Gesture detecting smart wearable

Jerome Hernandez
Haopeng Pi
Chen Yang
Terry Bai

Project Outline

- Smaller, more capable embedded systems
- Compact devices in daily life
- Smart home
- Smart wearables
- Traditional interactions (touch, voice) can be limiting or inaccessible
- A smart wearable for intuitive, hands-free gesture detection and control

Background

- Based around **Project 6: Hand washing quality monitoring…**
- Taking key ideas of **gesture recognition**
- From the reference paper: **Finger-writing with Smartwatch…**

(a) Arm gesture - drawing a triangle with arm

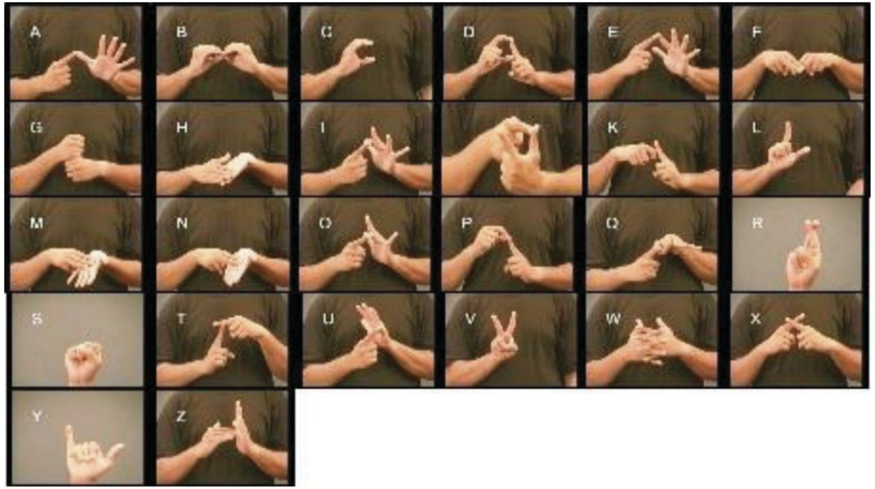
(b) Hand gesture - rotate hand right to increase volume

(c) Finger gesture - zoom out with fingers

Background

- Smart home control
  - Amazon Echo (and other)
  - Control4
- Gesture recognition
  - Apple watch
  - Myo armband

Related Work



IETE JOURNAL OF RESEARCH 2023, VOL. 69

Vision-based Hand Gesture Recognition for Indian Sign Language

- Capture the hand gestures with camera
- Hand Detection and Segmentation using deep neural network models
- Identify the hand gestures with a classification layer

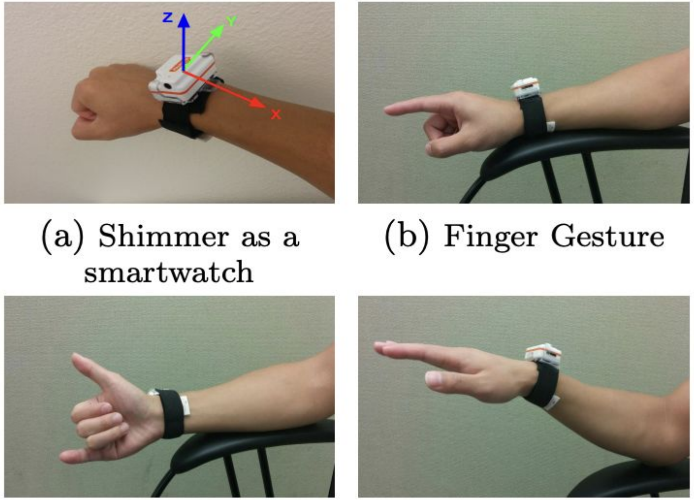
Related Work

ICACS'4, February 20-22 2023, Lahore, Pakistan

Hand gesture recognition with a hand glove

- Collect tilting, rotation, and acceleration of the hand movement using accelerometers and gyroscopes
- LDA and t-SNE for feature extraction
- Classify gestures using machine learning methods

Related Work



(a) Shimmer as a smartwatch (b) Finger Gesture

(c) Hand Gesture (d) Arm Gesture

HotMobile '15, February 12 – 13 2015, Santa Fe, NM, USA

Identify hand gestures performed in a fix-sized time with only one board

- Collect data based on the movement of tendons
- Extract information Gain-based features
- Build classifiers for gesture recognition

Goals

The purpose of our project is to control Bluetooth-enabled smart home devices through gestures by using the sensor information on the Nano board and BLE transmission.

