In-Ear Canal Deformation based Head Gesture Recognition Using In-ear Wearables

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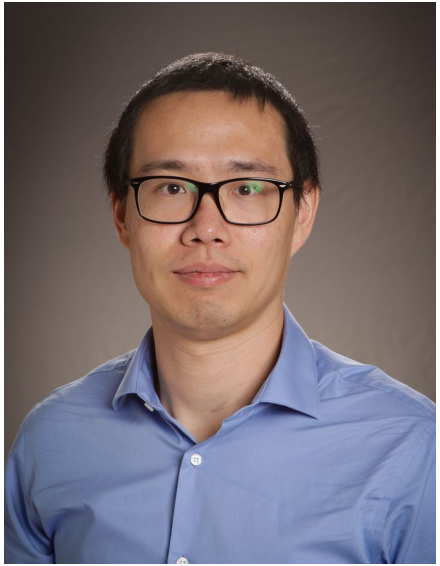
Researcher Information Corner



Sheng Tan

Assistant Professor in the Department of Computer Science at Trinity University.

He received his Ph.D. degree from the Department of Computer Science at Florida State University in 2019, supervised by Prof. Jie Yang.

His research interests:

- Mobile Computing
- Cybersecurity
- Human Computer Interaction and Computer Science Education

He published papers in premier venues such as ACM CHI, ACM CCS, ACM MobiHoc, IEEE INFOCOM and ACM Ubicomp. His current projects include mobile safety system for distracted driver/pedestrian and mobile sensing for human computer interaction applications.

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Undergraduate Computer Science Student at Trinity University.

She is a 3rd year student studying as a Computer Science Major and at Trinity University and expected to graduate in 2024.

She has interned and worked with the Open-Source Blockchain interoperability Project, Hyperledger Cactus through Accenture, then as a Business Data analyst during her second summer. She is an incoming intern for Summer 2023 as a software engineer at Workiva.

Presentation Roadmap

Introduction
- Current HCI for head gestures and their problems
- General proposal of *In-ear wearable based head gesture recognition system*

System Design
- Overview of the study

Feasibility Study
- Accuracy Results

General Summary + Conclusion

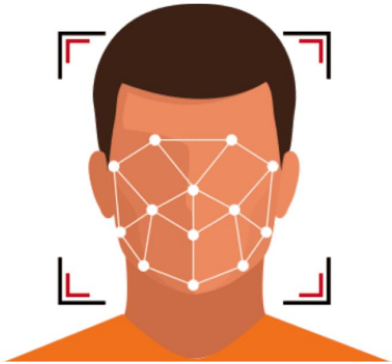
Current Human Interactions with Computers

Motion sensors

- relies on sensors (accelerometers, gyroscopes, etc) to infer the user's head motion speed and direction.

RF Devices (e.g. RFID tags, WiFi transceivers)

- mounted on the users and used to measure the relative distance to the access point for head gesture recognition.



Computer Vision (CV)

- Utilize cameras that can captures the user's head motion to achieve gesture recognition

