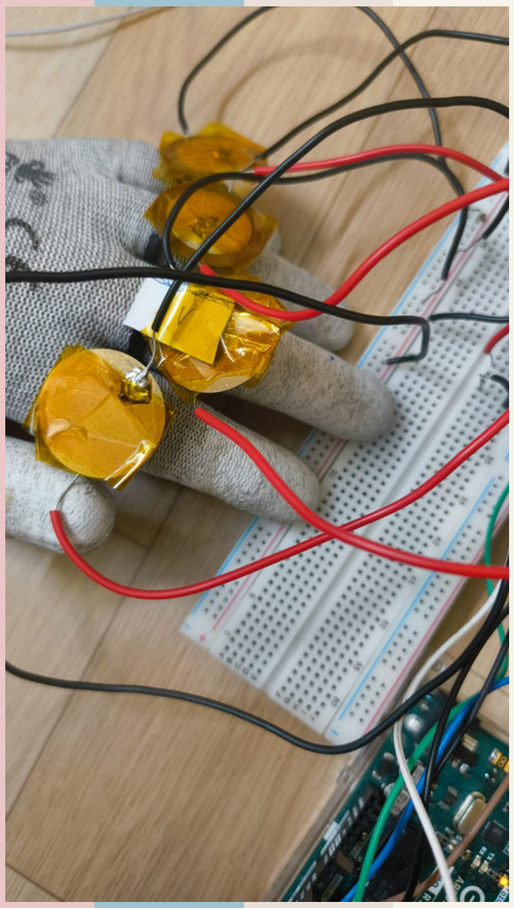


AI-DRIVEN SMART GLOVE

Guide: **Professor Prasanna Kumar S Mural**

MEMS, IIT BOMBAY | 2024

OVERVIEW

- Introduction
- Triboelectric effect
- Sensor I: Triboelectric sensor design, mechanism, circuit & challenges
- Piezoelectric effect
- Sesnor II: Piezoelectric sensor design, implementation
- Predictive model & visualization
- Conclusion & future improvements

INTRODUCTION

Objective:

To build a glove capable of detecting hand motion

Motivation:

Development of AI-enabled sign language predicting glove using 3D printed triboelectric sensors

Muhammad Wajahat[1], Abbas Z. Kouzani[1], Sui Yang Khoo[1], M. A. Parvez Mahmud[2,*]

Method:

Generated voltages using triboelectric and piezoelectric sensors on hand movement and classified the data using an AI model

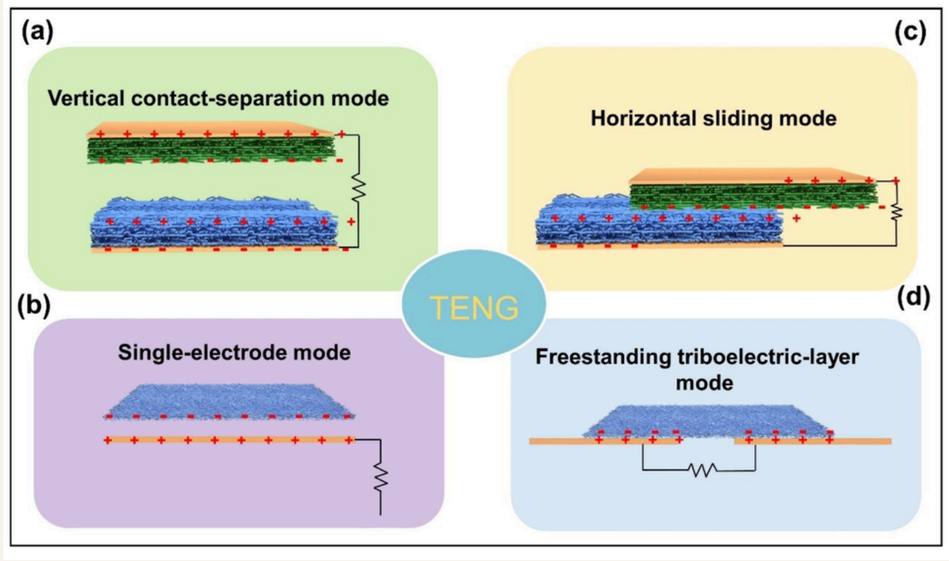
TRIBOELECTRIC MATERIALS

Triboelectric Effect:

- Definition: Generation of electric charge through friction between two materials.
- Mechanism: Works via contact electrification, where surfaces exchange electrons upon contact and separation.
- Applications: Common in energy harvesting, sensors, and self-powered devices due to its simplicity and versatility.

Configurations::

1. Vertical Contact Separation Mode
- Generates potential when two surfaces come into contact and then separate.
2. Horizontal Sliding Mode
- Generates potential when surfaces are rubbed against each other.
3. Single Electrode Mode
- Potential is generated through electron transfer to a single electrode.
4. Freestanding Triboelectric Mode
- Generates potential when one material slides over another, resulting in electron separation.



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MATERIAL USED AND WHY

PVDF (Polyvinylidene Fluoride):

- Reason: Exhibits strong triboelectric and piezoelectric properties, enhancing sensitivity in energy harvesting applications.

PLA (Polylactic Acid):

- Reason: Biodegradable and easy to print; selected for prototyping due to its good triboelectric response and environmental benefits.