Gestures	Smart light
Snap	Change the light switch state
Clockwise rotation	The lighting changes to warm tones
Counterclockwise rotation	Lighting turns to cool tones
Hand up	Improve brightness
Hand down	Dim the light

Challenges

1. **Identification logic settings** Dad's Hilarious Voice-Activated Lights Prank Goes Viral! (youtube.com)

   Design a protocol to actively turn on the control mode

   Figure out a better way to automatically identify the expected mode (calculate distance by signal strength lab4)

2. **Transmission rate issue 104 Hz**

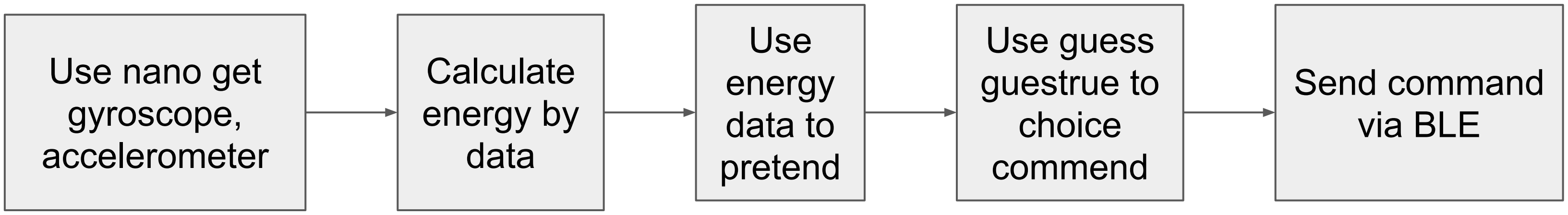
   Optimize packet size

   Hardware capability matching

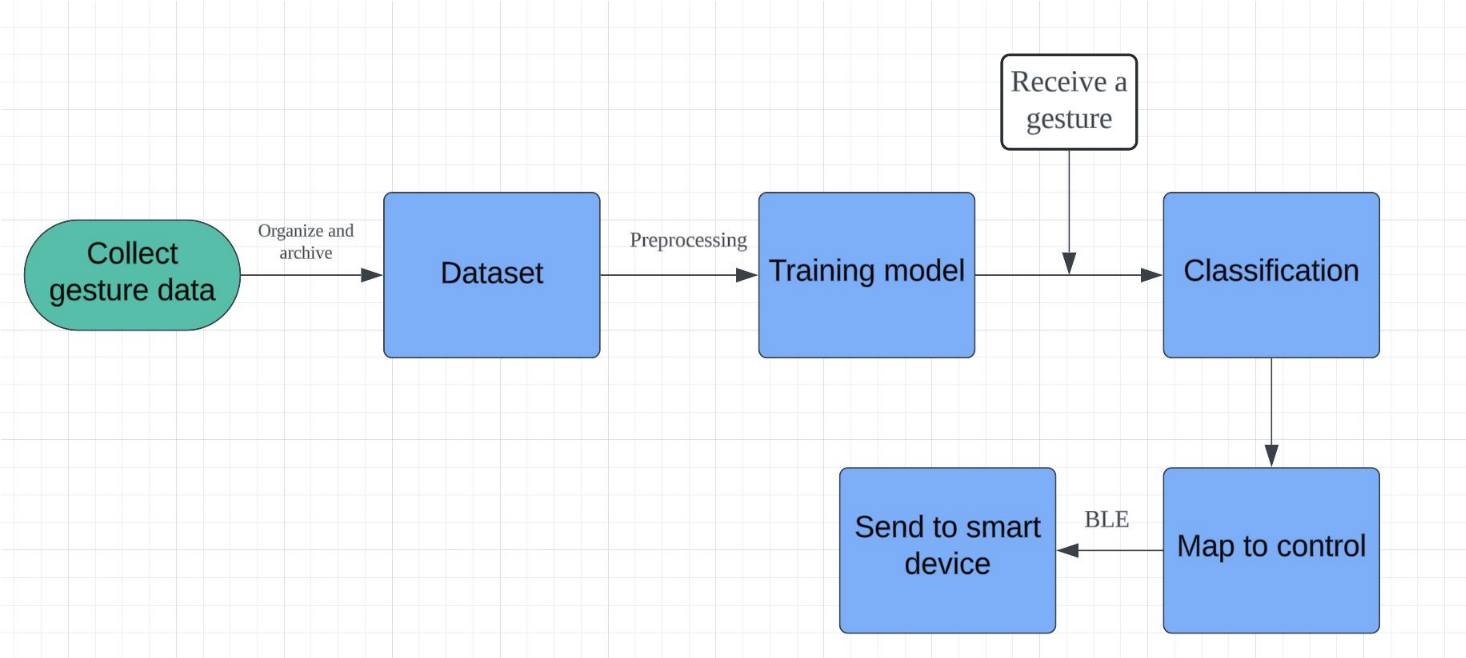
   Buffering mechanism

Proposed solution

Product Workflow



Method



Receive a gesture
Collect gesture data
Organize and archive
Dataset
Preprocessing
Training model
Classification
Send to smart device
BLE
Map to control

€545

Shimmer3 200g IMU

Individual Sensors

The Shimmer3 200g IMU is the latest additon to the Shimmer3 product range. Capable of measuring up to 200g's of force, the Shimmer3 200g unit is ideal for high force or impact event detection. The unit boasts additional sensing while retaining all the features of the Shimmer3 IMU allowing for best data quality 9DoF inertial sensing via accelerometer, gyroscope, magnetometer and altimeter.

