LEVERAGING MACHINE LEARNING WITH NANO-COMPOSITE BASED WEARABLE SENSORS FOR PHYSICAL REHABILITATION

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Introduction

- In the US, **2 million amputees** require prosthetics and managing effective weight balance during rehab is crucial to heal injuries.
- Utilizing a **nano-composite based textile sensors** for precise weight monitoring in limb rehabilitation.

- Pioneering a **patented sensor technology** that captures key gait aspects in real-time for an ML model.
- Targeting enhanced rehab methods and faster recovery via precise activity analysis and anomaly detection.

Objective

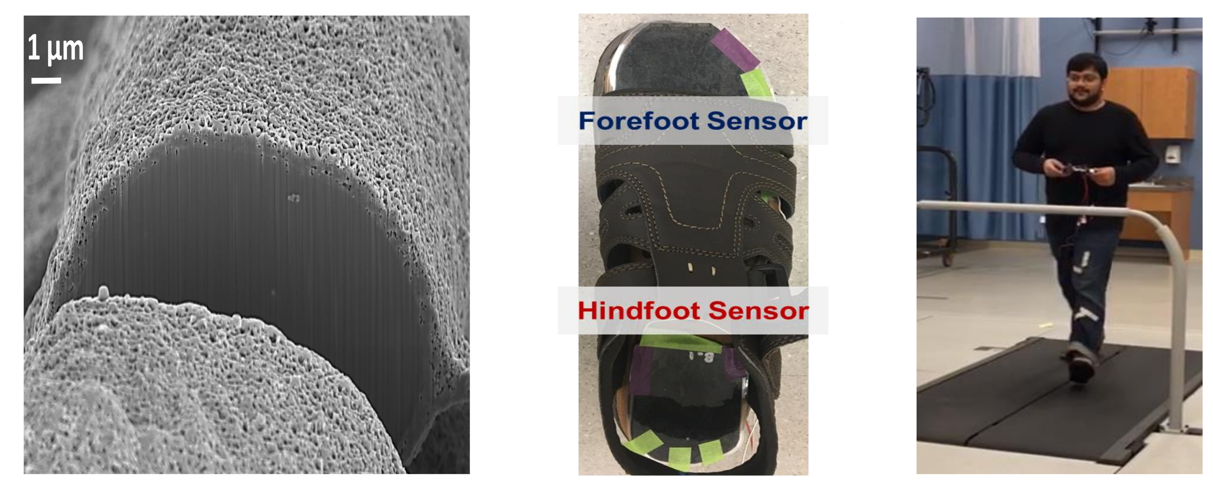
The key objective is to extend **advanced Machine Learning (ML) techniques to analyze data collected from our wearable sensors to evaluate critical gait parameters** such as load, walking surfaces (flat, up/down the stairs), walking speed, heel strike, and other abnormal gait events.

Methodology

- Integrating flexible sensors into footwear to record resistance shifts while walking.
- Utilizing the resulting dataset to train ML models to classify walking activities and estimate gait features.

Wearable Sensors → Data Processing using ML → Gait Features

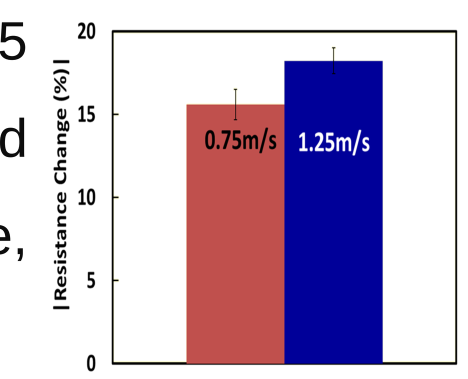
Sensor Integration



- Footwear with sensors captures unique walking patterns.
- 2 Sensors - heel and toe. Sensor values compared to force plate showed promising results.

Dataset

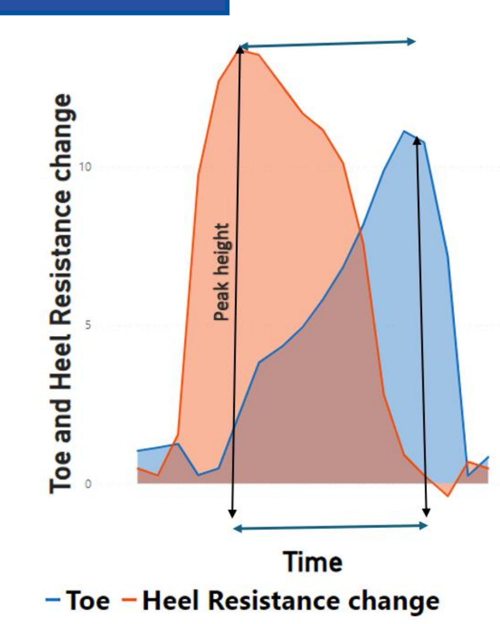
- 7 subjects, walking at 0.5, 1.0, and 1.5 m/s, 6 trials each on flat ground and another 13 walking on flat surface, upstairs and downstairs conditions.



