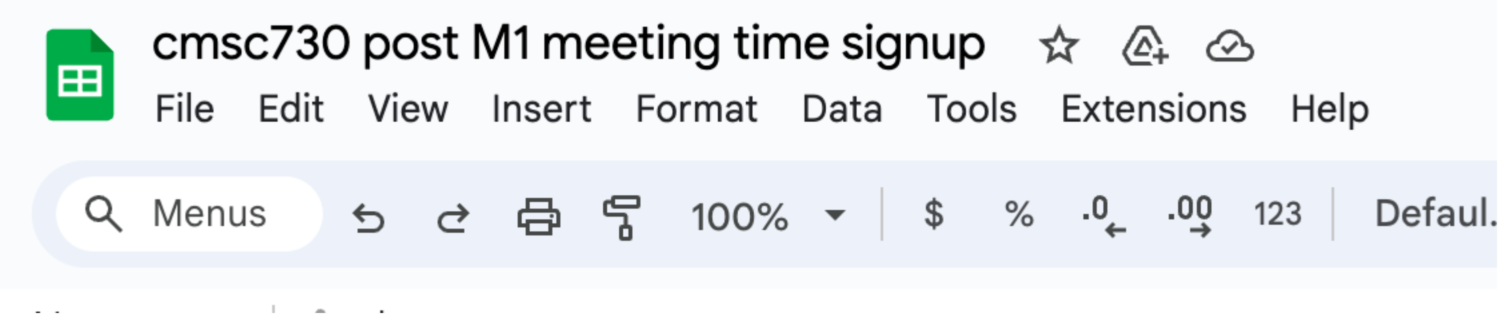

cmsc730 post M1 meeting time signup
File Edit View Insert Format Data Tools Extensions Help
Menus
100%
$ % .0 .00 123
Defaul.

# Smartwatch/Wearable Interaction

Huaishu Peng | UMD CS | Fall 2024

https://vimeo.com/265499838


1972, first digital watch
Hamilton Watch Company and
Electro/Data Inc


1985, Epson RC-20 Wrist Computer
Calculator, Memo, 2K RAM and a
Touchscreen


1999, Samsung SPH-WP10
Smartwatch that can make calls

Fat-finger syndrome

Small screen

One hand operation

Between devices interaction

Anything that a smartwatch can do but a smartphone can't?

2015, Apple Watch

Input

Output

Input

Output

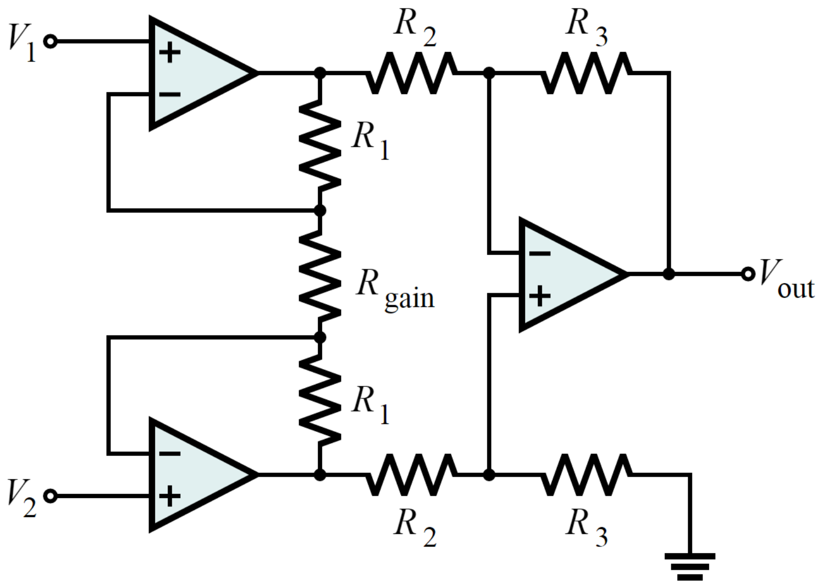
What if your hand is occupied

Your solution?

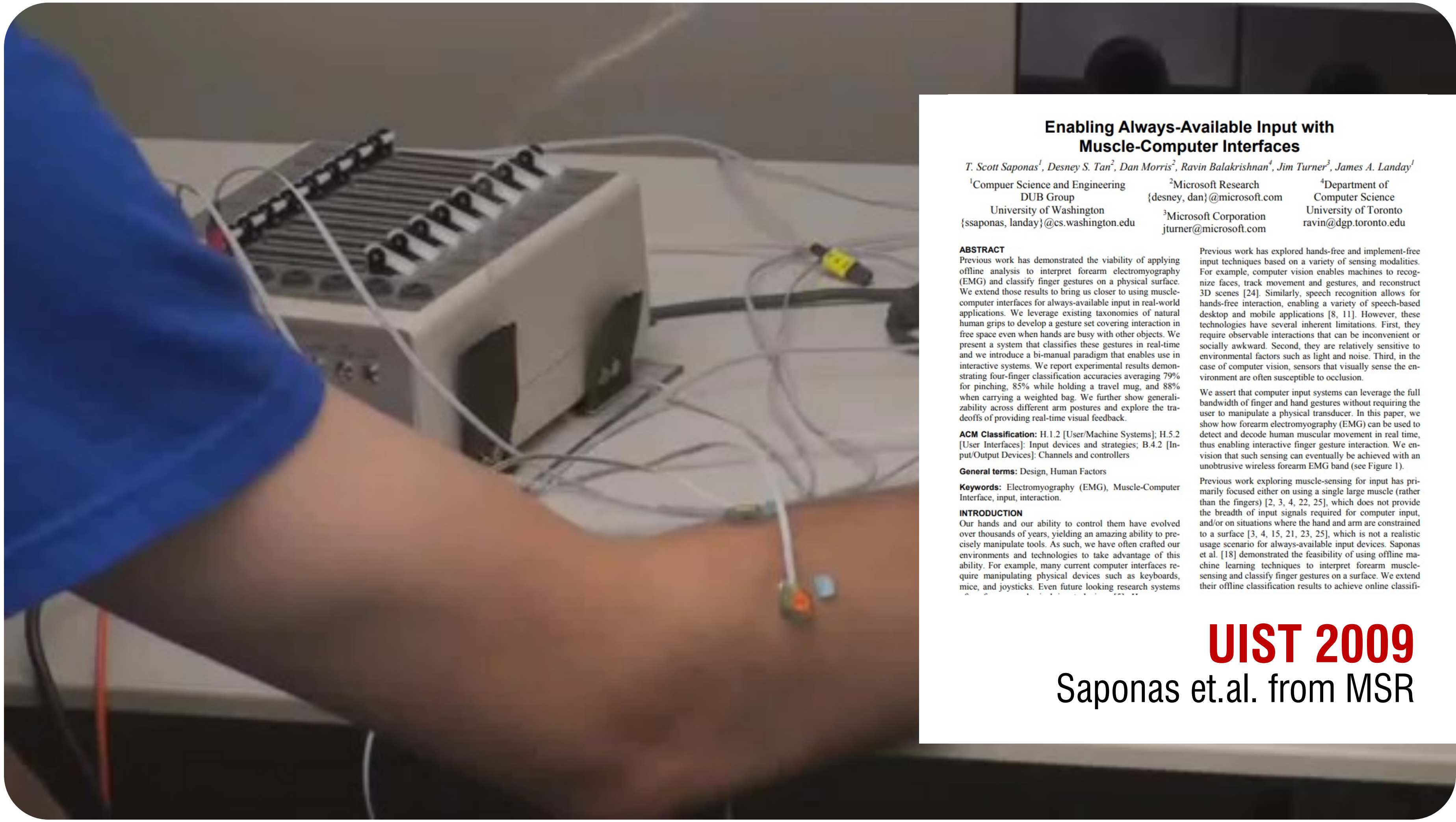
# Electromyography (EMG) Sensor

2008, Daito Manabe
https://www.youtube.com/watch?v=YxdlYFCp5Ic


416
1167


V1
V2
R2
R3
R1
Rgain
R1
R2
R3
Vout

# EMG Sensor



## Enabling Always-Available Input with Muscle-Computer Interfaces

*T. Scott Saponas[1], Desney S. Tan[2], Dan Morris[2], Ravin Balakrishnan[4], Jim Turner[3], James A. Landay[1]*

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**ABSTRACT**
Previous work has demonstrated the viability of applying offline analysis to interpret forearm electromyography (EMG) and classify finger gestures on a physical surface. We extend those results to bring us closer to using muscle-computer interfaces for always-available input in real-world applications. We leverage existing taxonomies of natural human grips to develop a gesture set covering interaction in free space even when hands are busy with other objects. We present a system that classifies these gestures in real-time and we introduce a bi-manual paradigm that enables use in interactive systems. We report experimental results demonstrating four-finger classification accuracies averaging 79% for pinching, 85% while holding a travel mug, and 88% when carrying a weighted bag. We further show generalizability across different arm postures and explore the tradeoffs of providing real-time visual feedback.

**ACM Classification:** H.1.2 [User/Machine Systems]; H.5.2 [User Interfaces]: Input devices and strategies; B.4.2 [Input/Output Devices]: Channels and controllers

**General terms:** Design, Human Factors

**Keywords:** Electromyography (EMG), Muscle-Computer Interface, input, interaction.

**INTRODUCTION**
Our hands and our ability to control them have evolved over thousands of years, yielding an amazing ability to precisely manipulate tools. As such, we have often crafted our environments and technologies to take advantage of this ability. For example, many current computer interfaces require manipulating physical devices such as keyboards, mice, and joysticks. Even future looking research systems

Previous work has explored hands-free and implement-free input techniques based on a variety of sensing modalities. For example, computer vision enables machines to recognize faces, track movement and gestures, and reconstruct 3D scenes [24]. Similarly, speech recognition allows for hands-free interaction, enabling a variety of speech-based desktop and mobile applications [8, 11]. However, these technologies have several inherent limitations. First, they require observable interactions that can be inconvenient or socially awkward. Second, they are relatively sensitive to environmental factors such as light and noise. Third, in the case of computer vision, sensors that visually sense the environment are often susceptible to occlusion.

We assert that computer input systems can leverage the full bandwidth of finger and hand gestures without requiring the user to manipulate a physical transducer. In this paper, we show how forearm electromyography (EMG) can be used to detect and decode human muscular movement in real time, thus enabling interactive finger gesture interaction. We envision that such sensing can eventually be achieved with an unobtrusive wireless forearm EMG band (see Figure 1).

Previous work exploring muscle-sensing for input has primarily focused either on using a single large muscle (rather than the fingers) [2, 3, 4, 22, 25], which does not provide the breadth of input signals required for computer input, and/or on situations where the hand and arm are constrained to a surface [3, 4, 15, 21, 23, 25], which is not a realistic usage scenario for always-available input devices. Saponas et al. [18] demonstrated the feasibility of using offline machine learning techniques to interpret forearm muscle-sensing and classify finger gestures on a surface. We extend their offline classification results to achieve online classifi-

**UIST 2009**
Saponas et.al. from MSR

HOME / PRODUCT CATEGORIES / BIOMETRICS / MYOWARE 2.0 MUSCLE SENSOR


# MyoWare 2.0 Muscle Sensor

DEV-21265

★★★★☆ 2

**$39.95**

Volume sales pricing

We do not currently have an estimate of when this product will be back in stock. **Notify Me**
**Note:** If this item is available for backorder it is subject to price changes at any time; additionally, we are unable to guarantee time frame for shipping or availability.

- 1 +  BACKORDER

Quantity discounts available

**DESCRIPTION** | FEATURES | DOCUMENTS

Using our muscles to control things is the way that most of us are accustomed to doing it. We push buttons, pull levers, move joysticks... but what if we could take the buttons, levers and joysticks out of the equation and control it with our muscles? The MyoWare® 2.0 Muscle Sensor is an Arduino-compatible, all-in-one electromyography (EMG) sensor from Advancer Technologies that allows you to do just that! The MyoWare 2.0 Muscle Sensor has been redesigned from the ground up with a

Myo Wristband ~$300+

What if your hand is occupied



Your solution?

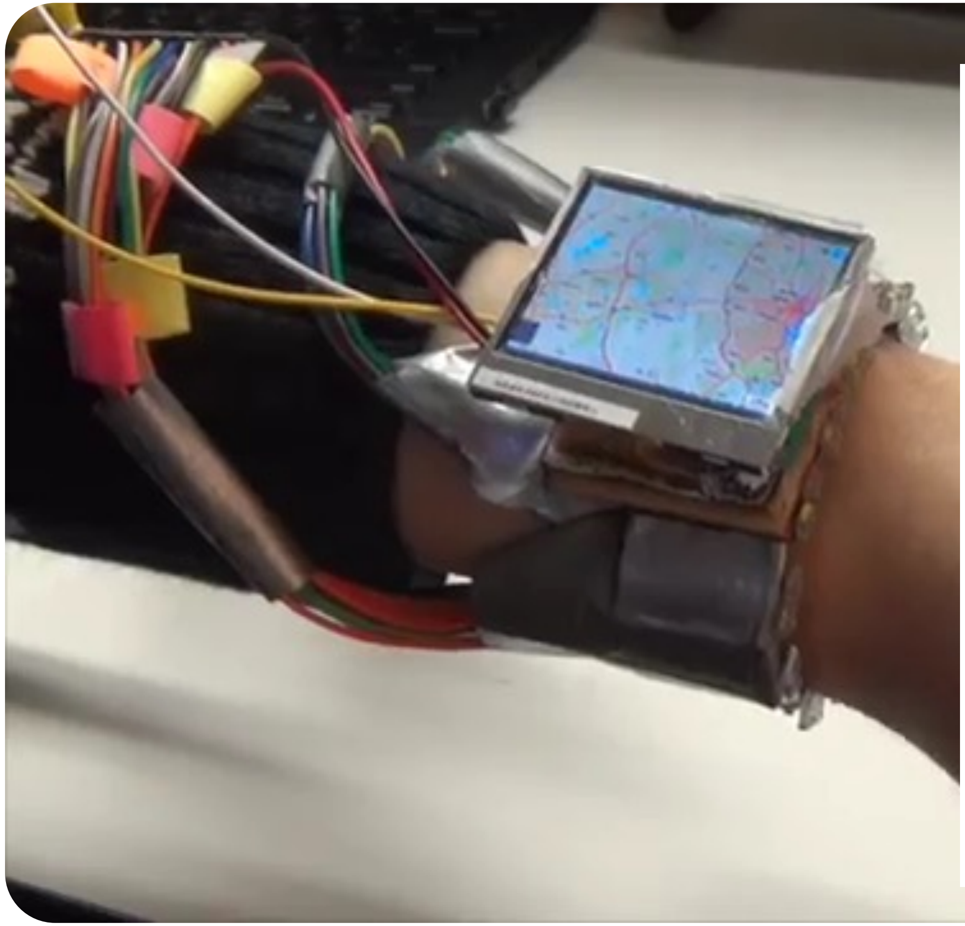
# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

## Contribution

One hand input

Continuous 2D input

Keeping the screen stable



WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

Jun Gong[1], Xing-Dong Yang[1], Pourang Irani[2]
Dartmouth College [1], University of Manitoba[2]
{jun.gong.gr; xing-dong.yang}@dartmouth.edu, pourang.irani@cs.umanitoba.ca

**ABSTRACT**
We propose and study a new input modality, WristWhirl, that uses the wrist as an always-available joystick to perform one-handed continuous input on smartwatches. We explore the influence of the wrist's bio-mechanical properties for performing gestures to interact with a smartwatch, both while standing still and walking. Through a user study, we examine the impact of performing 8 distinct gestures (4 directional marks, and 4 free-form shapes) on the stability of the watch surface. Participants were able to perform directional marks using the wrist as a joystick at an average rate of half a second and free-form shapes at an average rate of approximately 1.5secs. The free-form shapes could be recognized by a $1 gesture recognizer with an accuracy of 93.8% and by three human inspectors with an accuracy of 85%. From these results, we designed and implemented a proof-of-concept device by augmenting the watchband using an array of proximity sensors, which can be used to draw gestures with high quality. Finally, we demonstrate a number of scenarios that benefit from one-handed continuous input on smartwatches using WristWhirl.

**Author Keywords**
One-handed interaction; smartwatch; smartwatch input; continuous input; gestural input.

**ACM Classification Keywords**
H.5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

**INTRODUCTION**
Interacting with a smartwatch often necessitates both hands, especially for continuous input such as flicking the device screen with the opposite-side hand (OSH) [34]. This becomes tedious as such wearable devices are predominantly valuable for glancing at information when the users' hands are occupied while holding objects or busy at other tasks.