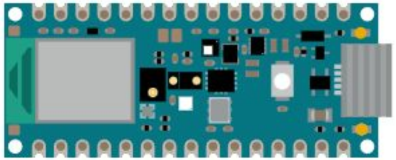
- 1 + Add to cart

Tag: Shimmer3 200g IMU

Sensor Data Collection: We use a Shimmer [6] device attached to a wristband as the smartwatch as shown in Fig. 2a. The Shimmer contains an accelerometer sensor and a gyroscope sensor. The sensor data is collected at 128 Hz on Shimmer and transferred to a smartphone via Bluetooth. We use the Shimmer instead of any commercially available smartwatch because most smartwatch available in market provide only a limited API support for collecting accelerometer and gyroscope data. The sampling frequency of 128 Hz for Shimmer is not too high since the typical sampling frequency for accelerometer on current smartphones and smartwatches is 200 Hz [10] and 100 Hz [7] respectively. This means that a Shimmer closely resembles a smartwatch in terms of the motion sensors.

Nano 33 BLE Sense Rev2

The Arduino Nano 33 BLE Sense Rev2 combines a tiny form factor, different environment sensors and the possibility to run AI using TinyML and TensorFlow™ Lite. Whether you are looking at creating your first embedded ML application or you want to use Bluetooth® Low Energy to connect your project to your phone, the Nano 33 BLE Sense Rev2 will make that journey easy.



