A Wearable System for Posture Monitoring: High-Fidelity Validation via 4D Scanning

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The Problem: Poor posture from office work is a major health concern

- A growing concern that comes with complications in the long term
- Leads to chronic back pain and musculoskeletal disorders
- How to provide continuous, real-time feedback in a casual setting?

Our Proposed Solution: A smart Garment

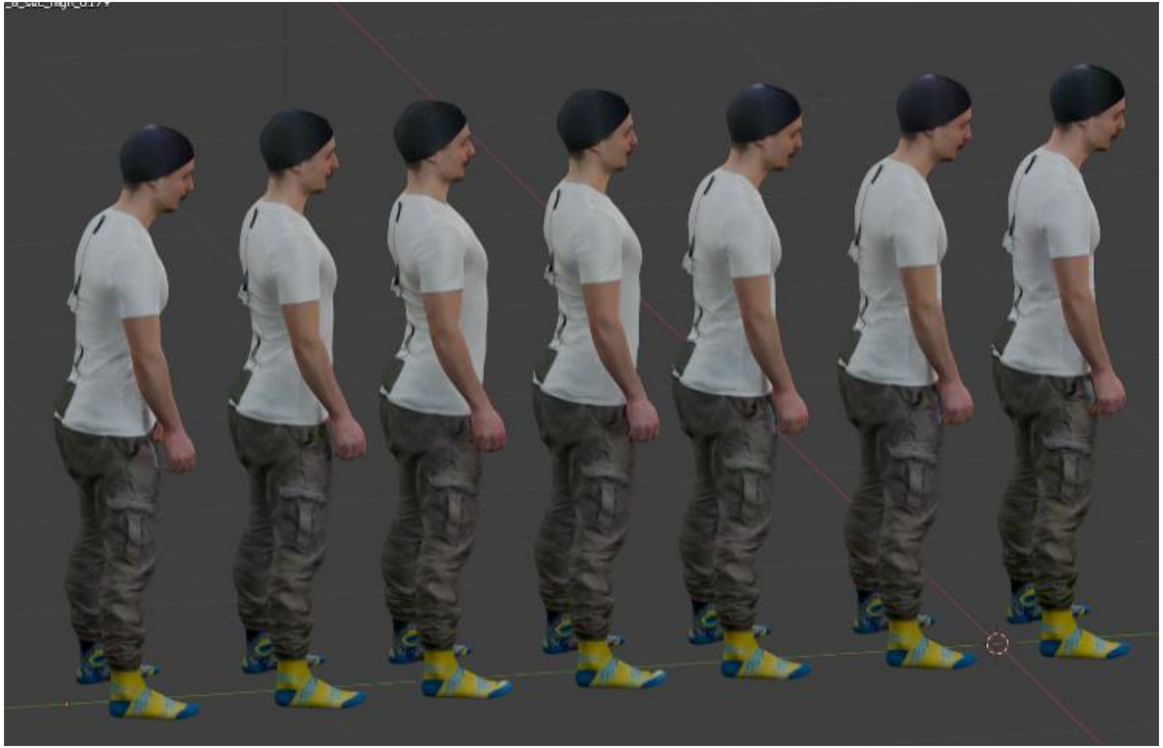
- **Concept:** a smart T-shirt with integrated sensors to monitor spinal posture
- **Goal:** Provide immediate, intuitive feedback to the wearer.
- **Key Question:** How do we know it is accurate?

4D Scanning - Measuring movement

High-fidelity validation of IMUs

We have used a 4D body scanning system as the **ground truth**.

The goal: compare the IMU sensors' output against the scan. How accurate are the results?