- Resistance values, differentiated by heel and toe readings.

Feature Extraction

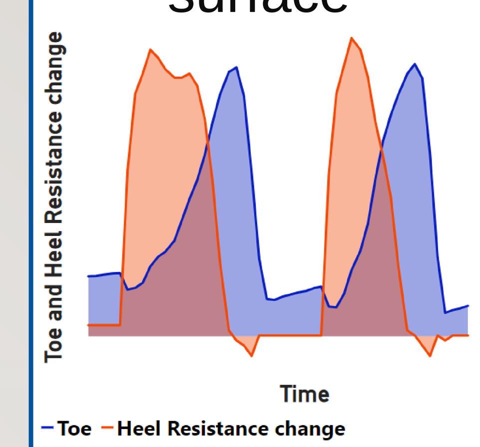
- Sensor max resistance value
- Peak resistance difference
- Time between peaks
- First peak sensor Indicator
- Area under the curve



Steps are isolated using local minima, set window size from which critical features are extracted for gait analysis.

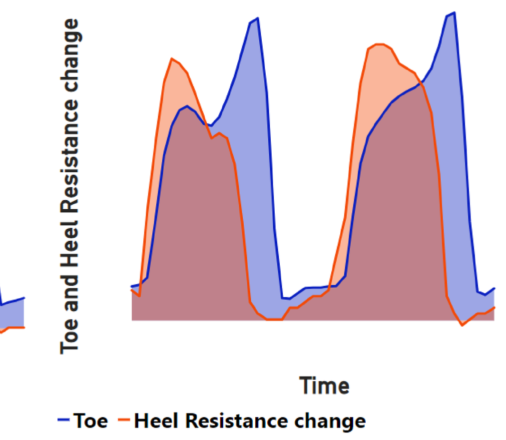
Pattern Analysis

Walking on flat surface



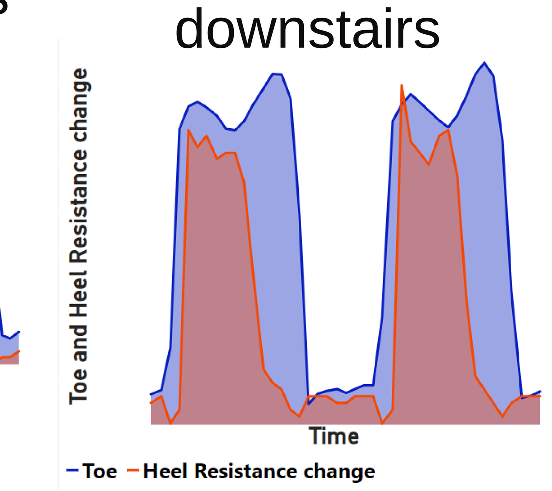
Heel pressure peaks first and then toe indicating flat steps

Walking upstairs



Simultaneous heel and toe pressure indicating up steps

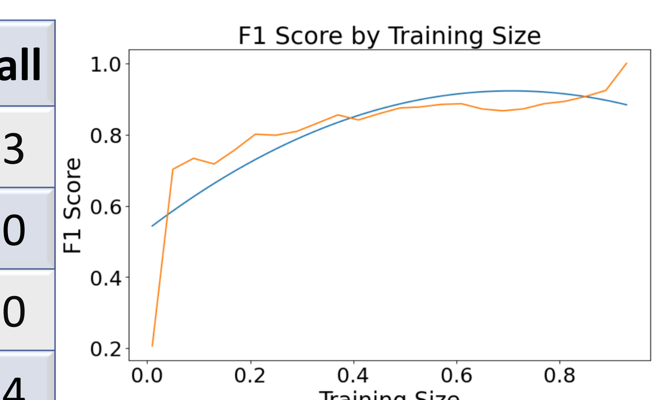
Walking downstairs



Toe pressure peaks first, as the foot reaches down steps

Results

Data	#Steps	ACC	F1	Prec	Recall
P1	74	0.93	0.90	0.88	0.93
P2	59	0.50	0.45	0.49	0.50
P1-P5	347	0.90	0.89	0.90	0.90
All 13	3337	0.94	0.94	0.94	0.94



- Classification results have high F1 scores; However, user-specific models perform inconsistently.
- E.g., Participant 2(P2) shows an unusual walking style that results in less heel pressure on stairs compared to others.
- We also observe strong model performance even as the training dataset size varies (Figure, Right).

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