‘Novel’ Interaction on Mobile Devices

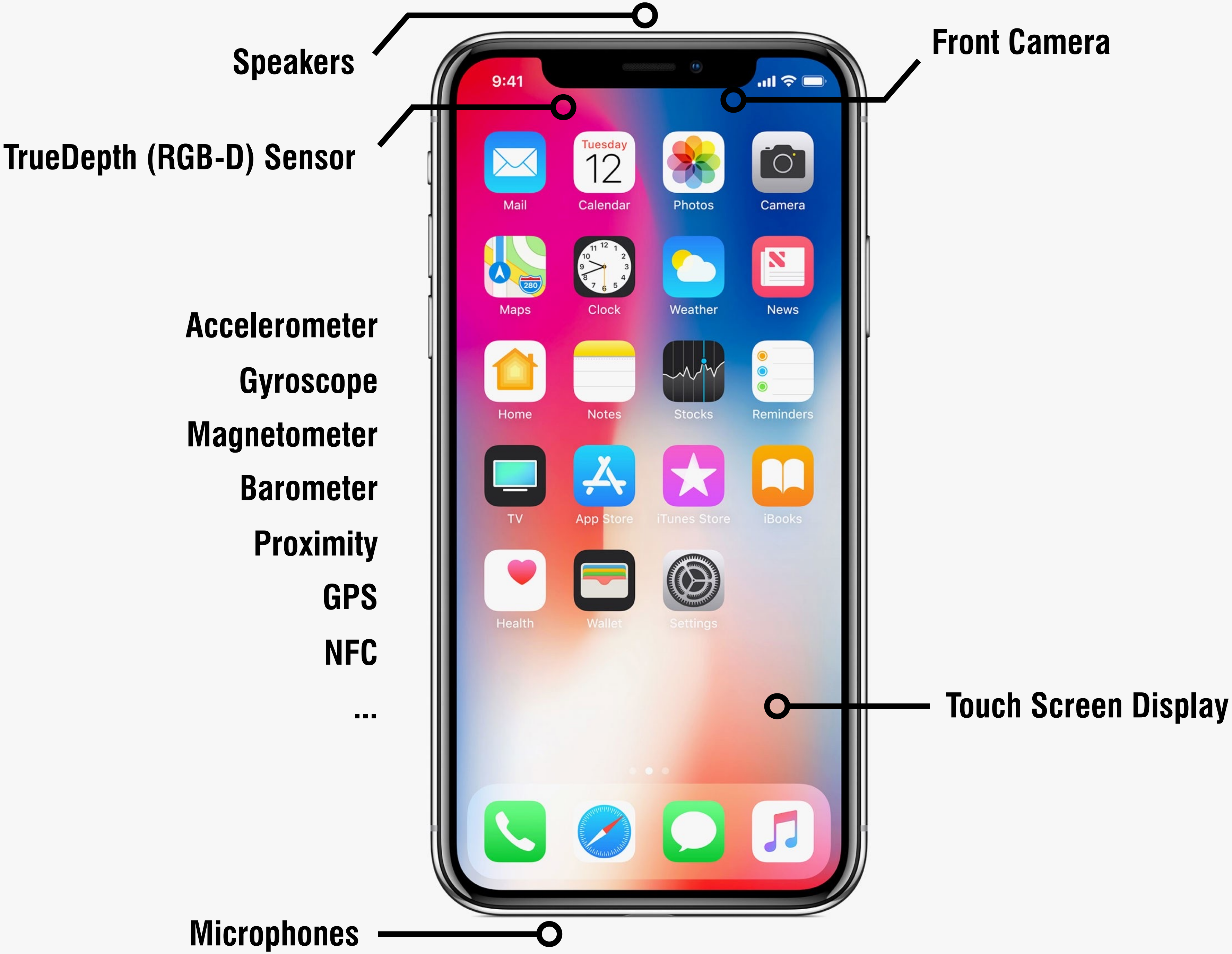
Huaishu Peng | UMD CS | Fall 2024

We have talked about multi-touch screen

What **other components** does a smartphone have that can be used for interaction?

And **how**?

1 min brainstorming


Speakers
Front Camera
TrueDepth (RGB-D) Sensor
Accelerometer
Gyroscope
Magnetometer
Barometer
Proximity
GPS
NFC
...
Touch Screen Display
Microphones
9:41
Tuesday
12
Mail
Calendar
Photos
Camera
Maps
Clock
Weather
News
Home
Notes
Stocks
Reminders
TV
App Store
iTunes Store
iBooks
Health
Wallet
Settings

Speakers

TrueDepth (RGB-D) Sensor

Front Camera

Accelerometer - Acceleration

Gyroscope - Orientation

Magnetometer - Magnetism

Barometer - Air Pressure

Proximity - Distance

GPS - Location

NFC

...

Touch Screen

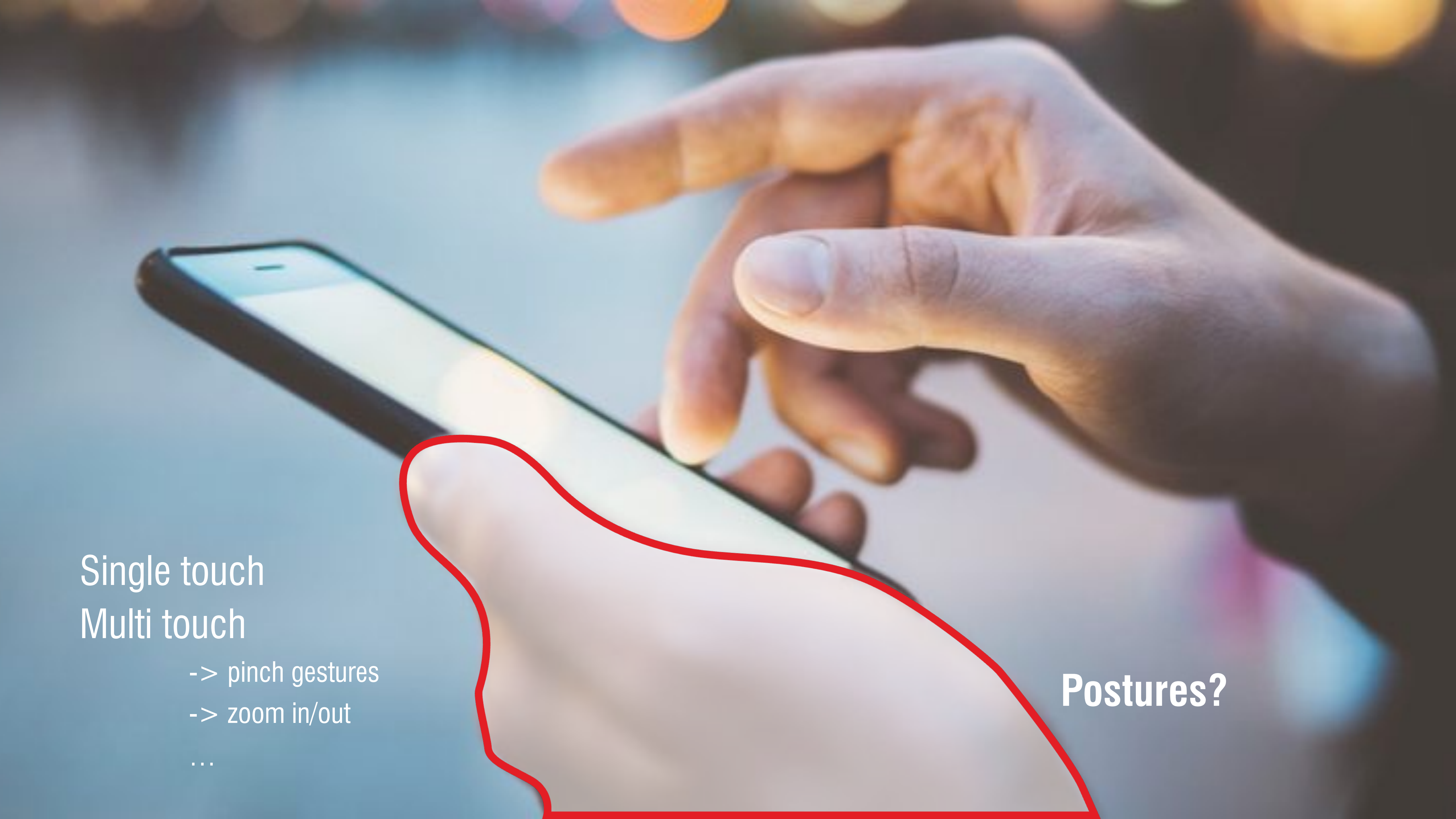
Microphones

Single user interaction
Multi-user interaction
Sensing beyond interaction

Single user interaction

Multi-user interaction

Sensing beyond interaction


Single touch
Multi touch
-> pinch gestures
-> zoom in/out
...
Postures?

GripSense: Using Built-In Sensors to Detect Hand Posture and Pressure on Commodity Mobile Phones

GripSense: Using Built-In Sensors to Detect Hand Posture and Pressure on Commodity Mobile Phones

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ABSTRACT

We introduce *GripSense*, a system that leverages mobile device touchscreens and their built-in inertial sensors and vibration motor to infer hand postures including one- or two-handed interaction, use of thumb or index finger, or use on a table. GripSense also senses the amount of pressure a user exerts on the touchscreen despite a lack of direct pressure sensors by observing diminished gyroscope readings when the vibration motor is "pulsed." In a controlled study with 10 participants, GripSense accurately differentiated device usage on a table *vs.* in hand with 99.7% accuracy; when in hand, it inferred hand postures with 84.3% accuracy. In addition, GripSense distinguished three levels of pressure with 95.1% accuracy. A usability analysis of GripSense was conducted in three custom applications and showed that pressure input and hand-posture sensing can be useful in a number of scenarios.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces—*graphical user interfaces*.

General terms: Design, Human Factors, Experimentation.

Keywords: Touchscreen; situational impairments; mobile; inertial sensors; gyroscope; hand posture; posture

INTRODUCTION

A typical computer user is no longer confined to a desk in a relatively consistent and comfortable environment. The world's typical computer user is now holding a mobile device smaller than his or her hand, is perhaps outdoors, perhaps in motion, and perhaps carrying more things than just a mobile device. A host of assumptions about a user's environment and capabilities that were tenable in comfortable desktop environments no longer applies to mobile users. This dynamic state of a user's environment can lead to *situational impairments* [28], which pose a significant chal-

Figure 1. (left) It is difficult for a user to perform interactions like *pinch-to-zoom* with one hand. **(right)** GripSense senses user's hand posture and infers pressure exerted on the screen to facilitate new interactions like zoom-in and zoom-out.

devices do not have much awareness of our environments or how those environments affect users' abilities [33].

One of the most significant contextual factors affecting mobile device use may be a user's hand posture with which he or she manipulates a mobile device. Research has shown that hand postures including grip, one or two hands, hand pose, the number of fingers used, and so on significantly affect performance and usage of mobile devices [34]. For example, the pointing performance of index fingers is significantly better than thumbs, as is pointing performance when using two hands versus one hand. Similarly, the performance of a user's dominant hand is better than that of his or her non-dominant hand. Research has found distinct touch patterns for different hand postures while typing on on-screen keyboards [1]. And yet our devices, for the most

UIST 2012

Goel et.al. from UW

GripSense: Using Built-In Sensors to Detect Hand Posture and Pressure on Commodity Mobile Phones

Problem definition: Detect a user’s **hand postures** and **touch pressure**

Solution: **touch** info + **IMU** and **IMU** + **vibration** motor

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Shape of swipe arc

Direction of the arc indicates different hands

Shape and position of thumb

Thumb touch size is larger on far side

Rotation of the devices

the phone rotates in response to touches at the top of the screen more than it does to touches at the bottom of the screen

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(a) left hand and operated with left thumb

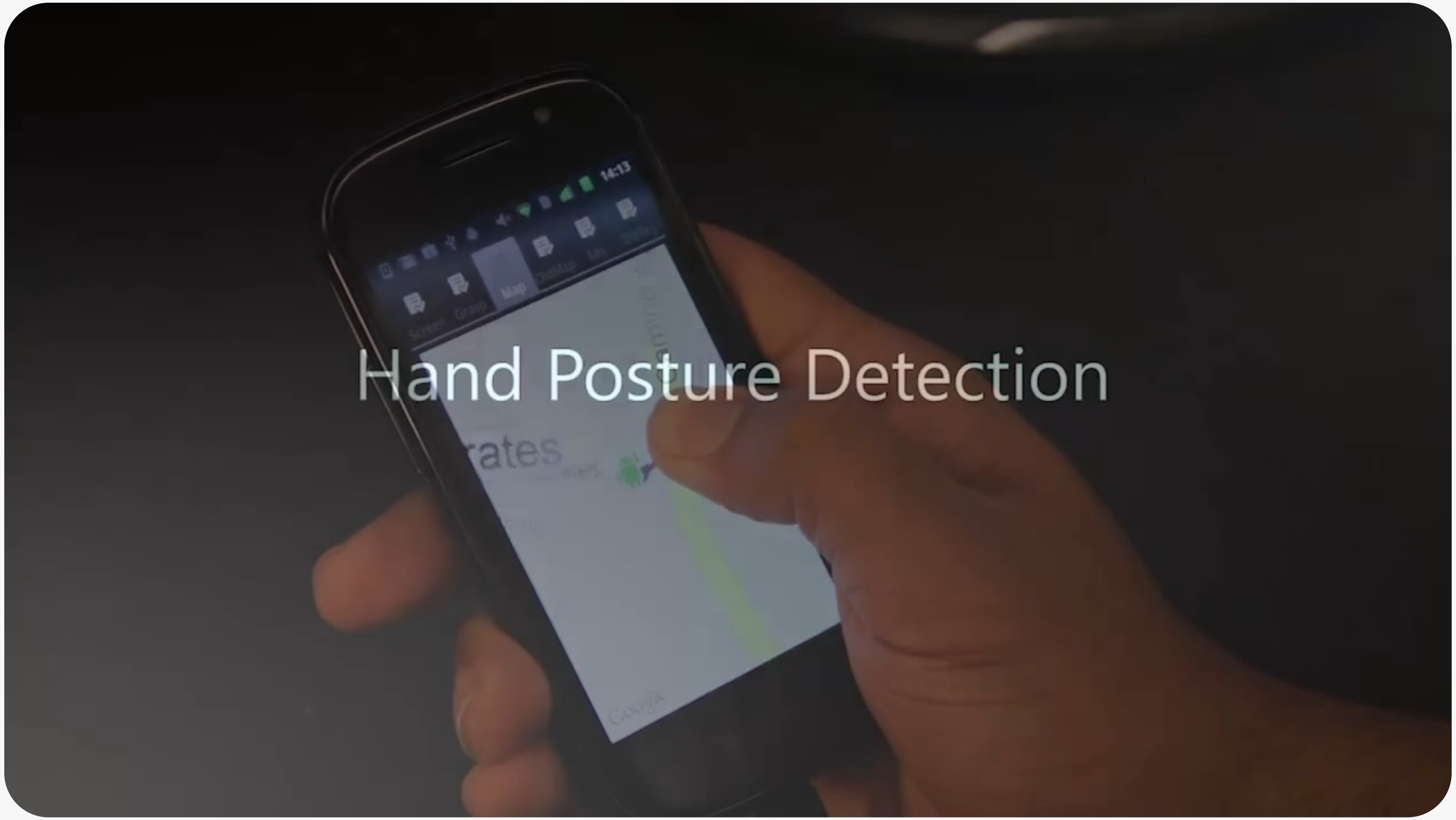
(b) right hand and operated with right thumb

(c) in either hand and operated with the index finger

(d) on a flat surface

(e) being only grasped by the user and not operated.

GripSense: Using Built-In Sensors to Detect Hand Posture and Pressure on Commodity Mobile Phones



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Key idea:

1) Trigger the **built-in vibration motor** when a user touches the screen
2) The user's hand **absorbs** a portion of these vibrations. (dumping effect)
3) Detect the vibration changes with the **gyro**

note that this is way before the 3D touch available on iPhone

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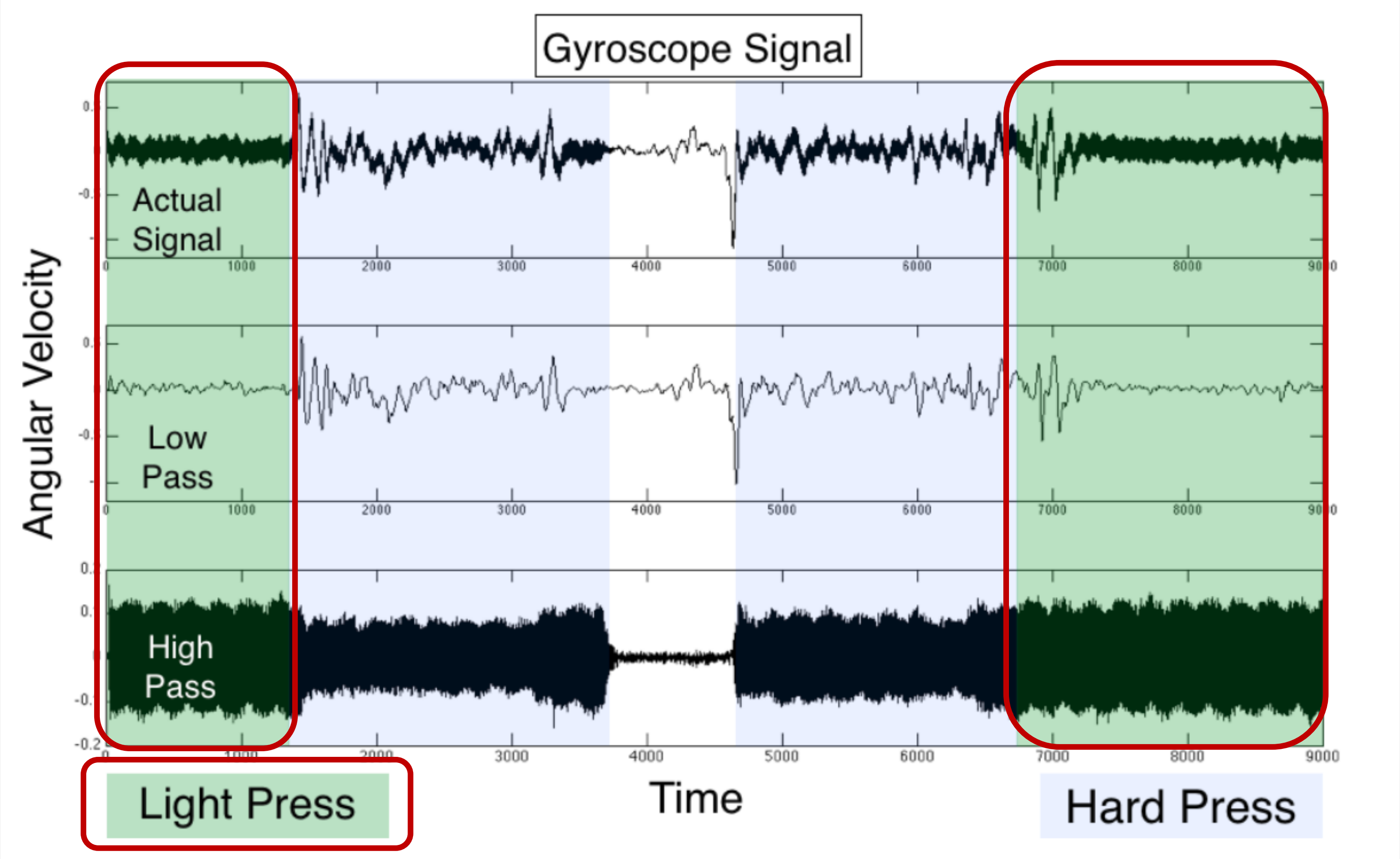