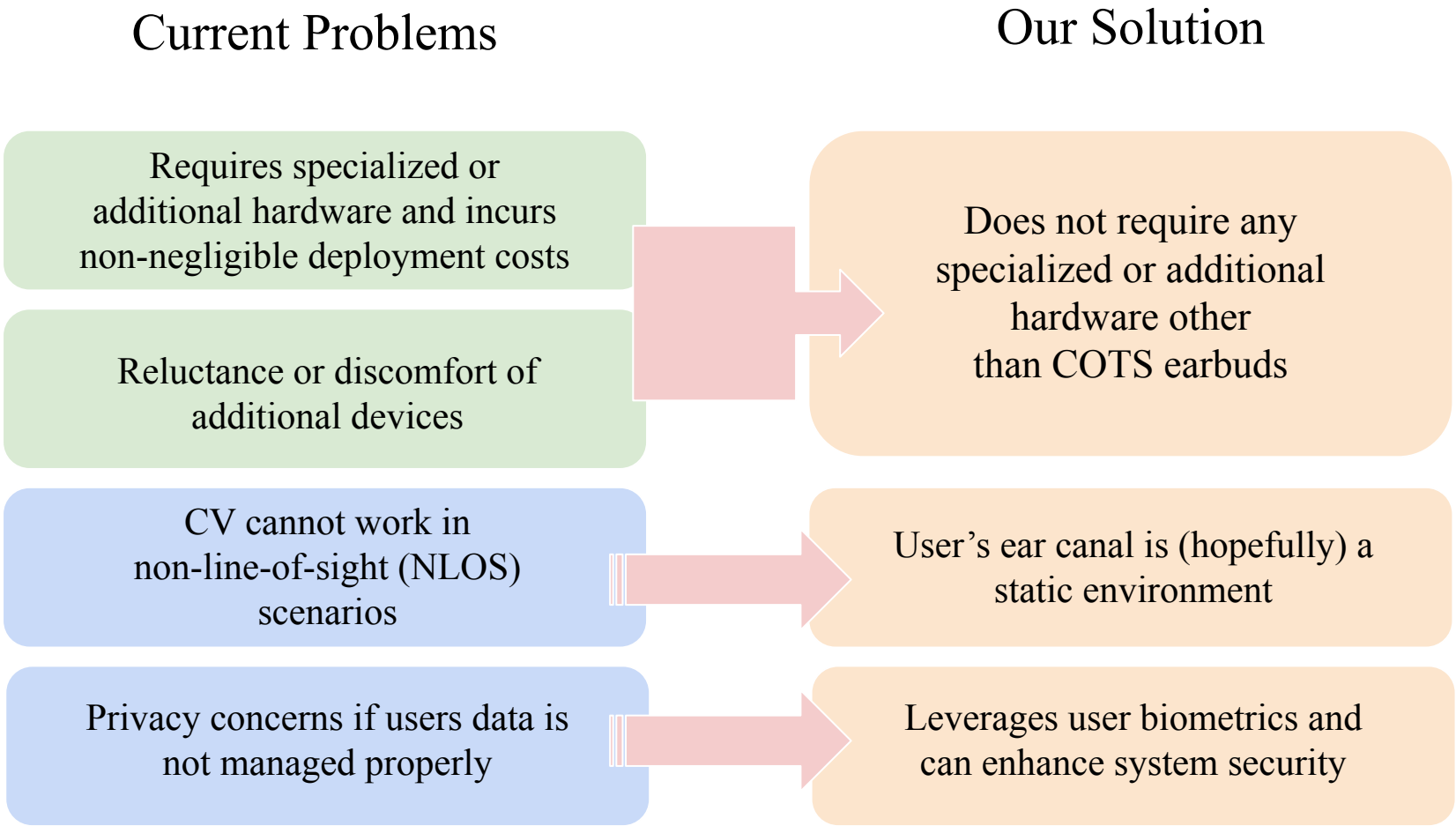
Challenges to our current solution

Challenges to RFs and Motion Sensor:

- specialized or customized hardware, incurs non-negligible deployment costs
- users might be reluctant or feel uncomfortable wearing additional devices

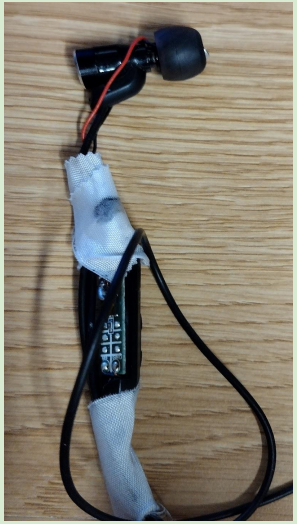
Challenges to Computer Vision:

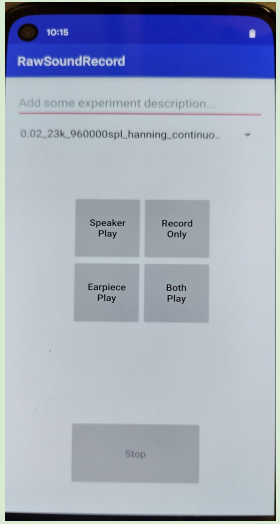
- CV cannot work in non-line-of-sight (NLOS) scenarios
  - Example: performance suffers in poor lighting conditions
- Privacy concerns if users data is not managed properly


Current Problems
Our Solution
Requires specialized or additional hardware and incurs non-negligible deployment costs
Reluctance or discomfort of additional devices
Does not require any specialized or additional hardware other than COTS earbuds
CV cannot work in non-line-of-sight (NLOS) scenarios
User's ear canal is (hopefully) a static environment
Privacy concerns if users data is not managed properly
Leverages user biometrics and can enhance system security

Technology + Concept Breakdown

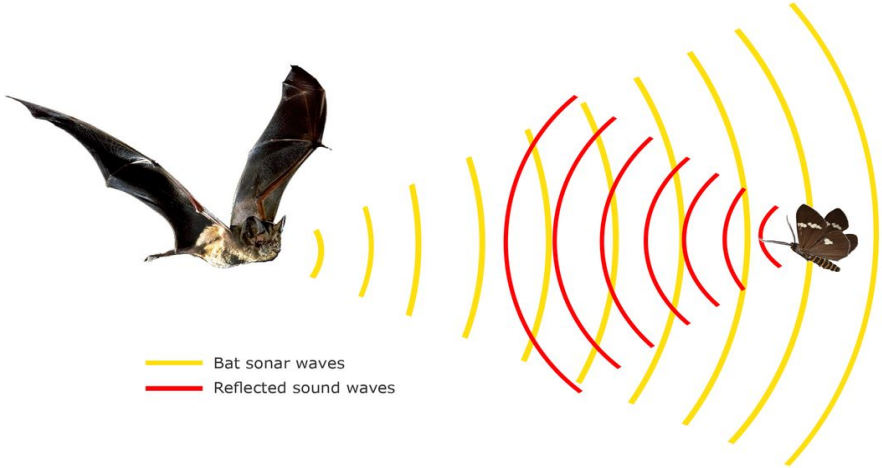
Commercial off-the-shelf (COTS) earbuds with a built-in microphone + App





How it works

- Send inaudible acoustic signal through the ear canal during a head gesture.
- in-ear microphone captures signal reflections about ear canal deformation