Efforts are underway at developing methods to allow same-side hand (SSH) operation on smartwatches. However, these have primarily targeted discrete input operations, such as in the case of micro-interactions [21, 33] or for assigning commands to finger postures [10, 24, 36]. Tilting the wrist is a viable approach [9], but comes at the cost of quickly losing visual contact with the display as tilt movements can exceed the acceptable screen viewing ranges [9, 23]. Performing more expressive continuous gestural input still remains challenging using the same-side hand.

We study and present an alternative approach, WristWhirl, an interaction technique that uses continuous wrist movements, or whirls, for one-handed operation on smartwatches (Figure 1). When observing the collective range-of-motions of the wrist along each of its axes of movement [12] (see Figure 2 and the WRIST AS JOYSTICK section), the hand can be viewed as a natural joystick. We explore the ability of the human wrist to perform complex gestures using full wrist motions, or wrist whirls. We first demonstrate that wrist whirl is sufficiently expressive to capture common touch interactions as well as generate free-form shapes (Figure 1 right) without impacting screen viewing stability. To validate the use of WristWhirl in different application scenarios, we implemented a proof-of-concept wristband sensor (Figure 1 left) by augmenting the strap of a smartwatch using an array of infrared proximity sensors, facing the user's palm. The sensors detect the wrist's joystick-like motion by sensing the degree of flexion/extension and ulnar/radial deviation of the wrist motion. Our preliminary system evaluation showed that the user could use the prototype to draw gestures at a quality comparable to that achieved by a commercial motion tracking system (e.g. Vicon [3]). Our approach does not seek to replace two-handed use of smartwatches, but instead provides an alternative to same-sided smartwatch input.



**UIST 2015**

Gong et.al. from Dartmouth

# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

Will the wrist input be useful?

Study before building

-- using external Vicon Tracker

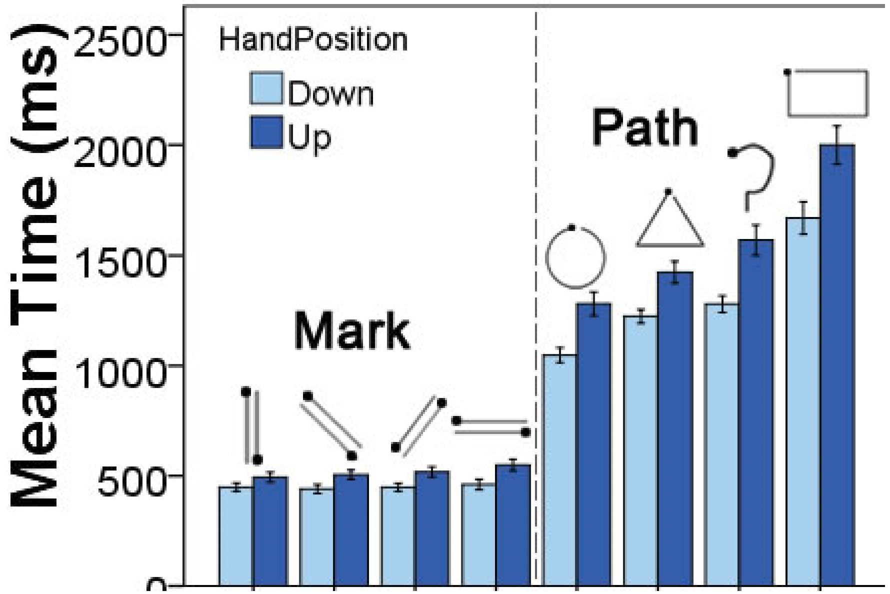
# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

Exploring the concept feasibility before implementation

8 gestures
Hand down while standing/walking
Hand up while standing/walking

# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

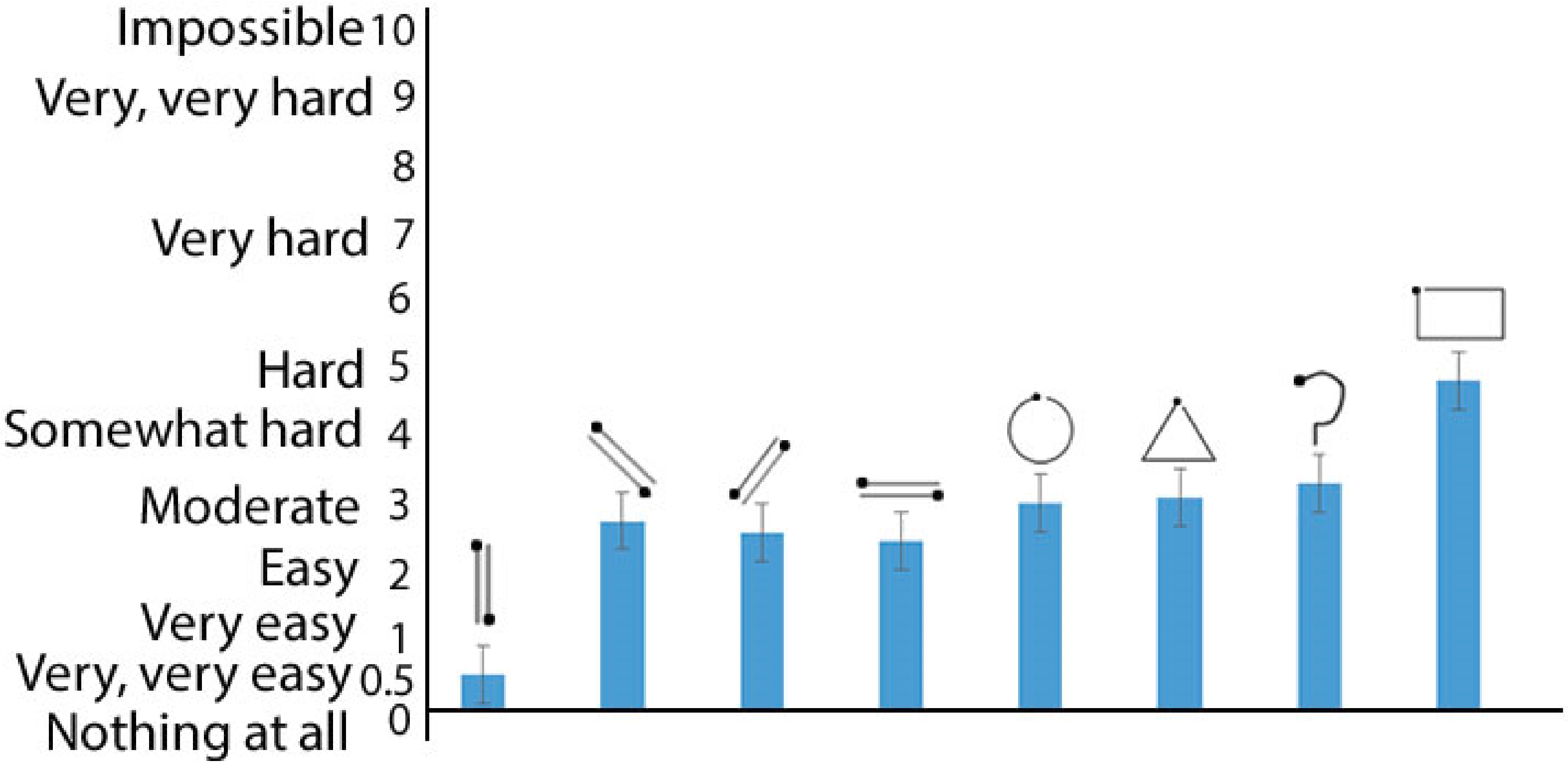
Exploring the concept feasibility before implementation




Time takes to complete each tasks

# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

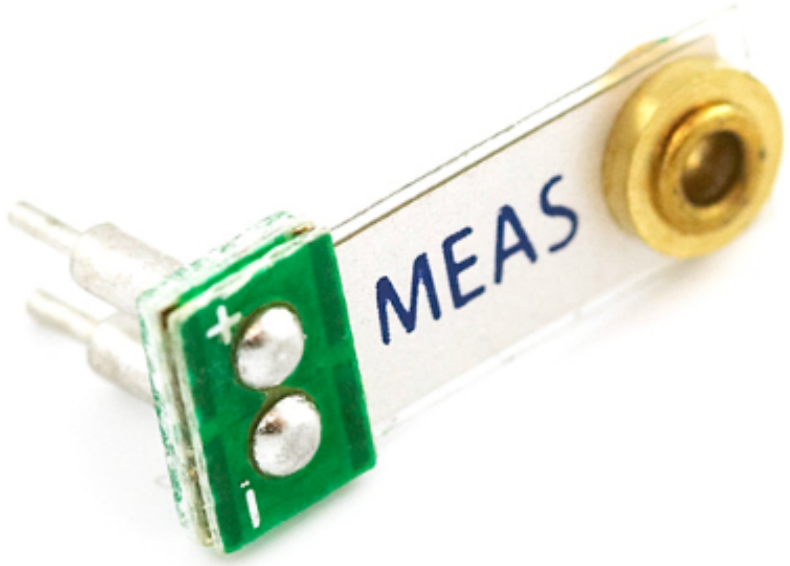
Exploring the concept feasibility before implementation




Self-report rating

# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

## Implementation




### Piezo Vibration Sensor - Small Horizontal

SEN-09198 ROHS✔

★★★☆☆ 2

**$2.95**

Volume sales pricing

| - | 1 | + |

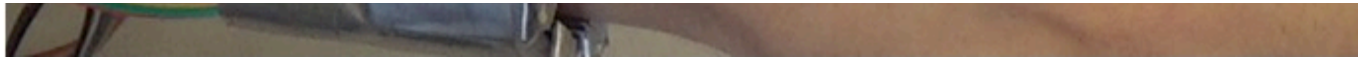
ADD TO CART

Quantity discounts available

**DESCRIPTION** DOCUMENTS

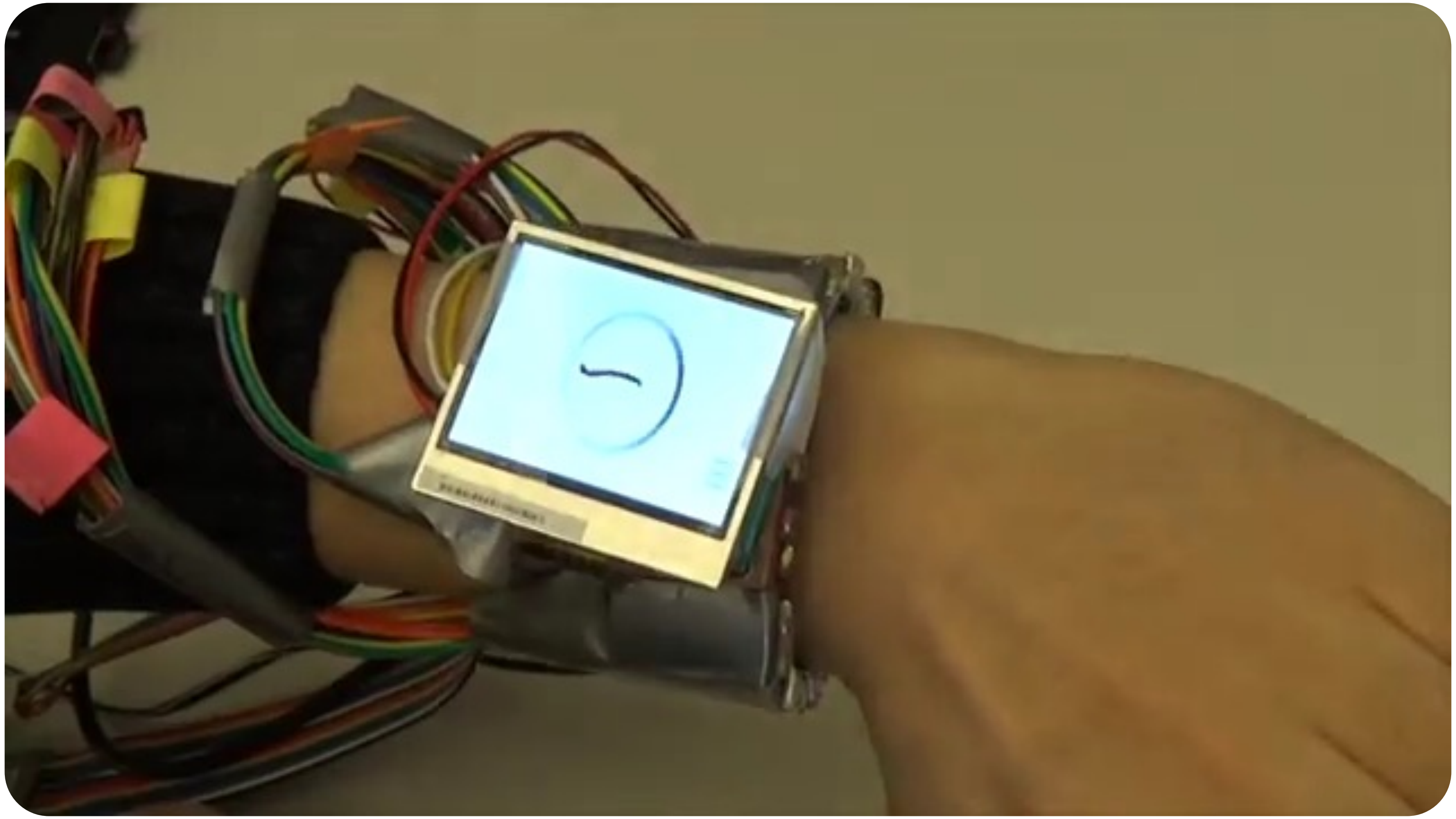
The Minisense 100 from Measurement Specialties is a low-cost cantilever-type vibration sensor loaded by a mass to offer high sensitivity at low frequencies. Useful for detecting vibration and 'tap' inputs from a user. A small AC and large voltage (up to +/-90V) is created when the film moves back an forth. A simple resistor should get the voltage down to ADC levels. Can also be used for impact sensing or a flexible switch.

Comes with machine pins that allows for horizontal mounting.



# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

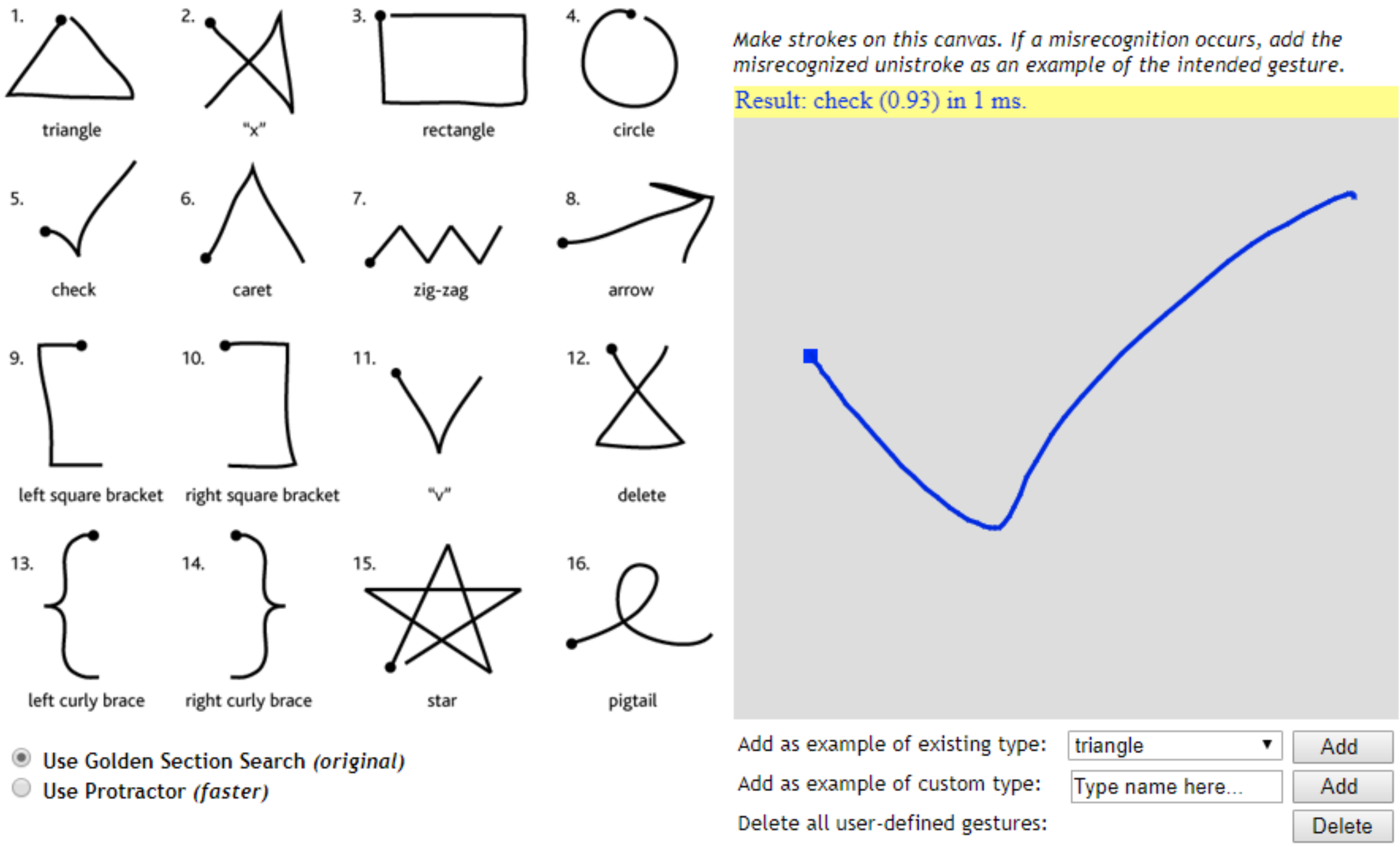
Implementation



# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

Recognition -> $1 Unistroke Recognizer

http://depts.washington.edu/madlab/proj/dollar/index.html



# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

Application

# WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

Application

Killer app?