GripSense: Using Built-In Sensors to Detect Hand Posture and Pressure on Commodity Mobile Phones

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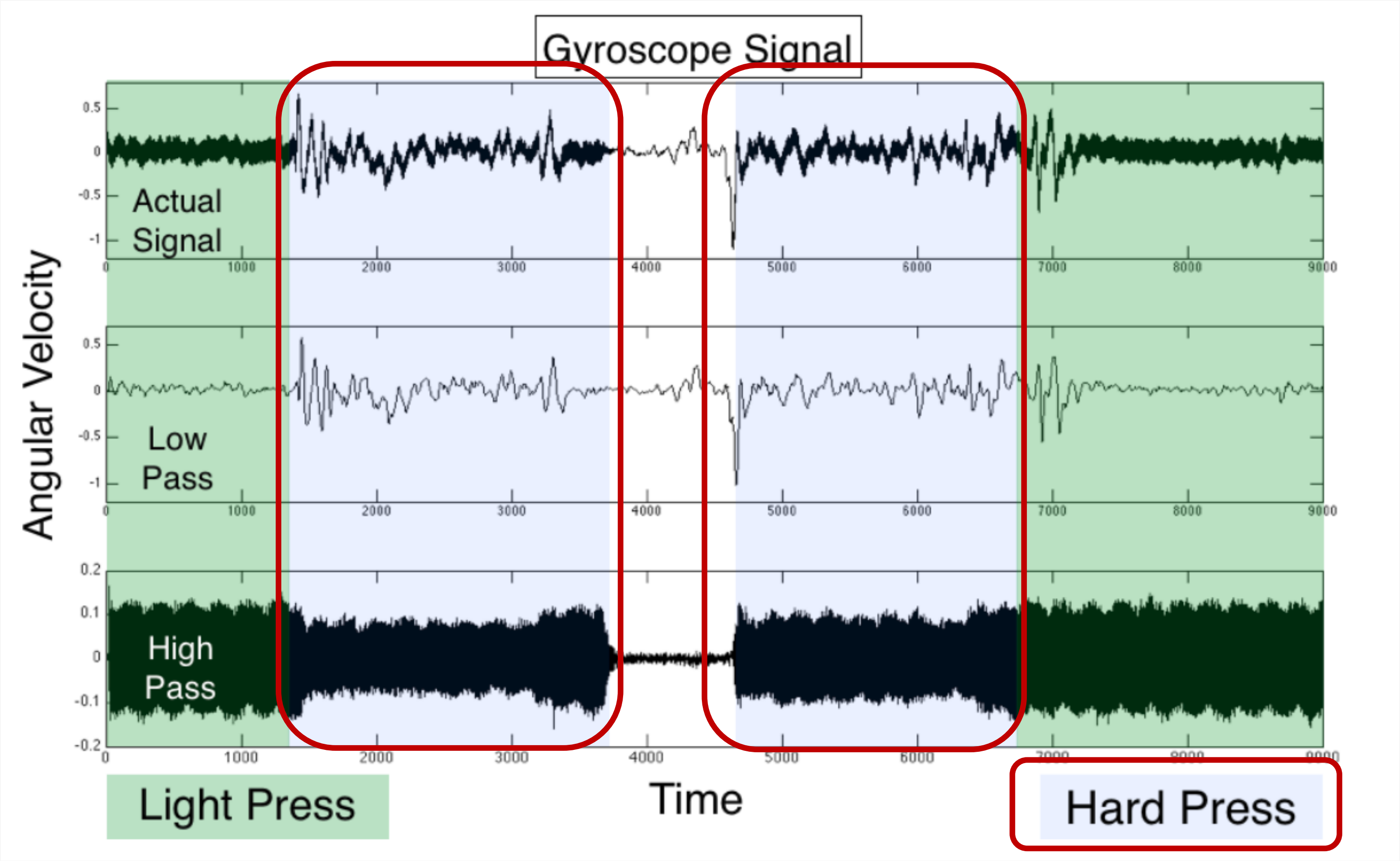

GripSense: Using Built-In Sensors to Detect Hand Posture and Pressure on Commodity Mobile Phones

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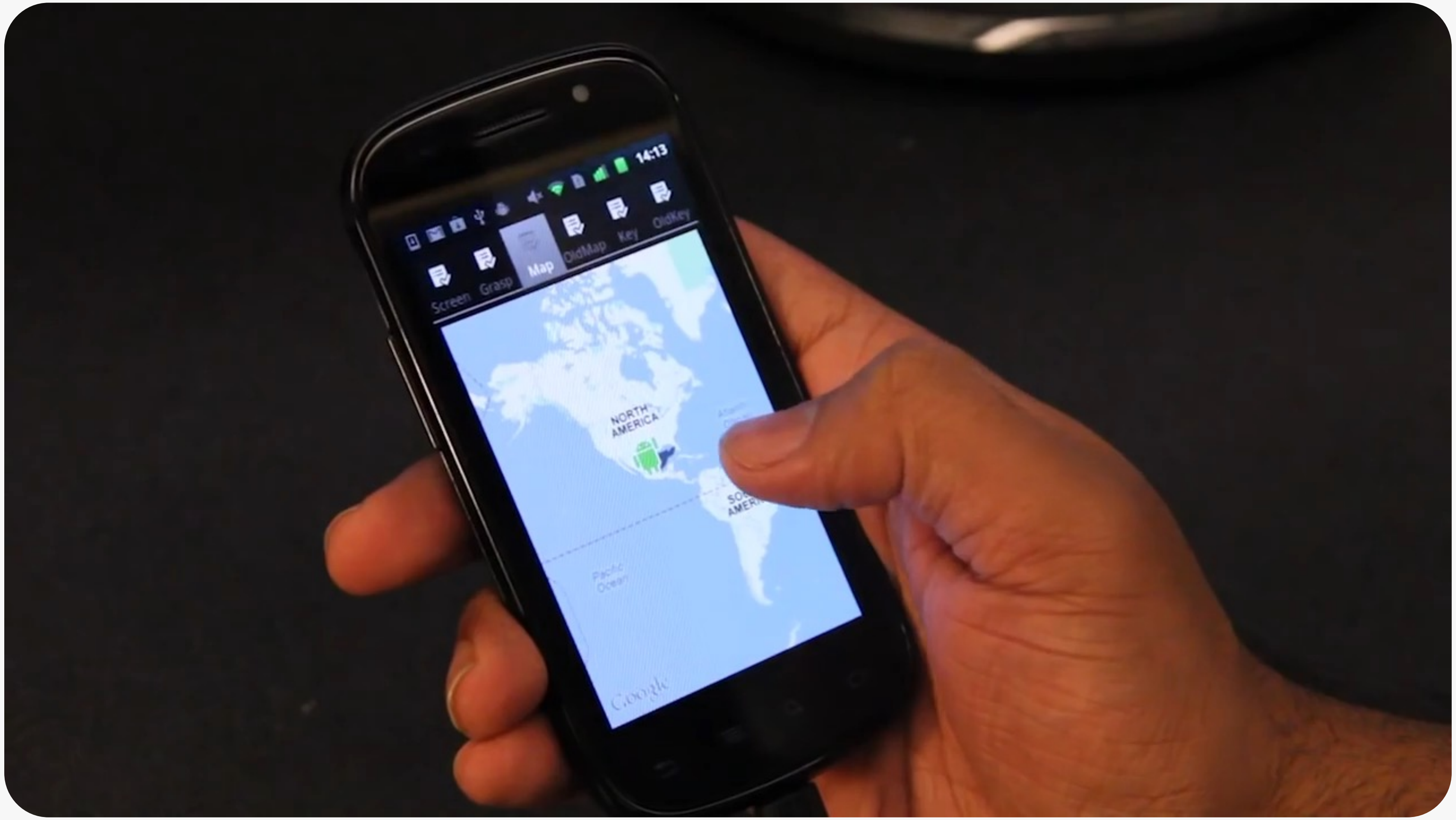
Applications:

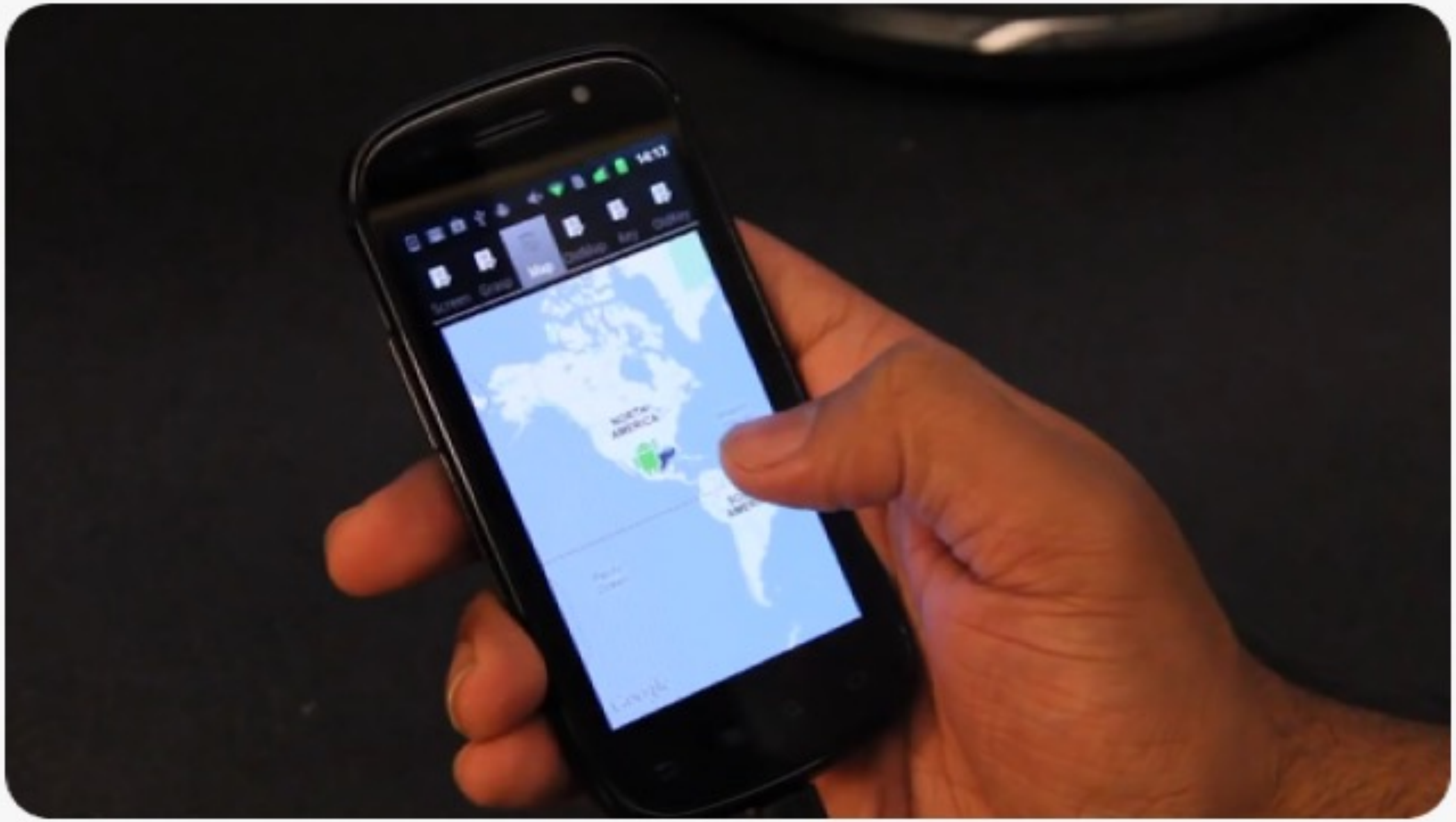


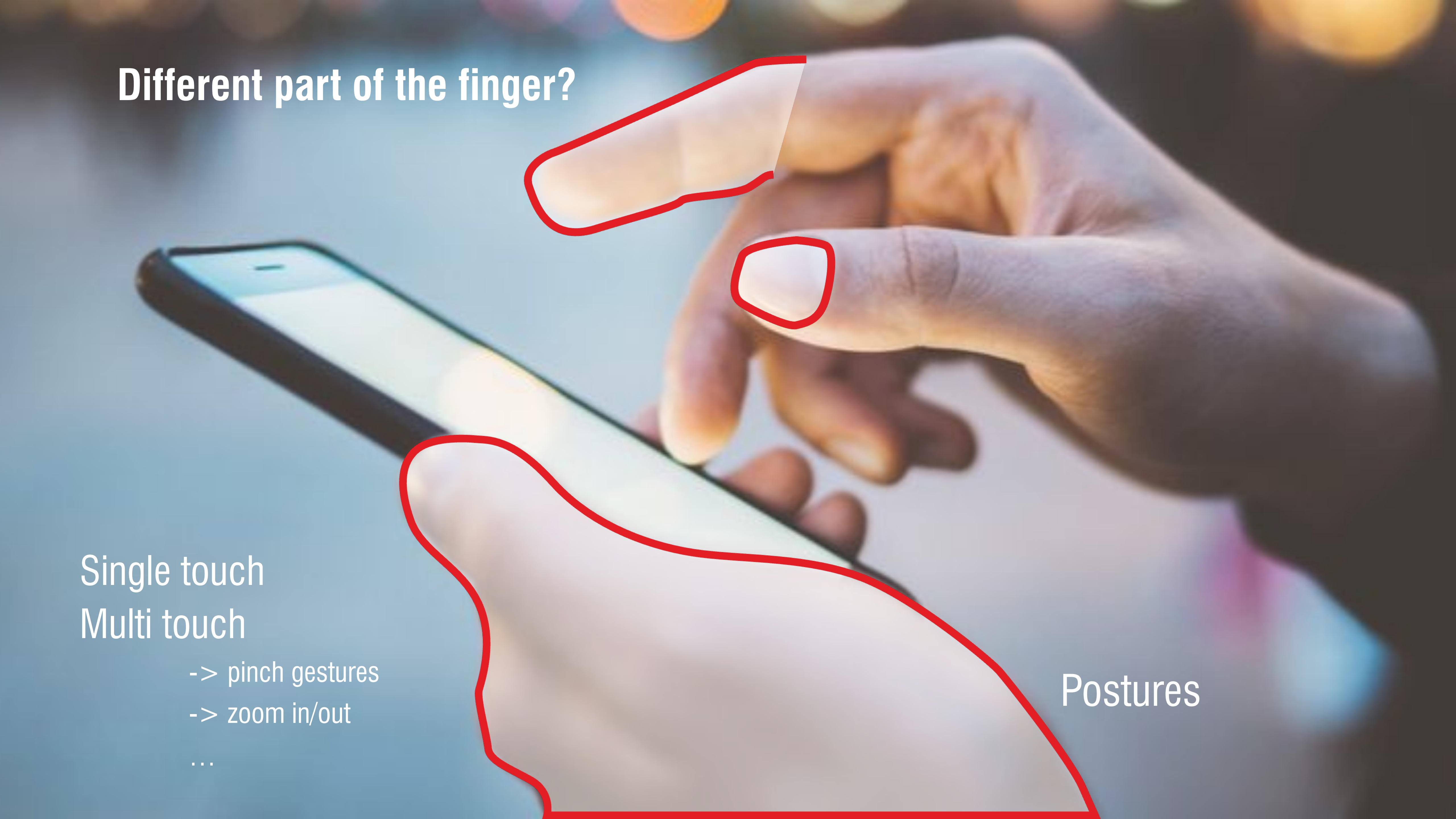
GripSense: Using Built-In Sensors to Detect Hand Posture and Pressure on Commodity Mobile Phones

What makes this work interesting?

Extract **extra** information (postures + pressure) based on **built-in** sensor

Enrich interaction vocabulary




Different part of the finger?
Single touch
Multi touch
-> pinch gestures
-> zoom in/out
…
Postures

TapSense: Enhancing Finger Interaction on Touch Surfaces

TapSense: Enhancing Finger Interaction on Touch Surfaces

Chris Harrison *Julia Schwarz* *Scott E. Hudson*

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ABSTRACT

We present *TapSense*, an enhancement to touch interaction that allows conventional surfaces to identify the type of object being used for input. This is achieved by segmenting and classifying sounds resulting from an object's impact. For example, the diverse anatomy of a human finger allows different parts to be recognized – including the tip, pad, nail and knuckle – without having to instrument the user. This opens several new and powerful interaction opportunities for touch input, especially in mobile devices, where input is extremely constrained. Our system can also identify different sets of passive tools. We conclude with a comprehensive investigation of classification accuracy and training implications. Results show our proof-of-concept system can support sets with four input types at around 95% accuracy. Small, but useful input sets of two (e.g., pen and finger discrimination) can operate in excess of 99% accuracy.

ACM Classification: H.5.2 [Information interfaces and presentation]: User Interfaces - Graphical user interfaces; Input devices and strategies.

General terms: Human Factors

Keywords: Acoustic classification, tabletop computing, interactive surfaces, tangibles, tools, pens, stylus, finger, multi-user, touchscreen, collaborative, input.

INTRODUCTION

Computers are increasingly featuring direct touch interfaces, found in forms as diverse as kiosks and interactive tabletops, to tablet computers and handheld mobile devices. At

and nail (Figure 1 and 2). The latter is especially valuable on mobile devices, where input bandwidth is limited due to small screens and "fat fingers" [16]. For example, a knuckle tap could serve as a "right click" for mobile device touch interaction, effectively doubling input bandwidth. Right-click-like functionality is currently achieved on touch surfaces with fairly unintuitive and un-scalable chording of fingers and tap-and-hold interactions. Finally, our approach requires no electronics or sensors to be placed on the user.

RELATED APPROACHES

Many technologies exist that have the ability to digitize different types of input. There are two main touch sensing approaches: active and passive.

The key downside of active approaches is that an explicit object must be used (e.g., a special pen), which is implemented with electronics (and batteries if not tethered). For example, pens augmented with infrared light emitters on their tips can be used on the commercially available Microsoft Surface [15]. There have also been efforts to move beyond pens, including, e.g., infrared-light-emitting brushes for painting applications [27]. Current systems generally do not attempt to discriminate among different pens (just perhaps pen from finger input). Variably-modulated infrared light enables identification, but requires specialized hardware. Additionally, ultrasonics can be used for input localization [19], and can provide pen ID as well. Capacitive coupling in [6,7] allows users or objects to be localized and identified, though this requires grounding plates or a physical connection to function.

