Smart Insole for Gait and Posture Analysis

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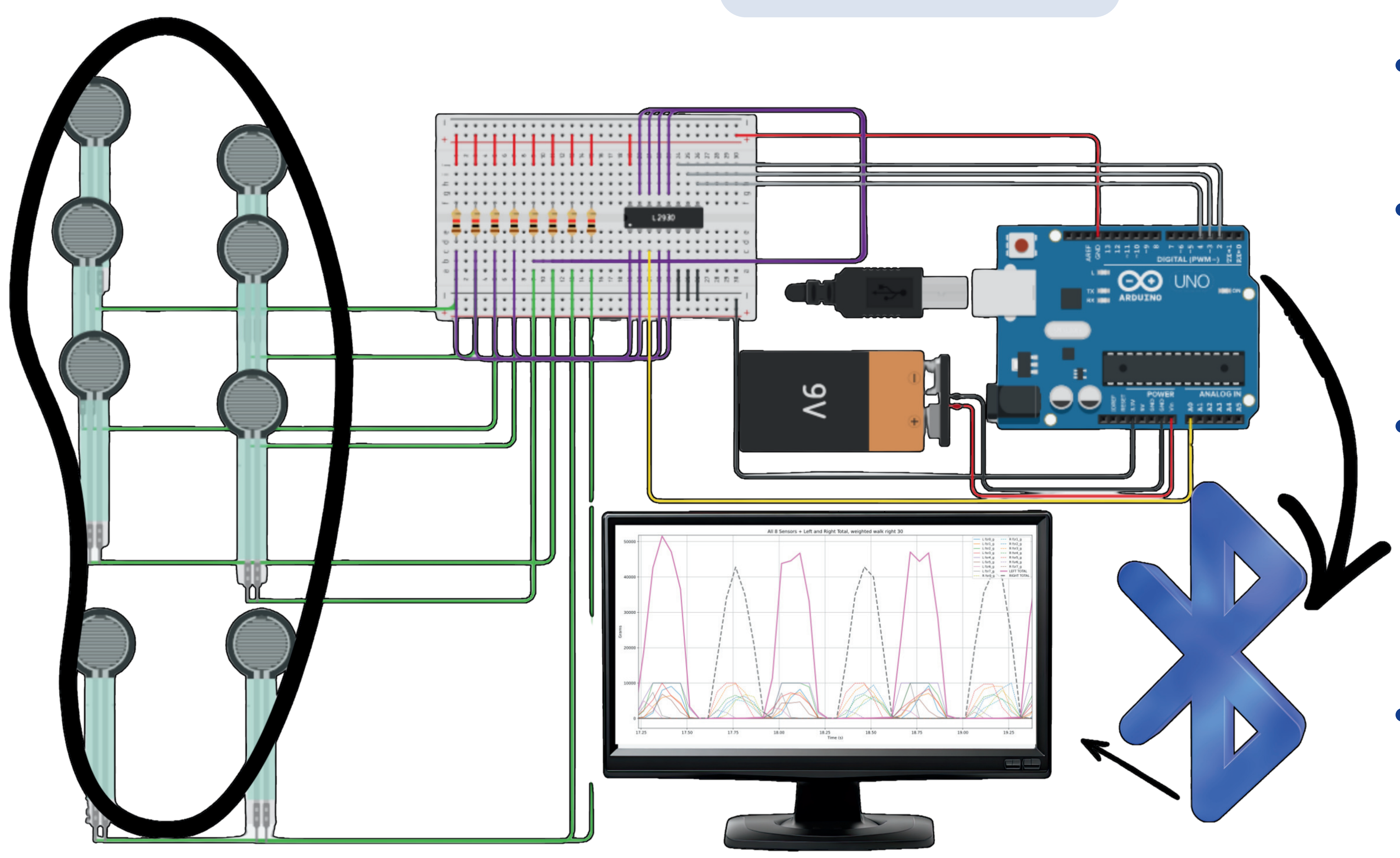
Motivation

Real-time, wearable monitoring for early injury detection and prevention.

Design Requirements

- Measure pressure at multiple locations
- Be wearable inside a shoe + compact
- Support real-time data acquisition
- Be portable +with battery-powered
- Support wireless communication
- Durable for repeated testing
- Produce data for pattern recognition