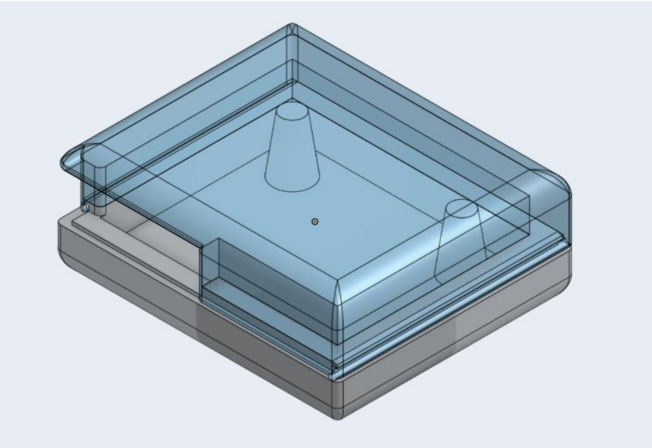


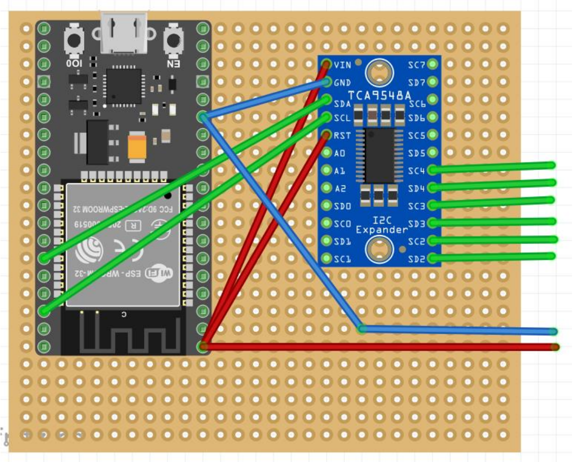
Methodology Pt. 1 - The Hardware System

Core: ESP32 microcontroller + I2C Multiplexer PCB

Sensors: 3x MPU6050 6-axis IMUs, placed in cases at C7, T10, L2 vertebrae markers on the T-Shirt

Connectivity: Wi-fi transmission to a desktop for real-time collection and graphing



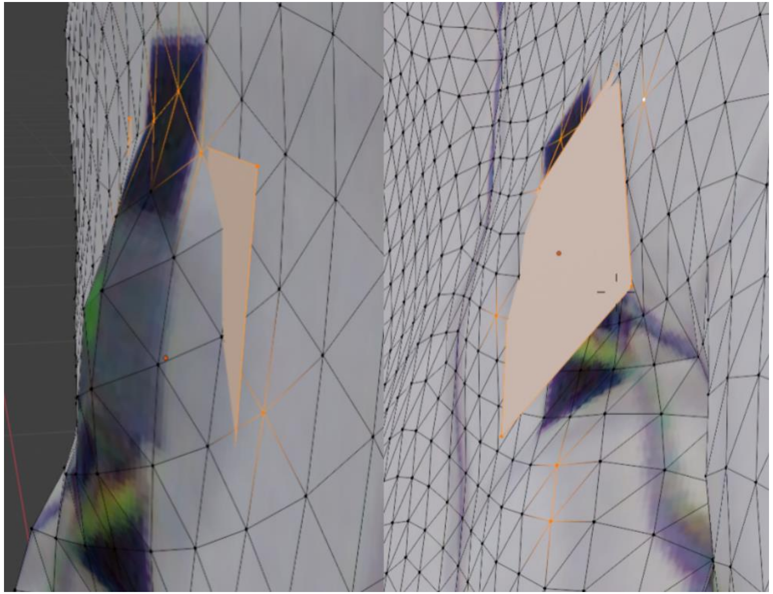


Methodology Pt. 2 - IBV MOVE4D Scanner

System: 30fps scanner that returns (per 6 seconds) 180 vertex meshes corresponding the position of the body and clothing to 1mm.

Goal: Calculate Best Fit Planes from vertices around the sensor positioning

Validation: Compare results to angle provided by the sensors



Results: Upper Sensor (Near-Perfect Match)

Across all three scans, the Upper Sensor (positioned at C7 vertebrae) achieved a near-perfect **Pearson correlation (r > 0.99)** and a low average **RMSE** of approximately **1°**.

This result validates that a single IMU placed at the upper thoracic/lower cervical region can accurately track the angles of the flexion and extension movements associated with slouching

Insightful Findings: Why Other Sensors Diverged

Medial Sensor (T10)
The Medial Sensor exhibited a “muffled” response. Of note is that while it maintained a strong correlation with the scanner data ($r > 0.95$ in two scans) its response was significantly attenuated, resulting in absolute error (RMSE >8.5°). This is due to the placement of the sensor near the **axis of the spinal rotation**, undergoing minimal tilting.

Lower Sensor (L2)
The Lower Sensor showed the poorest performance, with little to no dynamic response to spinal motion. This is due to **“Fabric Decoupling”** of a non compression T-Shirt.

Key Takeaways

Concept Validation

Can a IMU based smart garment accurately monitor slouching? **Yes**, with sensors placed at the cervical region (C7 vertebrae).

Challenges and Findings

Sensor placement and fabric-body coupling are critical findings that highlight the importance of a compression garment.

Future Work

Design a purpose-built compression garment to solve decoupling, as well as smaller, more integrated sensor profiles - or textile based stretch sensors.

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Thank you!

Questions

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