UIST 2012

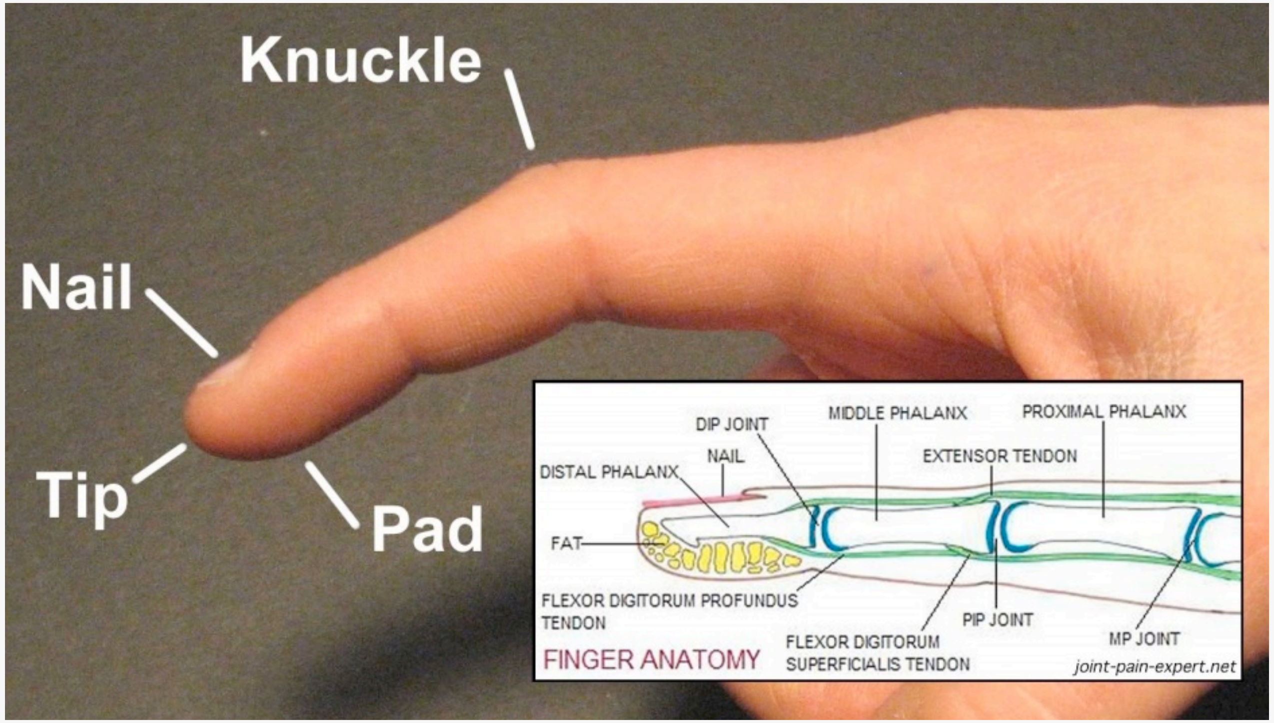
Harrison et.al. from CMU

TapSense: Enhancing Finger Interaction on Touch Surfaces

Problem definition: Detect a user's interaction with the touchscreen with different part of the finger

Tip **Nail** **Knuckle** **Pad**

Observation:



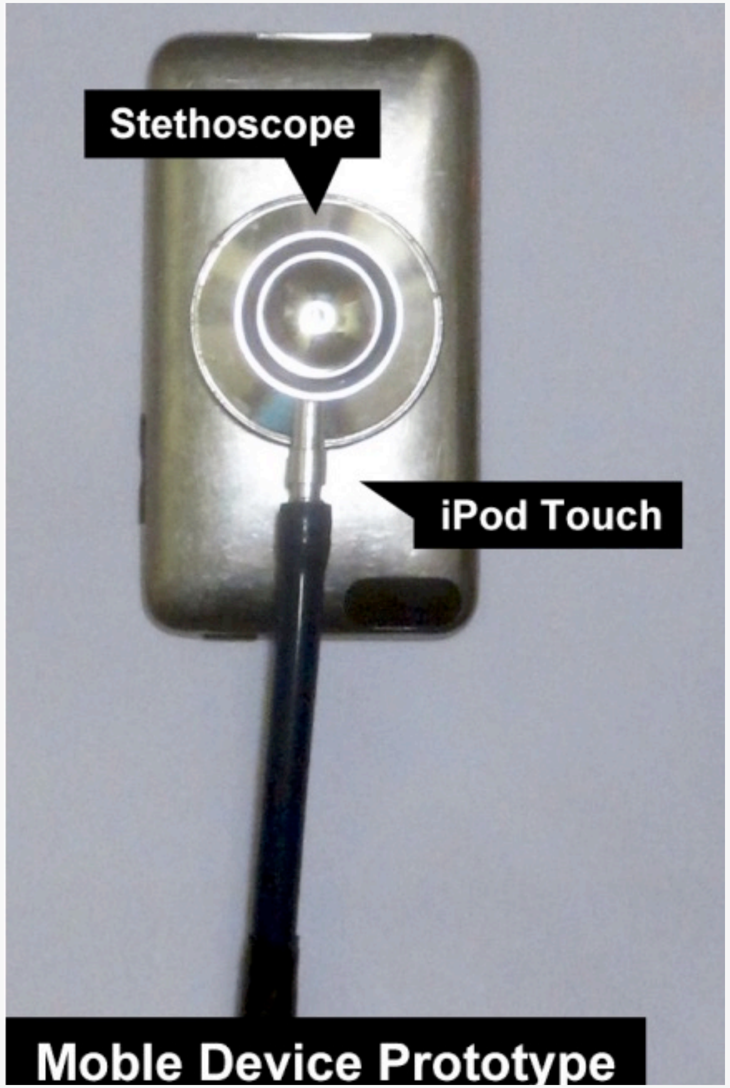
Solution: using **acoustic** features

- different materials produce **different acoustic signatures** and have different resonant frequencies

TapSense: Enhancing Finger Interaction on Touch Surfaces

Acoustic sensing: Sensing vibration –> Microphone; IMU, etc

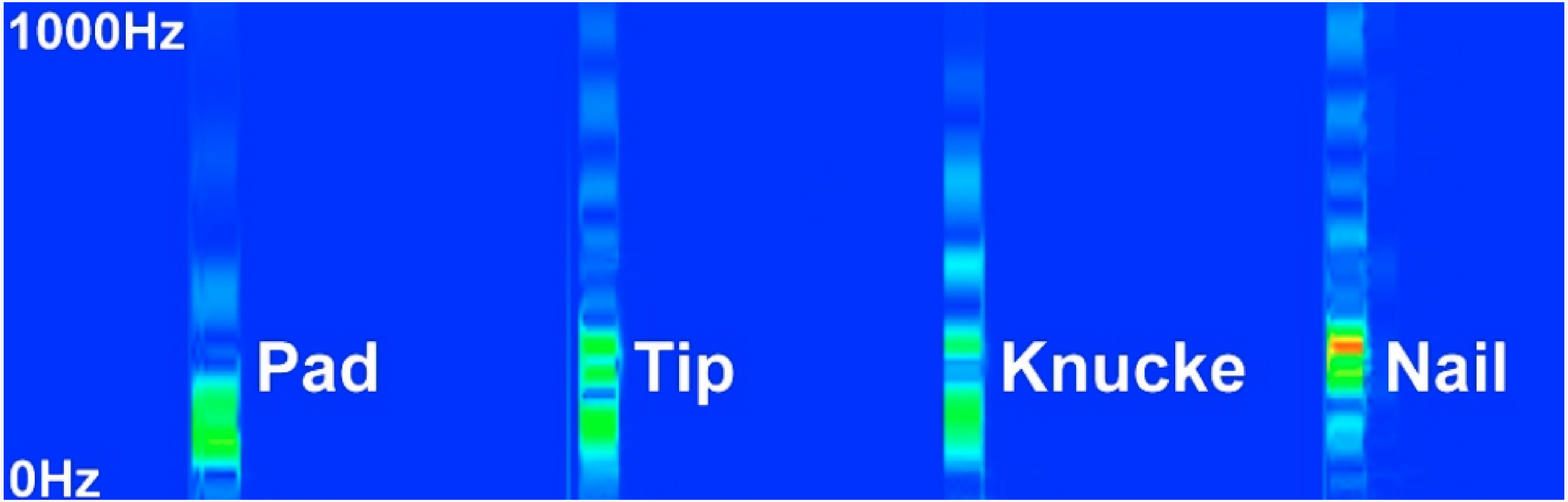
For prototyping?



Benefit?
fast and less noise

TapSense: Enhancing Finger Interaction on Touch Surfaces

Acoustic sensing: Sensing vibration –> Microphone; Accelerometer, etc



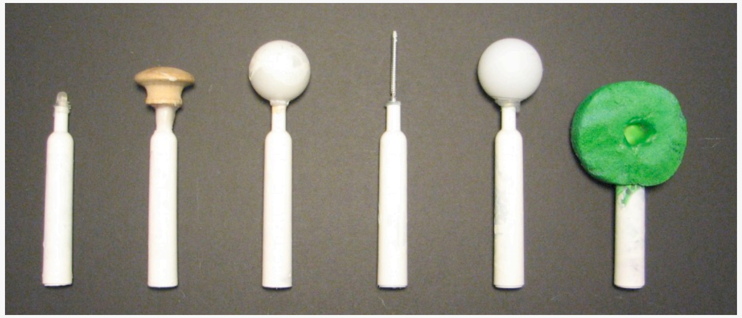
Features (amplitude + abs amplitude + FFT…) -> SVM

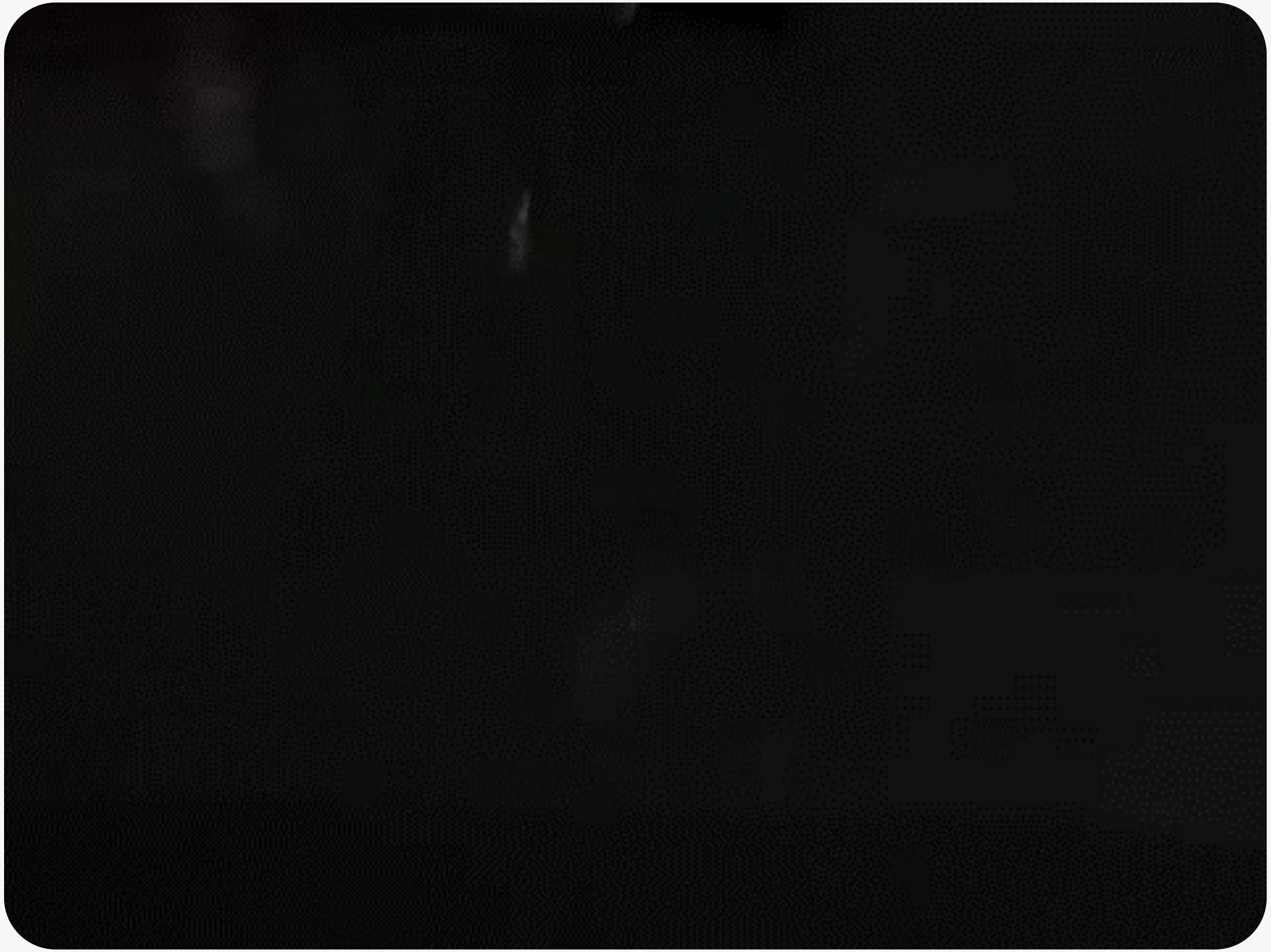
TapSense: Enhancing Finger Interaction on Touch Surfaces

Enhance interaction:

TapSense: Enhancing Finger Interaction on Touch Surfaces

Passive instruments
Beyond fingers:





TapSense: Enhancing Finger Interaction on Touch Surfaces

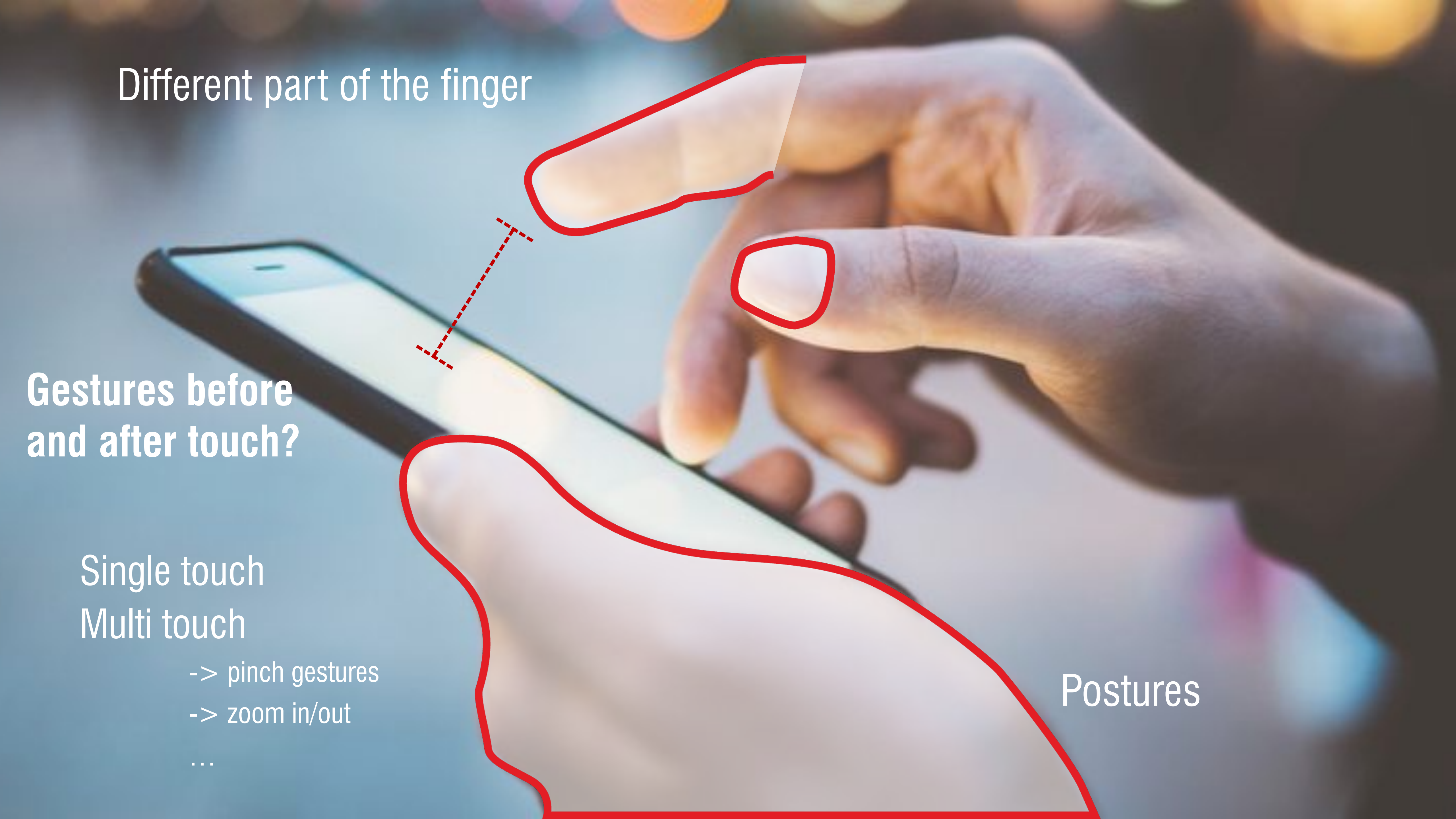
What makes this work interesting?

A general approach for enhancing interactions by identifying different parts of a finger.

Product vs Research

TapSense: Enhancing Finger Interaction on Touch Surfaces

Qeexo.com – spin off from CMU


Different part of the finger
Gestures before
and after touch?
Single touch
Multi touch
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Postures

Air+Touch: Interweaving Touch & In-Air Gestures

Air+Touch: Interweaving Touch & In-Air Gestures

Xiang 'Anthony' Chen, Julia Schwarz, Chris Harrison, Jennifer Mankoff, Scott E. Hudson
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ABSTRACT
We present Air+Touch, a new class of interactions that interweave touch events with in-air gestures, offering a unified input modality with expressiveness greater than each input modality alone. We demonstrate how *air* and *touch* are highly complementary: touch is used to designate targets and segment in-air gestures, while in-air gestures add expressivity to touch events. For example, a user can draw a circle in the air and tap to trigger a context menu, do a finger 'high jump' between two touches to select a region of text, or drag and in-air 'pigtail' to copy text to the clipboard. Through an observational study, we devised a basic taxonomy of Air+Touch interactions, based on whether the in-air component occurs before, between or after touches. To illustrate the potential of our approach, we built four applications that showcase seven exemplar Air+Touch interactions we created.

ACM Classification
H5.2 [Information interfaces and presentation]: User Interfaces - Input devices and strategies, Graphical user interfaces.

Keywords
Touch input; free space gestures; interaction techniques; input sensing; around device interaction.

INTRODUCTION
A generation of mobile devices has relied on touch as the primary input modality. However, poking with a fingertip lacks immediate expressivity. In order to support richer actions, touch must be overloaded in time (e.g., long press), space (e.g., drawing an 's' to silence the phone) or configuration (two-finger tap is 'alt click'). These approaches suffer from one or more of the following issues: scalability of gesture set, time consuming to perform, "Midas" touch, and significant finger occlusion on small screens. Thus, there is e.g., [7, 17]). These interactions are attractive as they can utilize a space many times larger than a device's physical boundaries, allowing for more comfortable and potentially richer interactions. However, in-air gestures are typically treated as a separate input modality, rather than integrated with existing touch-based techniques. Further, in-air gestures suffer from the challenge of segmentation: little literature has discussed how to systematically separate intentional gestures from accidental finger movements.

