked if there is anything they do with their phone where they do not want to use the touchscreen to interact. By far the most common response, from six people, related to watching videos. Participants said that they often want to simply pause or play a video, without bringing up the full menu of on-screen video controls. They wanted a way to interact with video that avoids on-screen menus, which are distracting and often obscure video content.

MODERATOR-PROPOSED INTERACTION IDEAS

During the card sorting task, participants commented on the proposed gestures and interactions. Our analysis found that several ideas garnered positive responses from many users, and the *Application Launch Shortcut* idea was very well-received by our participants.

Nearly all participants were enthusiastic about directly launching an application without accessing home screens or other menus. They could envision how they would use the feature and saw its usefulness. Nine participants proposed frequently used applications for which they would like a shortcut. In fact, some people liked this idea so much that they assigned several gestures to different applications. The most common gesture mapping for application launching was *Double Tap*, as people felt it was fast and easy.

A few of the other proposed ideas were liked by many participants, indicating that these ideas have promise, but may need refinement or rethinking.

Some participants wanted access to the *Notification Pull-Down Menu* from the fingerprint sensor. They struggled to reach the top of the display to pull down the menu during current one-handed use. Most participants mapped this interaction to *Swipe Up/Down* on the fingerprint sensor, mirroring the touchscreen gesture while being easily accessed during thumb use.

While some users wanted a new way to *Wake Up the Device*, others were content with existing methods that are less prone to inadvertent activation. Those who liked this feature mapped it to *Touch and Hold*.

Responses to the *Shrink Screen* idea were split between those who struggle to reach distant targets, and those who don't have this problem, or who have tried solutions and found them lacking. There was no conclusive gesture mapping for this interaction, but considering the extent of problems with thumb-reach, we feel it is worth pursuing further.

While some participants liked having a more convenient method to *Adjust Screen Brightness*, others were happy with occasional adjustments in the configuration menu, or said they never changed brightness. While only a few people mapped a gesture to this interaction, the most popular mapping was *Swipe Left/Right*.

The remaining ideas (*Screen rotation lock toggle*, *Notification mode toggle*, *Application switcher*) all received mostly negative comments. These actions are already easily accessible using the touchscreen and participants did not want or need another way to control them using a fingerprint sensor.

Discussion & Conclusions

Our study investigated the use of a mobile device fingerprint sensor for gestural input to augment touchscreen interactions. In our user research study we interviewed people, conducted a card sort task, developed Wizard-of-Oz prototypes, and collected ratings to understand user perceptions. We studied the high-level concept of fingerprint sensor gestural input, as well as specific gestures and interface interactions.

Overall, most participants reacted positively to our concept. The best gesture candidates were *Double Tap* and *Swipe Left/Right* for the wide rectangular form factor of our reference device fingerprint sensor. *Swipe Up/Down* would likely also work well on square or round fingerprint sensors. Nearly every person was concerned with accidental activations of gestures, which is a critical matter for any gestural system.

We probed desired interactions in a number of ways and found several features that users requested or preferred. Controlling video playback, specifically play and pause, without touching the screen and potentially invoking other actions was highly requested. People were also enthusiastic about using a fingerprint sensor gesture for an application launching shortcut, to get to their favorite application more easily. Some of the other interactions received positive feedback from users, but may require further development and research.

Overall, the addition of gestural input on a mobile device fingerprint sensor has promise. As highlighted previously, accidental activations are a significant concern and have to be considered carefully in the design and implementation of gestures. Building on this set of gestures and interactions, we will conduct user studies using a functioning device, to investigate the usability and user experience in actual use. We hope to create a compelling and useful new input method for users. Using the fingerprint sensor as a gestural input device can allow for access to important functionality, especially during one-handed thumb interaction.

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