Nylon:

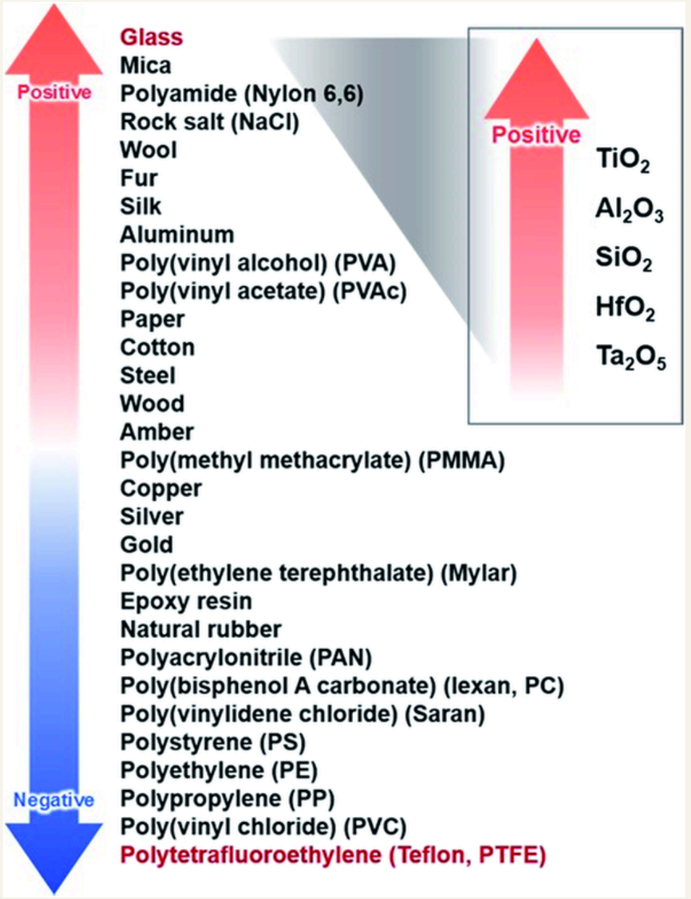
- Reason: High durability and flexibility, suitable for robust sensor designs where flexibility is required.

ABS (Acrylonitrile Butadiene Styrene):

- Reason: Strong triboelectric effect and excellent mechanical strength, ideal for applications needing resilience and impact resistance.

OHP SHEET(polystyrene)

- Reason: Transparent, durable, heat-resistant, smooth for writing, lightweight, and chemically resistant, making them ideal for projection and display use



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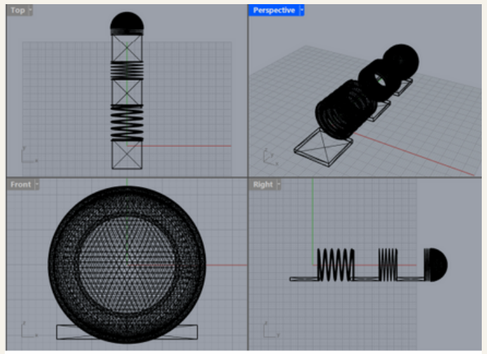
TRIBOELECTRIC SESNOR DESIGN

Material Preparation:

- Produced custom PVDF filaments in the polymer processing lab for optimal sensor performance(mention conditions and all).

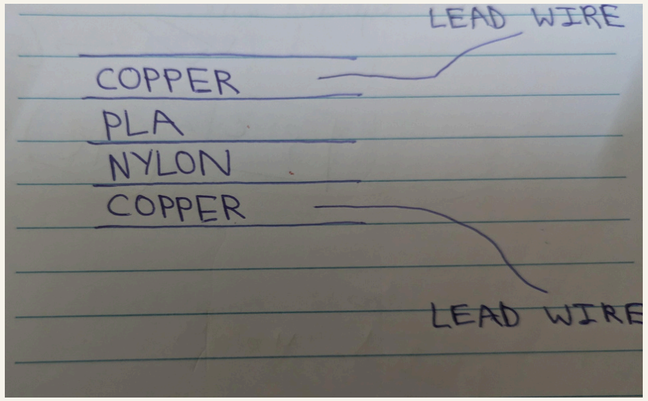


3D modellling and printing:

- Created detailed 3D models using Blender for accurate fabrication and visualization.
- Used Flashforge Guider IIs printer to fabricate multiple polymer strips, enabling testing of the triboelectric effect

Multi-Layer Structure and experimented with materials:

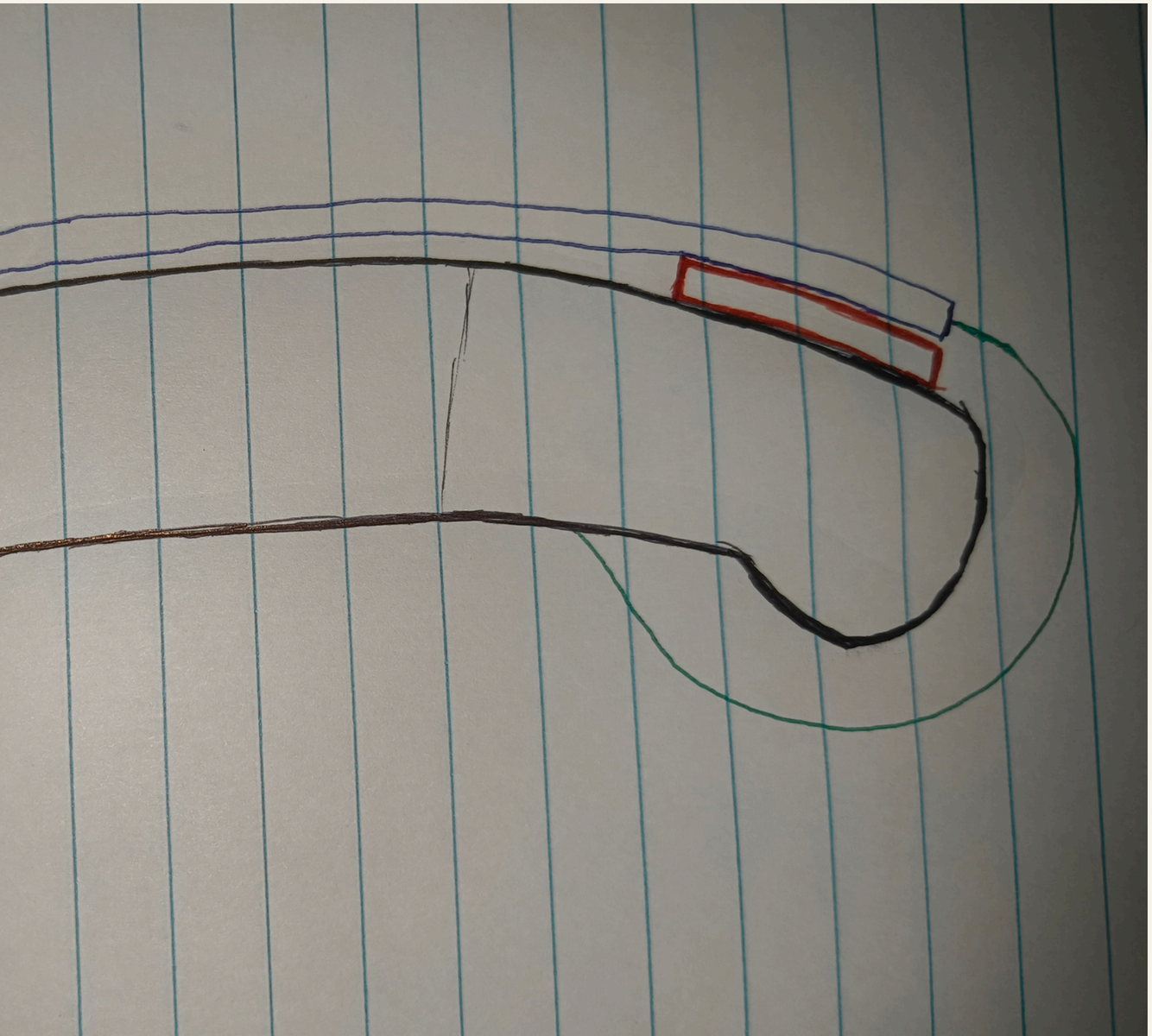
- Developed a layered configuration to enhance triboelectric behavior in a linear sliding setup.
- use combination of pair and identified Polystyrene is very compatible with PLA

