Smartwatch/Wearable Interaction

Huaishu Peng | UMD CS | Fall 2022
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
What if your hand is occupied

Your solution?
Electromyography (EMG) Sensor

2008, Daito Manabe
https://www.youtube.com/watch?v=YxdjYFCp5Ic
EMG Sensor

Enabling Always-Available Input with Muscle-Computer Interfaces

T. Scott Saponas, Denney X. Tao, Das Moritz, Karin Bäckström, John Turner, James A. Landay

Department of Computer Science and Engineering
Microsoft Research

ABSTRACT

Previous work has demonstrated the feasibility of applying computer interfaces to muscles through bioelectric signals (EMG) and directlyfinger gestures on a physical surface. We extend these results to bodies as close as using muscle-computer interfaces for always-available input in real-world environments. We describe the results of an interaction study of muscle-computer interfaces, report on our implementation, and propose the design of a muscle-computer interface to support low-latency natural input. We believe this work demonstrates that muscle-computer interfaces can be used to support natural input in real-world environments.

Previous work has explored hand-free and microinteract techneolog with the focus on improving standard technologies for always-available input. In this paper, we focus on improving standard technologies for always-available input. We believe this work demonstrates that muscle-computer interfaces can be used to support natural input in real-world environments.

UIST 2009

Saponas et.al. from MSR
EMG Sensor

MyoWare Muscle Sensor

$38 online

The bionics wizards at Advancer Technologies are changing the DIY electronics landscape by helping inventors flex their creative muscles. Our user-friendly, expandable muscle sensor, MyoWare, gives you the power to control an endless variety of devices, from robots to video games ...

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

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
WristWhirl: One-handed Continuous Smartwatch Input using Wrist Gestures

Implementation

Piezo Vibration Sensor - Small Horizontal

$2.95

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 and 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
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

\[ \lambda = \text{wave speed/frequency} \]

or

\[ \lambda = \frac{v}{f} \]

- \( \text{Frequency: 80MHz AC signal} \)
- \( \text{Speed: } 7.3 \times 10^7 \text{ m/s} \)
- \( \text{Length: 91cm wavelength} \)
- \( \text{1cm equals 4 degree phase shift} \)
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

![Graph showing button diameter comparison across different body parts: Back Hand, Front Hand, Back Arm, Front Arm, Hand, Arm, Cap. Touchscreen.]
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

Sensing principle

Existing Accelerometers: 100Hz
ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

Sensing principle

At this incredibly high speed, we can detect micro-vibrations propagating through the arm

Typical Use: 100Hz
ViBand: 4000Hz
3900% Increase
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
ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

Implementation

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>Units</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPPLY VOLTAGES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VDD</td>
<td></td>
<td>1.71</td>
<td>1.8</td>
<td>3.45</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>VDDIO</td>
<td></td>
<td>1.71</td>
<td>1.8</td>
<td>3.45</td>
<td>V</td>
<td>1</td>
</tr>
<tr>
<td>SUPPLY CURRENTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal Mode</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-axis</td>
<td>Normal</td>
<td>3.4</td>
<td>mA</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3-axis Gyroscope</td>
<td>Normal</td>
<td>3.2</td>
<td>mA</td>
<td>1</td>
<td></td>
<td>1</td>
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<tr>
<td>3-Axis Accelerometer 48Hz ODR</td>
<td>Normal</td>
<td>450</td>
<td>μA</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Accelerometer Low Power Mode</td>
<td></td>
<td>0.26 Hz update rate</td>
<td>7.27</td>
<td>μA</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>31.25 Hz update rate</td>
<td>16.65</td>
<td>μA</td>
<td>1.2</td>
<td></td>
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<tr>
<td>Standby Mode</td>
<td></td>
<td>1.6</td>
<td>mA</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Full-Chip Sleep Mode</td>
<td></td>
<td>6</td>
<td>μA</td>
<td>1</td>
<td></td>
<td>1</td>
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<tr>
<td>TEMPERATURE RANGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Specified Temperature Range</td>
<td>Performance parameters are not applicable beyond Specified Temperature Range</td>
<td>-40</td>
<td>+85</td>
<td>°C</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>ID</th>
<th>OBJECT</th>
<th>BIO-Acoustic Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Seagull S6 Acoustic Guitar</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Oster BRYL07-B Blender</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Wagner HT100 Heat Gun</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>2015 Dodge Avenger</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Krups Fast Coffee Grinder</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Dremel 300 EZ Twist</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Ryobi Drill Press DPL02L</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Craftsman Motion Sander</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>BHD9600 Dust Buster</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>Lasko 12&quot; Table Fan</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>Ryobi BGS12G Grinder</td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>Metal Hack Saw</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Conair Ionic Hair Dyer</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Black&amp;Decker Hand Drill</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>Wood Hand File</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>Hamilton Hand Mixer</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>Apple iPhone 5C</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>HP LaserJet 9050</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>LG Motion 4G</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>Shop-Vac Micro 202100</td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>Panasonic 950 Microwave</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Honda 250C Motorcycle</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Swingline Staple Gun</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>Irwin Wood Saw</td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>DeWalt Power Drill</td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>B&amp;D Mouse Sander</td>
<td></td>
</tr>
<tr>
<td>α</td>
<td>Sonicare Toothbrush</td>
<td></td>
</tr>
<tr>
<td>β</td>
<td>Shop-Vac 5 Gallon</td>
<td></td>
</tr>
<tr>
<td>γ</td>
<td>Hot Wheels Toy Car</td>
<td></td>
</tr>
</tbody>
</table>
ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