Before touch: circle-&-tap to trigger right-click menu
Between touch: 'high jump' between taps to select text
After touch: Tap-&-circle for continuously zoomming

Figure 1. We propose that touch and in-air gestures be interwoven to create fluid and expressive interactions.

In this paper, we reconsider touch and in-air gestures beyond their individual domains. We propose a synthesis of these two input modalities, achieving interaction richness and robustness that neither can provide alone. Indeed, we found in-air and touch inputs to be highly complementary: touch is used to designate targets and segment in-air gestures, while in-air gestures add expressivity and modality to touch events. This Air+Touch modality outlines a class of interactions that enable fluid use of a device's screen and the space above it.

To explore this possibility, we start with a focus on the scenario of single-finger interaction, where a person uses his or her thumb or index finger to gesture in the air and also touch the screen. Through an observational study, we de-

UIST 2014
Chen et.al. from CMU

Air+Touch: Interweaving Touch & In-Air Gestures

Problem definition: Design **in-air** gestures for mobile interaction

Solution? What if we don't have built-in sensors to sense above screen gestures?

-Using existing tools to simulate the technology in the future

Air+Touch: Interweaving Touch & In-Air Gestures

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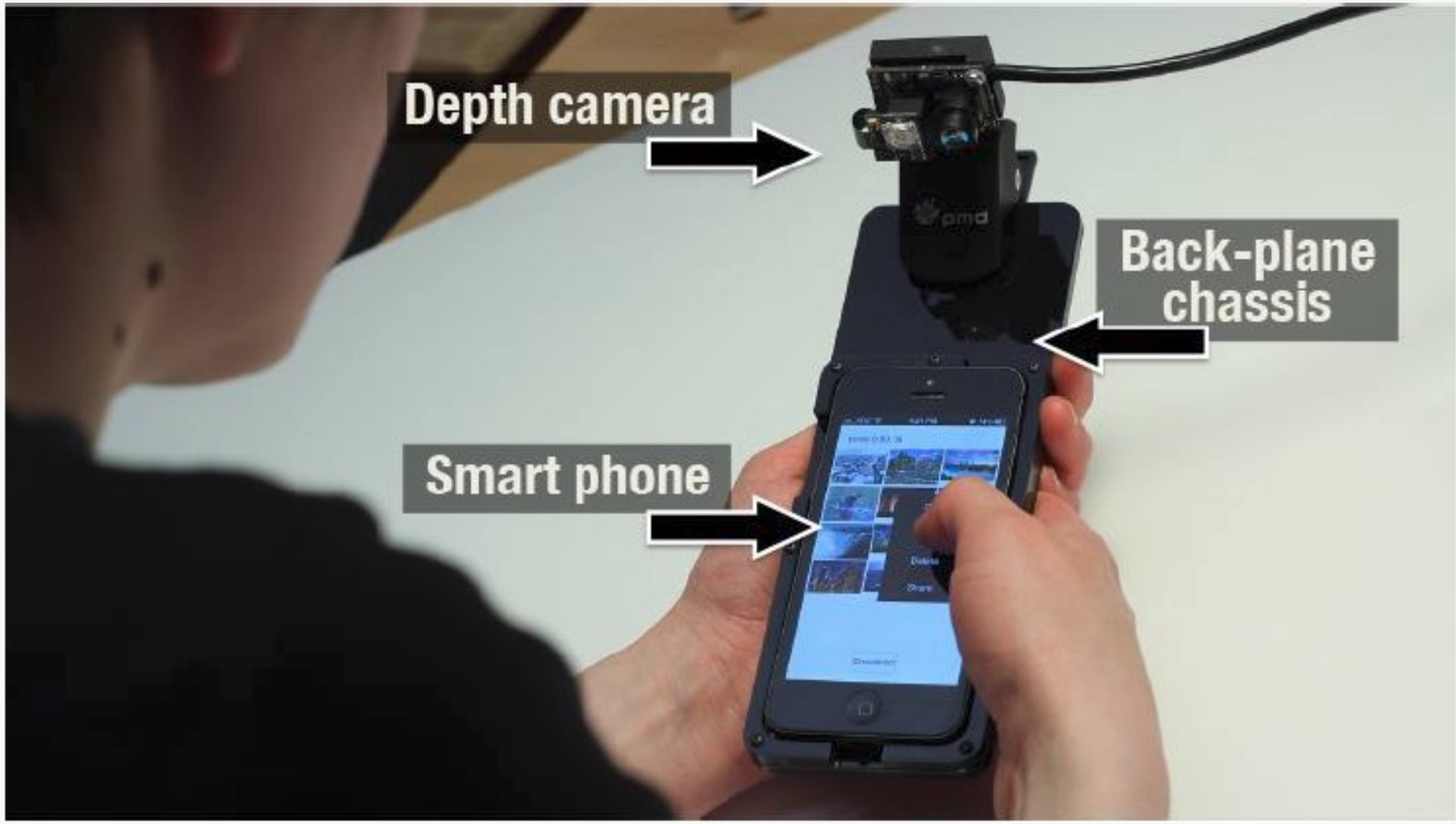
Solution:



Air+Touch: Interweaving Touch & In-Air Gestures

Interaction Design: Where to start to design in-air gestures?

User study/observation ;)

Participants: 12 (5 female, 7 male, ages 24-36)

Task: to perform a set of common tasks on a smartphone (e.g., compose a text message, navigate on a map).

Data analysis: Video coding

-> Distill a set of features that could translate into gestural input, while avoiding collisions

Air+Touch: Interweaving Touch & In-Air Gestures

Interaction Design: Where to start to design in-air gestures?

Some of the insights:

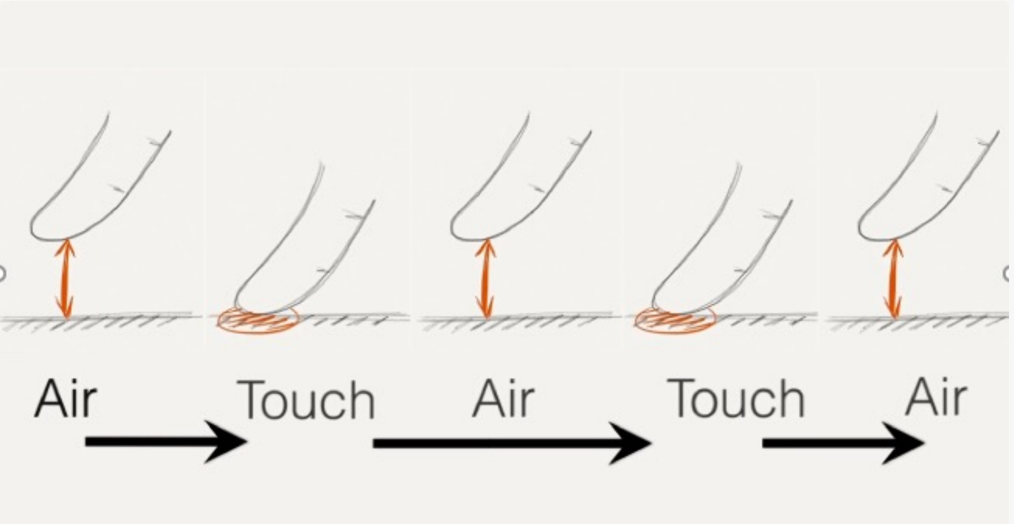
Touch event can serve to delimit in-air gestures

Few of the finger motions observed contains elliptical /rectangular/sharp angle paths

Air+Touch: Interweaving Touch & In-Air Gestures

Interaction Design: Where to start to design in-air gestures?

Some of the insights:



Touch event can serve to delimit in-air gestures

In-air gestures: before, between, after touches

Few of the finger motions observed contains elliptical /rectangular/sharp angle paths

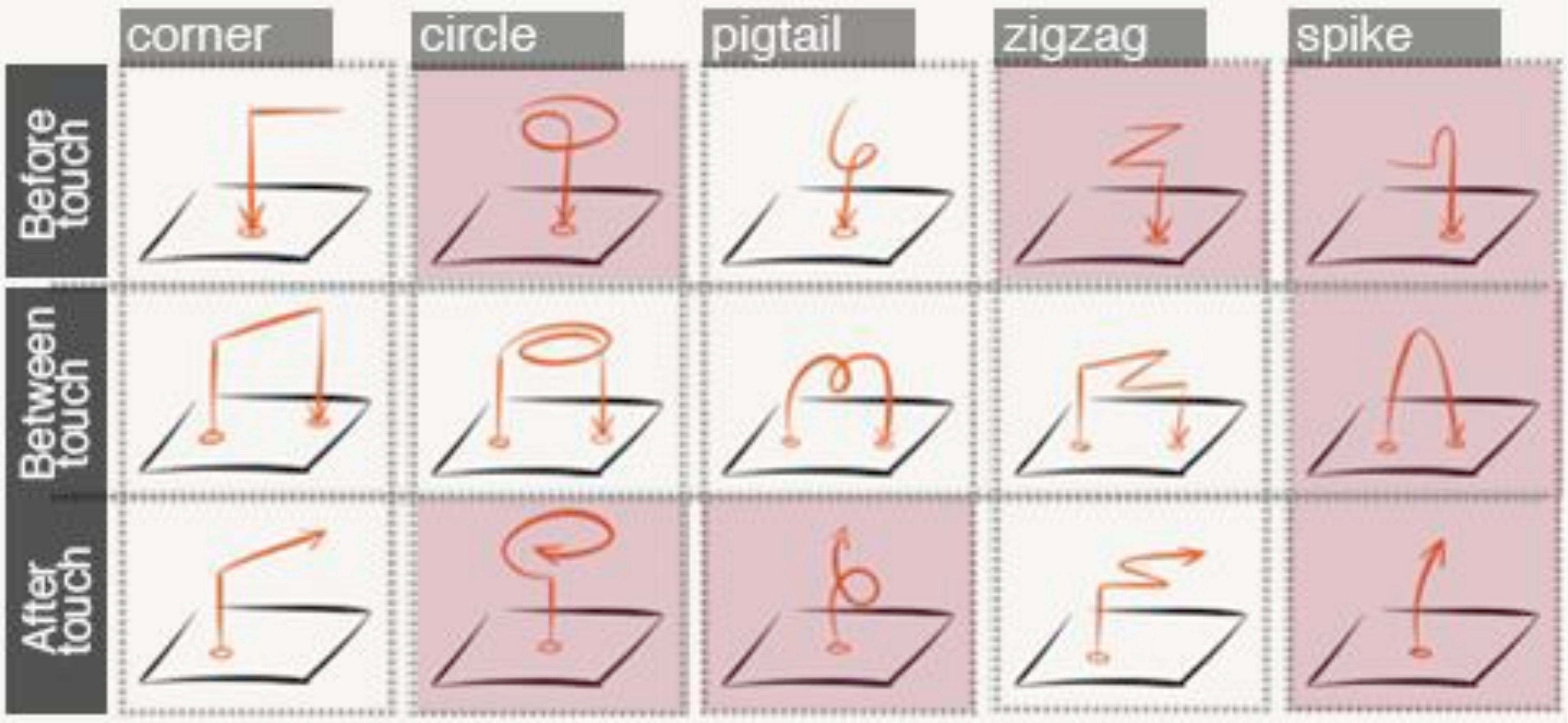
Circular/zigzag paths can be used as in-air gestures

Air+Touch: Interweaving Touch & In-Air Gestures

Interaction Design: Proof-of-concept gesture vocabulary

Circular/zigzag paths can be used as in-air gestures

In-air gestures: before, between, after touches



Air+Touch: Interweaving Touch & In-Air Gestures

Examples – Before touch

Circle in air and tap

High-up and tap for mode switching

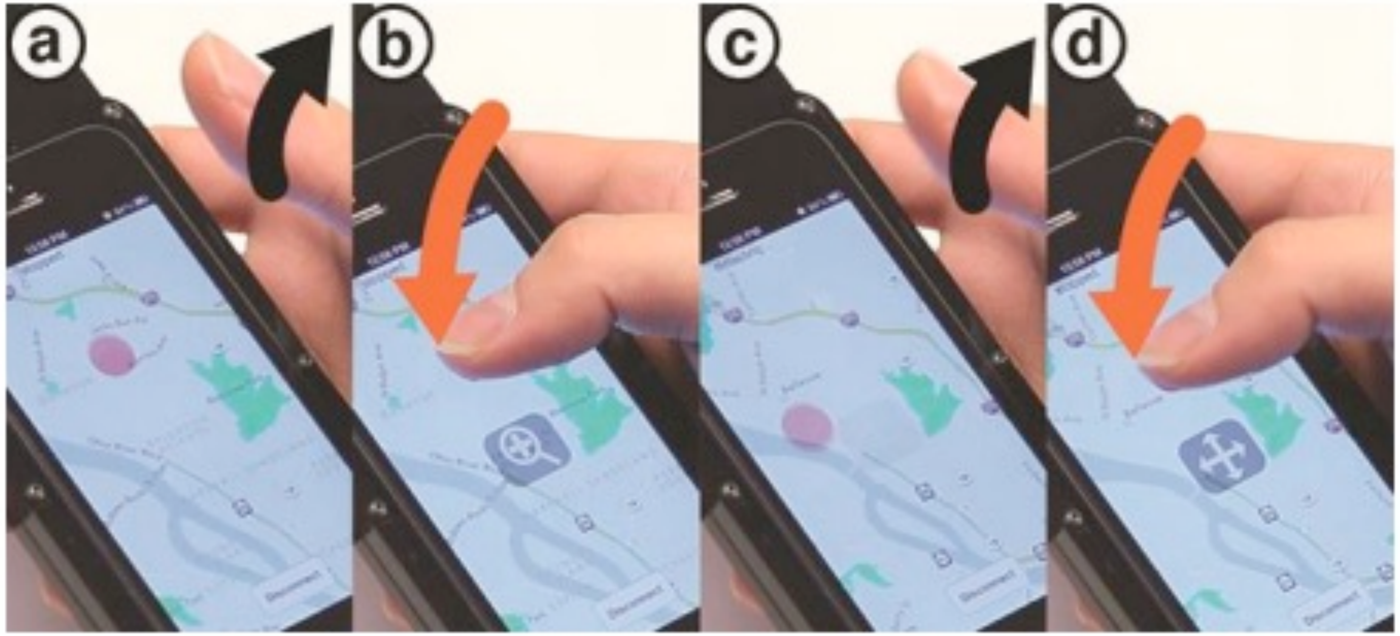


Figure 7. In our map app, raising the finger 'high-up' (a, c) before touch down switches between pan/zoom modes (b, d).

Air+Touch: Interweaving Touch & In-Air Gestures

Examples – Air Between Touch

Finger 'high jump' between touches to select text

Drawing an 'L' between touches for marquee-selection (sub-region of picture)

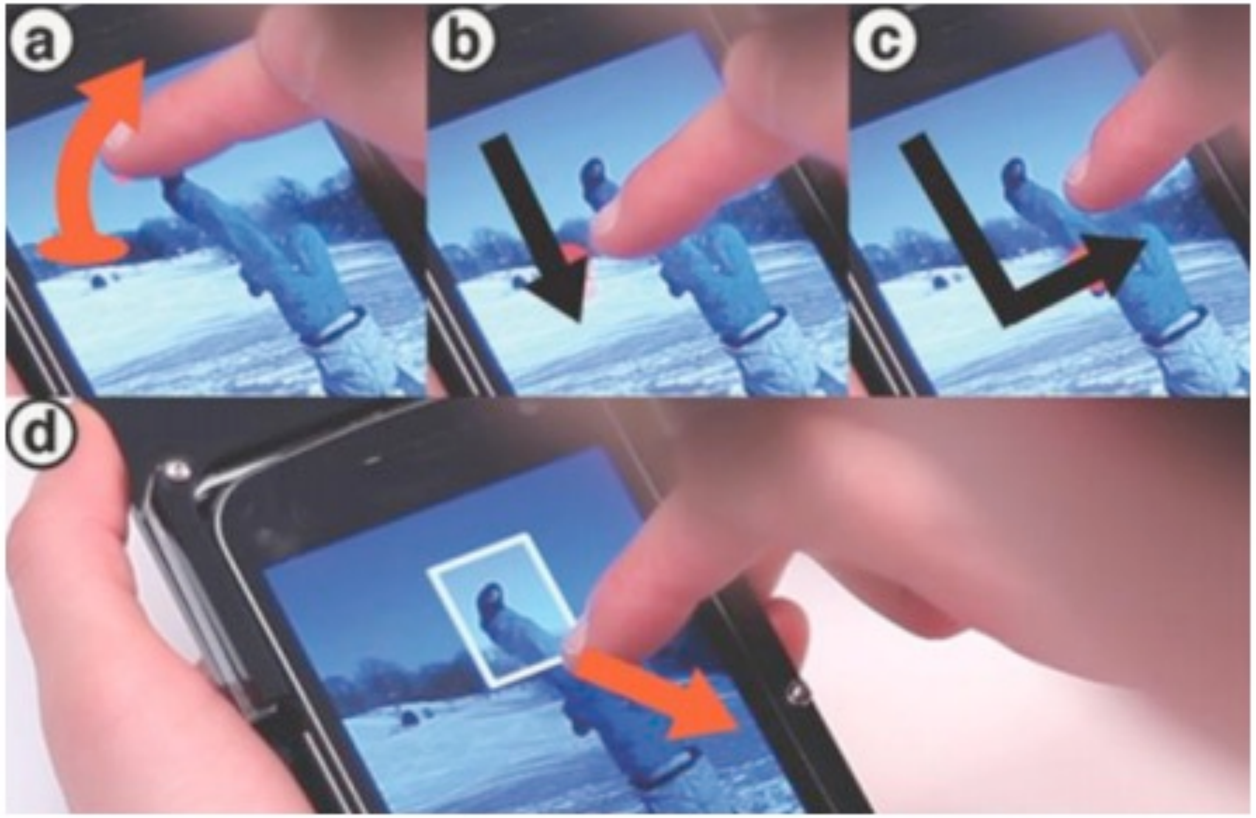


Figure 9. In the drawing app, a rectangular selection can be made by performing a tap (a), followed by drawing an in-air 'L' gesture (b.c), and finally closed by another tap (d).

Air+Touch: Interweaving Touch & In-Air Gestures

Examples – Air After Touch

Drawing a ‘pigtail’ after touch
for free-form selection

Cycling in-air after touch to
zoom on a map

Hovering after touch to change
scroll speed

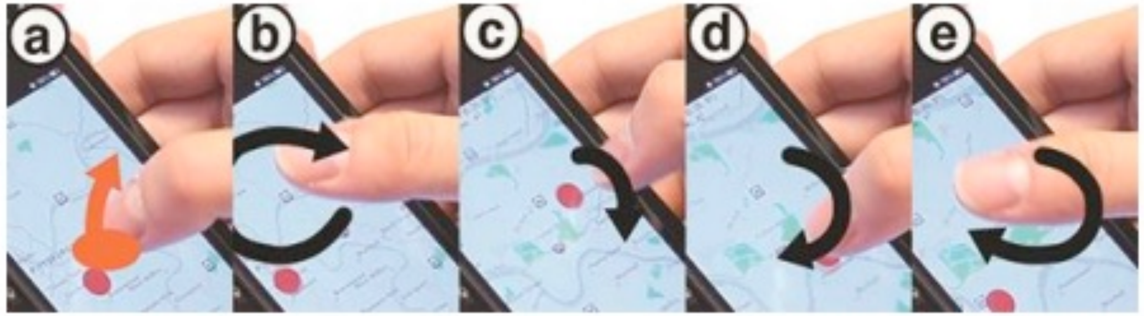


Figure 11. In our map app, a tap (a) followed by a ‘circle’ high above the screen (b) allows one to continuously zoom at the map by cycling the finger (c,d,e).