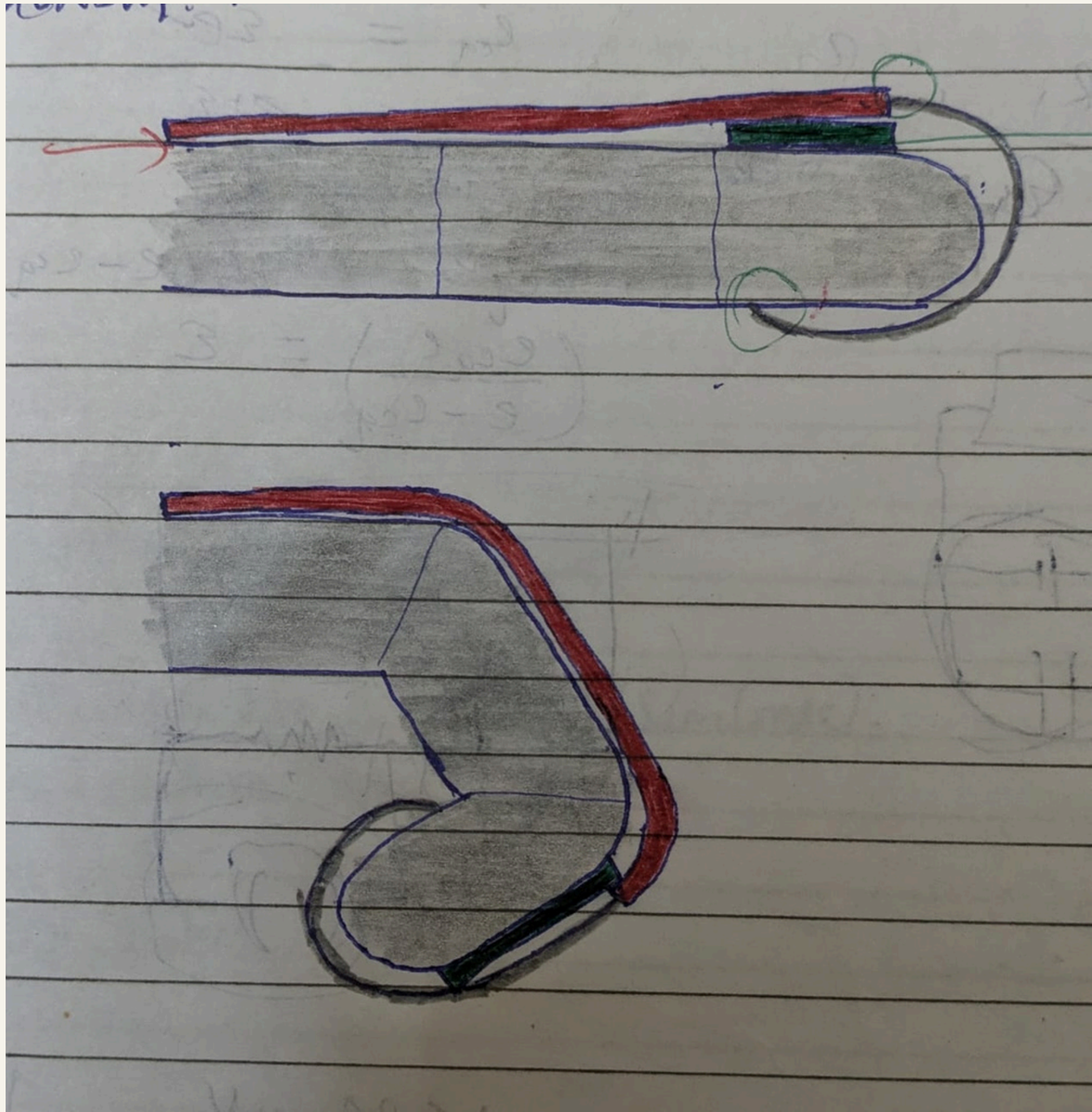


Design & configuration Finalization:

- Structural design completed through collaborative team discussions
- Utilizing horizontal sliding mode.

