Monitoring Dynamic Posture Changes Through Inertial Measurement Units

Amisha Anand, Chloe Bowen, Marek Gutke, Jeffrey Hickman, Lyla Toth, WARPSPEED program, Colorado Space Grant, University of Colorado Boulder

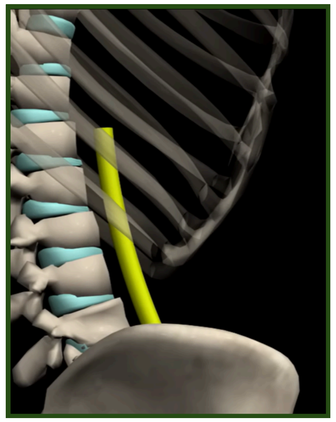
Abstract

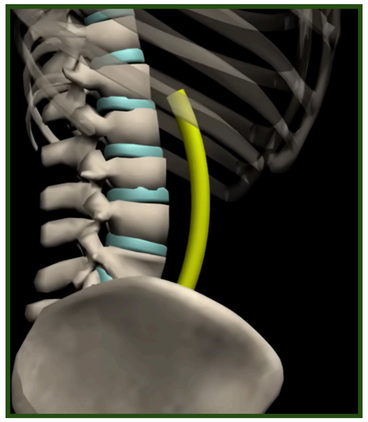
- Posture plays a critical role in musculoskeletal health
  - However, poor posture habits are often developed gradually and remain unnoticed until discomfort.
- Students, professionals, and those who spend long hours seated are susceptible to posture degradation

Using inertial measurement units (IMUs), we aim to create an accurate measurement system to moniter posture changes.

Background

- The lower and upper back are the largest factors in posture
  - This includes the section of the spine right above the hip and between the shoulder blades

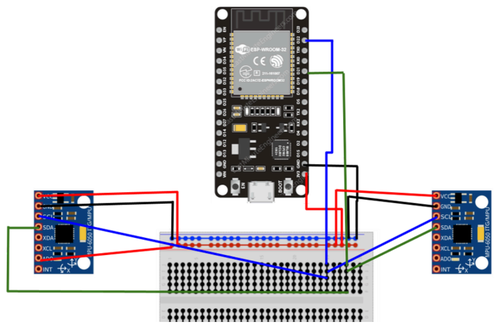


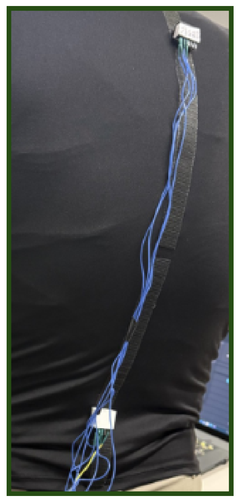


Spine on the left experiences prolonged slumped posture while the spine to the right is considered to be in a ‘neutral’ position (Stanford) .

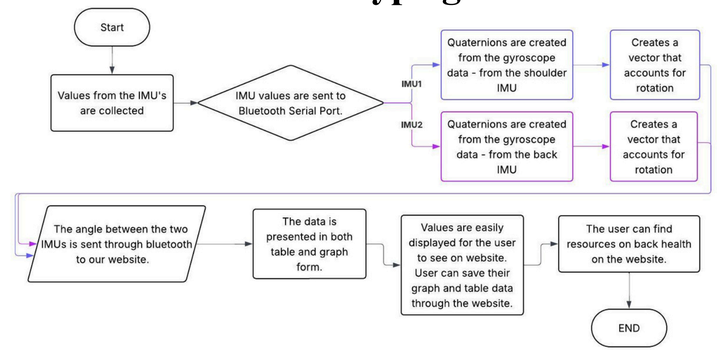
Methods and Materials

- Hardware
  - IMUs (Inertial measurement units)
    - IMU's are differentiated via the 3.3v wires running between the ESP32 – the shoulder IMU only has one 3.3v wire
  - ESP32 (microcontroller)
- Manufactured
  - Compression Shirt
  - Shell to hold IMUs is attached to the back of the shirt