System Overview

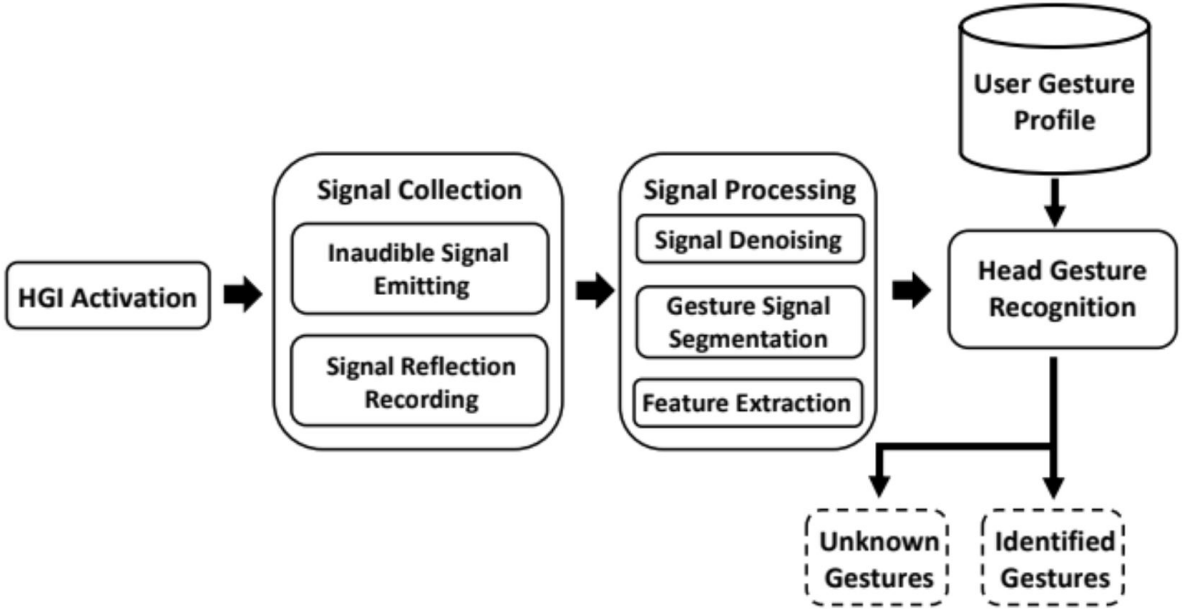


Fig. 1. Overview of system flow.

Experimental Setup

- COTS in-ear earbud with embedded microphone chip
  - Inwards facing microphone at the center of the speaker
- Google Pixel 4a with Android 12
  - Used to control inaudible probe signal emitting and the reflected signal recording
    - chirp signal range from 16kHz - 23kHz
- Four head gestures:
  - down and up
  - up and down
  - clockwise rotation
  - counter-clockwise rotation
- Four participants are recruited:
- 100 samples from each participant
  - 25 recordings per head gesture
- Typical living room and bedroom area

Results

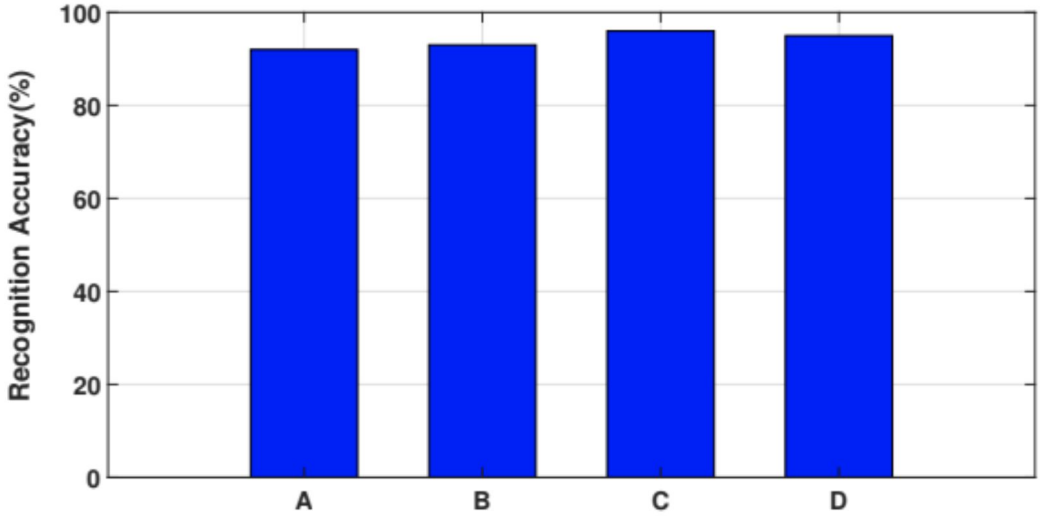


Fig. 2. Accuracy of recognition four different head gestures (A: down and up; B: up and down; C: clockwise rotation; D: counter-clockwise rotation).

Summary and Future Works

In this work, we propose a head gesture recognition system utilizing COTS in-ear wearable devices that does not require LOS or any specialized sensors while enhancing the system's security. The preliminary study shows that our system can recognize various head gestures with high accuracy.

For our future works, we are hoping to add more head gestures for recognition and maintain/improve upon the accuracy within a dynamic setting.