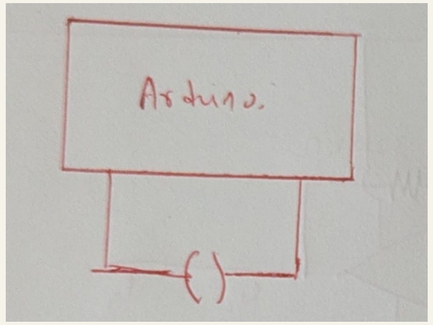
PROTOTYPE

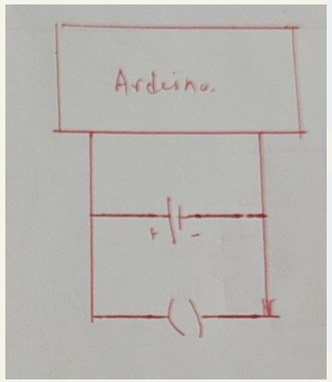


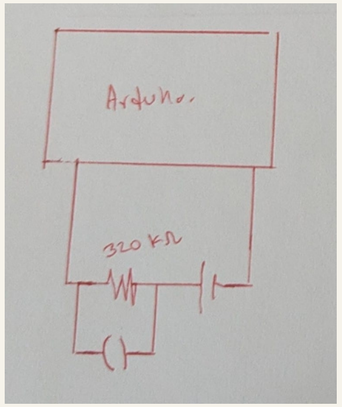


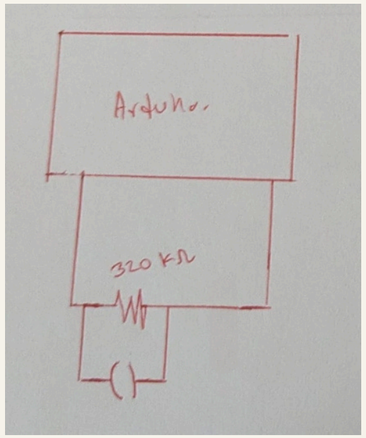
CIRCUITS USED & CHALLENGES

Circuit progress









Challenges

Arduino shows arbitrary voltage values in an open circuit

Need to design a circuit where we never have an open circuit condition.

Voltage generated was in the order of microvolt, which can’t be detected by an arduino

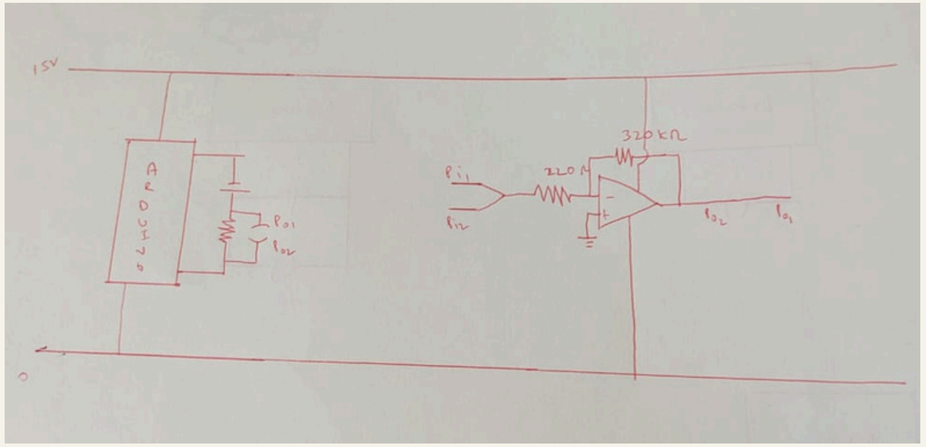
Conclusion

require to set a base value, to monitor the voltage generated from the polymer

require to amplify the voltage generated; as it is out of detectable range of arduino.

OP-AMP CIRCUIT

Circuit Changes



Op-Amp 751 was used

Challenges

The voltage after amplification was in order of millivolts, but Arduino detect voltage above 10 millivolts. (Least Count)

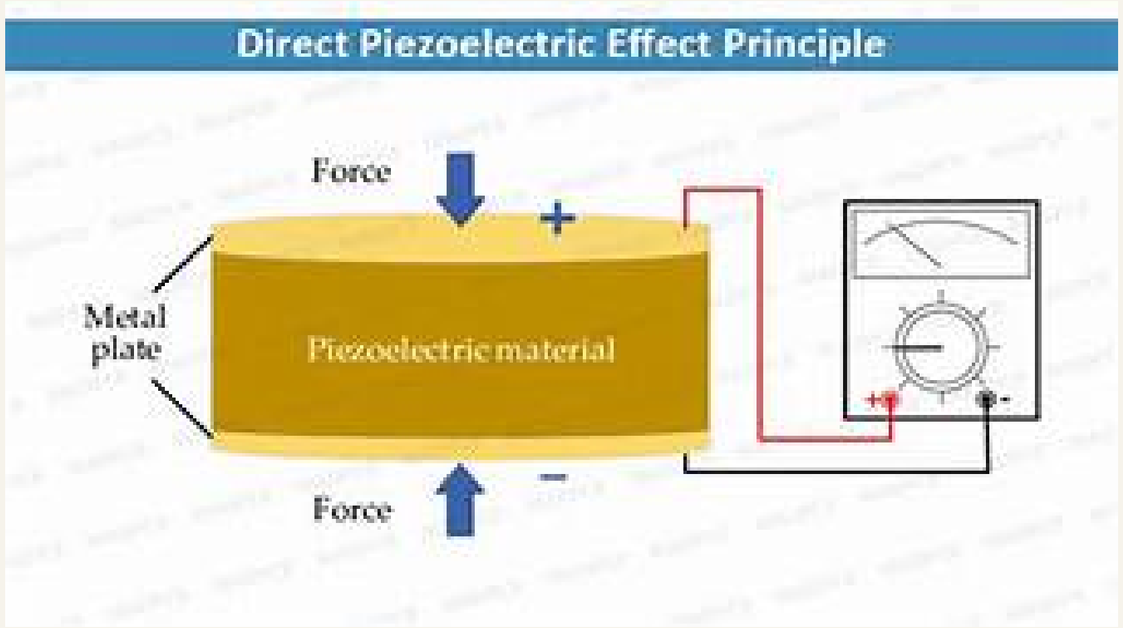
Conclusion

We can use better amplifiers but because of time constraints and increasing circuit complexity,
we shifted to piezo-sensors