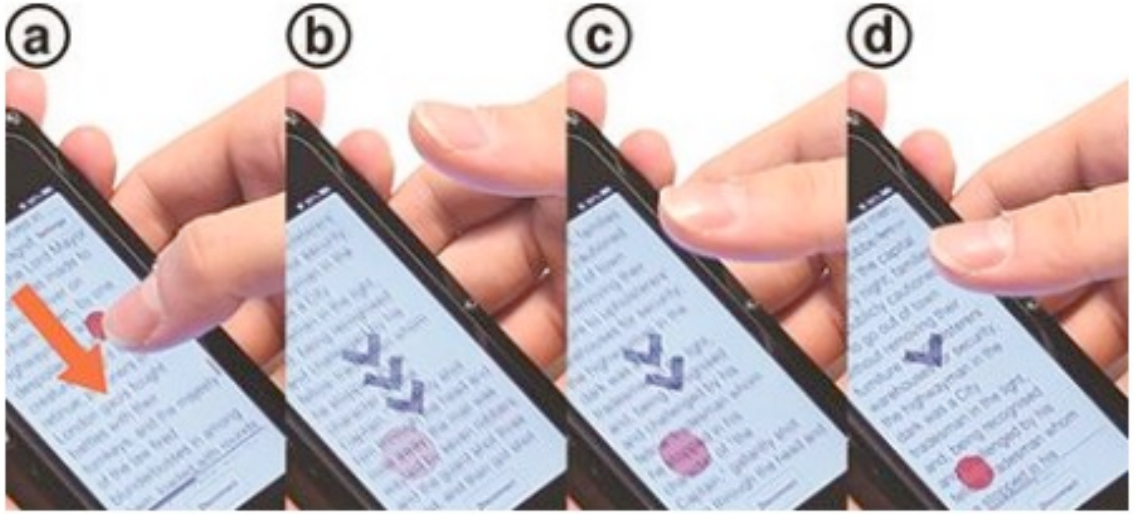


Figure 12. In our reader app, one can use the finger’s hover height to control the auto-scrolling speed.

Air+Touch: Interweaving Touch & In-Air Gestures

Is this the end of the work?

What would be the next step?

Single user interaction

Multi-user interaction

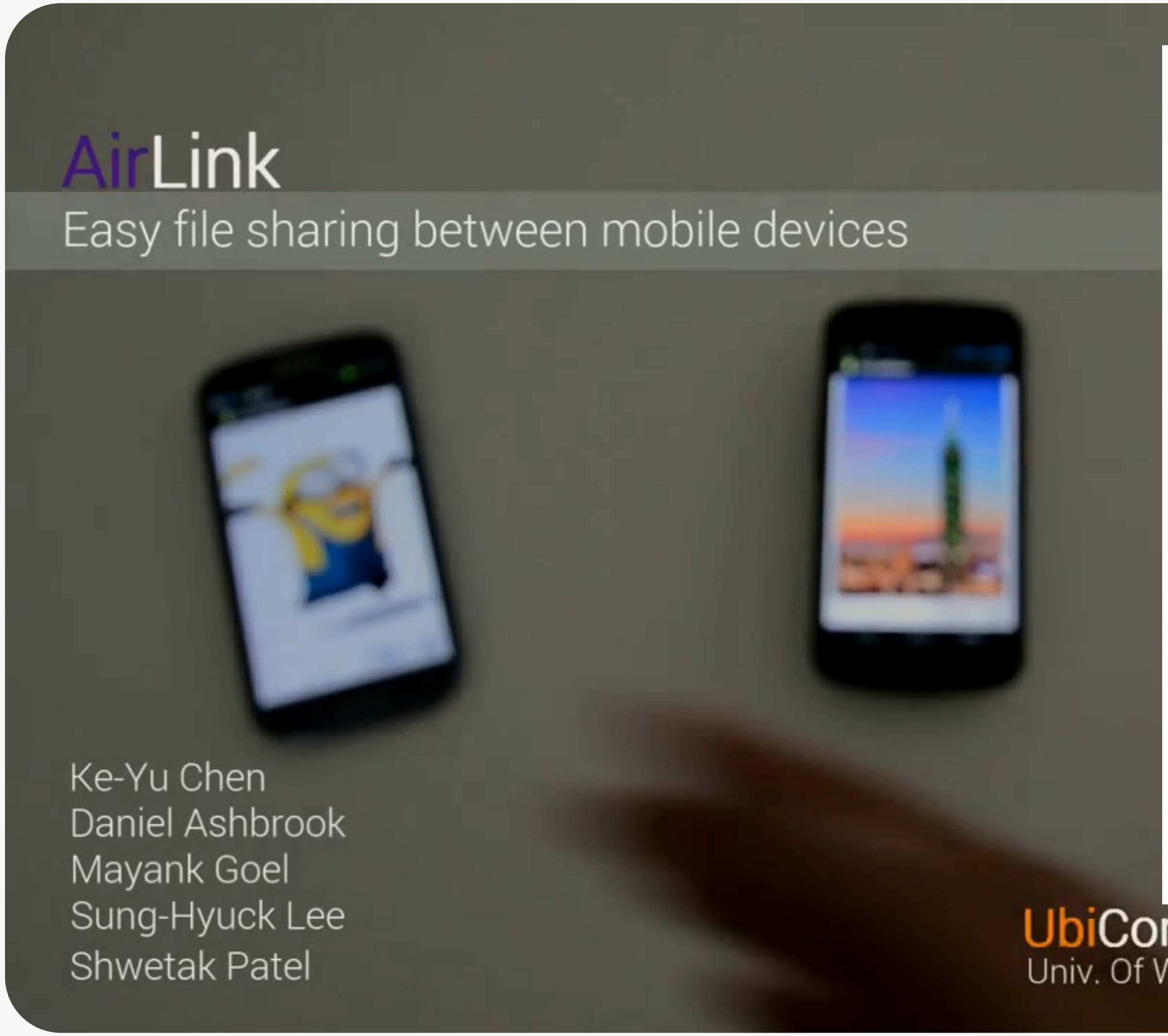
Sensing beyond interaction

Single user interaction

Multi-user interaction

Sensing beyond interaction

AirLink: sharing files between multiple devices using in-air gestures



UBICOMP '14, SEPTEMBER 13 - 17, 2014, SEATTLE, WA, USA

AirLink: Sharing Files Between Multiple Devices Using In-Air Gestures

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ABSTRACT

We introduce AirLink, a novel technique for sharing files between multiple devices. By waving a hand from one device towards another, users can directly transfer files between them. The system utilizes the devices' built-in speakers and microphones to enable easy file sharing between phones, tablets and laptops. We evaluate our system in an 11-participant study with 96.8% accuracy, showing the feasibility of using AirLink in a multiple-device environment. We also implemented a real-time system and demonstrate the capability of AirLink in various applications.

Author Keywords

Mobile phones; sensing; gestures; Doppler effect; multiple-device environment

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Sharing photos, text, and other information is a common task people engage in with their mobile devices. While many mechanisms for transferring this information exist, such as Bluetooth and WiFi, the ability for the user to select which device or devices to share with is still an open question. People still seem to resort to emailing content, even when the target device is just inches away. Existing interfaces such as those associated with Bluetooth or Apple's AirDrop require the user to browse through a possibly-lengthy list of receiving devices or users and choose where

Figure 1: AirLink allows file sharing between multiple devices by using in-air gestures and without adding new sensors.

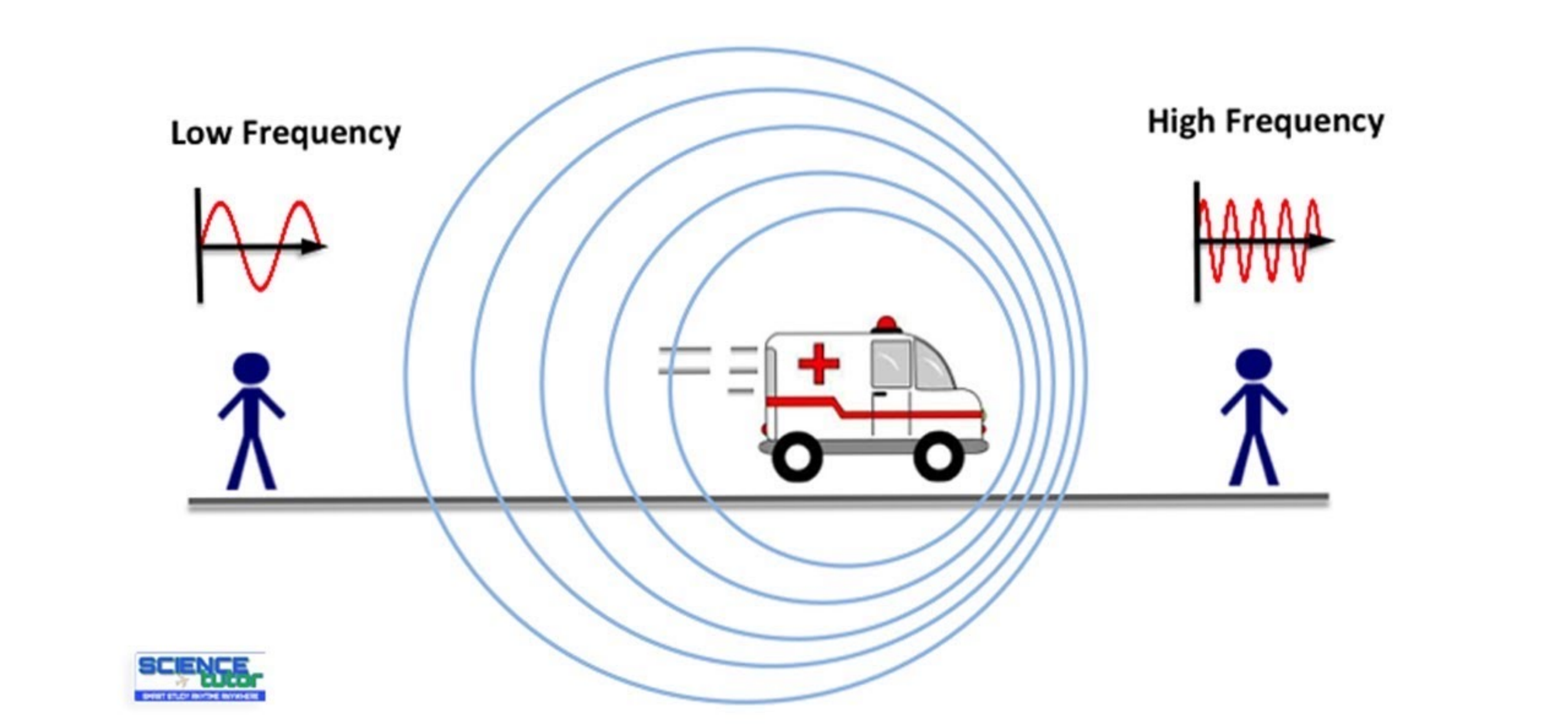
users to share files between multiple devices using in-air gestures (Figure 1). By waving the hand from one device to another, users can easily exchange information such as photos between multiple devices. AirLink leverages acoustic sensing to identify hand gestures. In particular, our algorithm measures the Doppler shift caused by hand movements and identifies the direction of hand movement from one device to another. By starting and stopping at the intended devices, there is no ambiguity as to which devices are sending and receiving the content. Furthermore, AirLink requires only standard microphones and speakers which are built into nearly all mobile devices.

Ubicomp 2014

Chen et.al. from UW

AirLink: sharing files between multiple devices using in-air gestures

How does it work? Doppler shift!



AirLink: sharing files between multiple devices using in-air gestures

How does it work? Doppler shift

Built-in sensing: Just microphone and speakers

High-frequency sound
(near ultrasound)

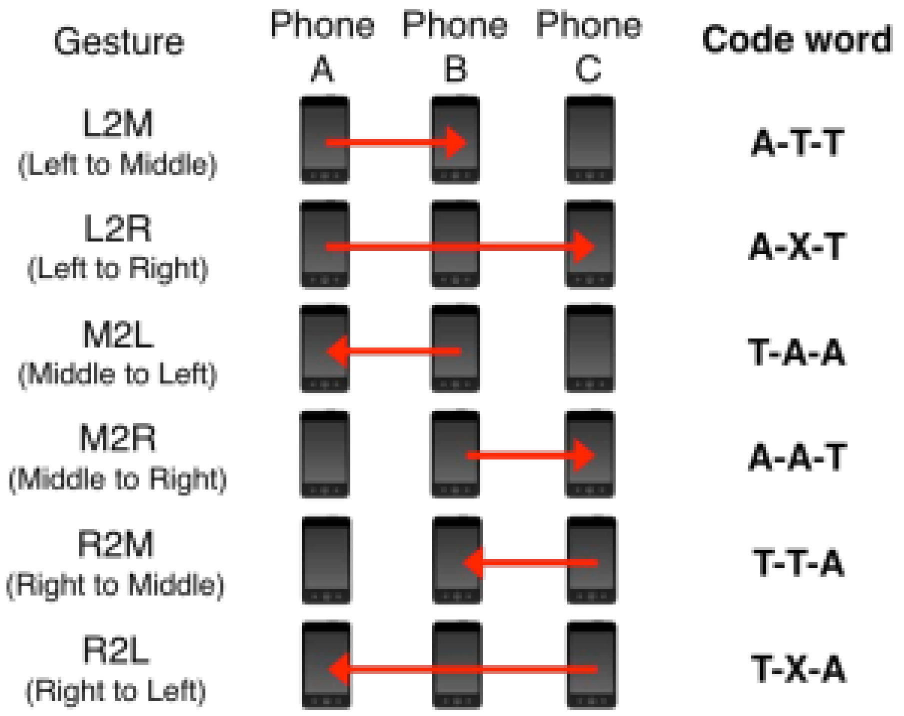


Figure 3. By combining 3 basic hand movements: *T* (toward), *A* (away), and *X* (toward and then away), each type of gestures can be represented as a unique codeword.

AirLink: sharing files between multiple devices using in-air gestures

How does it work? Doppler shift

Built-in sensing: Just microphone and speakers

High-frequency sound (near ultrasound)

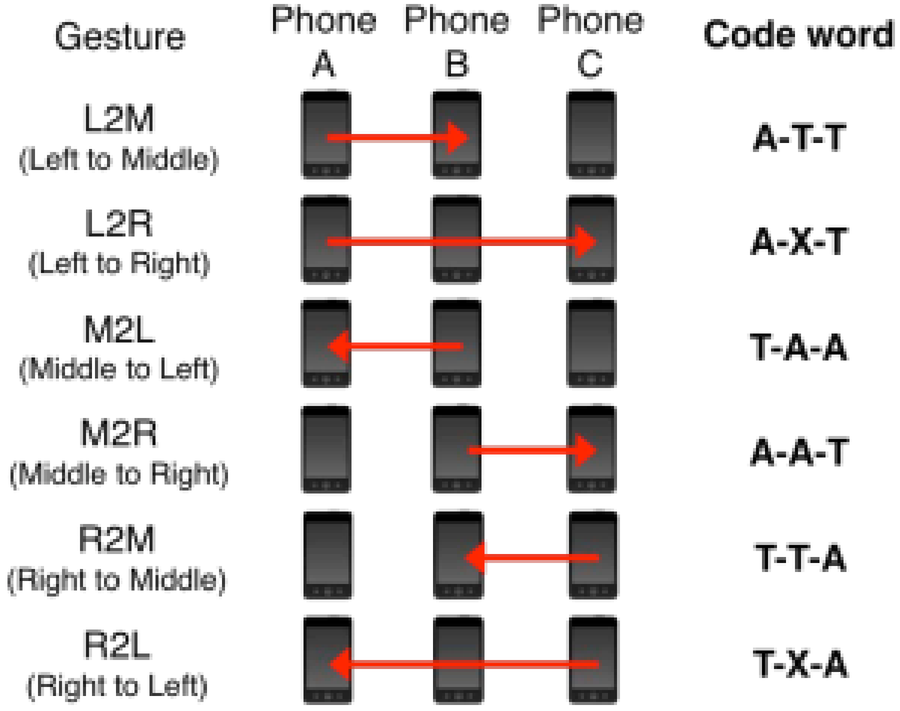


Figure 3. By combining 3 basic hand movements: *T* (toward), *A* (away), and *X* (toward and then away), each type of gestures can be represented as a unique codeword.