Buy now

BMI270

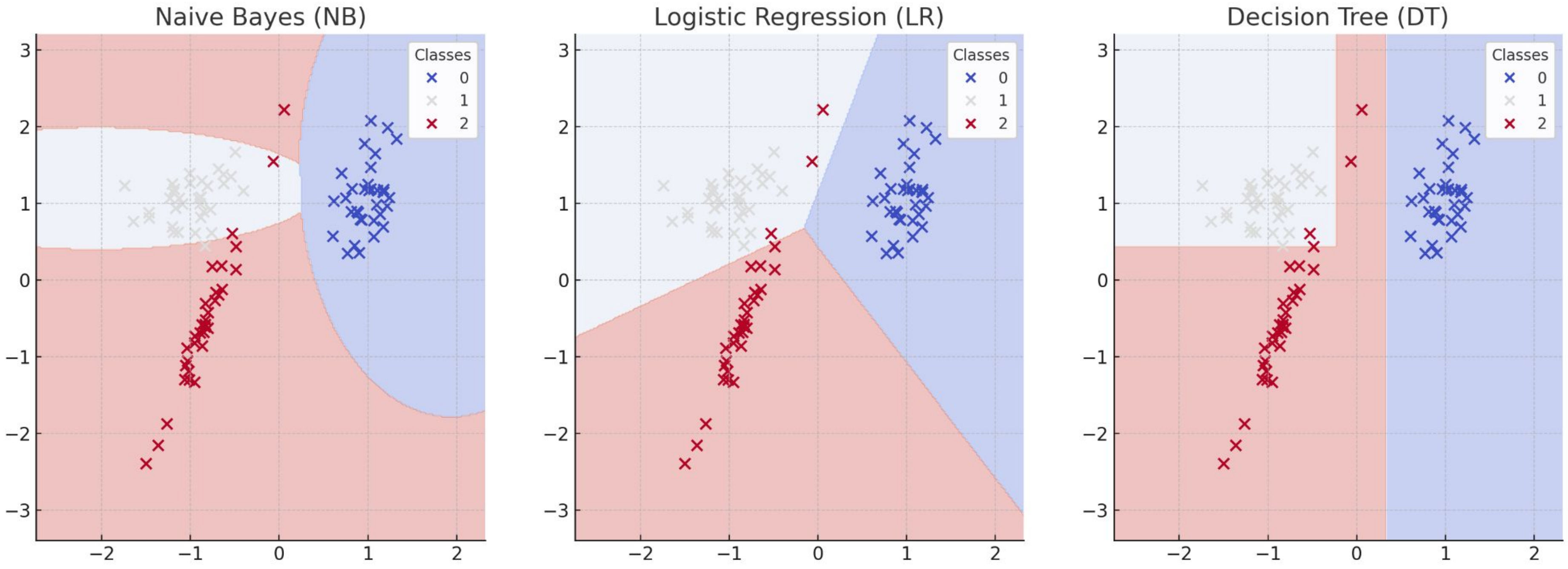
6-axis, smart, low-power Inertial Measurement Unit for high-performance applications

Key features

- Compact standard size LGA mold package, 14 pins, footprint 2.5x3.0mm² height 0.83mm
- Primary digital interface with 10 MHz slave SPI (4-wire, 3-wire) and up to 1MHz I²C (Fm+)
- Output data rates (ODR): 25 Hz ... 6.4 kHz (gyroscope) and 0.78 Hz ... 1.6 kHz (accelerometer)
- Programmable low-pass filter (accelerometer I gyroscope): bandwidth ca. 5 I 3 ... 680 I 890 Hz
- Wide power supply range: Analog VDD 1.71V ... 3.6V and independent VDDIO 1.2V...3.6V
- Ultra-low current consumption: typ. 685 µA (in full ODR and aliasing-free operation)
- Performance mode for gyroscope to minimize noise level: typ. < 8 mdps /√Hz.
- Built-in power management unit (PMU) for advanced power management and low power modes
- Rapid startup time: 2 ms for gyroscope (in fast start mode) and 2 ms for accelerometer