Piezoelectric phenomena

Piezoelectric Effect:

- **Definition: Generation of electric charge in response to mechanical stress in certain material**
- **Mechanism: Stress or pressure alters the crystal structure, creating an internal electric field.**
- **Applications: Widely used in precision sensors, actuators, and energy-harvesting systems.**



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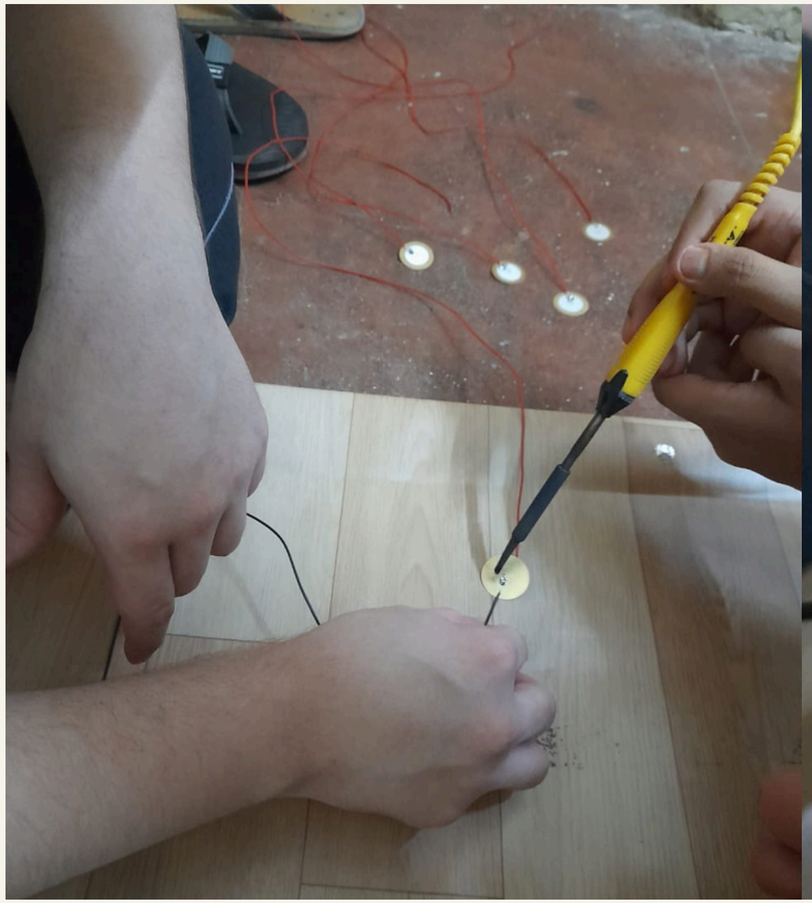
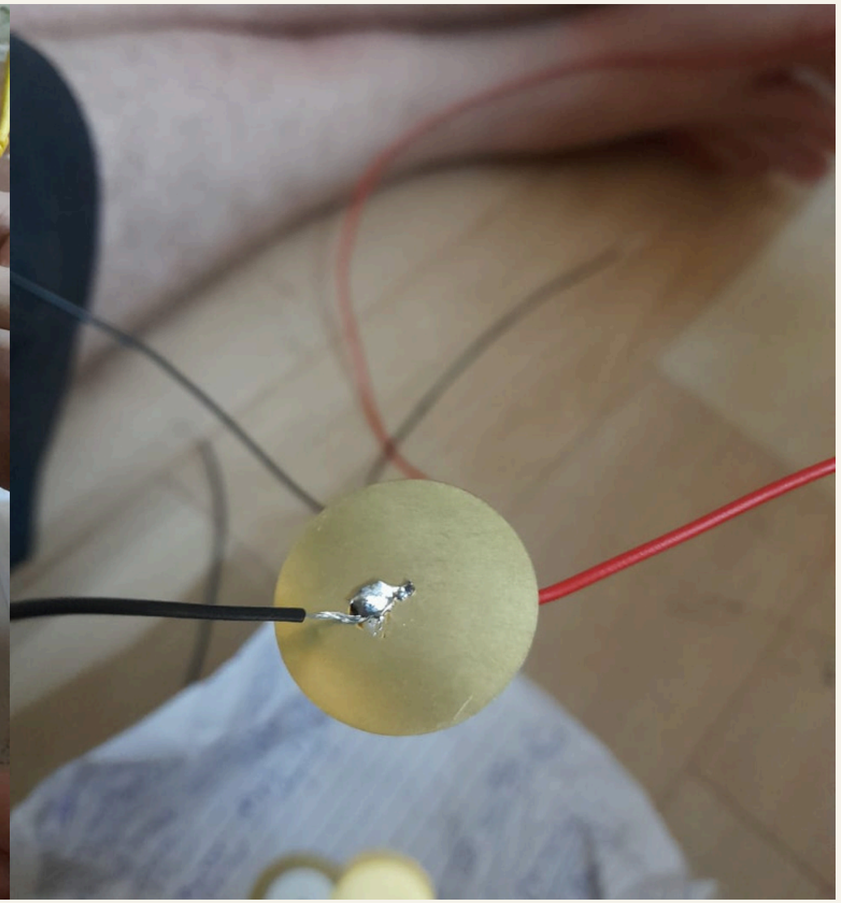
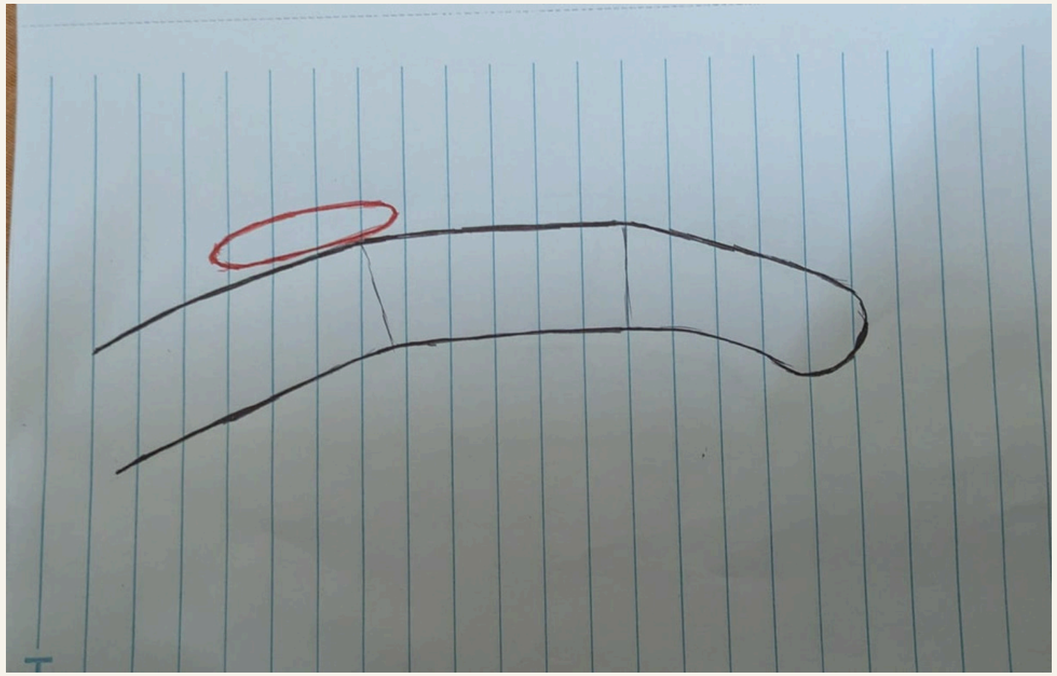
ADDITION OF PIEZOELECTRIC SENSORS IN GLOVE