Object detections
Input

Output
Cito: An Actuated Smartwatch for Extended Interactions

Cito: An Actuated Smartwatch for Extended Interactions

Gong et.al. from Dartmouth

Figure 1. Animated face movements and image sequence (top) face rotating in love state adaptive (the face translating outside above) at first pressing in relation to unimportant click (the face rotating in love symbol).
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

T1 (reorienting face)
## Cito: An Actuated Smartwatch for Extended Interactions

Exploring the concept feasibility before implementation

<table>
<thead>
<tr>
<th>Scenarios:</th>
<th>Using videos allowed our study to be highly controlled as participants had to see the same demos.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential solutions for each of the scenarios – 7 point Likert scale rating</td>
<td>The videos also encouraged “suspension of disbelief”, allowing them to focus on the Cito concept, rather than implementation details.</td>
</tr>
</tbody>
</table>
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
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

We present the first fully functional and self-contained projection solution that utilizes the movement and position of an arm to project images onto the skin. This system is designed to project graphics onto the body, allowing for an intuitive and interactive user interface. The LumiWatch system consists of a small, lightweight device that is worn on the arm, and a projection module that is activated when the arm is in a specific position. The system is capable of projecting graphics onto the skin in real-time, allowing for a seamless and natural interaction with the device.

**Abstract**

Compact, wearable computers with projected output enable novel interaction modalities. In this work, we present LumiWatch, a wearable computer that utilizes the arm's movement to project information onto the skin. This system is designed to provide users with a natural and intuitive interface for interacting with digital content. By projecting graphics onto the arm, LumiWatch offers a new way to engage with technology that is both immersive and interactive.

**Introduction**

Interactive surfaces are an attractive and widely studied area in the field of computer science. They provide a natural way for users to interact with technology and offer a range of potential applications. Although it introduces new challenges, such as a variable surface area and the need for non-planar input, interactive surfaces are becoming increasingly popular. Projected interfaces are one possible solution to these problems, as they allow for a flexible and adaptable user interface. In this work, we present LumiWatch, a wearable computer that utilizes the arm's movement to project information onto the skin. This system is designed to provide users with a natural and intuitive interface for interacting with digital content.

**Keywords**

FastCap, touch adaptation, depth sensing, time-of-flight on-body connection.

**ACM Classification Keywords**

H.5.1. Information interfaces and presentation (e.g. HCI); I.3.7. Evaluation/methodology.
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 …
LumiWatch: On-Arm Projected Graphics and Touch Input

System overview

Adafruit VL6180X Time of Flight Distance Ranging Sensor (VL6180)
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The VL6180X (sometimes called the VL6180) is a Time of Flight distance sensor like no other you’ve used! The sensor contains a...

Time of Flight Principle (simplified)

- **Emitter**
- **Receiver**
- **Detector**
- **Target**

light bounces off 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
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 ...

\[
d = \frac{c \times \Delta t}{2}
\]
LumiWatch: On-Arm Projected Graphics and Touch Input

System overview

Time of Flight Principle (simplified)
LumiWatch: On-Arm Projected Graphics and Touch Input