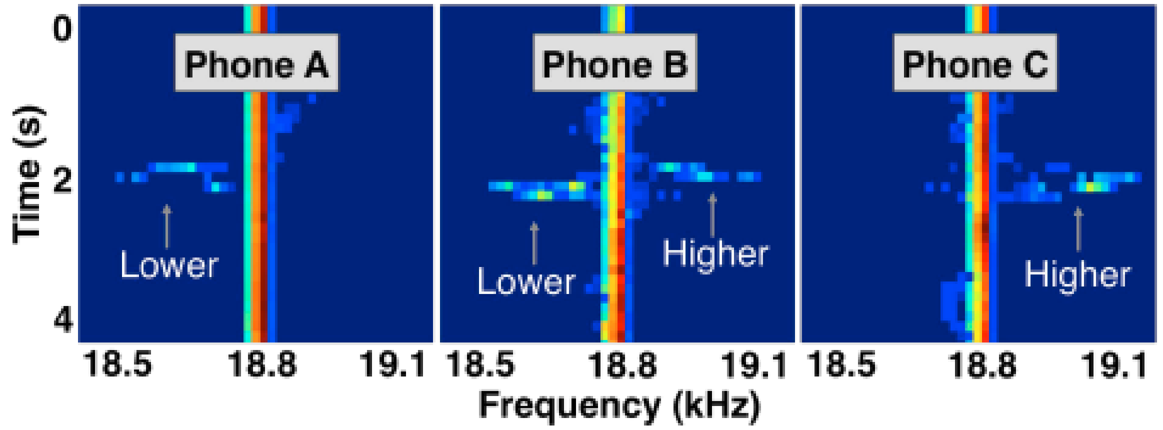


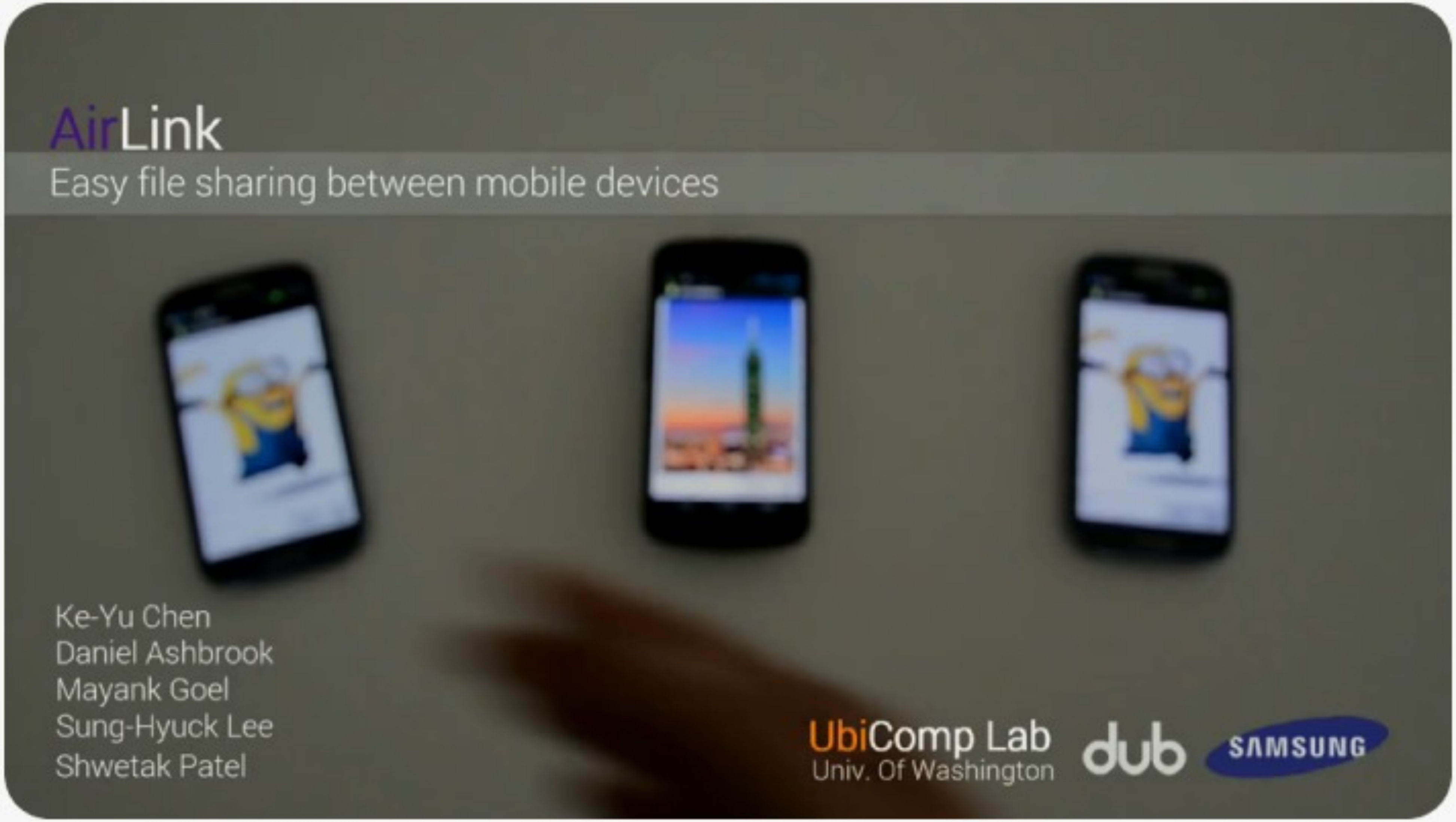
Figure 2. The detected Doppler-shifted signals of a L2R gesture (illustrated in Figure 3). This waterfall plot shows x-axis as frequency and y-axis as time. The pilot tone is emitted at 18.8 KHz on all three phones. On phone B (middle), the shifted frequency first appears on the *right* (higher than the pilot tone) and changes to the *left* (lower than the pilot tone).

AirLink: sharing files between multiple devices using in-air gestures

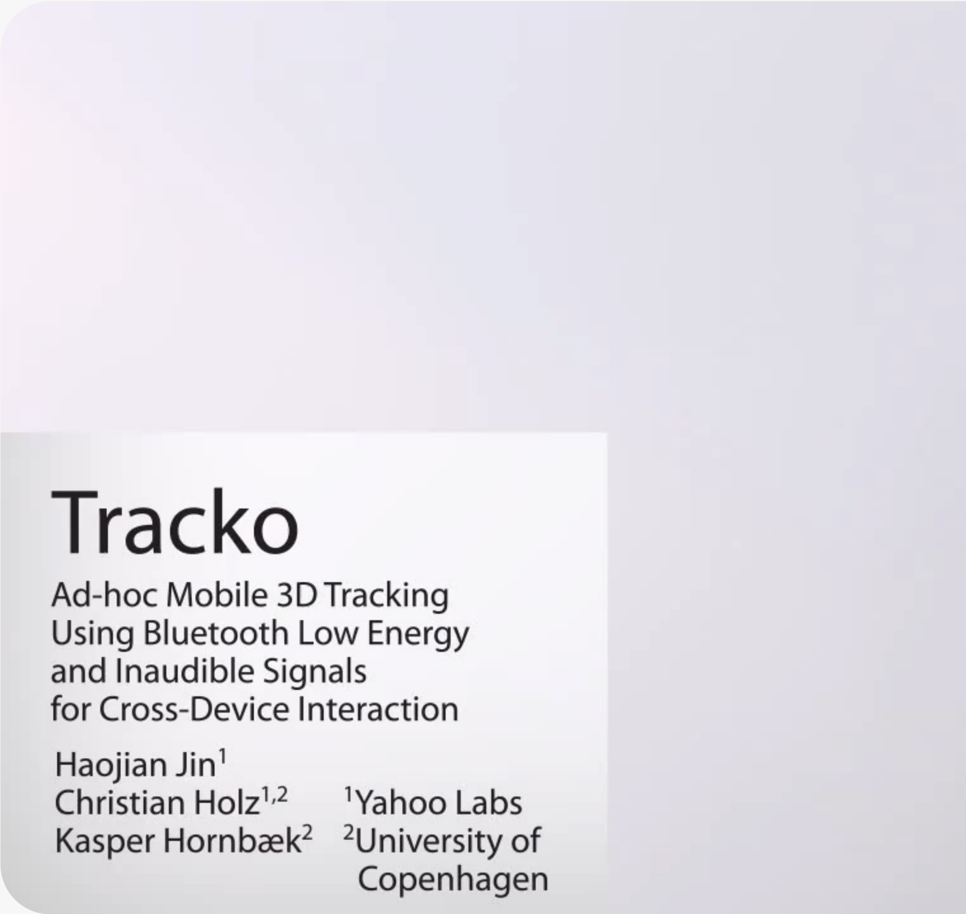
Limitation?

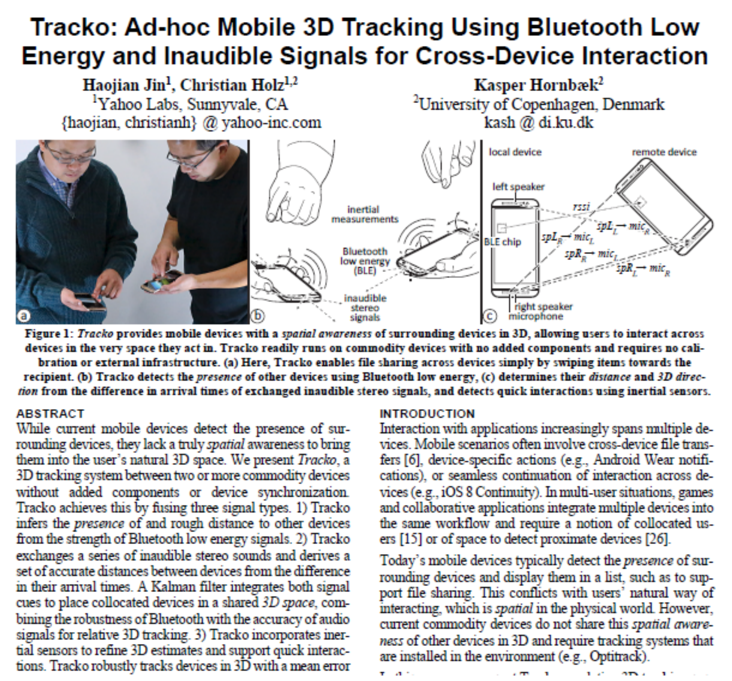
Limited gesture space

No distance detections



Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction





Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

Haojian Jin[1], Christian Holz[1,2]
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Kasper Hornbæk[2]
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Figure 1: ***Tracko*** **provides mobile devices with a** ***spatial awareness*** **of surrounding devices in 3D, allowing users to interact across devices in the very space they act in. Tracko readily runs on commodity devices with no added components and requires no calibration or external infrastructure. (a) Here, Tracko enables file sharing across devices simply by swiping items towards the recipient. (b) Tracko detects the** ***presence*** **of other devices using Bluetooth low energy, (c) determines their** ***distance*** **and** ***3D direction*** **from the difference in arrival times of exchanged inaudible stereo signals, and detects quick interactions using inertial sensors.**

ABSTRACT

While current mobile devices detect the presence of surrounding devices, they lack a truly *spatial* awareness to bring them into the user's natural 3D space. We present *Tracko*, a 3D tracking system between two or more commodity devices without added components or device synchronization. Tracko achieves this by fusing three signal types. 1) Tracko infers the *presence* of and rough distance to other devices from the strength of Bluetooth low energy signals. 2) Tracko exchanges a series of inaudible stereo sounds and derives a set of accurate distances between devices from the difference in their arrival times. A Kalman filter integrates both signal cues to place collocated devices in a shared *3D space*, combining the robustness of Bluetooth with the accuracy of audio signals for relative 3D tracking. 3) Tracko incorporates inertial sensors to refine 3D estimates and support quick interactions. Tracko robustly tracks devices in 3D with a mean error

INTRODUCTION

Interaction with applications increasingly spans multiple devices. Mobile scenarios often involve cross-device file transfers [6], device-specific actions (e.g., Android Wear notifications), or seamless continuation of interaction across devices (e.g., iOS 8 Continuity). In multi-user situations, games and collaborative applications integrate multiple devices into the same workflow and require a notion of collocated users [15] or of space to detect proximate devices [26].

Today's mobile devices typically detect the *presence* of surrounding devices and display them in a list, such as to support file sharing. This conflicts with users' natural way of interacting, which is *spatial* in the physical world. However, current commodity devices do not share this *spatial awareness* of other devices in 3D and require tracking systems that are installed in the environment (e.g., Optitrack).

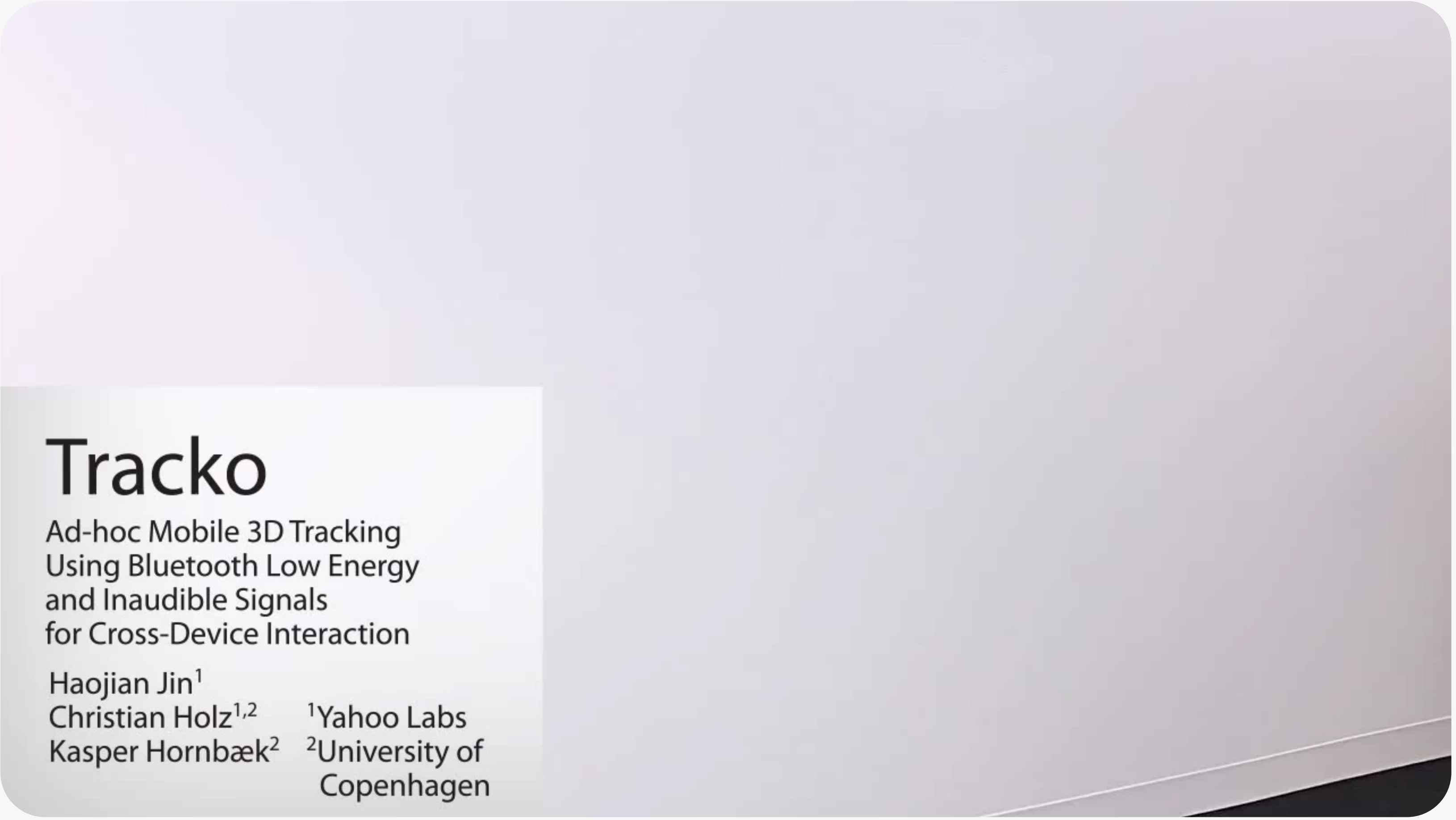
UIST 2015

Jin et.al. from Yahoo Labs

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

BLE (only) knows the **presence** of a neighbor device

Tracko knows the **actual locations**



Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Fuses 3 signal types on commodity devices

1. Bluetooth low energy (BLE)
2. Inertial motion (gyro+accelerometers, etc)
3. Inaudible stereo signals (ultrasound)

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Bluetooth low energy (BLE)

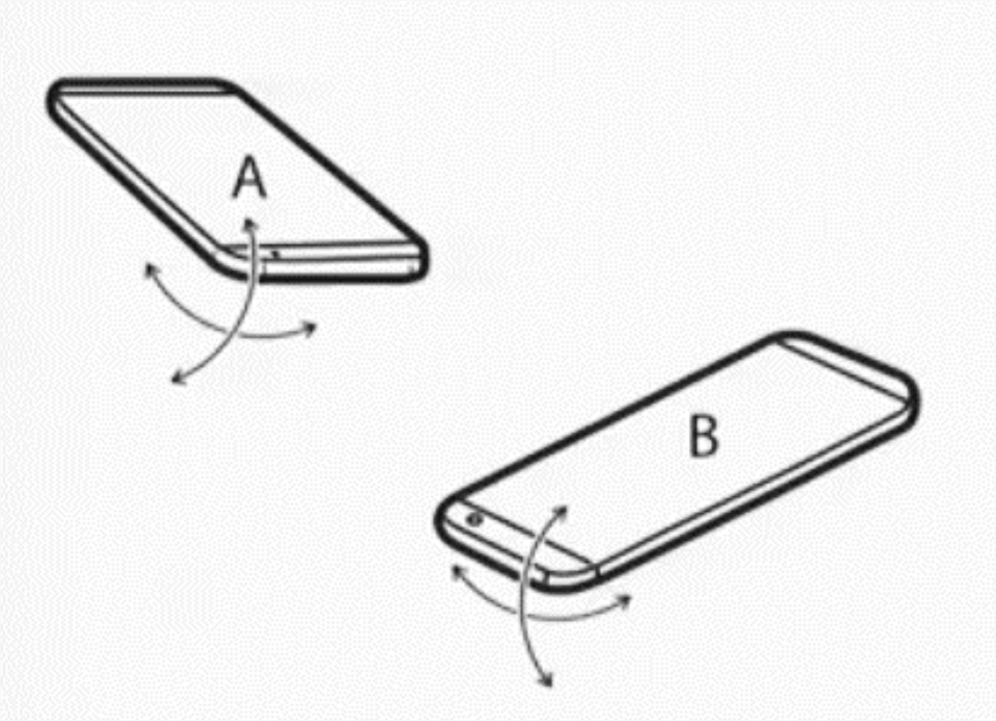
Robust signal -> detects the **presence** of surrounding devices

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inertial motion (gyro+accelerometers, etc)

Track each phone's **3D orientations**



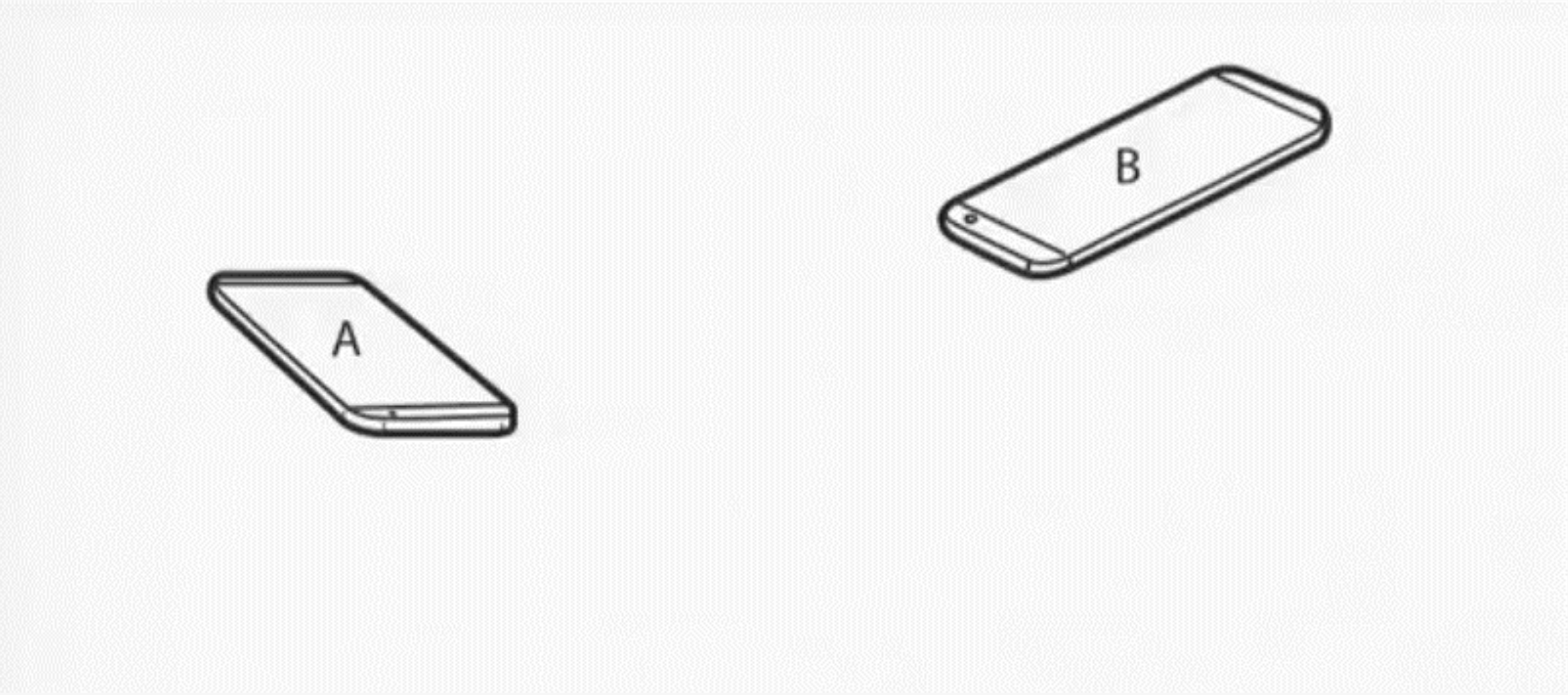
https://www.youtube.com/watch?v=Bv3c97BYXvE