Fat-finger syndrome

Small screen

One hand operation

Between devices interaction

Anything that a smartwatch can do but a smartphone can't?

# SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin

Interaction on skin

Continuous touch tracking

Non-obtrusive


Tracking Fingers #chi4good, CHI 2016, San Jose, CA, USA

**SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin**

Yang Zhang[1] Junhan Zhou[2] Gierad Laput[1] Chris Harrison[1]
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5000 Forbes Avenue, Pittsburgh, PA 15213
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**ABSTRACT**
SkinTrack is a wearable system that enables continuous touch tracking on the skin. It consists of a ring, which emits a continuous high frequency AC signal, and a sensing wristband with multiple electrodes. Due to the phase delay inherent in a high-frequency AC signal propagating through the body, a phase difference can be observed between pairs of electrodes. SkinTrack measures these phase differences to compute a 2D finger touch coordinate. Our approach can segment touch events at 99% accuracy, and resolve the 2D location of touches with a mean error of 7.6mm. As our approach is compact, non-invasive, low-cost and low-powered, we envision the technology being integrated into future smartwatches, supporting rich touch interactions beyond the confines of the small touchscreen.

**Author Keywords**
Finger tracking; waveguide; smartwatch; on-body interaction; around-device interaction; ADI

**ACM Classification Keywords**
H.5.2. [User interfaces] – Input devices and strategies.

**INTRODUCTION**
Small wearable devices—such as smartwatches and digital jewelry—are fast becoming viable computing platforms. However, their small size severely limits the user experience. For example, touchscreens on smartwatches suffer not only from a paucity of interactive surface area, but also must contend with significant finger occlusion. In general, the interfaces on these devices rely on basic input modalities (often four or fewer onscreen buttons, or even just directional swipes). In response, many research efforts have investigated how to leverage the area *around* devices to

Sensor Band
Signal Emitting Ring
A
B

Figure 1. Our sensor band and signal-emitting ring allow the arm to be appropriated for continuous, on-skin touch tracking (top), expanding interaction beyond the small confines of a smartwatch touchscreen (bottom).

In this paper, we propose a novel sensing approach for appropriating the skin as an interactive, touch-tracking surface (Figure 1). Our system, *SkinTrack*, has two key components. First is a ring that emits an imperceptible and harmless 80MHz, 1.2Vpp AC signal into the finger on which it is worn. The second component is a wristband, worn on the opposite arm, and instrumented with a structured electrode pattern. When the user's finger touches the skin, the electrical signal propagates into the arm tissue and

**CHI 2016**

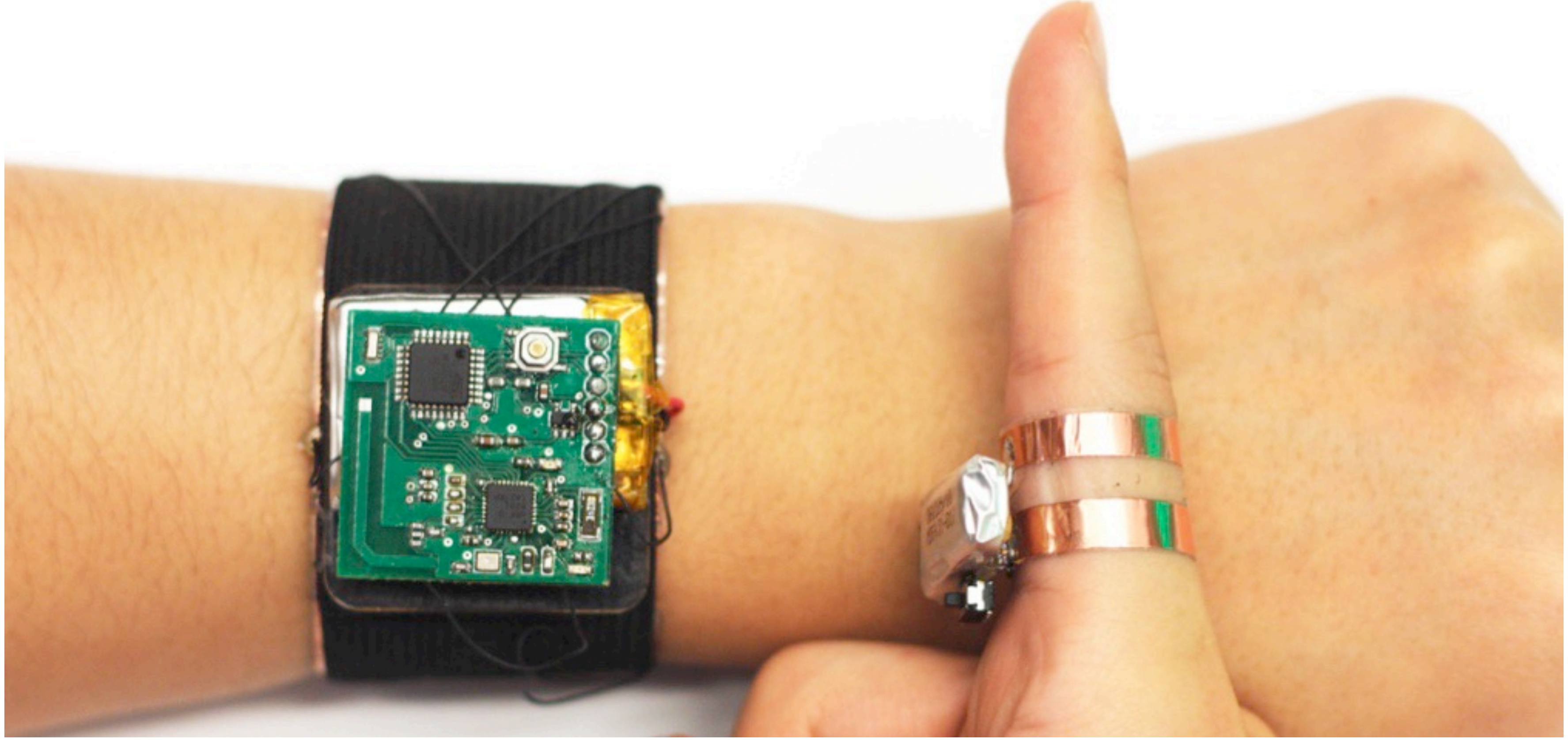
Zhang et.al. from CMU

# SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin

Will IR array work?

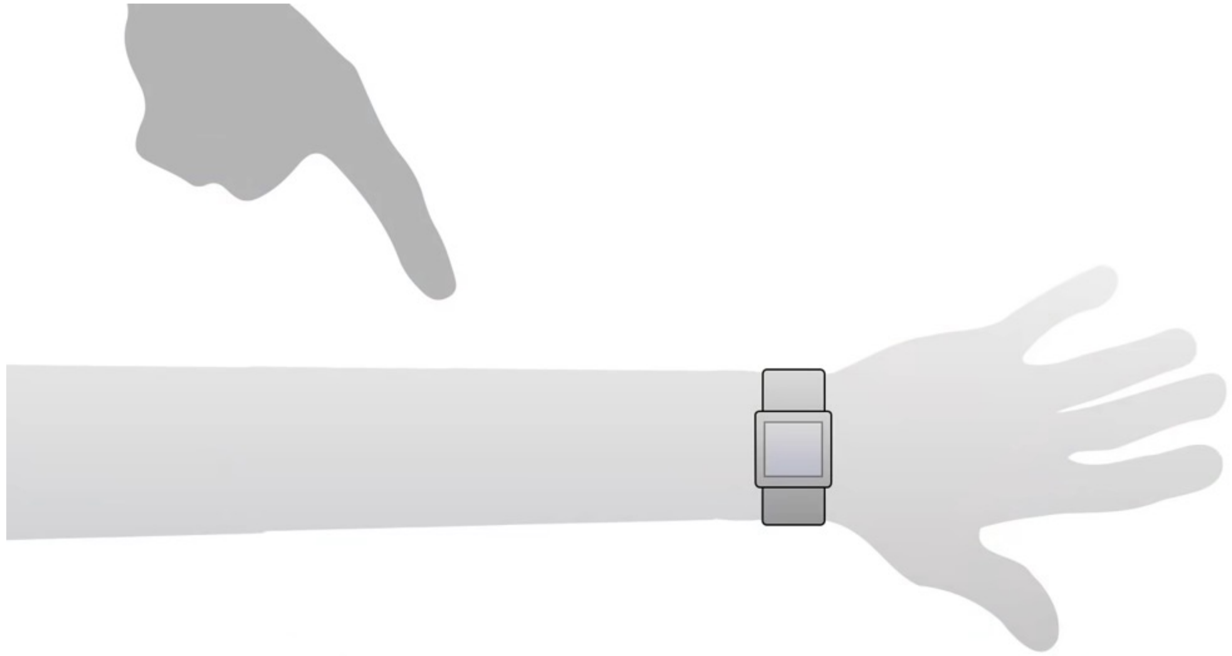
# SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin

Solution



# SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin

Sensing principle



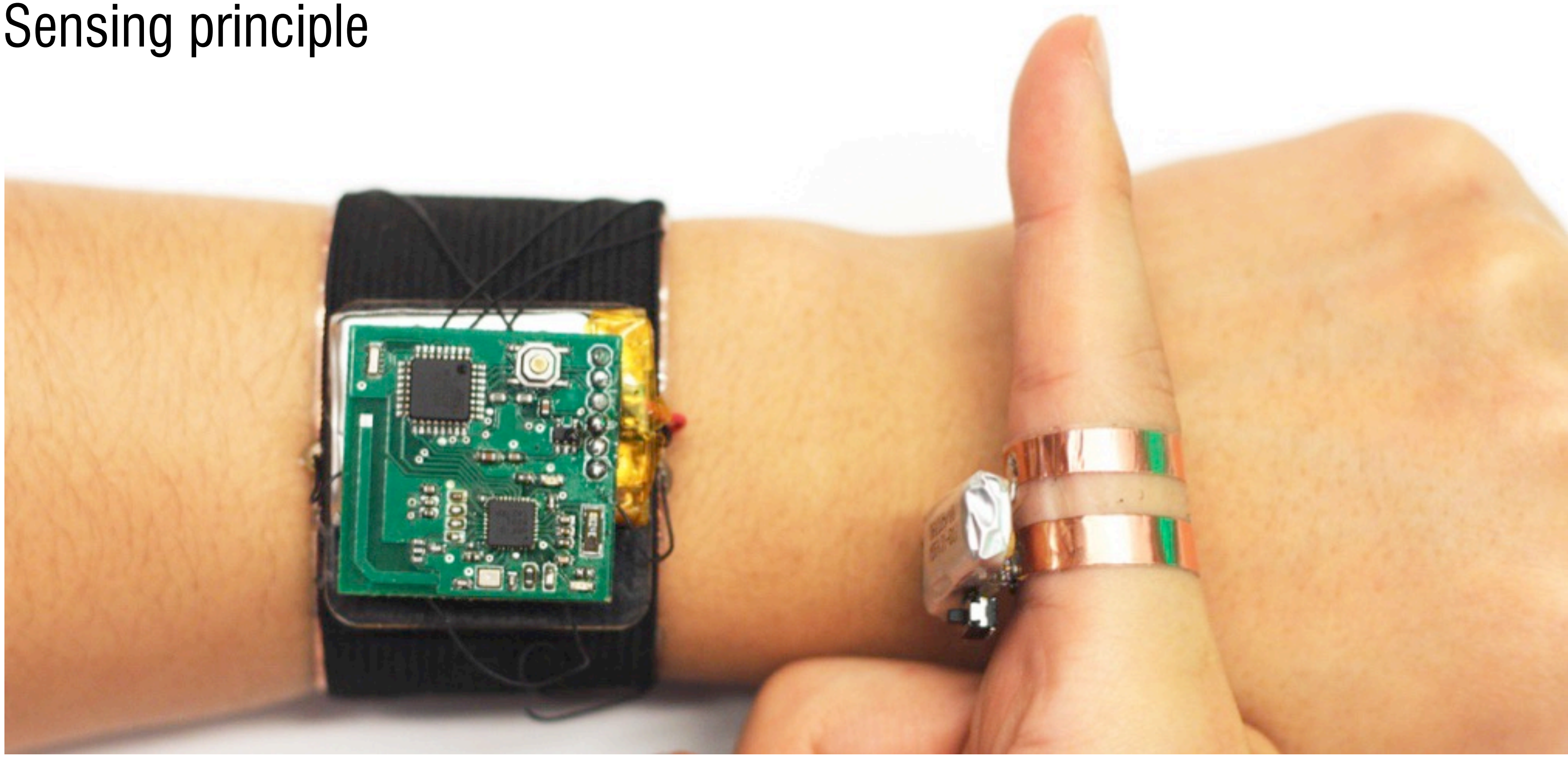
# SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin

Sensing principle

$\lambda$ = wave speed/frequency
or
$\lambda = v / f$

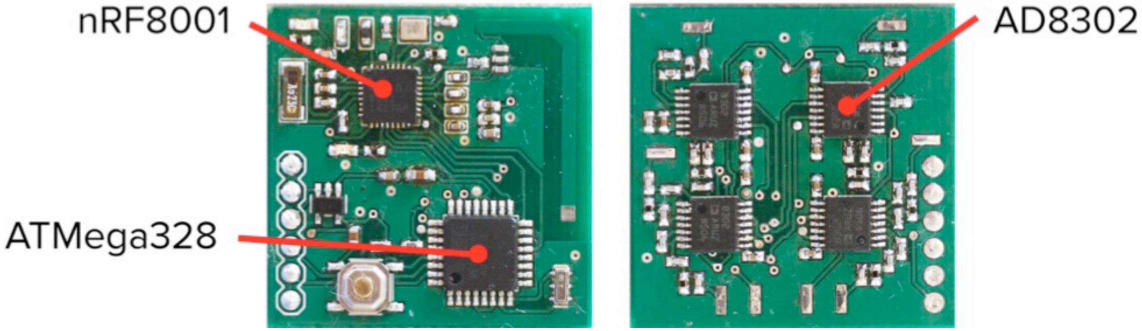
-> Frequency: 80MHz AC signal
-> Speed: $7.3 \times 10^7$ m/s