$$\text{Energy} = \sum_{i=1}^{\text{window\_length}/2} \text{magnitude}_i^2$$

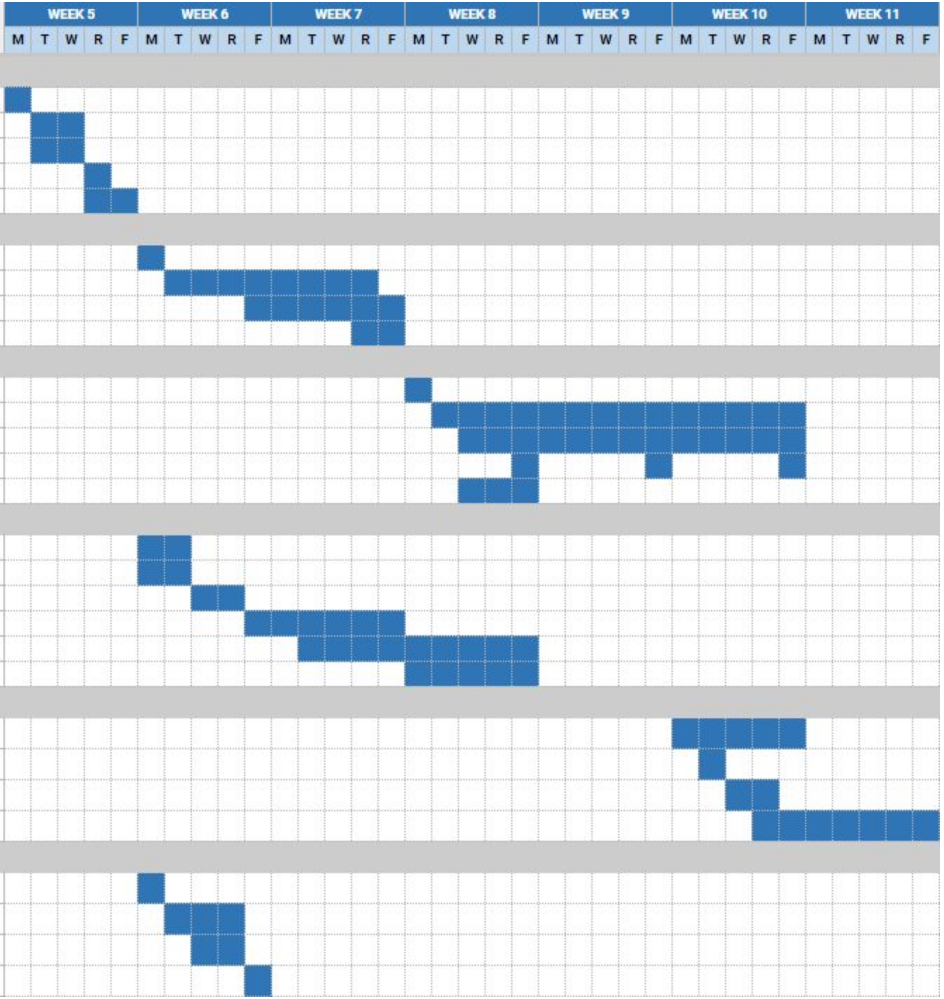
window length = all frame rate when recording
magnitude = FFT coefficients calculated over the time window



Naive Bayes (NB)
Logistic Regression (LR)
Decision Tree (DT)
Classes
0
1
2
3
2
1
0
−1
−2
−3
−2
−1
0
1
2

Milestones and Gantt Chart

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION
1	**Define gesture set and control mapping**				
1.1	Research common gestures	Jerome, Chen	Jun 24	Jun 24	1
1.2	List common smart-home devices		Jun 25	Jun 26	2
1.3	Research common smart-home controls		Jun 25	Jun 26	2
1.4	Select gestures for implementation		Jun 27	Jun 27	1
1.5	Map gestures to controls		Jun 27	Jun 28	2
2	**Collect sensor data for different gestures**				
2.1	Create data collection plan	Chen, Terry	Jul 1	Jul 1	1
2.2	Develop data collection program		Jul 2	Jul 11	10
2.3	Conduct data collection		Jul 5	Jul 12	8
2.4	Verify overall data accuracy		Jul 11	Jul 12	2
3	**Train a machine-learning model to identify gestures**				
3.1	Pre-process sensor data	All	Jul 15	Jul 15	1
3.2	Select and implement ML algorithm		Jul 16	Aug 2	17
3.3	Train model		Jul 17	Aug 2	16
3.4	Test model accuracy		Jul 19	Aug 2	14
3.5	Integrate model into wearable		Jul 17	Jul 19	3
4	**Control third-party smart-home devices with Bluetooth**				
4.1	Research BLE protocols of devices	Jerome, Haopeng	Jul 1	Jul 2	2
4.2	Research BLE communication libraries		Jul 1	Jul 2	2
4.3	Implement BLE connection		Jul 3	Jul 4	2
4.4	Implement BLE control command		Jul 5	Jul 12	8
4.5	Test BLE control accuracy and reliability		Jul 9	Jul 19	11
4.6	Implement BLE control through wearable		Jul 15	Jul 19	5
5	**Integrating gesture detection and Bluetooth commands**				
5.1	Optimise wearable code efficiency	All	Jul 29	Aug 2	5
5.2	Develop gesture-detection and BLE code		Jul 30	Jul 30	1
5.3	Test integrated code programatically		Jul 31	Aug 1	2
5.4	Test integrated code on wearable		Aug 1	Aug 9	9
6	**Create the housing for the components**				
6.1	Design enclosure	Haopeng, Terry	Jul 1	Jul 1	1
6.2	Create enclosure		Jul 2	Jul 4	3
6.3	Assemble prototype		Jul 3	Jul 4	2
6.4	Test wearability		Jul 5	Jul 5	1



