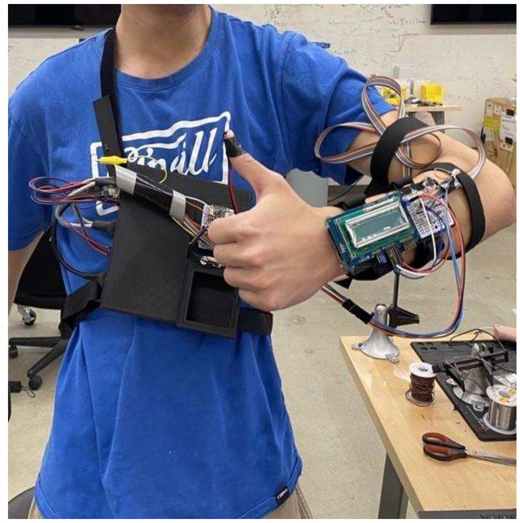
Fitness Tracker
Team 12

Yongxin Wu

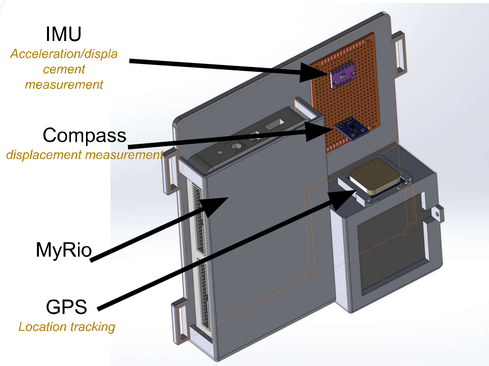
Kyle Liu



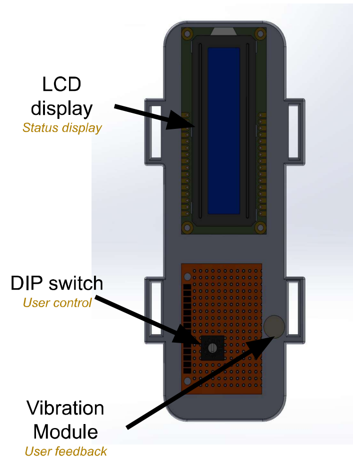
Motivation

- To learn more about Labview, microcontrollers & electronics through implementation
- Gain experience on implementing position tracking via the use of accelerometers and magnetometers
- Find potential solutions and feedback control measures to improve accuracy of positions derived from sensor readings
- Create a wearable device for real time health monitoring and fitness tracking to help detect health issues and encourage proactive health management

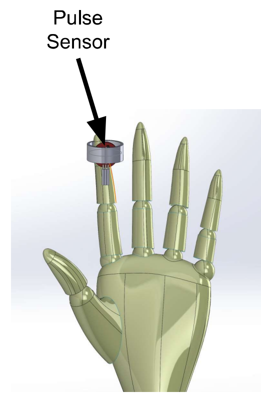
System Snapshot



Chest Mount Assembly (Displacement Data)



Wrist Mount Assembly (User Interface)

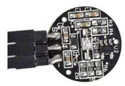
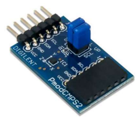


Finger Mount Assembly (Pulse Measurement)

Desired performance goals

Performance measurements	Performance Metrics	Evaluation methods
Pulse rate data	• Heart beat/minute (±5bpm)	• Count manually
Displacement data (step count)	• Distance traveled (±10m)	• Strava
GPS position	• Latitude and longitude (±10m)	• Strava & Google Maps

Sensor & Actuator selection

Sensors/actuators	Images	Justification
BE-280 GPS Module		• Efficient Performance with 10m accuracy, low power use (3.3-5V, <100mA) and high sampling rate. • Affordable and Available Priced under $30, with shipments ready within one week. • Well-Supported (documentation, tutorials, and libraries for integration).
PulseSensor Heart Rate Monitoring Sensor Module		• Accurate performance with 330x signal amplification and low power consumption (5V, < 4mA). • Cost-Effective: Priced under $30. • Easy Integration (Compatible with the myRio interface).
10 position DIP switch		• Available in Lab • Small and easy for integration • Enough states for different function features
PMOD CMPS2		• Available in Lab • Accurate performance up to ±1° heading accuracy • Well-Supported (documentation, tutorials, and libraries for integration).