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inaudible stereo signals

Track **distance** between a pair of phones



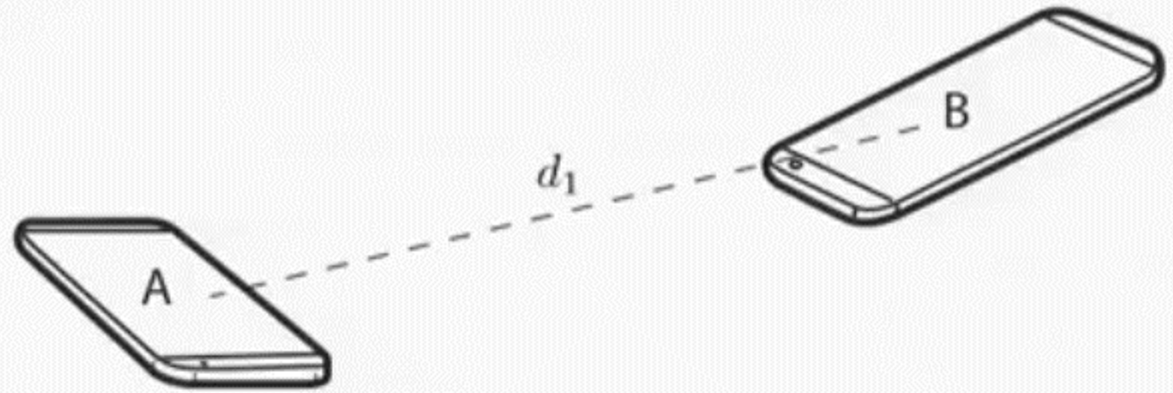
https://www.youtube.com/watch?v=Bv3c97BYXvE

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inaudible stereo signals

Track **distance** between a pair of phones



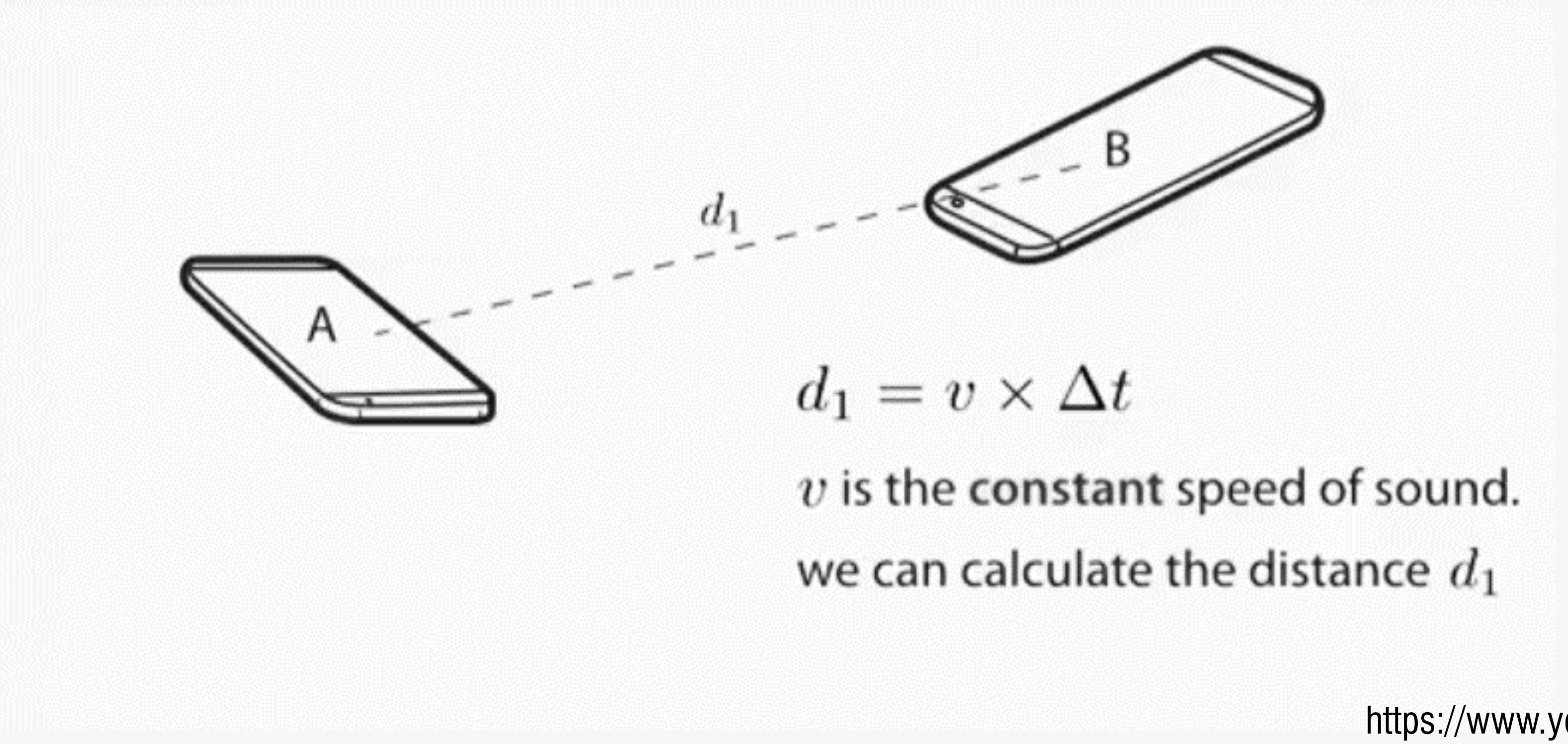
https://www.youtube.com/watch?v=Bv3c97BYXvE

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inaudible stereo signals

Track **distance** between a pair of phones



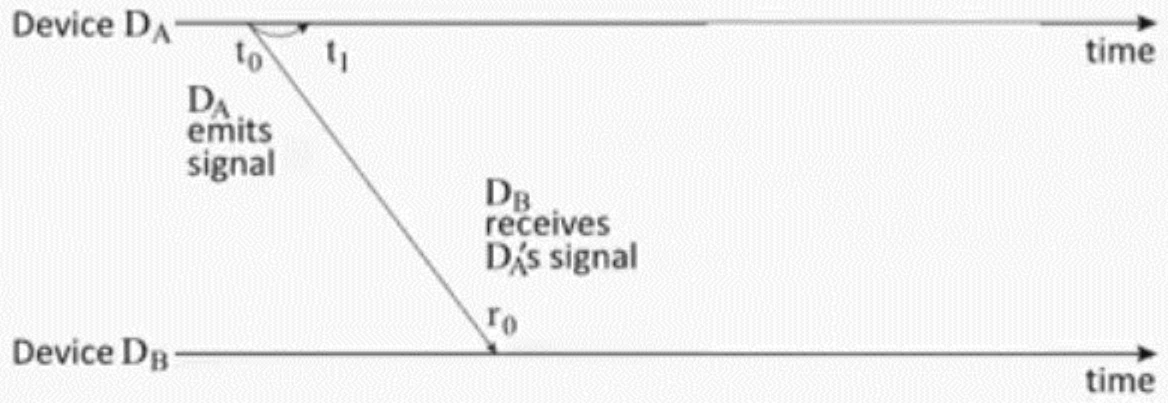
https://www.youtube.com/watch?v=Bv3c97BYXvE

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inaudible stereo signals

Track **distance** between a pair of phones



https://www.youtube.com/watch?v=Bv3c97BYXvE

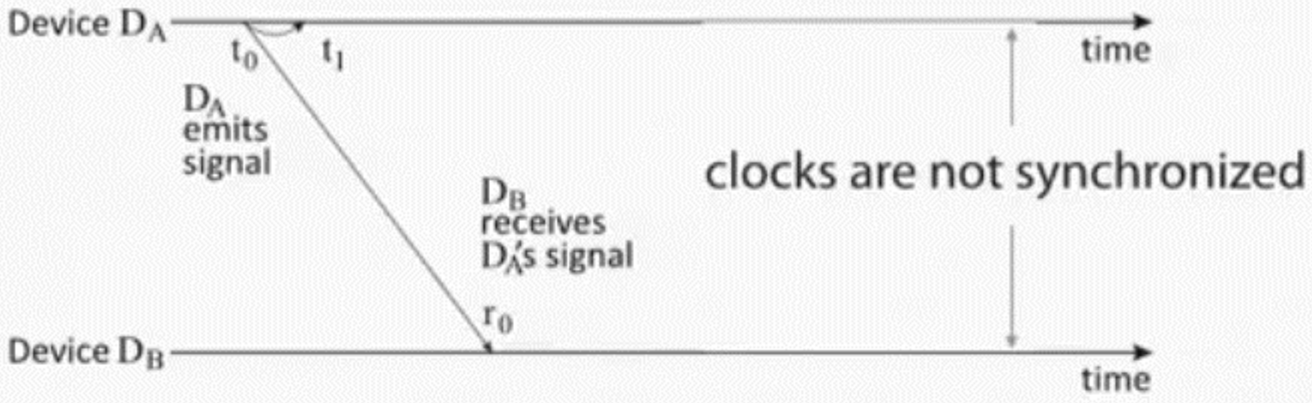
Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inaudible stereo signals

Track **distance** between a pair of phones

Problem? No time sync between two devices



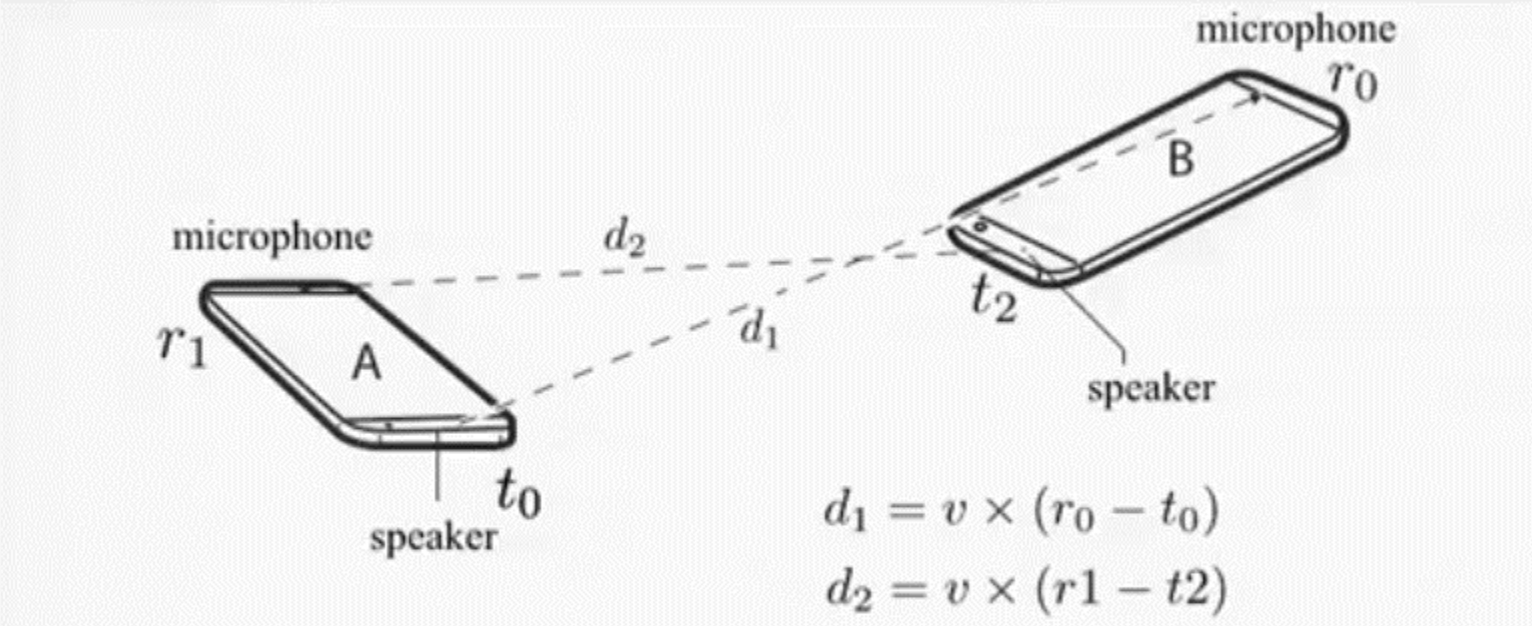
https://www.youtube.com/watch?v=Bv3c97BYXvE

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inaudible stereo signals

Track **distance** between a pair of phones



Solution: capture round-trip

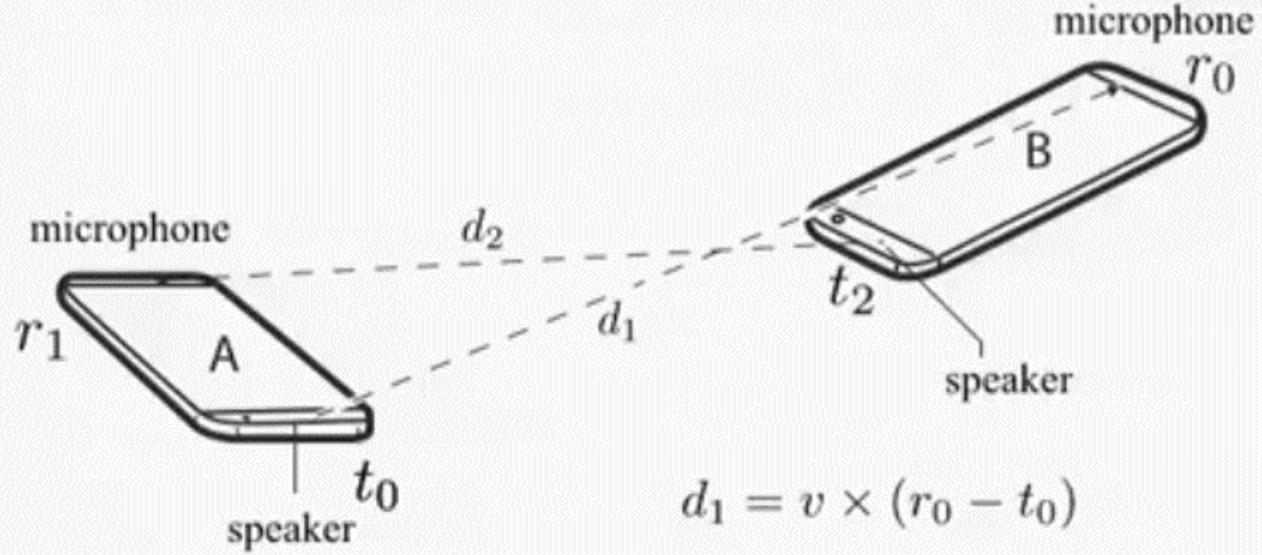
https://www.youtube.com/watch?v=Bv3c97BYXvE

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inaudible stereo signals

Track **distance** between a pair of phones



$$d_1 = v \times (r_0 - t_0)$$

$$d_2 = v \times (r1 - t2)$$

$$d_1 + d_2 = v \times (r_0 - t_0) + v \times (r_1 - t_2)$$

Solution: capture round-trip

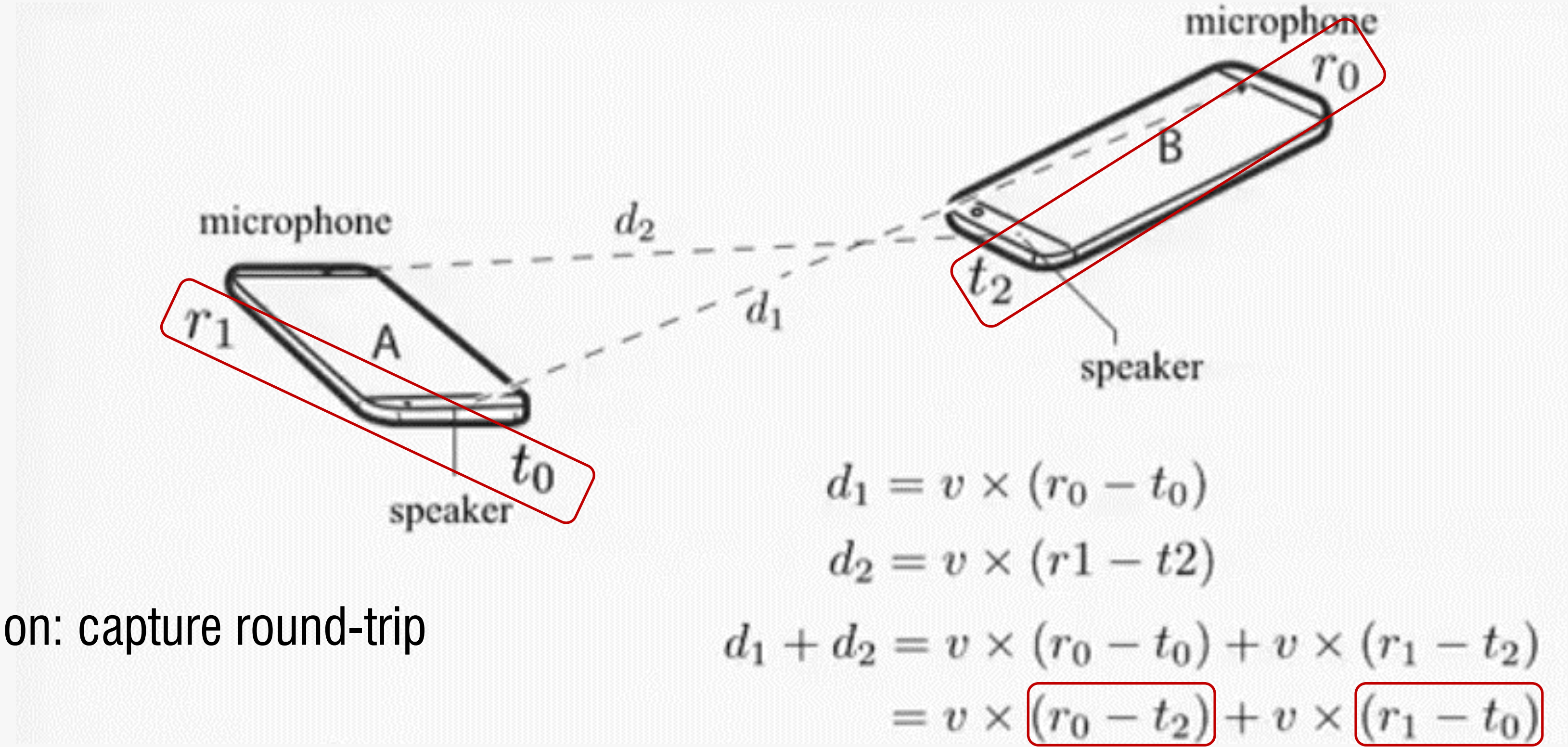
https://www.youtube.com/watch?v=Bv3c97BYXvE