-> Length: 91cm wavelength
->1cm equals 4 degree phase shift



# SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin

## Hardware

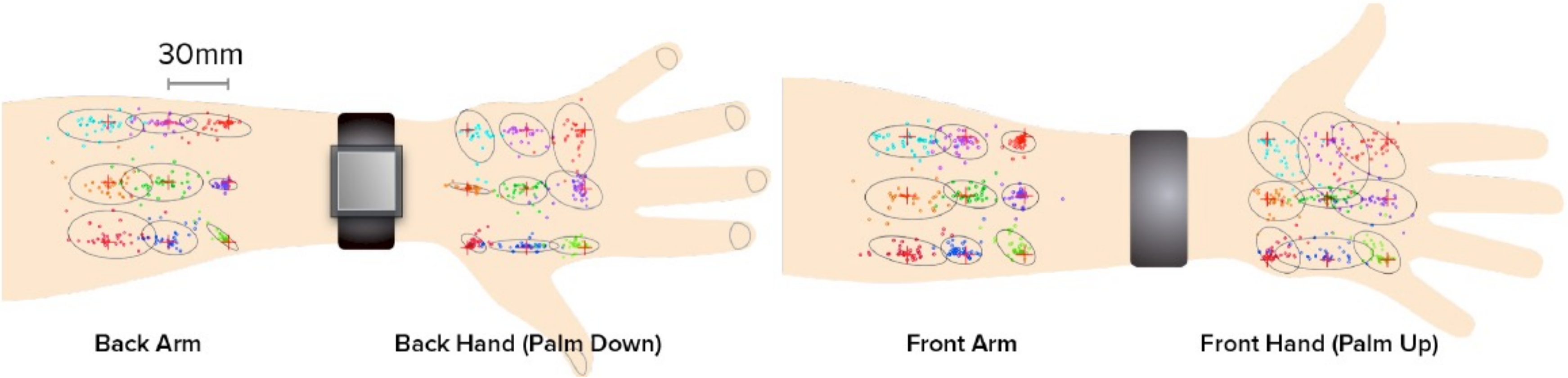



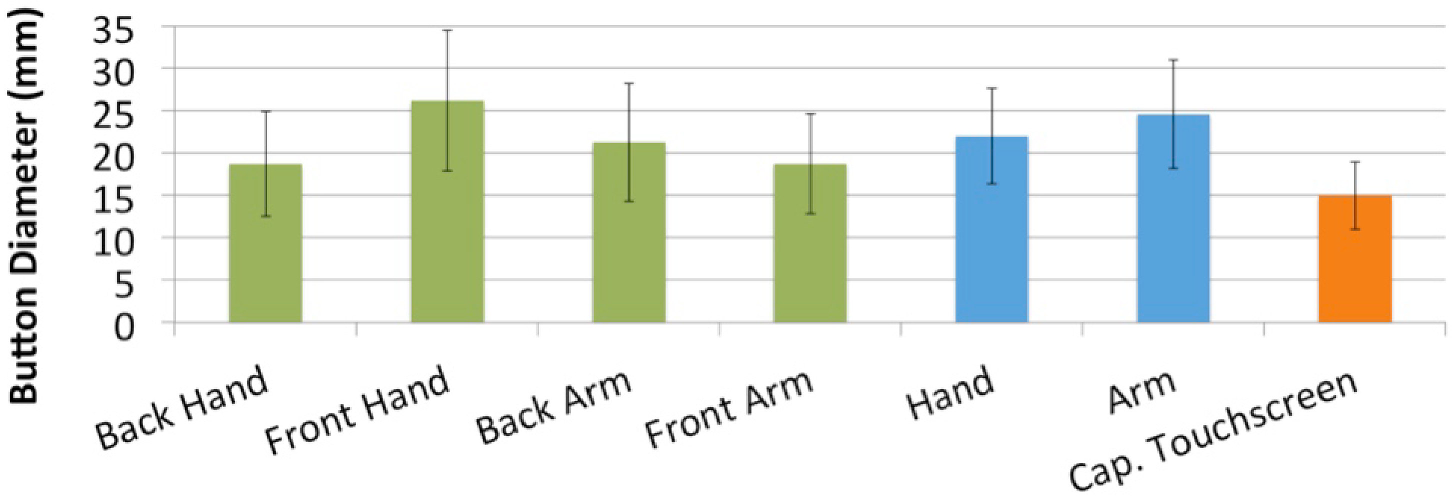

Ring: 80MHz oscillator
110 mAh
15h battery life

Band: 4 electrode pairs

# SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin

## Evaluation



# SkinTrack: Using the Body as an Electrical Waveguide for Continuous Finger Tracking on the Skin

## Application

Fat-finger syndrome

Small screen

One hand operation

Between devices interaction

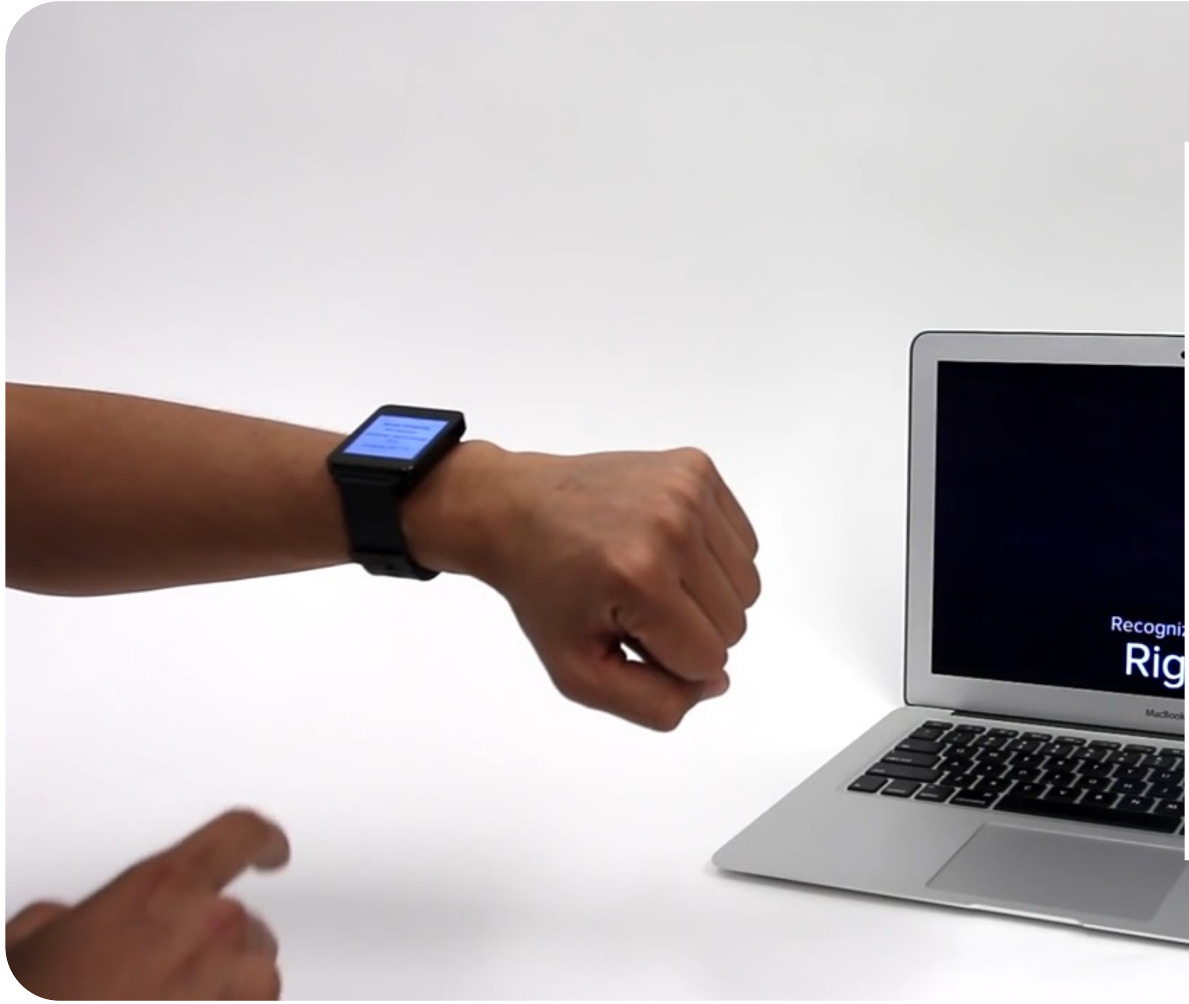
Anything that a smartwatch can do but a smartphone can't?

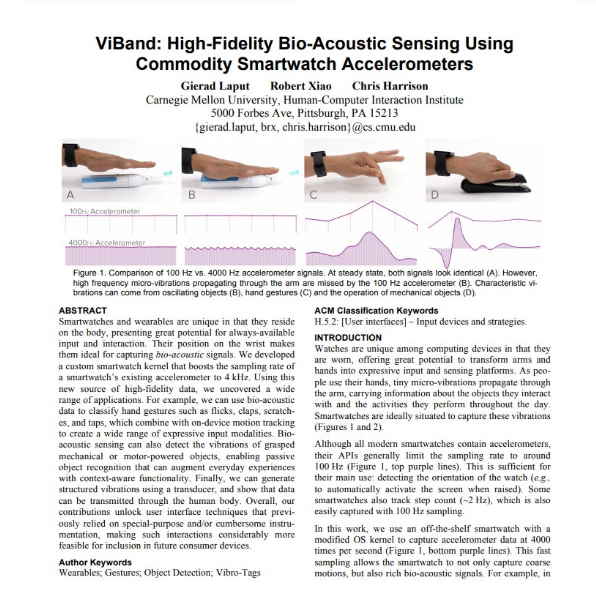
# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

Gesture detection

Object detection

All with built-in sensors





## ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers


Gierad Laput  Robert Xiao  Chris Harrison
Carnegie Mellon University, Human-Computer Interaction Institute
5000 Forbes Ave, Pittsburgh, PA 15213
{gierad.laput, brx, chris.harrison}@cs.cmu.edu




Figure 1. Comparison of 100 Hz vs. 4000 Hz accelerometer signals. At steady state, both signals look identical (A). However, high frequency micro-vibrations propagating through the arm are missed by the 100 Hz accelerometer (B). Characteristic vibrations can come from oscillating objects (B), hand gestures (C) and the operation of mechanical objects (D).


### ABSTRACT

Smartwatches and wearables are unique in that they reside on the body, presenting great potential for always-available input and interaction. Their position on the wrist makes them ideal for capturing *bio-acoustic* signals. We developed a custom smartwatch kernel that boosts the sampling rate of a smartwatch's existing accelerometer to 4 kHz. Using this new source of high-fidelity data, we uncovered a wide range of applications. For example, we can use bio-acoustic data to classify hand gestures such as flicks, claps, scratches, and taps, which combine with on-device motion tracking to create a wide range of expressive input modalities. Bio-acoustic sensing can also detect the vibrations of grasped mechanical or motor-powered objects, enabling passive object recognition that can augment everyday experiences with context-aware functionality. Finally, we can generate structured vibrations using a transducer, and show that data can be transmitted through the human body. Overall, our contributions unlock user interface techniques that previously relied on special-purpose and/or cumbersome instrumentation, making such interactions considerably more feasible for inclusion in future consumer devices.



### Author Keywords

Wearables; Gestures; Object Detection; Vibro-Tags

### ACM Classification Keywords

H.5.2: [User interfaces] – Input devices and strategies.


### INTRODUCTION

Watches are unique among computing devices in that they are worn, offering great potential to transform arms and hands into expressive input and sensing platforms. As people use their hands, tiny micro-vibrations propagate through the arm, carrying information about the objects they interact with and the activities they perform throughout the day. Smartwatches are ideally situated to capture these vibrations (Figures 1 and 2).

Although all modern smartwatches contain accelerometers, their APIs generally limit the sampling rate to around 100 Hz (Figure 1, top purple lines). This is sufficient for their main use: detecting the orientation of the watch (*e.g.*, to automatically activate the screen when raised). Some smartwatches also track step count (~2 Hz), which is also easily captured with 100 Hz sampling.

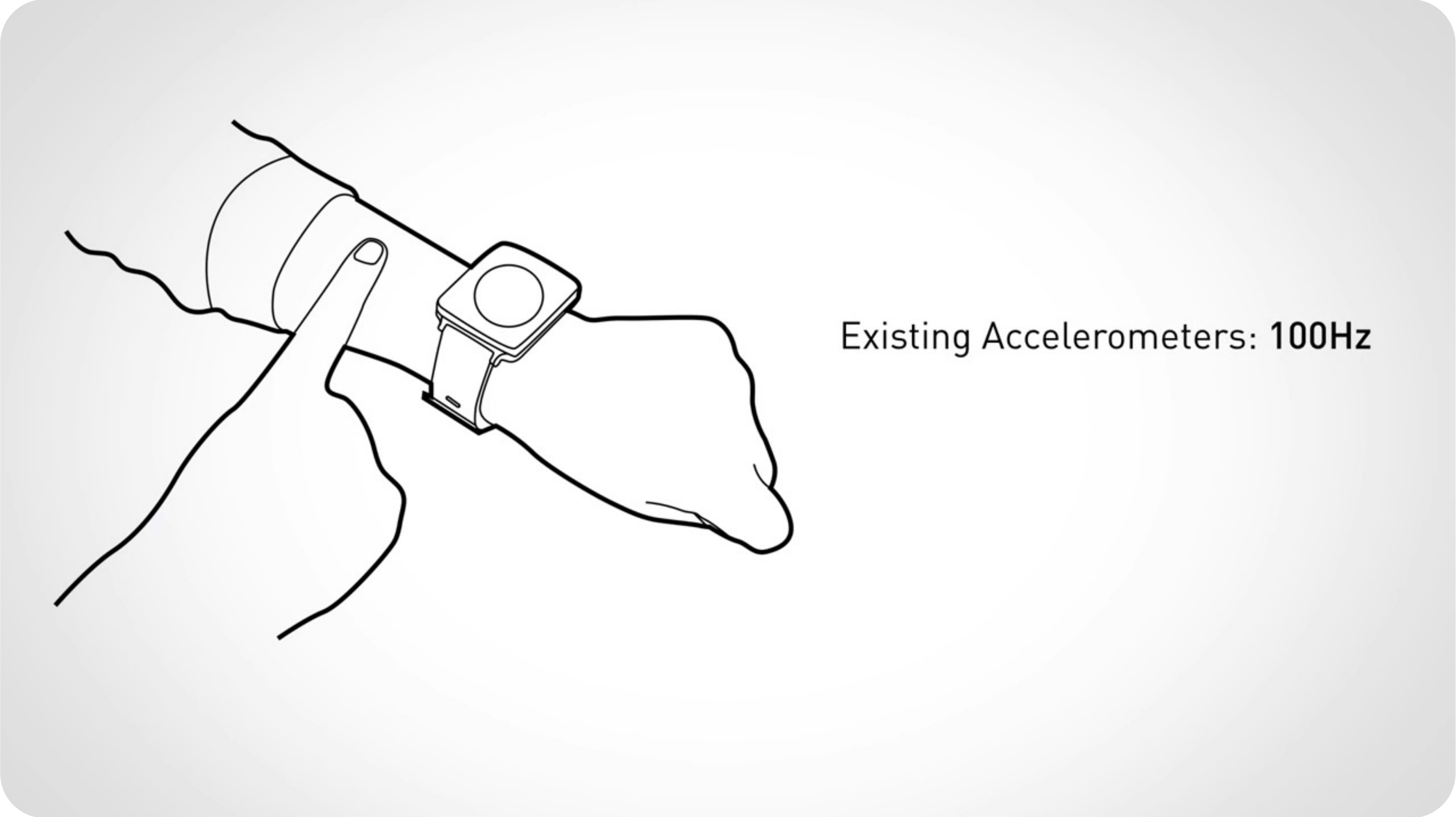
In this work, we use an off-the-shelf smartwatch with a modified OS kernel to capture accelerometer data at 4000 times per second (Figure 1, bottom purple lines). This fast sampling allows the smartwatch to not only capture coarse motions, but also rich bio-acoustic signals. For example, in