Our system

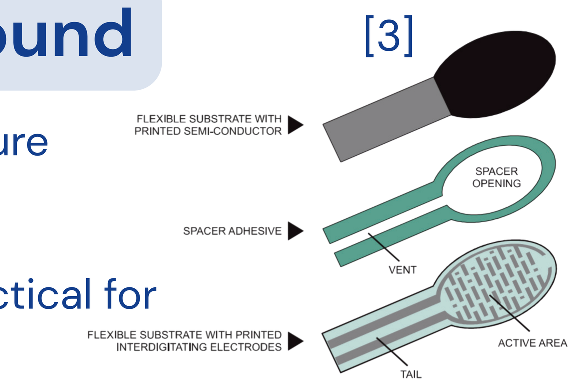


- Two insoles, left + right
- 8 FSR sensors per foot
- 2 Arduino Nano microcontrollers
- PVC foam sleeves attaachable to shin bone with velcro tape
- BLE packet transmission: sync byte, device ID, timestamp, 16 total sensor readings
- Real-time data processing, recording into CSV files

Problem Definition & Background

- Gait and posture problems affect plantar pressure distribution and asymmetry [1]
- Existing lab-based gait analysis tools aren't practical for daily monitoring.
- **Project goals:** 1. develop a dual-insole system capturing plantar-pressure data in re time 2. uses the system to identify abnormal movement patterns
- Brief background on FSR sensors: they change resistance when force is applied

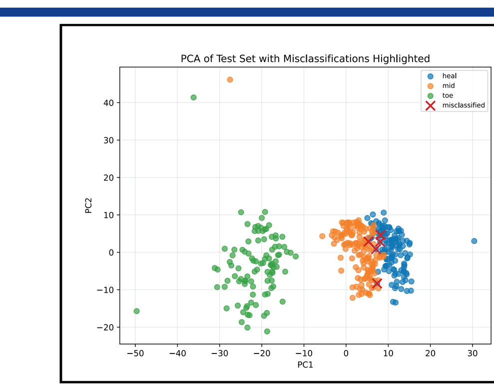
[3]

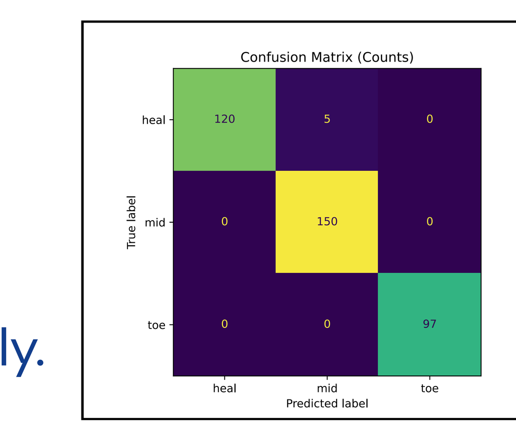


FSR sensor

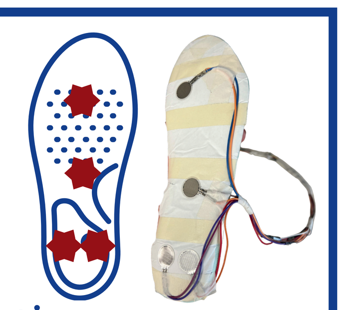
Machine Learning

Using a Random Forest Model, we were able to classify running strike type. PCA here shows good class separation with minor overlap near boundaries. The confusion matrix shows high accuracy, with most predictions classified correctly.





Design Alternatives

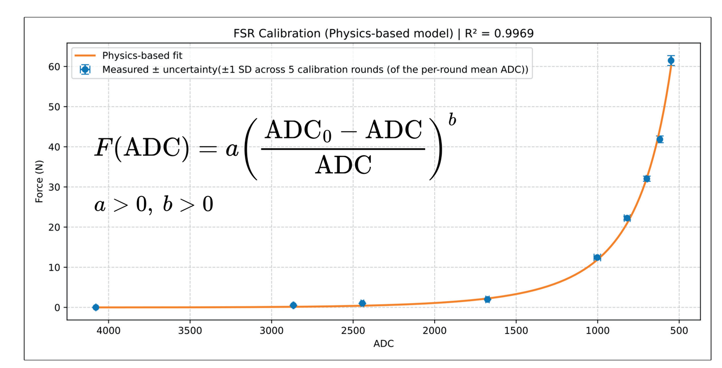


- Single insole vs dual insole,
- 4 vs 8 sensing points in differetn configurations
- Controller options: Arduino Uno from first semester vs Arduino Nano setup adopted later
- Wired bench setup vs portable battery-powered / BLE-based system
- Output options: raw ADC-only recording vs calibrated force output

Calibration

$$ADC = ADC_{max}\frac{V_{out}}{V_{cc}} \qquad R = kF^{-n}$$

$$ADC = ADC_{max}\frac{R}{R+R_f}$$



A two-layer calibration was used:

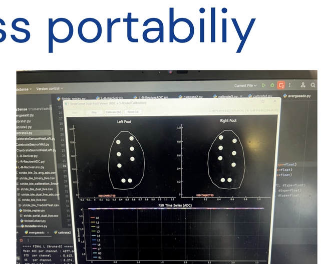
- Repeated measurements ensured stable sensor readings (5, 20s long sets).
- Averaged ADC responses were fit to a nonlinear model to map sensor output to force