To extract its electrical properties, we first soldered it using a standard soldering technique and then tested its properties using a manometer to measure the voltage generation range.

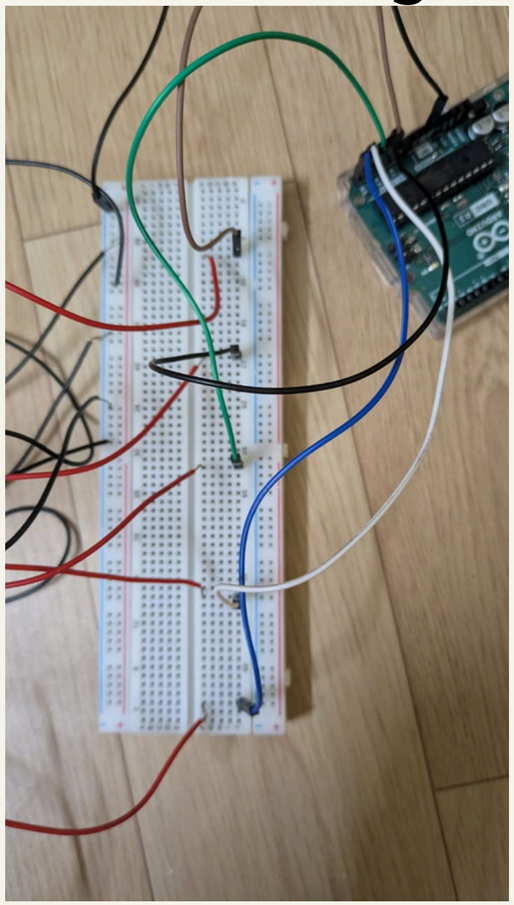
GLOVE WITH PIEZOELECTRIC SENSORS

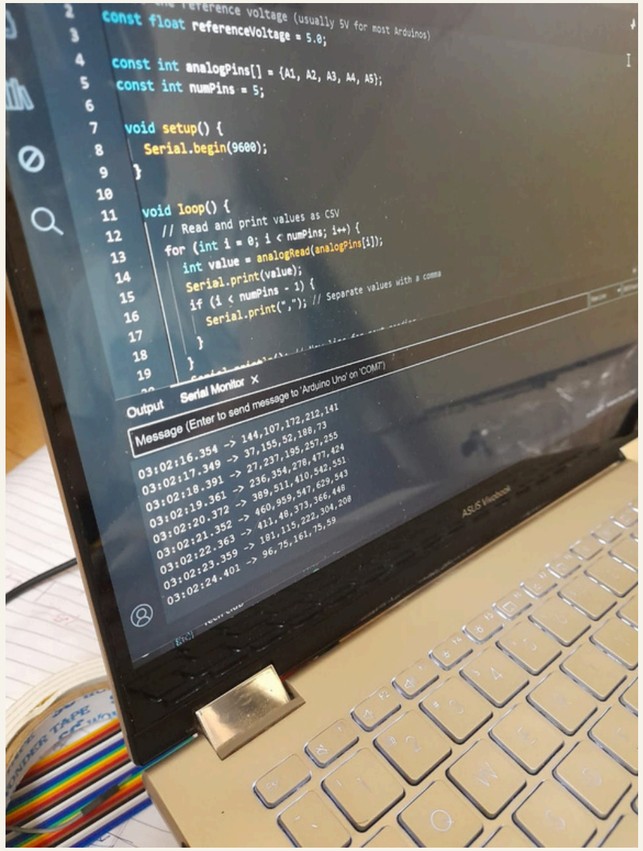


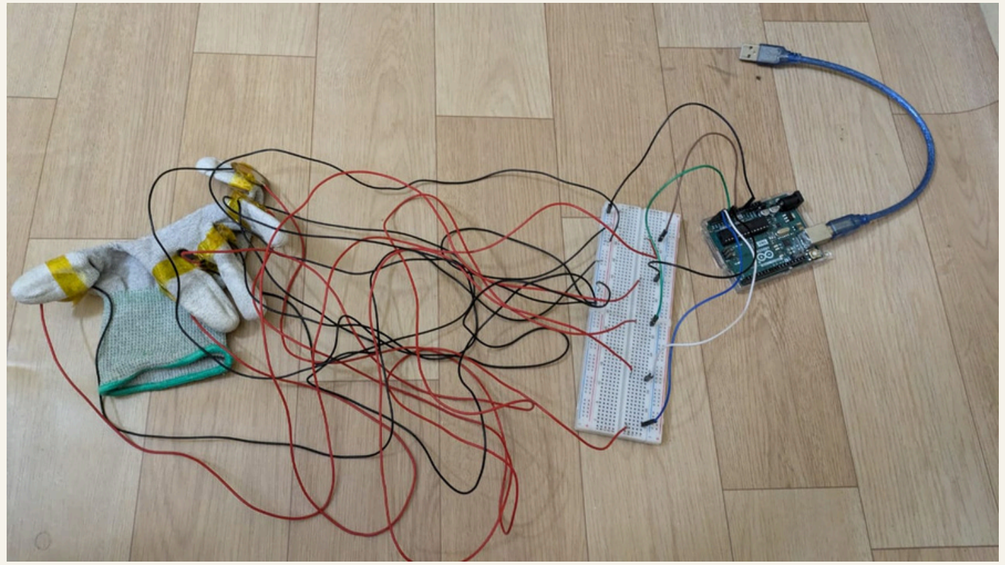
We placed this near the middle joint of the finger using Kapton tape, as this area experiences more bending stress. When the finger moves, it creates stress, and due to the bending motion combined with the Kapton tape mechanism, a potential of up to 2V was generated.

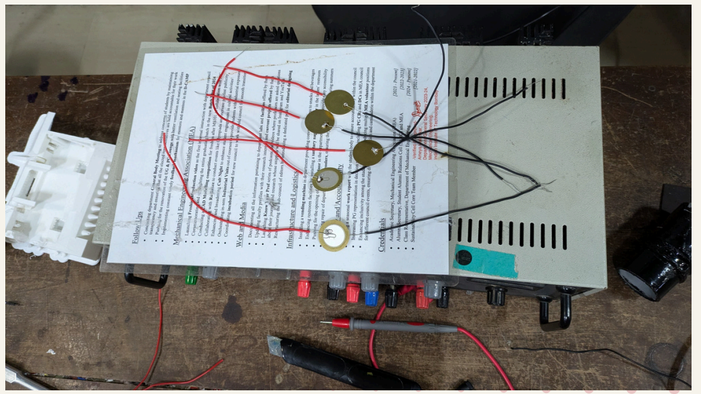
IMPLEMENTATION

Circuit design:





