Smart Socks for Physical Activity Recognition

ELEC-E7840 Smart Wearables — Topic 3

PRELIMINARY PLAN — FOR TEAM DISCUSSION

This document outlines our initial approach and task breakdown. Please review and bring your feedback, questions, and suggested modifications to our next meeting. All assignments are flexible and open for discussion.

1. Project Overview

As a 3-person team, we must recognize all five activity categories:

• Walking: forward/backward detection + step counting

• Stair climbing: up/down detection + step counting

• Sitting: feet on floor vs. cross-legged

• Sit-to-stand: detection + timing (seconds)

• Standing: upright vs. leaning left/right

Constraint: Textile-based sensors only (pressure, bend, strain). No IMUs permitted.

2. Team Strengths & Suggested Roles

Team Member	Key Strengths	Suggested Focus Areas
Saara	ML, biosignals, crafts, writing	Feature engineering, model development, sensor fabrication, documentation
Alex	Physical prototyping, user testing, design, CAD	Sock integration, wearability testing, user studies, design iteration
Jing	Systems integration, EE background, hardware/software	Circuit design, ESP32 programming, architecture, coordination

Note: These are suggestions based on stated backgrounds. Feel free to propose adjustments.

3. Technical Approach Summary

3.1 Sensing Strategy

Most activity distinctions reduce to **pressure distribution across the foot** plus **temporal patterns**. We propose 5 pressure sensing zones per sock (10 total channels):

• Heel — ground contact timing

• Arch — weight distribution

• Metatarsal medial — inside forefoot

• Metatarsal lateral — outside forefoot

• Toe — push-off detection

3.2 Hardware Architecture

Piezoresistive fabric sensors → Voltage divider circuit → ESP32S3 ADC → Serial/BLE → Computer → ML classification

3.3 Software Pipeline

• Data collection: Arduino sketch sampling all sensors at 50+ Hz

• Preprocessing: Calibration, filtering, normalization

• Feature extraction: Time-domain statistics, pressure ratios, temporal patterns

• Classification: Multi-class ML model (likely Random Forest to start)

• Step counting: Peak detection algorithm running in parallel

4. Project Phases & Timeline

Phase 1: Sensor Characterization (Priority: HIGH)

Before committing to a design, we must understand our piezoresistive fabric's behavior.

Task	Description	Suggested Lead
Build test sensor	Cut 2×2cm piezoresistive + two 2.5×2.5cm conductive squares, assemble sandwich structure	Saara
Set up ESP32	Install Arduino IDE, configure ESP32S3 board, verify basic serial communication	Jing
Wire test circuit	Voltage divider with 10kΩ resistor, connect to breadboard and ESP32 ADC	Jing
Run characterization	Apply known weights (100g to 5kg), record ADC values, test response time	All
Analyze results	Plot pressure vs. ADC curve, assess sensitivity, check hysteresis and recovery time	Saara
Document findings	Photos of setup, data plots, key measurements	Alex

Phase 2: Prototype Design & Fabrication

Task	Description	Suggested Lead
Finalize sensor layout	Decide sensor count/placement based on characterization results	All (decision)
Cut all sensor pieces	Precise cutting of piezoresistive and conductive fabric for both socks	Saara
Design sock integration	Plan how sensors attach to sock, wire routing, ESP32 mounting	Alex
Research reference designs	Review papers from MyCourses reading list, identify useful approaches	Alex
Assemble prototype v1	Build first functional sock with sensors	Saara + Alex
Circuit implementation	Full circuit for all sensors, verify all channels read correctly	Jing
Wearability assessment	Initial comfort check, movement restriction, wire interference	Alex

Phase 3: Data Collection (Mid-term deliverable)

Task	Description	Suggested Lead
Write collection software	Arduino sketch + Python receiver for labeled data recording	Jing

Define collection protocol	Exact activities, repetitions, rest periods, labeling scheme	Saara
Recruit subjects	Minimum 8-9 people (6 train, 3 test), diverse foot sizes/gaits	All
Run collection sessions	Record all 5 activity types + unknown class for each subject	All
Video synchronization	Record video for ground truth labeling and step counting verification	Alex
Data organization	File naming, backup, initial quality check	Saara

Phase 4: Machine Learning & System Integration (Period IV)

Note: Saara and Alex are completing Period III only. These tasks will primarily fall to Jing, but early input on feature design is valuable.

Task	Description	Lead
Feature engineering	Extract time-domain, frequency, and ratio features	Jing (Saara input)
Model training	Train/validate classifier, tune hyperparameters	Jing
Real-time pipeline	Deploy model for live classification	Jing
Step counting algorithm	Implement and validate peak detection	Jing
System integration	End-to-end: sensor → display	Jing

Phase 5: User Testing & Final Evaluation

Task	Description	Lead
Test on held-out subjects	Evaluate accuracy on subjects not in training set	Jing
Wearability study	WEAR Scale + SUS questionnaire with 5+ users	Jing
Confusion matrix analysis	Document per-class accuracy, failure modes	Jing
Final presentation	Slides covering all required sections	Jing

5. Materials Inventory

Item	Status	Notes
Piezoresistive fabric	Have (~16×16cm)	May need more for both socks
Conductive fabric	Have (2 pieces)	For electrodes
Conductive thread	Have (1 spool)	For sewing connections
ESP32S3 XIAO	Have (1)	Single board for both feet
Breadboard + wires	Have	For prototyping
Alligator clips	Have	Useful for quick testing
Resistors	Have	Need to verify values (10kΩ, etc.)
Sock	Have (1)	Need second sock for pair
Multimeter	Available at school	For resistance measurements
Scissors, needle, thread	Available	For fabrication

6. Questions for Team Discussion

• Are the suggested role assignments reasonable given everyone's interests and availability?

• What is our preferred meeting schedule? (Weekly in-person at Aalto + async?)

• Should we create a shared workspace (Google Drive, Notion, etc.) for documentation?
• Do we have access to enough test subjects for data collection?
• Any concerns about the 5-sensor-per-foot design? Should we start simpler?
• What's our contingency if the piezoresistive fabric has poor characteristics?

7. Proposed Next Steps (Before Next Meeting)

• **All:** Review this document and prepare feedback/questions
• **All:** Confirm availability for in-person working sessions
• **Jing:** Set up ESP32 development environment, verify basic functionality
• **Saara:** Prepare to build test sensor at next session
• **Alex:** Find 2-3 reference smart sock/insole designs from course reading list

> *This plan is a starting point for discussion. All tasks, assignments, and approaches are open for modification based on team input. Looking forward to your feedback!*