**UIST 2016**

Laput et.al. from CMU

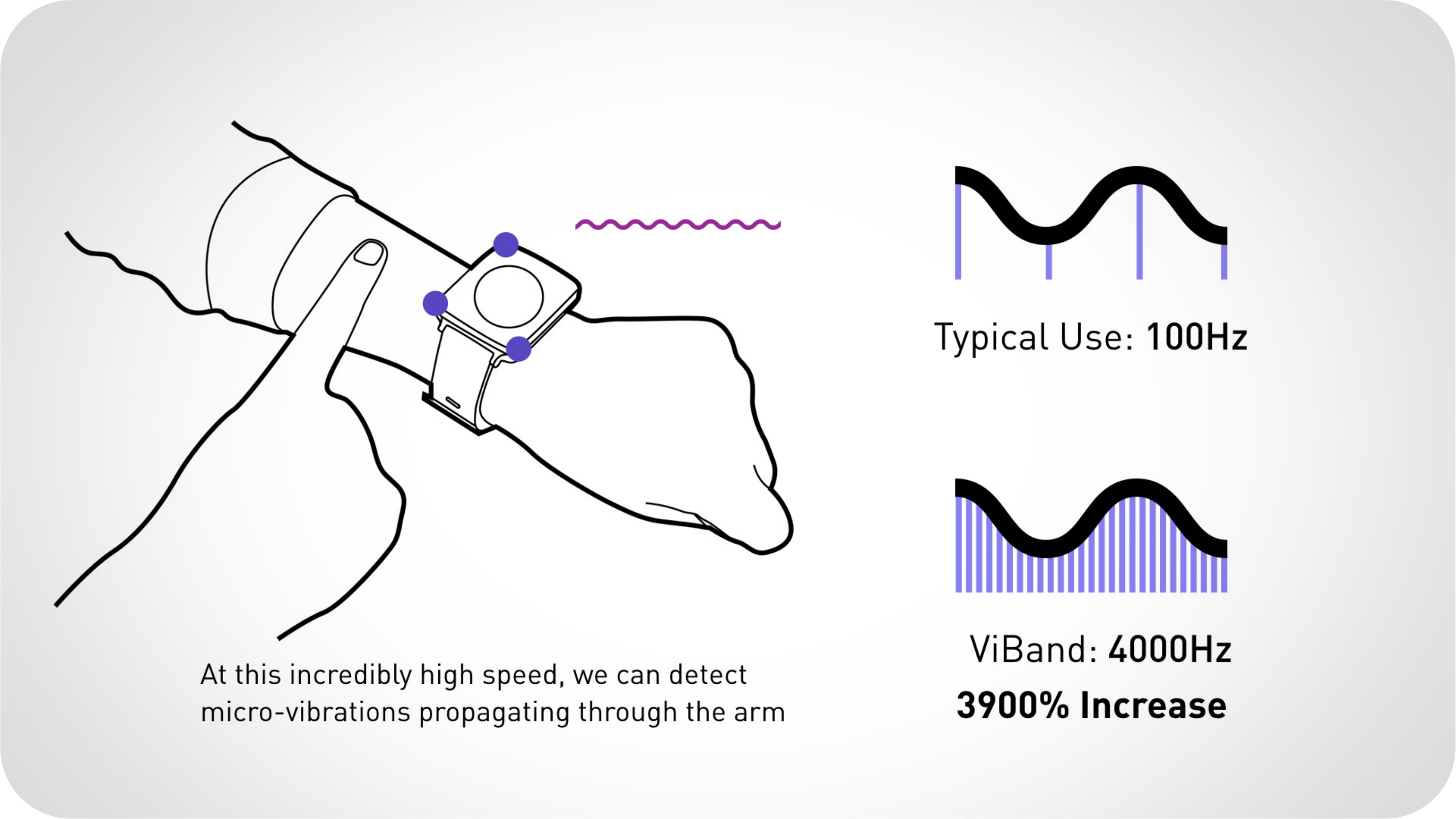
# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

Sensing principle



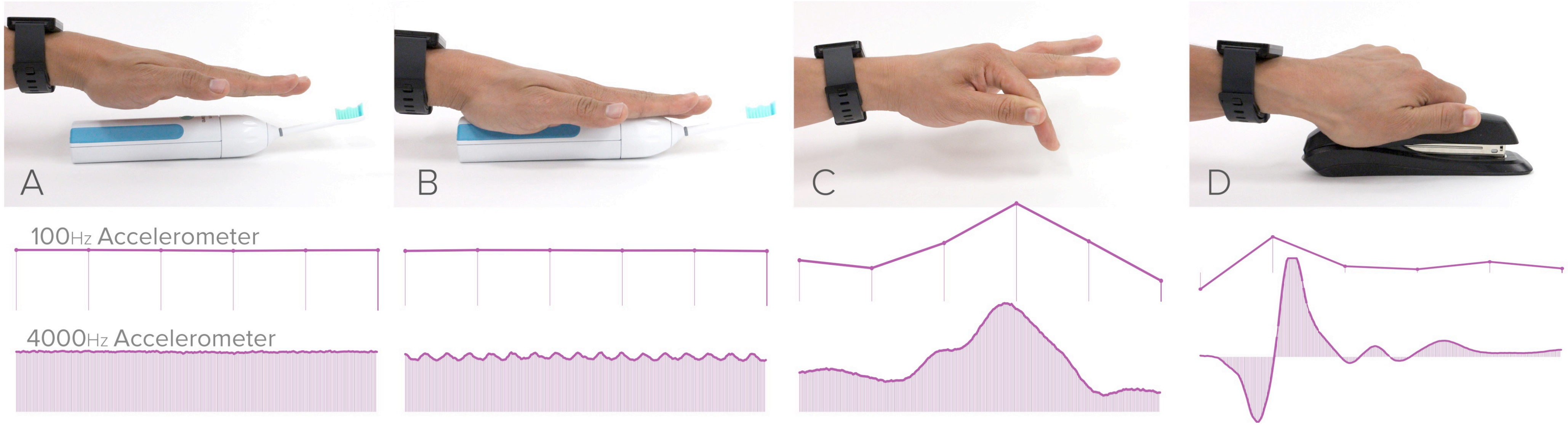
# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

## Sensing principle



# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

## Sensing principle

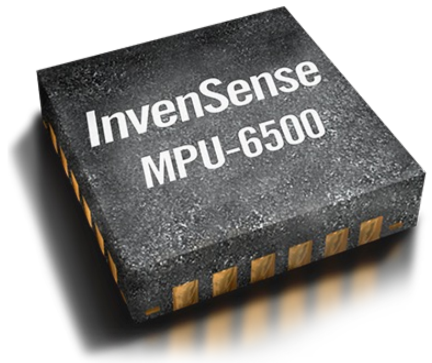



Use the high-speed mode of existing accelerometer

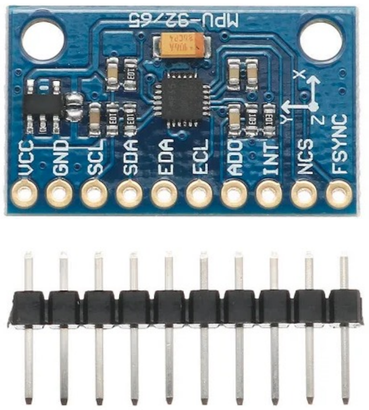
Only need to modify it’s kernel – pure software solution!

# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

## Implementation








Banggood GY-6500 MPU6500 6DOF 6 Axis Attitude Acceleration Gyroscope Sensor Module SPI Interface

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Description MPU 6500 module three axis gyroscope three axis acceleration Module Model GY 6500 Use the chip MPU 6500 Power supply 3 5v internal low voltage regulator ...

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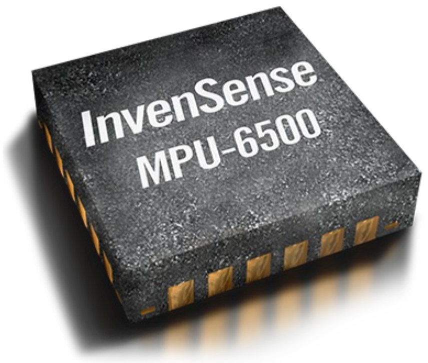
# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

## Implementation




| PARAMETER | CONDITIONS | MIN | TYP | MAX | Units | Notes |
|---|---|---|---|---|---|---|
| **SUPPLY VOLTAGES** | | | | | | |
| VDD | | 1.71 | 1.8 | 3.45 | V | 1 |
| VDDIO | | 1.71 | 1.8 | 3.45 | V | 1 |
| **SUPPLY CURRENTS** | | | | | | |
| Normal Mode | 6-axis | | 3.4 | | mA | 1 |
| | 3-axis Gyroscope | | 3.2 | | mA | 1 |
| | 3-Axis Accelerometer, 4kHz ODR | | 450 | | µA | 1 |
| Accelerometer Low Power Mode | 0.98 Hz update rate | | 7.27 | | µA | 1,2 |
| | 31.25 Hz update rate | | 18.65 | | µA | 1,2 |
| Standby Mode | | | 1.6 | | mA | 1 |
| Full-Chip Sleep Mode | | | 6 | | µA | 1 |
| **TEMPERATURE RANGE** | | | | | | |
| Specified Temperature Range | Performance parameters are not applicable beyond Specified Temperature Range | -40 | | +85 | °C | 1 |

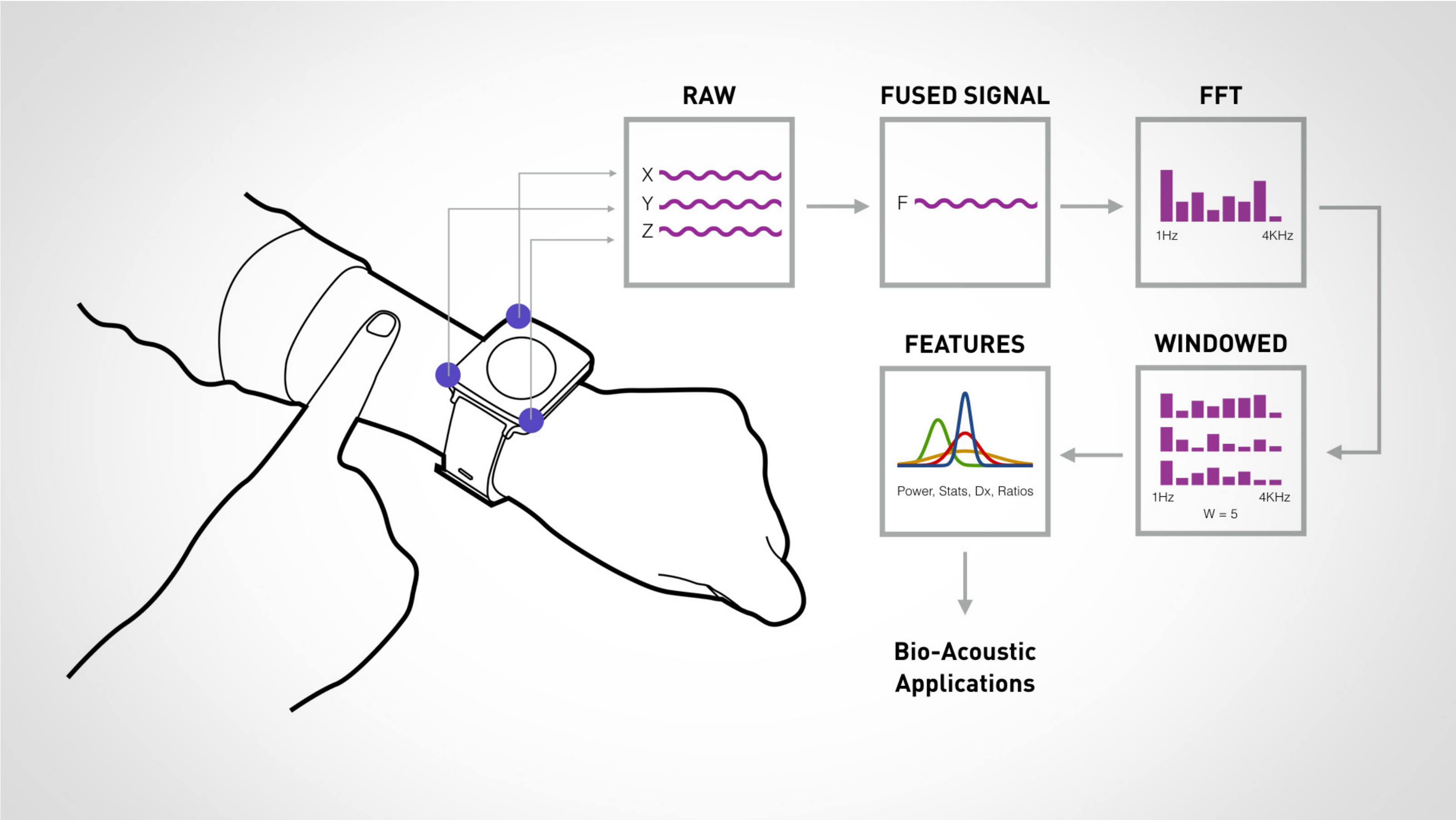
**Table 3: D.C. Electrical Characteristics**

**Notes:**

1. Derived from validation or characterization of parts, not guaranteed in production.
2. Accelerometer Low Power Mode supports the following output data rates (ODRs): 0.24, 0.49, 0.98, 1.95, 3.91, 7.81, 15.63, 31.25, 62.50, 125, 250, 500Hz. Supply current for any update rate can be calculated as:
   a. Supply Current in µA = 6.9 + Update Rate * 0.376

# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

## Implementation



# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

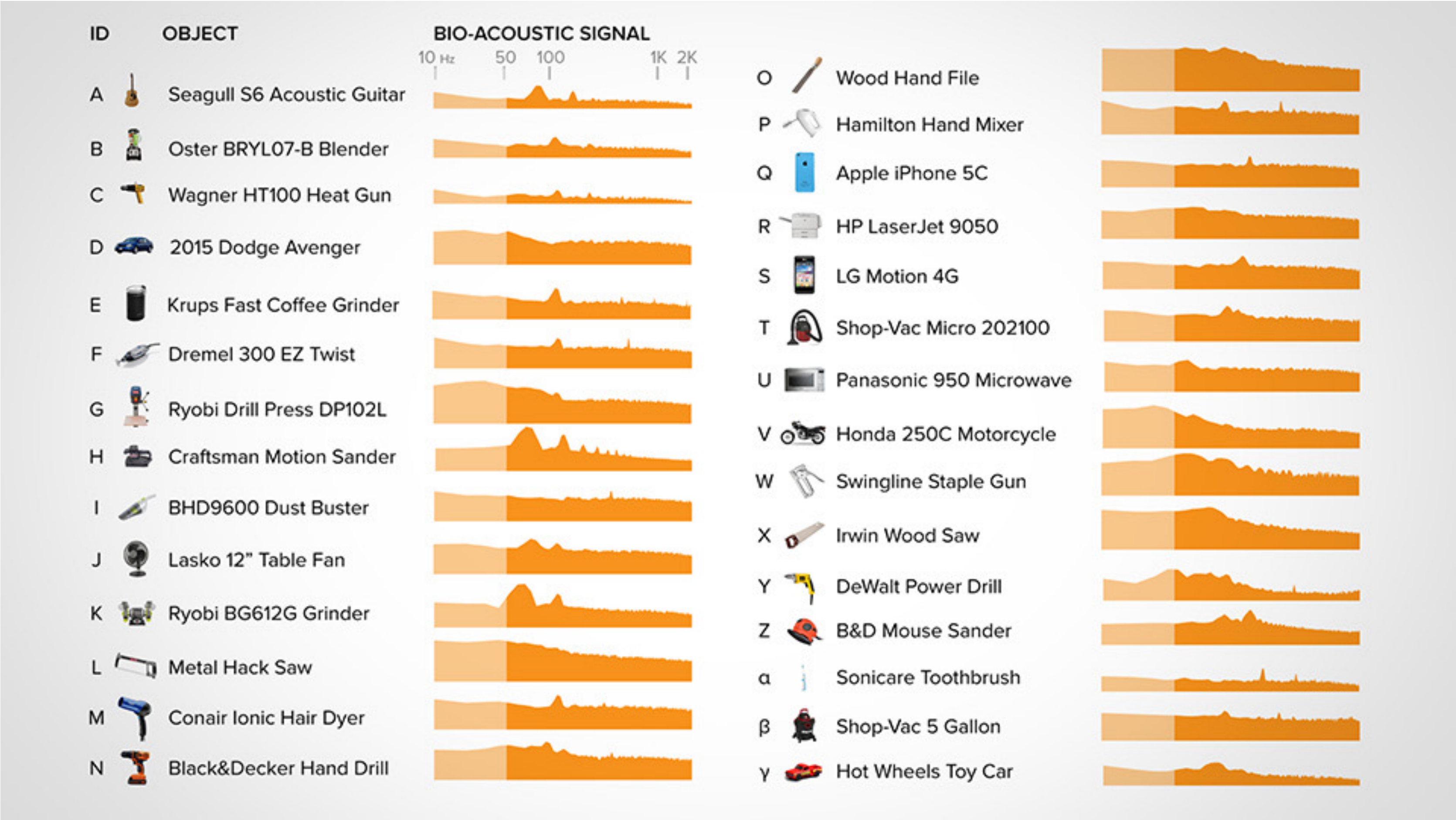
## Gestures

# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

## Gestures

# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

## Object detections



# ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

Object detections

Input

Output

Input

**Output**

# Cito: An Actuated Smartwatch for Extended Interactions

Online and On-the-go CHI 2017, May 6–11, 2017, Denver, CO, USA

## Cito: An Actuated Smartwatch for Extended Interactions

**Jun Gong[1], Lan Li[2], Daniel Vogel[3], Xing-Dong Yang[1]**
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**Figure 1. Actuated face movements and usage scenarios: (a) face orbiting for view adaption; (b) face translating outside sleeve; (c) face rotating to indicate an important call; (d) face tilting for sharing; (e) face rising for force feedback.**

### ABSTRACT
We propose and explore actuating a smartwatch face to enable extended interactions. Five face movements are defined: rotation, hinging, translation, rising, and orbiting. These movements are incorporated into interaction techniques to address limitations of a fixed watch face. A 20-person study uses concept videos of a passive low fidelity prototype to confirm the usefulness of the actuated interaction techniques. A second 20-person study uses 3D rendered animations to access social acceptability and perceived comfort for different actuation dynamics and usage contexts. Finally, we present Cito, a high-fidelity proof-of-concept hardware prototype that investigates technical challenges.