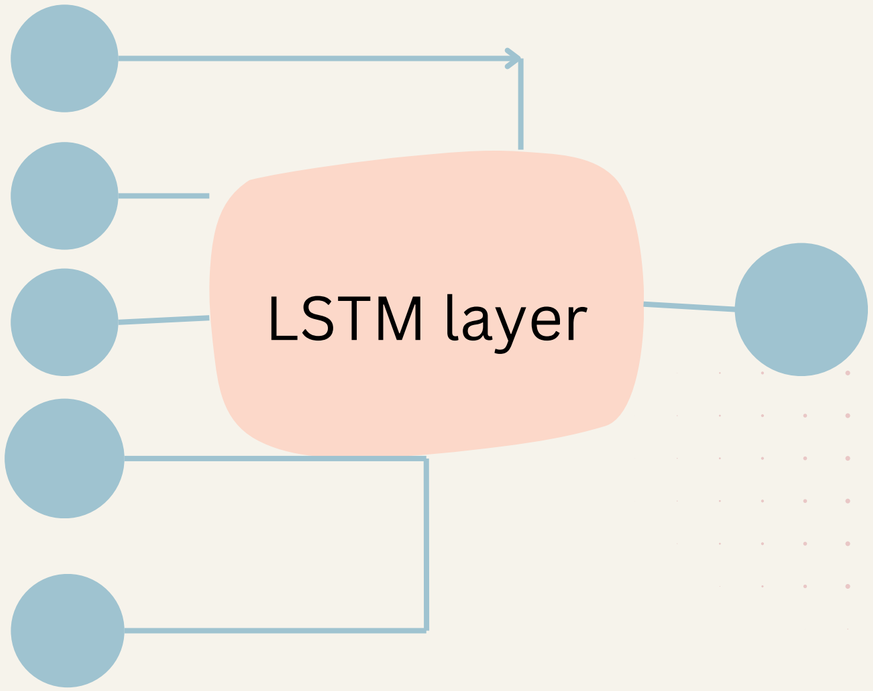




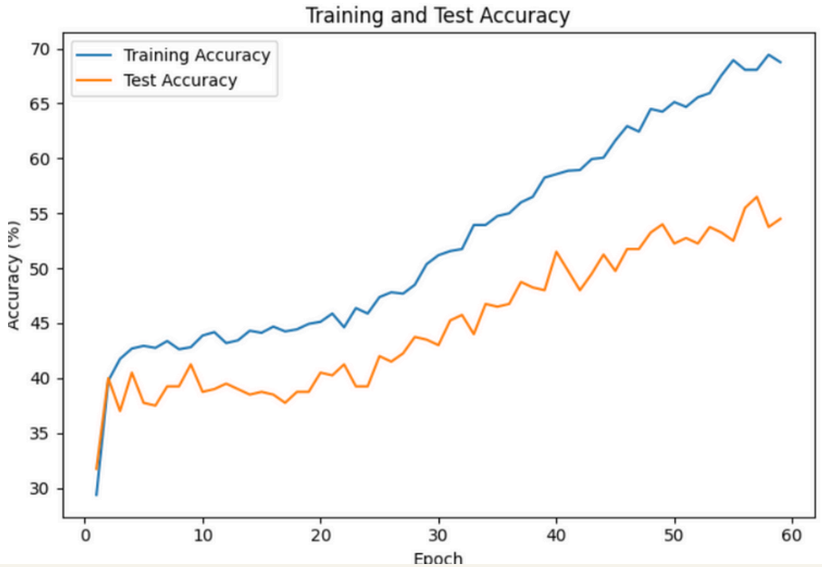
PREDICTION MODEL

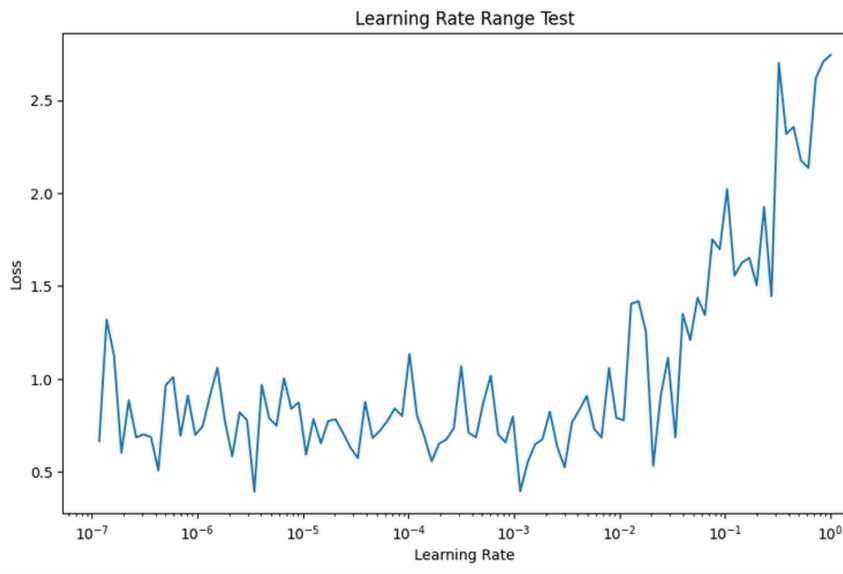
About model and synthetic data:
Input: Sequence of five values at five different times [5x5]
Output: Label (finger)
Model: LSTM layer

Testing Accuracy: 46 %



ADDITIONAL VISUALIZATION





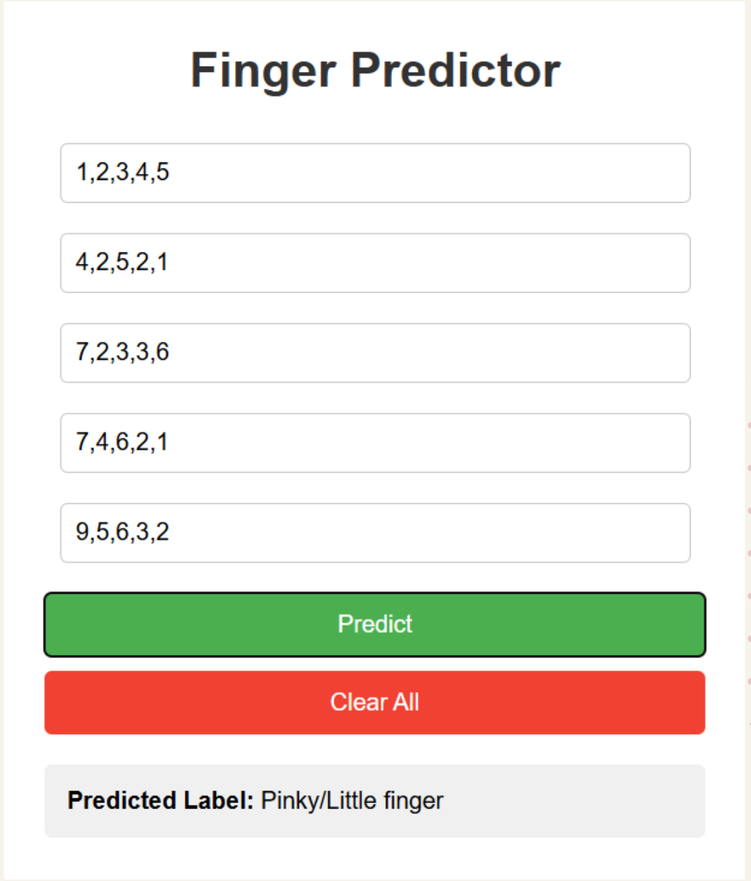
Hyperparameter tuned: Learning rate, epoch, synthetic data

WEB APPLICATION

Technologies used:

Front end - React (JavaScript)

Back end - Flask (Python)



CONCLUSION

- Sensor-Based Motion Tracking
  - Utilized piezoelectric sensors with Arduino to quantify finger motion
  - Real-time data capture enables detailed analysis and processing
- Adaptable Mechanism Design
  - Ring-free setup for flexibility in adaptable applications
- Data Capture and Augmentation
  - Collected time-sequential data at fixed intervals for precise motion timing and dynamics
  - Integrated synthetic data with real data to speed up model training and validation
- AI-Driven Motion Pattern Recognition
  - Applied LSTM networks and Self-Supervised Learning (SSL) for finger motion differentiation
  - Achieved enhanced accuracy and responsiveness in recognizing movement patterns

FUTURE WORK

- Use of Raspherry Pi/ ESP 32
- Use of intrumental amplifer
- Use of EEG signal from pulses
- Reusability and packaging
- Use of real time data

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DEMO TIME!!

THANK YOU

Our team:

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Jai (210110054)

Dev (210110038)

LITERARY REVIEW & RESOURCES

1. **“Development of AI-enabled sign language predicting**
glove using 3D printed triboelectric sensors” Muhammad Wajahat, Abbas Z. Kouzani1 , Sui Yang Khoo1, M. A. Parvez Mahmud*

2. https://people.ece.cornell.edu/land/courses/ece4760/FinalProjects/f2014/rdv28_mjl256/webpage/#:~:text=We%20designed%20and%20built%20a,translations%20regardless%20of%20those%20differences

3. Drive resources :
https://drive.google.com/drive/folders/1cRVClPs9fimA5zLxJXl9ex43f2y4njQU