Risk assessment

Risk	Likelihood	Impact	Mitigation
Team member leaves	Rare	Major	• Ensure proper documentation of all work completed and required tasks. • Assign multiple team members to each task • Encourage team members to be early on deadlines.
Team member sick	Moderate	Moderate	• Have backup plans for team members to cover for important tasks. • Work flexibly and remotely to involve sick team member(s). • Encourage team members to be early on deadlines.
Sensor data inaccurate	Moderate	Major	• Ensure calibration of sensors under various conditions • Filter and/or preprocess inaccurate data • Use multiple sensors or multiple devices with the same sensor to cross-verify accuracy
Gesture recognition model inaccurate	Unlikely	Major	• Ensure accuracy of training data • Continuously iterate and retrain the model with new data • Perform hyperparameter tuning to improve model performance • Explore other machine learning algorithms/techniques • Collect a large and diverse dataset
BLE communication unreliable	Unlikely	Moderate	• Ensure reliability in various environments, especially before important demonstrations or tests • Handle communication failures with reconnections and/or retransmissions • Implement fallback mechanisms, such as relaying via a third-party (e.g. laptop)

Risk assessment

Risk	Likelihood	Impact	Mitigation
Third-party device integration issues	Moderate	Major	● Thoroughly research compatibility between Arduino Nano and other third-party devices
High power consumption	Likely	Moderate	● Effectively use low-power modes and sleep states on Arduino Nano ● Optimise efficiency of algorithm/code to reduce unnecessary power usage in processing or communication
Hardware malfunction	Unlikely	Major	● Maintain spare components for quick replacement ● Use high-quality and reliable components from reputable suppliers ● Ensure careful handling and best-practice use of small and/or delicate components
Budget issues	Unlikely	Major	● Seek assistance or guidance from course staff/faculty ● Utilise resources/components available through the University
Project scope creep	Moderate	Moderate	● Clearly define project scope and objectives ● Regularly review project progress and adjust plans and tasks as required to fit deadlines
Intellectual property issues	Rare	Major	● Thoroughly research to ensure no infringement on IP rights

References

[1] Xu, C., Pathak, P.H. and Mohapatra, P., 2015, February. Finger-writing with smartwatch: A case for finger and hand gesture recognition using smartwatch. In Proceedings of the 16th international workshop on mobile computing systems and applications (pp. 9-14).
[2] Gangrade, J. and Bharti, J., 2023. Vision-based hand gesture recognition for Indian sign language using convolution neural network. IETE Journal of Research, 69(2), pp.723-732.
[3] Muneeb, M., Rustam, H. and Jalal, A., 2023, February. Automate appliances via gestures recognition for elderly living assistance. In 2023 4th International Conference on Advancements in Computational Sciences (ICACS) (pp. 1-6). IEEE.
[4] https://www.control4.com/os3/
[5] https://docwiki.embarcadero.com/IoT/en/Myo_Armband

Questions?