Prototyping



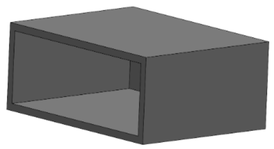
Math Overview

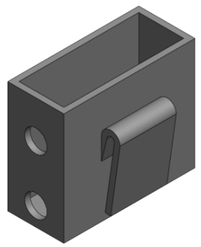
- The IMUs collect gyroscope and accelerometer data and send it to the ESP32, where the gyroscope data is integrated with respect to time and stored as a quaternion (4D vector with imaginary numbers)
- During integration, gradient descent is applied — treating the accelerometer reading as a gravity vector — to correct drift error in the gyro.
- The arcsine of the two resulting quaternions is then used to find the angle between the two IMUs.

```
float angleBetweenOrientations(MadgwickFilter &f1, MadgwickFilter &f2)
  float rw =  f1.q0*f2.q0 + f1.q1*f2.q1 + f1.q2*f2.q2 + f1.q3*f2.q3;
  float rx = -f1.q0*f2.q1 + f1.q1*f2.q0 + f1.q2*f2.q3 - f1.q3*f2.q2;
  float ry = -f1.q0*f2.q2 - f1.q1*f2.q3 + f1.q2*f2.q0 + f1.q3*f2.q1;
  float rz = -f1.q0*f2.q3 + f1.q1*f2.q2 - f1.q2*f2.q1 + f1.q3*f2.q0;
  float pitch = asinf(constrain(2.0f * (rw*ry - rz*rx), -1.0f, 1.0f));
  return pitch * (180.0f / PI);
```

Shell Prototype

- Contains foam so IMUs won’t be accidentally squished and provides comfort for user
  - Another layer of elastic fabric is placed on top
- Shell attached to the compression shirt via Velcro
- Belt attachment to hold rechargeable battery and ESP32



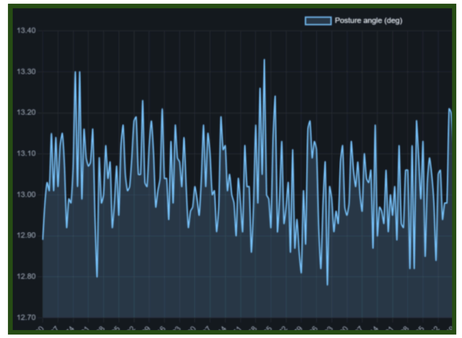


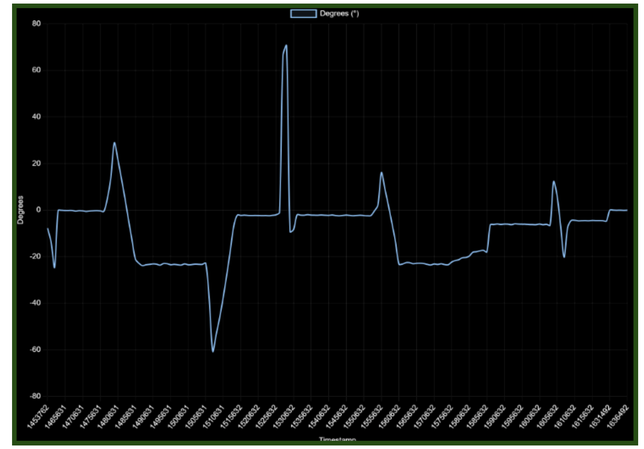
Testing

The calculated angle corresponds to three qualitative benchmarks:

- ‘good’ θ <10 degrees
- ‘mild/slight bend’ 10 < θ < 20
- ‘poor/slouching’ 20 < θ < 35
- ‘bad/severe bend’ 35 < θ

Posture reading are uploaded to the website via Bluetooth LE, where the data is displayed on a graph





Live updated graph on the user interface with consistent good posture values, consistent 'poor’ posture, and spikes of ‘bad’ posture. Timestamp is in milliseconds and side bar records angles in degrees.

Conclusion

The system of IMUs can be used to approximate the angle of the user’s spine, allowing data on posture to be recorded and analyzed to improve posture and awareness of it.

Future Steps

- Placements of IMUs adjustable
  - Can cater to different height and body types within same device
- IMUs with 9 degrees of freedom for improved accuracy
- Create a warning system for user (in the moment adjustments)

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