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Inaudible stereo signals

Track **distance** between a pair of phones



Solution: capture round-trip

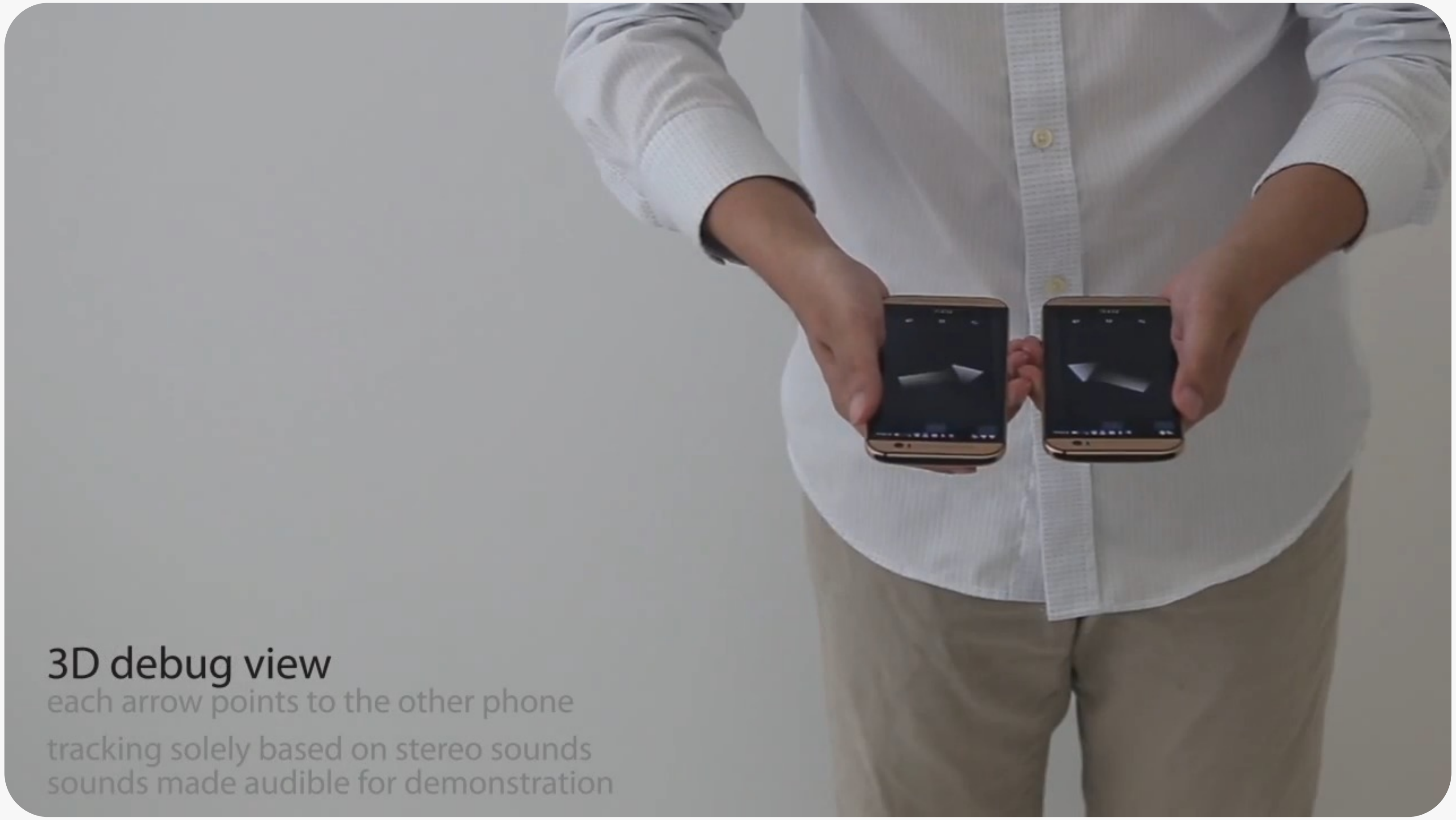
Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction

How does it work?

Fuses 3 signal types on commodity devices

1. Bluetooth low energy (BLE) -> coarse presence
2. Inertial motion (gyro+accelerometers, etc) -> phone orientation
3. Inaudible stereo signals (ultrasound) -> 3D offset

Tracko: Ad-hoc Mobile 3D Tracking Using Bluetooth Low Energy and Inaudible Signals for Cross-Device Interaction



Enough technologies -> here is a fun project

THAW: Hybrid Interactions with Phones on Computer Screens

Making Connections — TEI 2015, January 15–19, 2015, Stanford, CA, USA

THAW: Tangible Interaction with See-Through Augmentation for Smartphones on Computer Screens

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MIT Media Lab, 75 Amherst Street, Cambridge, MA, United States

Figure 1: A smartphone screen can be used as a user interface intervening into the display space of a computer screen.

ABSTRACT
The huge influx of mobile display devices is transforming computing into multi-device interaction, demanding a fluid mechanism for using multiple devices in synergy. In this paper, we present a novel interaction system that allows a collocated large display and a small handheld device to work together. The smartphone acts as a physical interface for near-surface interactions on a computer screen. Our system enables accurate position tracking of a smartphone placed on or over any screen by displaying a 2D color pattern that is captured using the smartphone's back-facing camera. As a result, the smartphone can directly interact with data displayed on the host computer, with precisely aligned visual feedback from both devices. The possible interactions are described and classified in a framework, which we exemplify on the basis of several implemented applications. Finally, we present a technical evaluation and describe how our system is unique compared to other existing near-surface interaction systems. The proposed technique can be implemented on existing devices without the need for additional hardware, promising immediate integration into existing systems.

Author Keywords
Multi-device Interaction; Tangible Magic Lens;

ACM Classification Keywords
H.5.2 User Interfaces: Input devices and strategies (e.g., mouse, touchscreen)

General Terms
Human Factors; Design;

INTRODUCTION
A growing number of people own a smartphone in addition to their computer. The collocated interaction with those devices poses the question of how to seamlessly connect the different display spaces and their afforded interactions. Some existing systems mediate users' actions across multiple devices, however, their use scenarios are mostly focused on using a secondary device as mere a remote controller or a viewport [2, 3, 6].

To challenge this limitation, our research focuses on the spatial fusion of the two display devices through near-surface interaction. This allows to best leverage both device's affordances to create a fluid experience: The physical body of the phone affords tangible manipulation, while the screens on both devices can display virtual graphics that augment or interact with each other. If the interaction between the devices happens in close proximity, the phone's physicality and the graphics on each device in combination with our strong visual-motor skills bridges the gap between spatial reality and the digital as shown in prior research in the fields of Augmented Reality (AR) [10] and Tangible User Interfaces (TUI) [14]. The two domains are not mutually exclusive, having slightly different focuses on visual augmentation and tangible interaction respectively.

TEI 2015
Leigh et.al. from MIT

Single user interaction

Multi-user interaction

Sensing beyond interaction

Single user interaction
Multi-user interaction
Sensing beyond interaction

SpiroCall: Measuring Lung Function over a Phone Call

SpiroCall: Measuring Lung Function over a Phone Call

Mayank Goel[1], Elliot Saba[1], Maia Stiber[2], Eric Whitmire[1], Josh Fromm[1], Eric C. Larson[3], Gaetano Borriello[1], Shwetak N. Patel[1]

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ABSTRACT
Cost and accessibility have impeded the adoption of spirometers (devices that measure lung function) outside clinical settings, especially in low-resource environments. Prior work, called SpiroSmart, used a smartphone's built-in microphone as a spirometer. However, individuals in low- or middle-income countries do not typically have access to the latest smartphones. In this paper, we investigate how spirometry can be performed from *any* phone—using the standard telephony voice channel to transmit the sound of the spirometry effort. We also investigate how using a 3D printed vortex whistle can affect the accuracy of common spirometry measures and mitigate usability challenges. Our system, coined SpiroCall, was evaluated with 50 participants against two gold standard medical spirometers. We conclude that SpiroCall has an acceptable mean error with or without a whistle for performing spirometry, and advantages of each are discussed.

Author Keywords
Health sensing; spirometry; mobile phone sensing; signal processing; machine learning.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (*e.g.*, HCI): Miscellaneous.

Figure 1. A user using SpiroCall on a feature phone (Sony w580i) with, and without a SpiroCall whistle.

Recently, a number of health applications have been developed to estimate physiological measures such as heart rate [13], respiratory rate [8,12], pupillary dilation [14], and newborn jaundice [5]. Larson *et al.* [9] introduced

CHI 2016
Goel et.al. from UW

Seismo: Blood Pressure Monitoring using Built-in Smartphone Accelerometer and Camera

CHI 2018 Honourable Mention   CHI 2018, April 21–26, 2018, Montréal, QC, Canada

Seismo: Blood Pressure Monitoring using Built-in Smartphone Accelerometer and Camera

Edward Jay Wang[1], Junyi Zhu[1], Mohit Jain[2], Tien-Jui Lee[1], Elliot Saba[1], Lama Nachman[3], Shwetak N. Patel[1,2]
[1]University of Washington, Department of Electrical Engineering, Seattle, WA
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ABSTRACT
Although cost-effective at-home blood pressure monitors are available, a complementary mobile solution can ease the burden of measuring BP at critical points throughout the day. In this work, we developed and evaluated a smartphone-based BP monitoring application called *Seismo*. The technique relies on measuring the time between the opening of the aortic valve and the pulse later reaching a periphery arterial site. It uses the smartphone's accelerometer to measure the vibration caused by the heart valve movements and the smartphone's camera to measure the pulse at the fingertip. The system was evaluated in a nine participant longitudinal BP perturbation study. Each participant participated in four sessions that involved stationary biking at multiple intensities. The Pearson correlation coefficient of the blood pressure estimation across participants is 0.20-0.77 (μ=0.55, σ=0.19), with an RMSE of 3.3-9.2 mmHg (μ=5.2, σ=2.0).

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous; I.5.4. Image Processing and Computer Vision: Applications

Author Keywords
Physiological sensing; noninvasive blood pressure; pulse transit time; photoplethysmography; seismocardiography; PTT; PPG; SCG

Figure 1. Measuring blood pressure using Seismo, a smartphone application that uses the built-in accelerometer and camera to calculate pulse transit time.

hypertension and effectiveness of treatments over infrequent in-clinic monitoring [1]. Currently, at home monitoring of BP relies on automated oscillometry-based BP arm cuffs for daily measurements. Although this way of automated way of measuring blood pressure enable out of clinic monitoring, they are cumbersome and inconvenient [20, 19].Due to these drawbacks, patients typically only perform arm cuff-based measurements once a day, and thus cannot capture the fluctuations in BP that occurs throughout the day due to exercise, activities, and other stressors.

Advances in mobile technologies now present an opportunity to have always available health monitoring capabilities as more and more people carry a smartphone around with them.

CHI 2018
Wang et.al. from UW

Single user interaction
Multi-user interaction
Sensing beyond interaction
Beyond sensing

MobiLimb: Augmenting Mobile Devices with a Robotic Limb *Marc Teyssier, Gilles Bailly, Catherine Pelachaud, Eric Lecolinet* ***UIST 18***

Recap


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Tuesday
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iTunes Store
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Health
Wallet
Settings

Recap

Accelerometer

Gyroscope

Magnetometer

Barometer

Proximity

GPS

Bluetooth

NFC

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Recap

Accelerometer
Gyroscope
Magnetometer
Barometer
Proximity
GPS
Bluetooth
NFC
...

Single user interaction
Multi-user interaction
Sensing beyond interaction

Recap

Speakers

TrueDepth (RGB-D) Sensor

Front Camera

Accelerometer
Gyroscope
Magnetometer
Barometer
Proximity
GPS
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Single user interaction
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Touch Screen

Microphones

Recap

Speakers

TrueDepth (RGB-D) Sensor

Front Camera

Accelerometer
Gyroscope
Magnetometer
Barometer
Proximity
GPS
Bluetooth
NFC
...

Single user interaction
Multi-user interaction
Sensing beyond interaction

Touch Screen

Microphones

Recap

Single user interaction
Multi-user interaction
Sensing beyond interaction

Special thanks to Prof. Cheng Zhang for the material

Optional readings

EarTouch: Facilitating Smartphone Use for Visually Impaired People in Mobile and Public Scenarios

Ruolin Wang[12], Chun Yu[123†], Xing-Dong Yang[4], Weijie He[1], Yuanchun Shi[123]

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[2]Key Laboratory of Pervasive Computing, Ministry of Education, China
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[4]Department of Computer Science, Dartmouth College, Hanover, New Hampshire, United States
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ABSTRACT

Interacting with a smartphone using touch input and speech output is challenging for visually impaired people in mobile and public scenarios, where only one hand may be available for input (e.g., while holding a cane) and using the loud-speaker for speech output is constrained by environmental noise, privacy, and social concerns. To address these issues, we propose EarTouch, a one-handed interaction technique that allows the users to interact with a smartphone using the ear to perform gestures on the touchscreen. Users hold the phone to their ears and listen to speech output from the ear speaker privately. We report how the technique was designed, implemented, and evaluated through a series of studies. Results show that EarTouch is easy, efficient, fun and socially acceptable to use.

CCS CONCEPTS

• **Human-centered computing → Accessibility technologies**; *Participatory design*;

KEYWORDS

Accessibility; Vision Impairment; Smartphone; One-handed Interaction; EarTouch; Capacitive Sensing

ACM Reference Format:
Ruolin Wang, Chun Yu, Xing-Dong Yang, Weijie He, Yuanchun Shi. 2019. EarTouch: Facilitating Smartphone Use for Visually Impaired People in Mobile and Public Scenarios. In *CHI Conference on Human Factors in Computing Systems Proceedings (CHI 2019), May 4–9, 2019, Glasgow, Scotland Uk.* ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/3290605.3300254

† denotes the corresponding author.

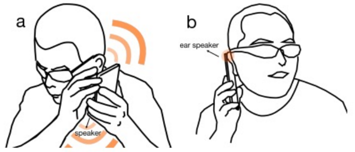

Figure 1: (a) FingerTouch vs. (b) EarTouch. The Shadow indicates the range of sound propagation of speech output.

1 INTRODUCTION

Smartphones have become an important part of the life for Blind and Visually Impaired (BVI) persons, who rely on screen readers (e.g., VoiceOver [31] and Talkback [41]) to interact with the phone. However, interacting with a smartphone using touch and speech output has significant limitations for BVI users in mobile and public scenarios as input often requires both hands, with one hand holding the phone and the other interacting with the screen. This can be frustrating while in transit, especially when one hand is occupied, such as holding a cane. Additionally, using the smartphone speaker for output is constrained by environmental noise, privacy and social concerns in public settings. BVI users have to hold the smartphone close to the ear, which enables auditory comprehension at the expense of input comfort and convenience (Figure 1.a).

In this paper, we propose EarTouch, a one-handed interaction technique that allows BVI persons to interact with a smartphone using the ear to tap or draw gestures on the touchscreen. Since the smartphone is held against the ear, the user can hear the speech output played via the ear speaker privately (Figure 1.b). This technique is unique because it supports touch and auditory reception in one natural posture, facilitating one-handed use and addressing privacy and

CHI 2019
Wang et.al.

Surround-See: Enabling Peripheral Vision on Smartphones during Active Use

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ABSTRACT

Mobile devices are endowed with significant sensing capabilities. However, their ability to 'see' their surroundings, during active use, is limited. We present Surround-See, a self-contained smartphone equipped with an omni-directional camera that enables peripheral vision around the device to augment daily mobile tasks. Surround-See provides mobile devices with a field-of-view collinear to the device screen. This capability facilitates novel mobile tasks such as, pointing at objects in the environment to interact with content, operating the mobile device at a physical distance and allowing the device to detect user activity, even when the user is not holding it. We describe Surround-See's architecture, and demonstrate applications that exploit peripheral 'seeing' capabilities during active use of a mobile device. Users confirm the value of embedding peripheral vision capabilities on mobile devices and offer insights for novel usage methods.

Author Keywords

Peripheral mobile vision, mobile 'seeing', mobile surround vision.

ACM Classification Keywords

H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

INTRODUCTION

Smartphones are equipped with powerful sensors, such as accelerometers, GPS and cameras that facilitate a variety of daily tasks. On commercial and research platforms, such sensors have been utilized in numerous contexts such as for distinguishing user activity [26], for sensing on, behind and around a mobile device [5, 41], for context awareness [46] and for interactive document exploration [13]. The integration of an ever expanding suite of embedded sensors is a key driver in making mobile devices smarter [26]. However, current capabilities are mostly focused on *sensing*. We distinguish 'sensing' from 'seeing' in that the latter facilitates some higher level of recognition or interpretation of objects, people and places in the mobile device's surroundings. What new applications might be possible if mobile devices had advanced *seeing* abilities?

We explore the above theme of empowering mobile devices with enhanced peripheral vision capabilities. Our prototype, Surround-See, consists of a smartphone fitted with an omnidirectional lens that gives the device peripheral vision, of its surroundings (Figure 1). During active use, Surround-See effectively extends the smartphone's limited field-of-sight provided by its front- and back-facing cameras. With an ability to 'see' the rich context of the region around the device, smartphones can trigger environment specific reminders and can respond to peripheral interactions, such as pointing at a smart-appliance for efficient access to its control panel on the mobile device.

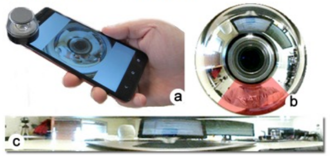

Figure 1 - (a) Surround-See enables peripheral 'sight' on smartphones by means of an omni-directional mirror attached to the mobile device's front facing camera. (b) Surround-See image shows the corresponding scene. (c) The unwrapped image can be used for recognizing the device's peripheral environment (after removing the user's body – shaded in red)

The scenario below captures some of the rich applications Surround-See enables. John, a professional is often using his mobile device. In the morning, he reads the news on Surround-See while his car engine warms-up. Recognizing this, Surround-See triggers a reminder on the danger of eyes-busy mobile use and driving. Later, as he settles into his office while checking email on Surround-See, he points at the speakers in the office, which Surround-See recognizes and provides a control panel to increase the speakers' volume. Laura, a colleague enters his office and asks about his weekend. John picks up his smartphone to show Laura pictures on the phone which Surround-See reorients as the device is positioned closer to Laura. Finally, Laura asks John for directions to the restaurant which John draws using a stylus and his finger to erase both of which are recognized as distinct by Surround-See. Shortly after doing some work he decides to step out for only a few

UIST 2013
Yang et.al.

Wed: Electronics – Analog + Sensing