#### Author Keywords
Actuated UI; Smartwatch; Interaction Techniques

#### ACM Classification Keywords
H.5.2. Information Interfaces (e.g., HCI): Input devices.

### INTRODUCTION
Exploiting the full potential of smartwatches requires useful and usable input and output. This is challenging considering the small form factor and wearable context. Existing research has primarily focused on smartwatch input [7, 12, 14, 16, 19, 21, 29, 37, 46, 57, 65, 72] with little work on output. Smartwatch output has mainly focused on extending the display region such as projecting visual content onto the forearm [45], adding a miniature secondary display on the watch band [4], adding a second watch face [63], or converting the entire watch band into a touchscreen [38]. Haptic output has also been explored, and was found effective in many usage sce-

We propose extending smartwatch output by physically actuating a watch face in five ways: rotating on its normal axis, hinging on side, rising vertically, translating along the forearm, and orbiting around the wristband (Figure 1). These movements can be used for a variety of new interactions. For example, when a user has dirty hands (e.g. gardening), the watch face can *translate* outside of a shirt sleeve to make it visible when a notification arrives. When a user is carrying something heavy, the watch face can *orbit* to a visible part of the watch band. When a user shows a picture on their watch to someone else, the face can *hinge* towards the other person to provide a better viewing angle. If a user needs to receive GPS navigation instructions while they do something else on the watch, the face can physically *rotate* to indicate when to turn a corner. Finally, the watch could *rise* when the phone rings, enabling the user to decline the call eyes-free by pressing the face down like a haptic force-feedback button.

Our focus is on the Human-Computer Interaction aspect of an actuated watch, we iteratively evaluated prototypes of different fidelities presented in different formats. In our first study, we elicit user feedback from 20 participants about actuated watch movements in seven usage scenarios via conceptual videos using a passive prototype. The result confirmed the usefulness of an actuated smartwatch for addressing limitations of a fixed watch face. To further advance our understanding, we conducted another 20-participant study to investigate the social acceptability and comfort of various actuation dynamics when performed in front of different audiences. Forty actuations were presented using 3D animations. The results suggest kinds of movements that should be

**CHI 2017**
Gong et.al. from Dartmouth

# Cito: An Actuated Smartwatch for Extended Interactions

Will this concept be useful?

Generate design space ➡ Create low-fi model ➡ Study before implementation

# Cito: An Actuated Smartwatch for Extended Interactions

Exploring the concept feasibility before implementation

# Cito: An Actuated Smartwatch for Extended Interactions

## Exploring the concept feasibility before implementation

Scenarios:

Carry heavy obj
Exposure to dust
Covered with sleeve
Gaming with notification
Missing notification
Multitasking
Sharing
…

# Cito: An Actuated Smartwatch for Extended Interactions

## Exploring the concept feasibility before implementation

Scenarios:

Potential solutions for each of the scenarios – 7 point Likert scale rating

# Cito: An Actuated Smartwatch for Extended Interactions

## Exploring the concept feasibility before implementation

Scenarios:

Potential solutions for each of the scenarios – 7 point Likert scale rating

Using videos allowed our study to be highly controlled as participants had to saw the same demos.

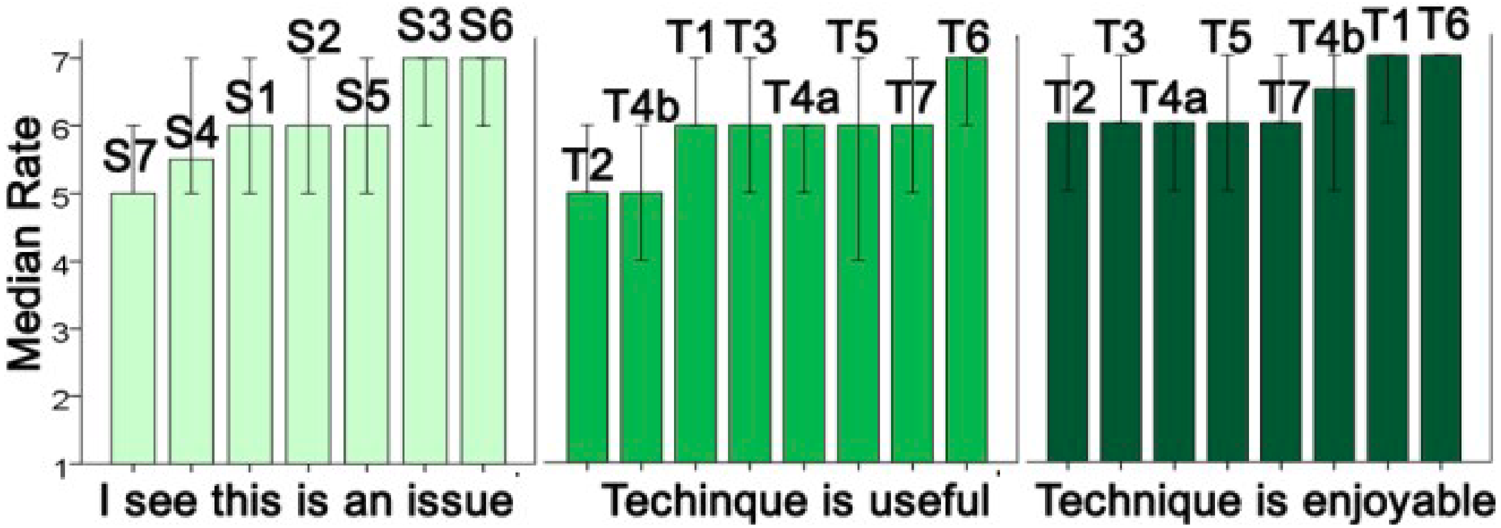
The videos also encouraged “suspension of disbelief”, allowing them to focus on the Cito concept, rather than implementation details.

# Cito: An Actuated Smartwatch for Extended Interactions

Exploring the concept feasibility before implementation

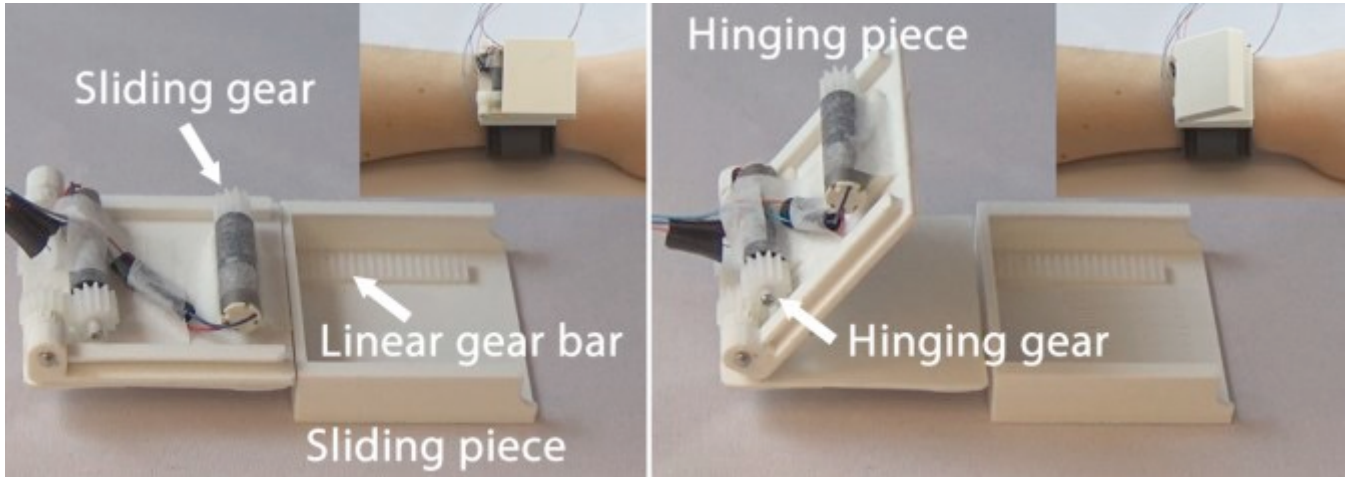
Scenarios:

Potential solutions for each of the scenarios – 7 point Likert scale rating



# Cito: An Actuated Smartwatch for Extended Interactions

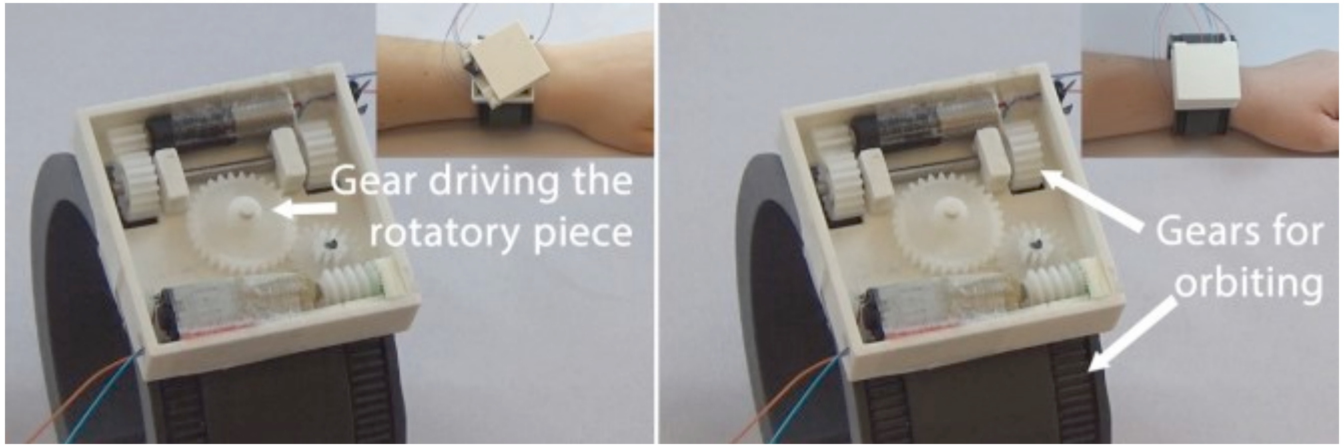
## Implementation




The hinge-translate module

# Cito: An Actuated Smartwatch for Extended Interactions

## Implementation




The orbit-rotate module

# Cito: An Actuated Smartwatch for Extended Interactions

Plastic Planetary Micro DC Motor with OD: 6mm L: 16.3/18.8/21mm 3VDC / L: 16.3mm / Gear Ratio: 26

from Firgelli Automations

These micro planetary motors are made with plastic gears at low speed and low noiser but high torque comparatively speaking. They are commonly used in medical field. However, ...

See more details at Firgelli Automations »

**$12.20**

+$14.88 shipping. No tax
Firgelli Automations

Visit site

# Cito: An Actuated Smartwatch for Extended Interactions

Plastic Gear Package 62 Kinds Of Motor Gear Gearbox Robot Model Accessories Diy

from eBay - 0059627

plastic gear package 62 kinds of motor gear gearbox robot model accessories DIY 0059627 Description: 62 kinds of gear pack: Spindle motor gear: 12 kinds Single gear: 19 kinds ...

See more details at eBay - 0059627 »