**System overview**

<table>
<thead>
<tr>
<th>mini Interactive projector module make any projector interactive for kids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place of Origin: China</td>
</tr>
<tr>
<td>Brand Name: Hivista</td>
</tr>
<tr>
<td>Model Number: IM-300</td>
</tr>
<tr>
<td>Certification: CE, FCC, RoHS</td>
</tr>
<tr>
<td>Focus length: Long focus</td>
</tr>
<tr>
<td>Function: Make any projectors to interactive</td>
</tr>
<tr>
<td>Projected size: 10-150 inch</td>
</tr>
<tr>
<td>Strength: Small volume, easy to carry, for teaching</td>
</tr>
<tr>
<td>Interface: USB port</td>
</tr>
<tr>
<td>Max users: 64 person</td>
</tr>
<tr>
<td>Transmission FPS: 65-70 frame/sec</td>
</tr>
<tr>
<td>Positioning accuracy: 4096*4096</td>
</tr>
<tr>
<td>Application: Education and business</td>
</tr>
<tr>
<td>OEM: Welcome</td>
</tr>
<tr>
<td>Usage: Education in school</td>
</tr>
<tr>
<td>Price: 55-99 dollars per pc</td>
</tr>
<tr>
<td>Packaging Details: Negotiable</td>
</tr>
<tr>
<td>Delivery Time: Negotiable</td>
</tr>
<tr>
<td>Payment Terms: T/T, Western Union, PayPal</td>
</tr>
<tr>
<td>Supply Ability: 3000/month</td>
</tr>
<tr>
<td>MOQ: 50</td>
</tr>
</tbody>
</table>
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

We present the first fully functional and self-contained projection smartwatch.
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-choth Wearables with Fast, Reliable, and Precise Locomotion

ANUP SATHYA, University of Maryland, College Park, USA
JAHENG LI, University of Maryland, College Park, USA
TALHIDUR RAHMAN, University of California, San Diego, USA
GE GAO, University of Maryland, College Park, USA
HUMHUI FENG, University of Maryland, College Park, USA

Fig. 1. A Calico system deployed on a user. A Calico on-the-waist, on-the-back moving on the parts. Different colored tracks can be used to blend into clothing. At Calico moving towards a trailer to switch tracks. Running while wearing the Calico system.

We explore Calico, a relocatable relocatable wearable system with fast and precise locomotion for our body orientation, locomotion, and sensing. Calico consists of a small soft robot and an on-body track mechanism or "tracks," on which the robot travels. The robot is in constant, small motion, and has additional motion regulation options. The tracks enable the robot to move along the user's body and track the user's position and orientation. It also helps maintain a steady, reliable, and fast locomotion while minimizing compromises to the wearer's motions and movements.

Additional Key Words and Phrases: wearable computing, agile computing, on-body wearable computing, interactive computing

Authors: Anup Sathy, University of Maryland, College Park, Department of Computer Science, USA; Sathy, Sathy, University of Maryland, College Park, Department of Computer Science, USA; Sathy, Sathy, University of Maryland, College Park, Department of Computer Science, USA; Sathy, Sathy, University of Maryland, College Park, Department of Computer Science, USA.

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http://doi.org/10.1145/3581104.3581603

IMWUT 22
Sathy et.al.
Optional readings

**CHI 2014, One of a CHird, Toronto, ON, Canada**

**Session: Watches and Small Devices**

---

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

**Xiang ‘Anthony’ Chen**, Tori Grossman, Daniel Wigdor, George Fitzmaurice

**User Interface Group**

**Autodesk Research**

[anthony.chen@autodesk.com]

---

**CHI 2019, May 4–9, 2019, Glasgow, Scotland, UK**

**BeamBand: Hand Gesture Sensing with Ultrasonic Beamforming**

**Yasha Iravanchi, Mayank Goel, Chris Harrison**

**Carnegie Mellon University, Human-Computer Interaction Institute**

[3800 Forbes Avenue, Pittsburgh, PA 15213]

[yl, 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 insensible sound in a raster-scene-like manner, from multiple viewpoints. We use the resulting, characteristic reflections to recognize hand poses 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 re-worn later, accuracy remains high 92.6%. 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 Reflectometry, Acoustic Beamforming, Acoustic Interaction Techniques, Wearables

Preliminary results presented at CHI 2019.

---

**Introduction**

Robust hand gesture detection holds the promise to enrich user interfaces and improve immersion, 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 [18][19], bio-acoustics [20][21], electrical impedance tomography [22][23], contour sensing [7], and worn cameras [24]. While each approach possesses its strengths and drawbacks, a common weakness is robustness across users and worn sensors.

In this paper, we present our work on BeamBand, a new approach for wristband hand gesture sensing, which leverages acoustic beamforming. We use small-in-to-ultrasonic transducers arranged along the contour of the wrist (Figure A), which is 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 B). We also multiplex our transducers, capturing beamformed reflections from slightly different viewpoints (Figure C) and offering rich signals for machine-learning-driven hand gesture recognition (Figure C).

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 has six gestures along three axes of rotation. On these two gesture sets, BeamBand demonstrates accuracies of 92.5% and 94.6%.
Monday: Electronics - Digital IO
You will need to install Arduino environment, we will post the details on Piazza
Bring your laptop and class box