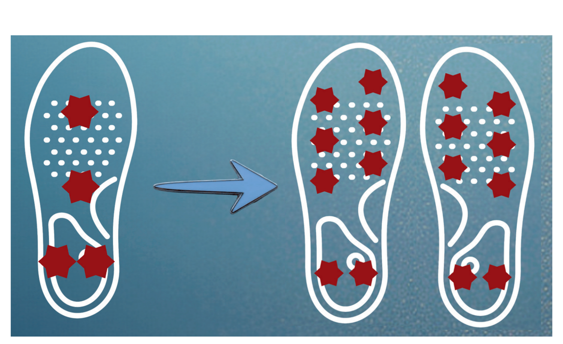
Discussion, Conslusions, Recommendations

We produced a working dual-insole system for real-time plantar-pressure monitoring. Calibration enabled force estimation from raw sensor data. Results showed asymmetry and movement patterns analysis. Future work includes upgrading the wearable, expanding testing, adding new pattern recognition.

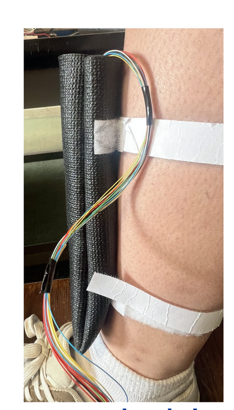
Iterative Process

- Switched from 4 sensors per foot to 8
- Switched to smaller microcontrollers
- Updated from 5 kgf to 50 kgf to 10 kgf sensors
- Started from single-insole, added the second
- Upgraded interface, displayed 16 channels
- Ran calibration multiple times
- Added wireless portabiliy

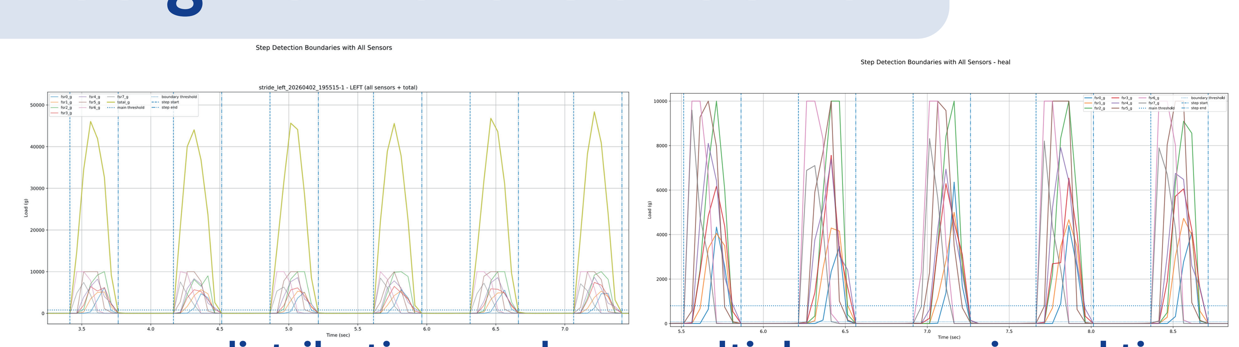




Final Design & Data Collection



attachable shin sleeves

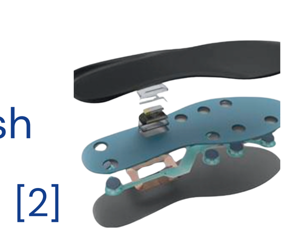


pressure distribution graphs on multiple sensors in real time

With both insoles placed into running shoes, the subjects were instructed to perform a set of movements - including standing, walking (with optional addition of assymetric loading), and running with and without different enforced gait patterns for analysis and data for ML model

Design Evaluation

We evaluated ensor repeatability, calibration accuracy, signal stability, performance. The system could successfully distinguish standing, walking, and running, along with gait patterns.



[2]

Acknowledgements

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- Professor Cheng for advice
- TRAVELLERS for sponsorship
- Professor Palladino for providing LiPo batteries

References

[1] Fry, Andrew C., et al. "Validation of a motion capture system for deriving accurate ground reaction forces without a force plate." Big Data Analytics 1.1 (2016): 11.

[2] Gawande, Prashant & Deshmukh, Amol & Dhangar, Rameshwari & Gare, Komal & More, Shital. (2020). A SMART FOOTWEAR SYSTEM FOR HEALTHCAREAND FITNESS APPLICATION – A REVIEW. Journal of Research in Engineering and Applied Sciences. 05. 10-14. 10.46565/jreas.2020.v05i01.003.

[3] Mbed, "FSR image 2," image. Accessed: Apr. 6, 2026. https://os.mbed.com/media/uploads/saporiti/fsrimage2.jpg