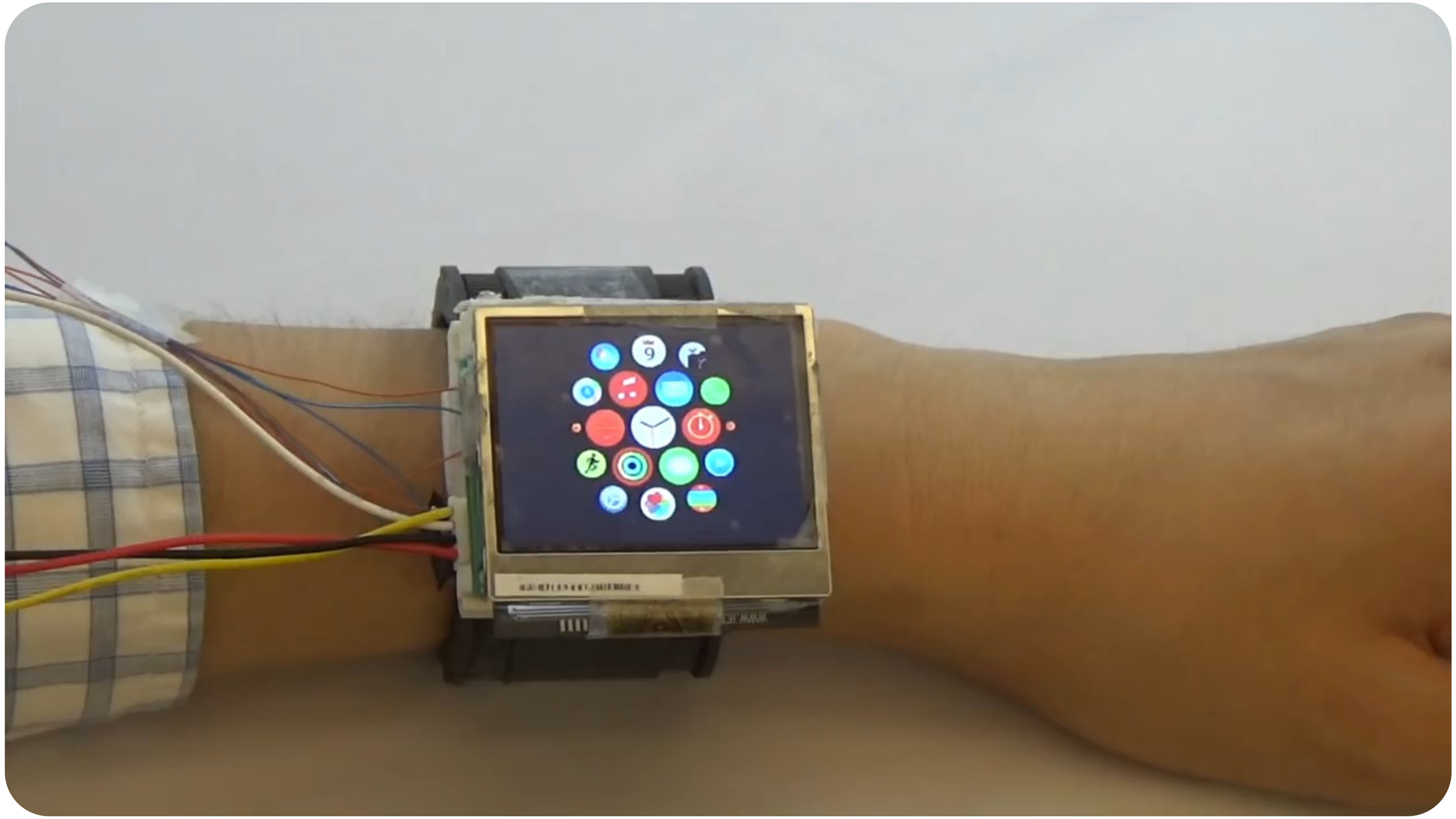
**$4.89**

+$1.60 shipping. No tax

eBay - 0059627

Visit site

# Cito: An Actuated Smartwatch for Extended Interactions



Fat-finger syndrome

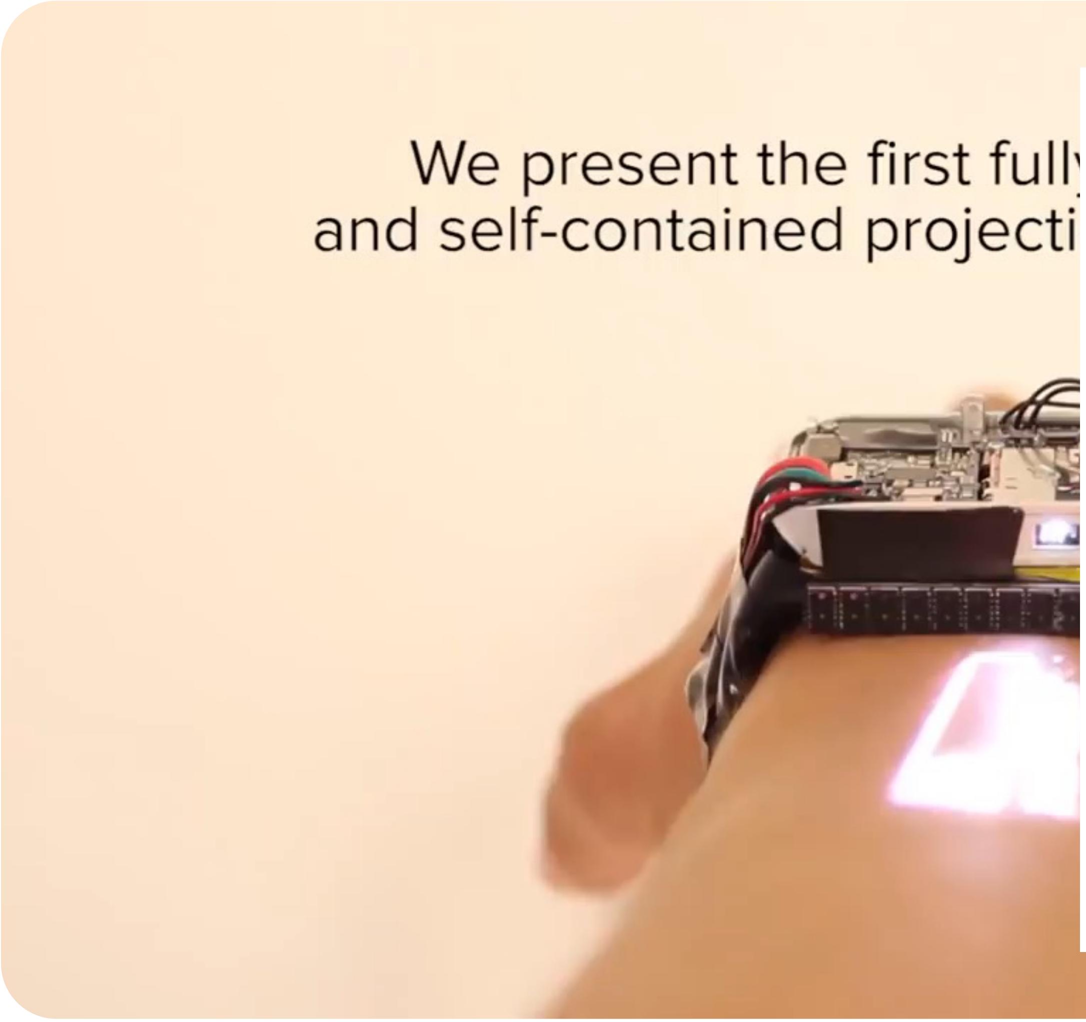
Small screen

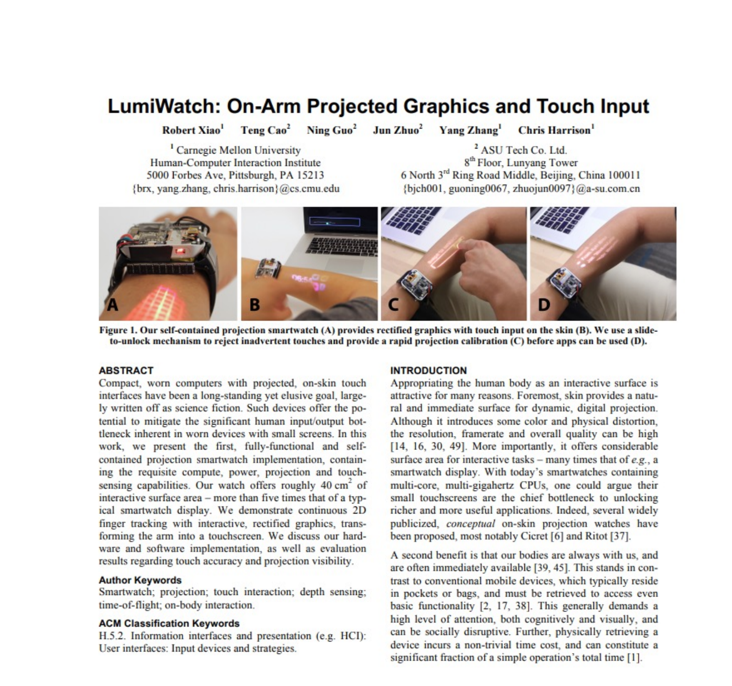
One hand operation

Between devices interaction

Anything that a smartwatch can do but a smartphone can't?

# LumiWatch: On-Arm Projected Graphics and Touch Input



## LumiWatch: On-Arm Projected Graphics and Touch Input


Robert Xiao[1] Teng Cao[2] Ning Guo[2] Jun Zhuo[2] Yang Zhang[1] Chris Harrison[1]

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**Figure 1. Our self-contained projection smartwatch (A) provides rectified graphics with touch input on the skin (B). We use a slide-to-unlock mechanism to reject inadvertent touches and provide a rapid projection calibration (C) before apps can be used (D).**


### ABSTRACT
Compact, worn computers with projected, on-skin touch interfaces have been a long-standing yet elusive goal, largely written off as science fiction. Such devices offer the potential to mitigate the significant human input/output bottleneck inherent in worn devices with small screens. In this work, we present the first, fully-functional and self-contained projection smartwatch implementation, containing the requisite compute, power, projection and touch-sensing capabilities. Our watch offers roughly 40 $cm^2$ of interactive surface area – more than five times that of a typical smartwatch display. We demonstrate continuous 2D finger tracking with interactive, rectified graphics, transforming the arm into a touchscreen. We discuss our hardware and software implementation, as well as evaluation results regarding touch accuracy and projection visibility.



### Author Keywords
Smartwatch; projection; touch interaction; depth sensing; time-of-flight; on-body interaction.

### ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g. HCI): User interfaces: Input devices and strategies.


### INTRODUCTION
Appropriating the human body as an interactive surface is attractive for many reasons. Foremost, skin provides a natural and immediate surface for dynamic, digital projection. Although it introduces some color and physical distortion, the resolution, framerate and overall quality can be high [14, 16, 30, 49]. More importantly, it offers considerable surface area for interactive tasks – many times that of *e.g.*, a smartwatch display. With today's smartwatches containing multi-core, multi-gigahertz CPUs, one could argue their small touchscreens are the chief bottleneck to unlocking richer and more useful applications. Indeed, several widely publicized, *conceptual* on-skin projection watches have been proposed, most notably Cicret [6] and Ritot [37].

A second benefit is that our bodies are always with us, and are often immediately available [39, 45]. This stands in contrast to conventional mobile devices, which typically reside in pockets or bags, and must be retrieved to access even basic functionality [2, 17, 38]. This generally demands a high level of attention, both cognitively and visually, and can be socially disruptive. Further, physically retrieving a device incurs a non-trivial time cost, and can constitute a significant fraction of a simple operation's total time [1].

**CHI 2018**

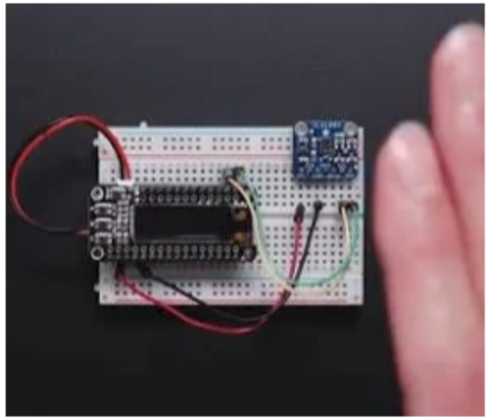
Xiao et.al. from CMU

# LumiWatch: On-Arm Projected Graphics and Touch Input

Previous “work”

# LumiWatch: On-Arm Projected Graphics and Touch Input

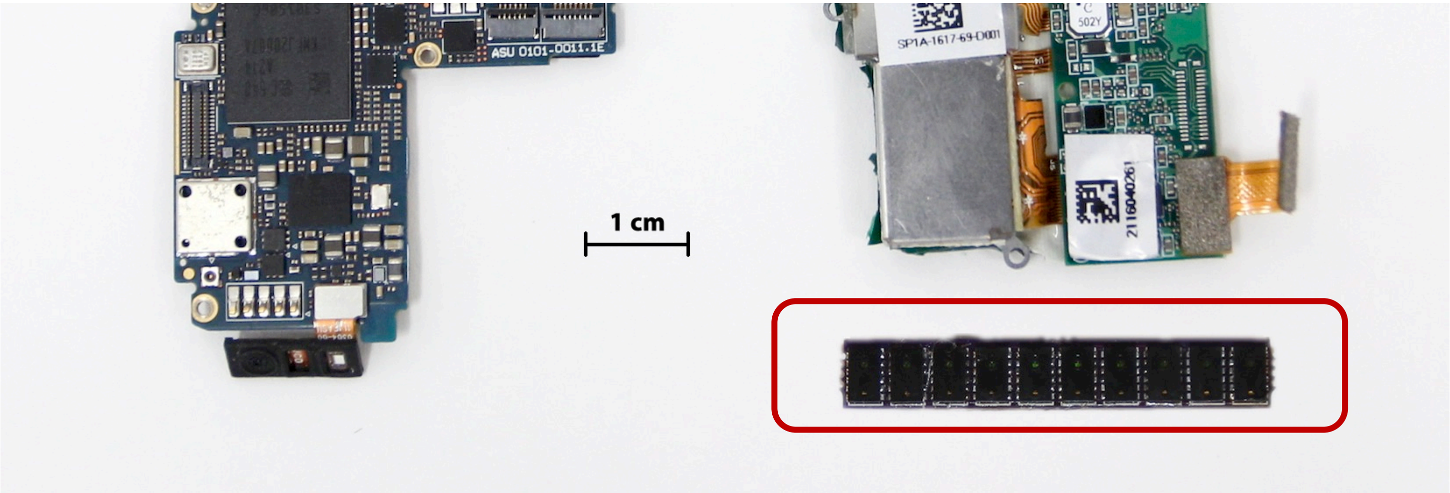
System overview



Adafruit VL6180X Time of Flight Distance Ranging Sensor (VL6180)

**$13.95** from Adafruit Industries **89%** positive (4,446)

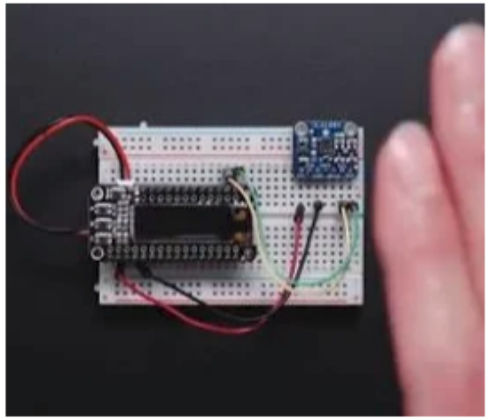
The **VL6180X** (sometimes called the VL6180) is a Time of Flight distance sensor like no other you've used! The sensor contains a ...




STMicro VL6180X ToF sensor

# LumiWatch: On-Arm Projected Graphics and Touch Input

System overview



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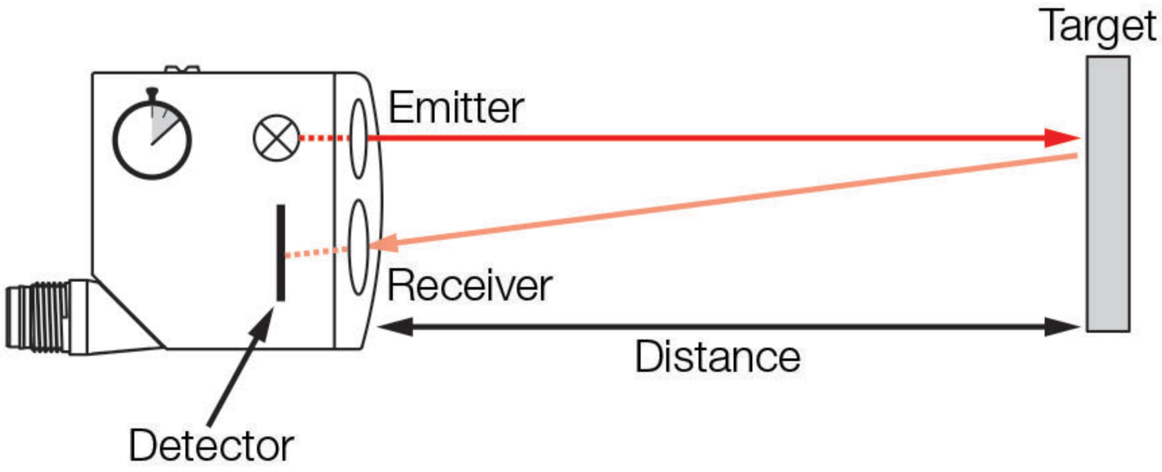
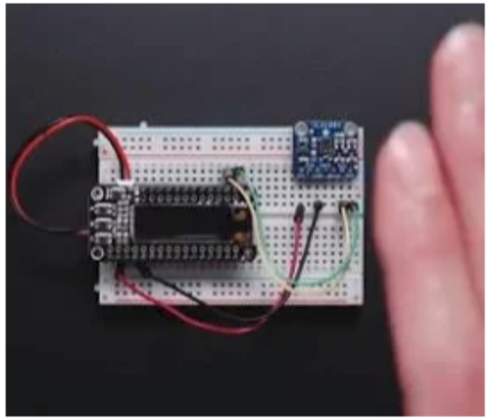



light bounces of nearby objects and reflects back
measure time until the light hits the sensor
closer objects = less time until the light reaches them
far away objects = more time until the light reaches them

Time of Flight Principle (simplified)

# LumiWatch: On-Arm Projected Graphics and Touch Input

System overview



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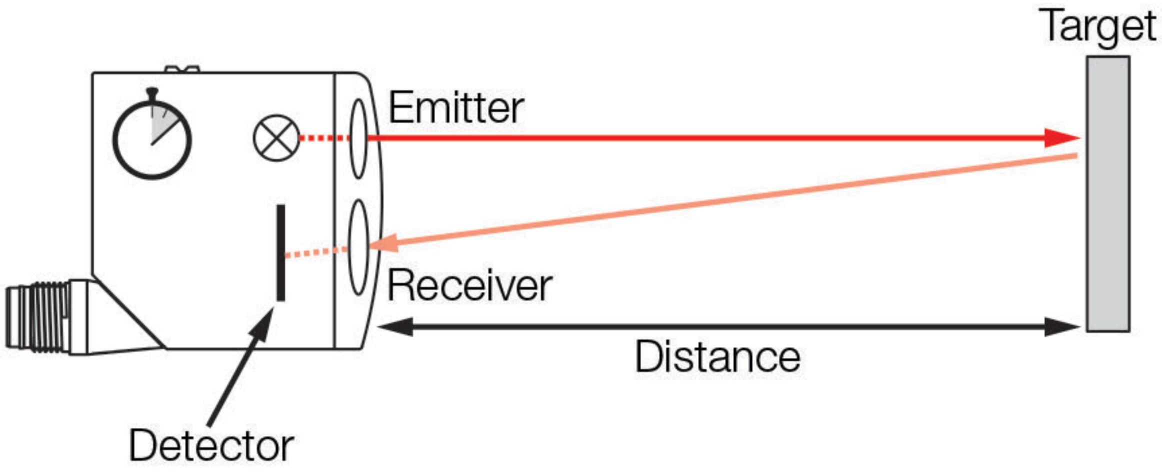
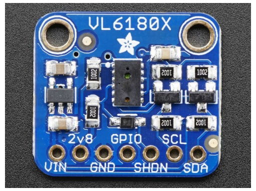


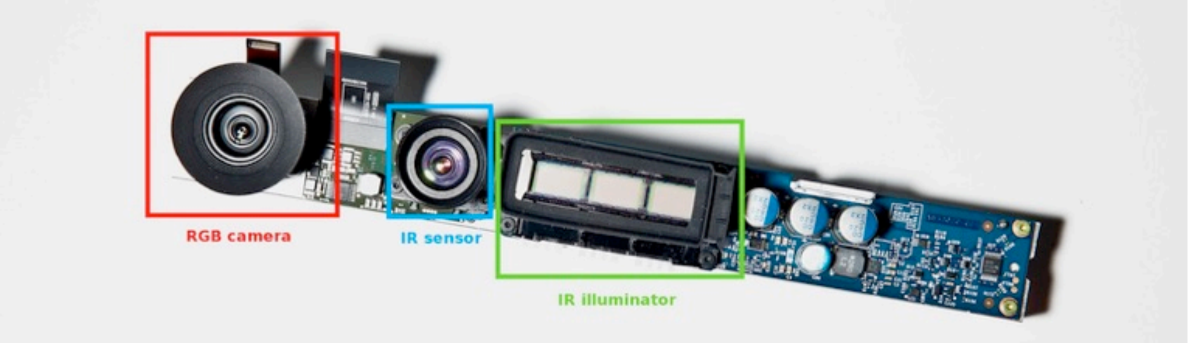

$$d = \frac{c \times \Delta t}{2}$$

Time of Flight Principle (simplified)

# LumiWatch: On-Arm Projected Graphics and Touch Input

System overview




Time of Flight Principle (simplified)

# LumiWatch: On-Arm Projected Graphics and Touch Input

System overvie

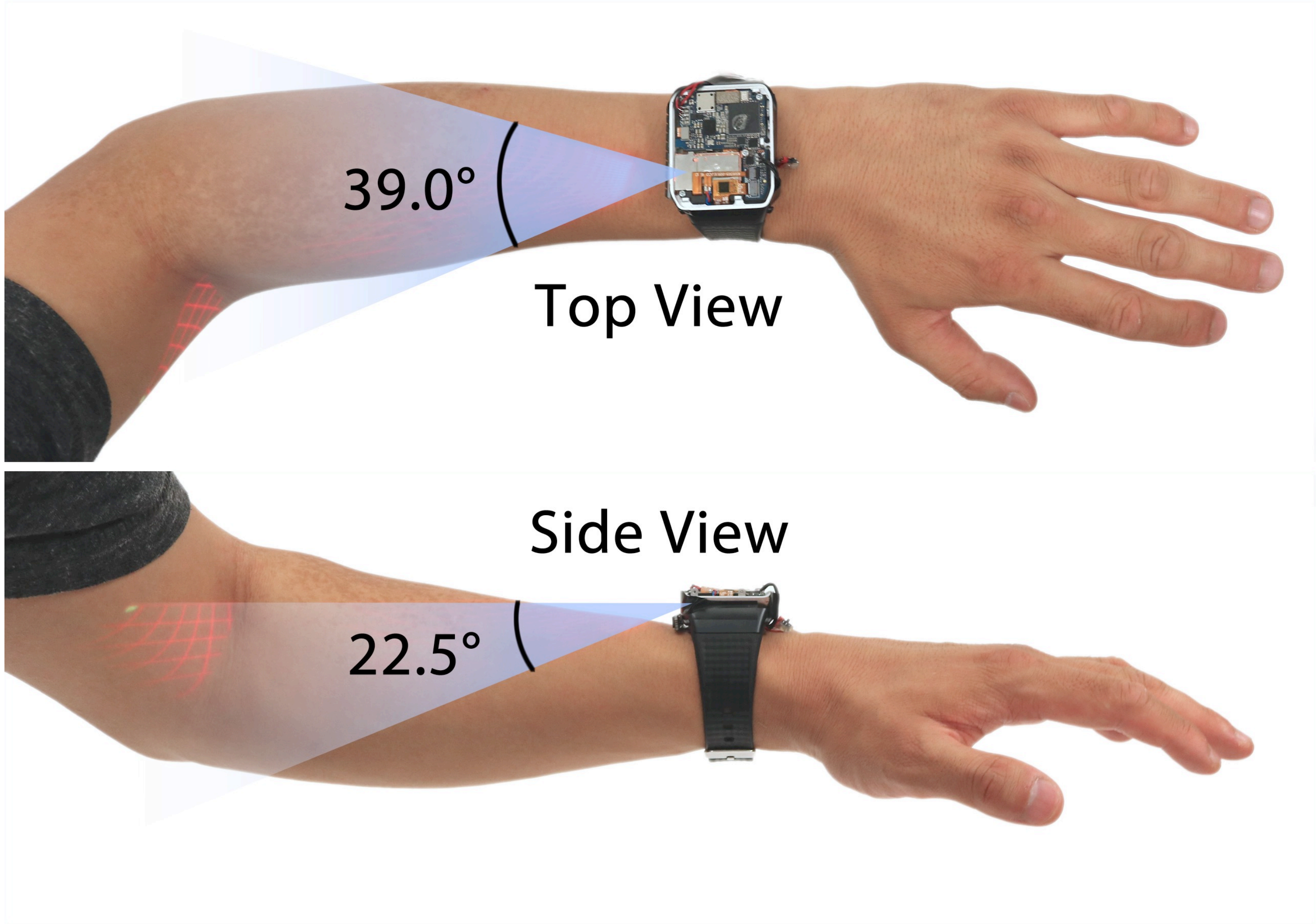
**mini Interactive projector module make any projector interactive for kids**

mini Interactive projector module make any projector interactive for kids

| | |
|---|---|
| Place of Origin : | China |
| Brand Name : | Hivista |
| Model Number : | IM-300 |
| Certification : | CE,FCC,RoHS |
| focus length : | long focus |
| Function : | make any projectors to interactive |
| Projected size : | 10-150inch |
| Strength : | Small volume,easy to carry,for teaching |
| Interface : | USB port |
| Max users : | 64 person |
| Transmission FPS : | 65~70 frame/sec |
| Positioning accuracy : | 4096*4096 |
| Application : | education and bussiness |
| OEM : | welcome |
| usage : | education in school |
| Price : | 55-88 dollars per pc |
| Packaging Details : | negotiable |
| Delivery Time : | negotiable |
| Payment Terms : | T/T/, Western Union,Paypal |
| Supply Ability : | 3000/month |
| MOQ : | 50 |

# LumiWatch: On-Arm Projected Graphics and Touch Input

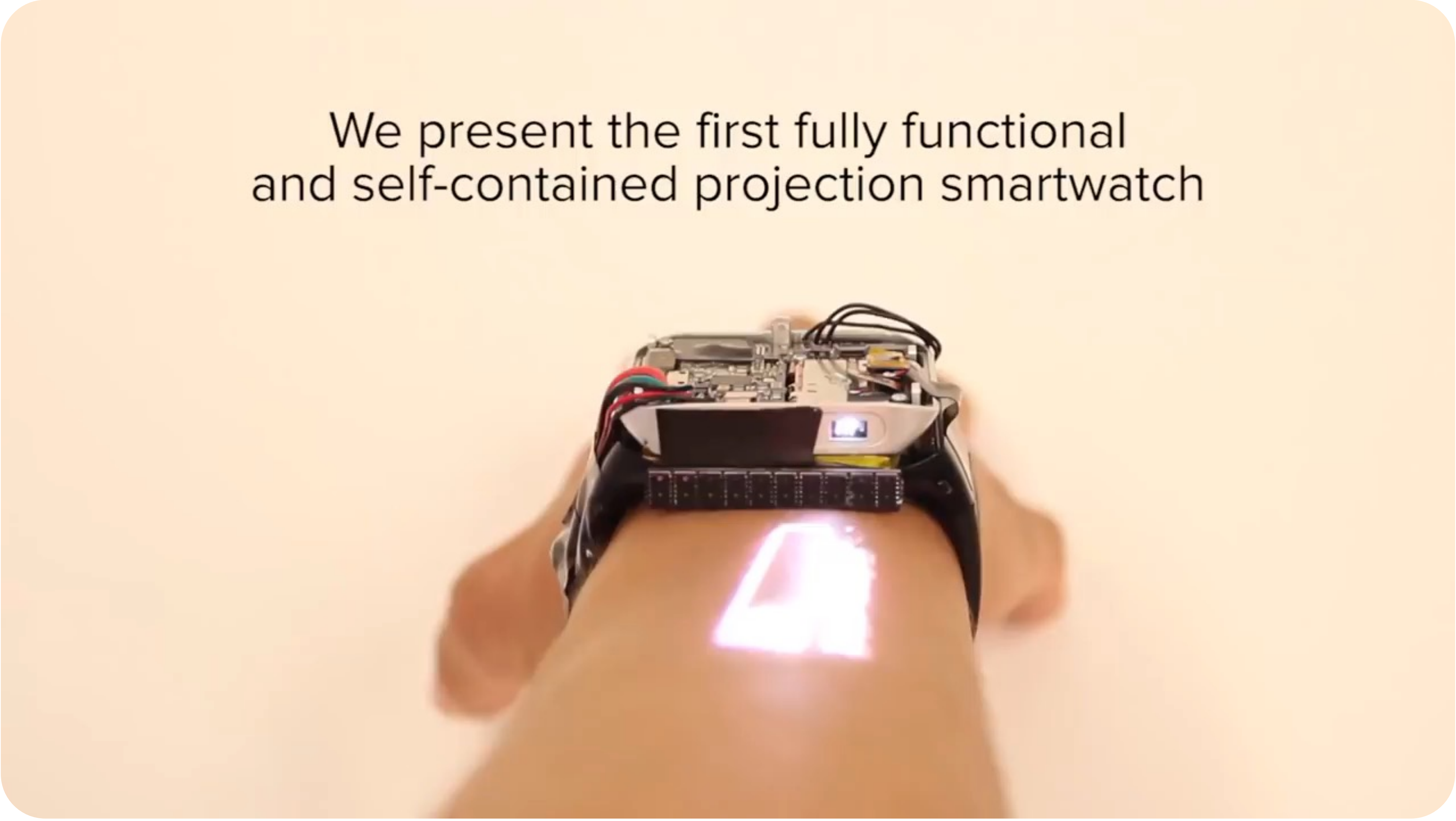
System overview



# LumiWatch: On-Arm Projected Graphics and Touch Input

Finger tracking

# LumiWatch: On-Arm Projected Graphics and Touch Input



Input

**Output**

# Recap

IR array for 1D sensing

IR ToF for 2D sensing

EM wave for 2D sensing

High frequency Accelerometer for micro-vibration sensing

(all very affordable, and you can try with your Arduino)

Material is in part based on the lectures by Prof. Cheng Zhang at Cornell

Calico: Relocatable On-cloth Wearables with Fast, Reliable, and Precise Locomotion

ANUP SATHYA, University of Maryland, College Park, USA
JIASHENG LI, University of Maryland, College Park, USA
TAUHIDUR RAHMAN, University of California, San Diego, USA
GE GAO, University of Maryland, College Park, USA
HUAISHU PENG, University of Maryland, College Park, USA

Fig. 1. a) Calico system deployed on a user. b) Calico wearable on the wrist. c) Calico robot moving on the pants. Different colored tracks can be used to blend into clothing. d) Calico moving towards a turntable to switch tracks. e) Running while wearing the Calico system.

We explore Calico, a miniature relocatable wearable system with fast and precise locomotion for on-body interaction, actuation and sensing. Calico consists of a two-wheel robot and an on-cloth track mechanism or "railway," on which the robot travels. The robot is self-contained, small in size, and has additional sensor expansion options. The track system allows the robot to move along the user's body and reach any predetermined location. It also includes rotational switches to enable complex routing options when diverging tracks are presented. We report the design and implementation of Calico with a series of technical evaluations for system performance. We then present a few application scenarios, and user studies to understand the potential of Calico as a dance trainer and also explore the qualitative perception of our scenarios to inform future research in this space.

CCS Concepts: • **Human-centered computing → Ubiquitous and mobile devices**; **Interaction devices**; **Mobile computing**.

Additional Key Words and Phrases: wearables, ubiquitous computing, kinetic wearables, mobile computing, interactive computing

Authors' addresses: Anup Sathya, University of Maryland, College Park, Department of Computer Science, USA; Jiasheng Li, University of Maryland, College Park, Department of Computer Science, USA; Tauhidur Rahman, University of California, San Diego, Halıcıoğlu Data Science Institute, USA; Ge Gao, University of Maryland, College Park, School of Information Studies, USA; Huaishu Peng, University of Maryland, College Park, Department of Computer Science, USA.


2474-9567/2022/9-ART136 $15.00
https://doi.org/10.1145/3550323



IMWUT 22

Sathya et.al.

# Optional readings



## Duet: Exploring Joint Interactions on a Smart Phone and a Smart Watch

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[1]User Interface Group, Autodesk Research, {firstname.lastname}@autodesk.com
[2]HCI Institute, Carnegie Mellon University, xiangchen@acm.org
[3]Department of Computer Science, University of Toronto, dwigdor@dgp.toronto.edu


**Figure 1. A duet of interaction between a handheld and a wrist worn device (a): the watch is used as a tool palette when annotating text on the phone (b); a simultaneous pinch-to-close swipe gesture on both devices mute their notifications (c); the watch's orientation indicates which hand part causes a touch, thus enabling a seamless transition between modes: for example, writing with the pad of the finger (d), scrolling with side of the finger (e), and text selection with the knuckle (f).**

### ABSTRACT

The emergence of smart devices (e.g., smart watches and smart eyewear) is redefining mobile interaction from the solo performance of a smart phone, to a symphony of multiple devices. In this paper, we present Duet – an interactive system that explores a design space of interactions between a smart phone and a smart watch. Based on the devices' spatial configurations, Duet coordinates their motion and touch input, and extends their visual and tactile output to one another. This transforms the watch into an active element that enhances a wide range of phone-based interactive tasks, and enables a new class of multi-device gestures and sensing techniques. A technical evaluation shows the accuracy of these gestures and sensing techniques, and a subjective study on Duet provides insights, observations, and guidance for future work.

### INTRODUCTION

Interactive computing technology is becoming increasingly ubiquitous. Advances in processing, sensing, and displays have enabled devices that fit into our palms and pockets (e.g., [2, 15]), that are wrist-worn [27, 40] or head-mounted [20, 29], or that are embedded as smart clothing [28, 37]. Commercialization is rapidly catching up with the research community's vision of mobile and ubiquitous form factors: smart phones, smart watches, and smart eyewear are all available for purchase. Soon, many of us may carry not one smart device, but two, three, or even more on a daily basis.

For interaction designers, this introduces a new opportunity to leverage the availability of these devices to create new interactions beyond the usage of a single device alone. At present, the space of interaction techniques making use of this opportunity is underexplored, primarily focusing on

**CHI 2014**

chen et.al. from CMU & Autodesk



## BeamBand: Hand Gesture Sensing with Ultrasonic Beamforming

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Carnegie Mellon University, Human-Computer Interaction Institute
5000 Forbes Avenue, Pittsburgh, PA 15213
{ysi, mayank, chris.harrison}@cs.cmu.edu

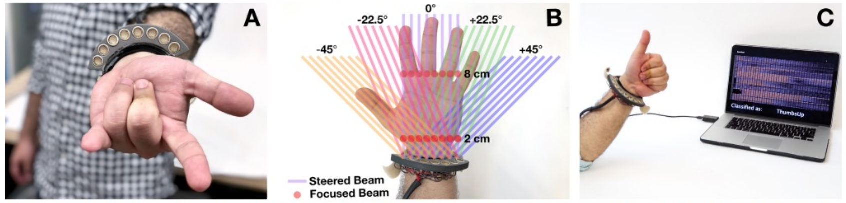


**Figure 1. Beamband is a wrist worn sensor containing eight transducers (A) that uses beamforming to direct and focus ultrasound at areas of interest (B) in order to recognize a variety of hand gestures (C).**

### ABSTRACT

BeamBand is a wrist-worn system that uses ultrasonic beamforming for hand gesture sensing. Using an array of small transducers, arranged on the wrist, we can ensemble acoustic wavefronts to project acoustic energy at specified angles and focal lengths. This allows us to interrogate the surface geometry of the hand with inaudible sound in a raster-scan-like manner, from multiple viewpoints. We use the resulting, characteristic reflections to recognize hand pose at 8 FPS. In our user study, we found that BeamBand supports a six-class hand gesture set at 94.6% accuracy. Even across sessions, when the sensor is removed and reworn later, accuracy remains high: 89.4%. We describe our software and hardware, and future avenues for integration into devices such as smartwatches and VR controllers.

### CCS CONCEPTS

Human-centered computing → Human computer interaction (HCI) → Interaction techniques → Gestural input

### KEYWORDS

Hand Input; Hand Gesture; Acoustic Reflectrometry; Acoustic Beamforming; Acoustic; Interaction Techniques; Wearables



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DOI: https://doi.org/10.1145/3290605.3300245

### 1 INTRODUCTION

Robust hand gesture detection holds the promise to enrich user interfaces and improve immersiveness, whether it be smartwatches to AR/VR systems. Unfortunately, identifying hand gestures without instrumenting the hand (e.g., gloves, controllers) has proven to be challenging, which motivates the need to identify new methods. Prior research includes leveraging electromyography [38][39], bio-acoustics [23][15], electrical impedance tomography [50][51], contour sensing [7], and worn cameras [20]. While each approach has its strengths and drawbacks, a common weakness is robust accuracy across users and worn sessions.

In this paper, we present our work on BeamBand, a new approach for worn hand gesture sensing, which leverages acoustic beamforming. We use small in-air ultrasonic transducers arranged along the contour of the wrist (Figure 1A), which offers a stable vantage point from which to capture hand pose. Using active beamforming, we steer and focus ultrasound towards areas of interest on the hand (Figure 1B). We also multiplex our transducers, capturing beamformed reflections from slightly different viewpoints (Figure 1B), offering rich signals for machine-learning-driven hand gesture recognition (Figure 1C).

To assess BeamBand's recognition performance, we conducted a ten-participant study, adopting two gesture sets from the literature in order to enable direct comparison (i.e., rather than developing a custom set). The first set contained seven hand poses, while the second set has six gestures along three axes of rotation. On these two gesture sets, BeamBand demonstrates accuracies of 92.5% and 94.6%



**CHI 2019**

Iravantchi et.al.