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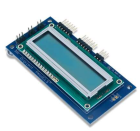
Sensor & Actuator selection

Sensors/actuators	Images	Justification
Vibrating Mini Motor Disc		• Flexible and Efficient Power Use • Cost-Effective and Rapid Availability • Simple Control with Adequate Support • 1.0G(AVG) for average vibrational acceleration
PMOD CLS LCD Display		• Low development time (Available in lab) • Display with sufficient characters and manageable form • Compatible size for wearability
Adafruit TDK InvenSense ICM-20948 9-DoF IMU		• High-resolution (0.05 ms-2, 5° heading) and broad range (±16g, ±2000°/s), with low noise and fast sampling at 1kHz. • Affordable (less than $20) • Supports easy I2C integration with detail implementation documents. • Compact (combines multiple sensors in one small package).

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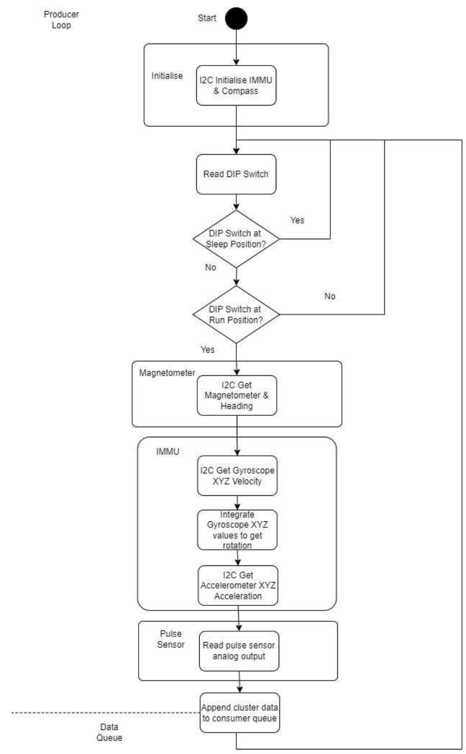
State Machine Diagram

Producer Loop



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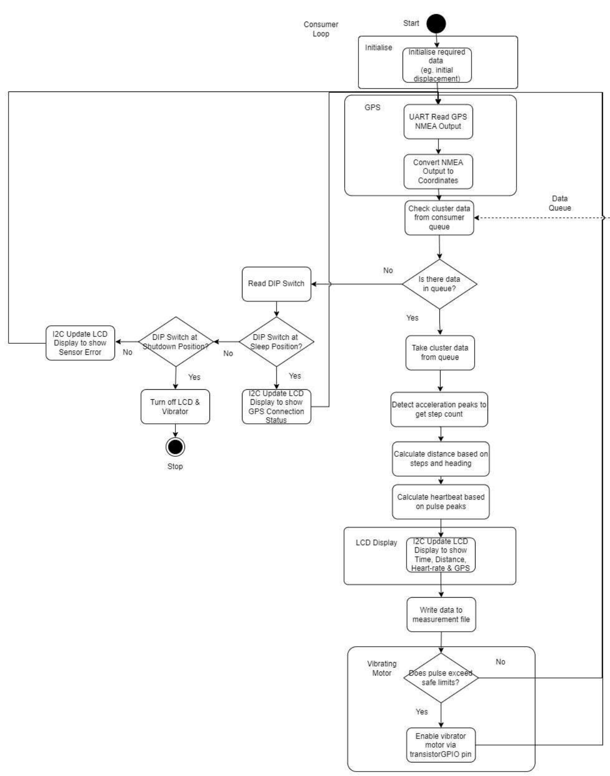
State Machine Diagram

Consumer Loop



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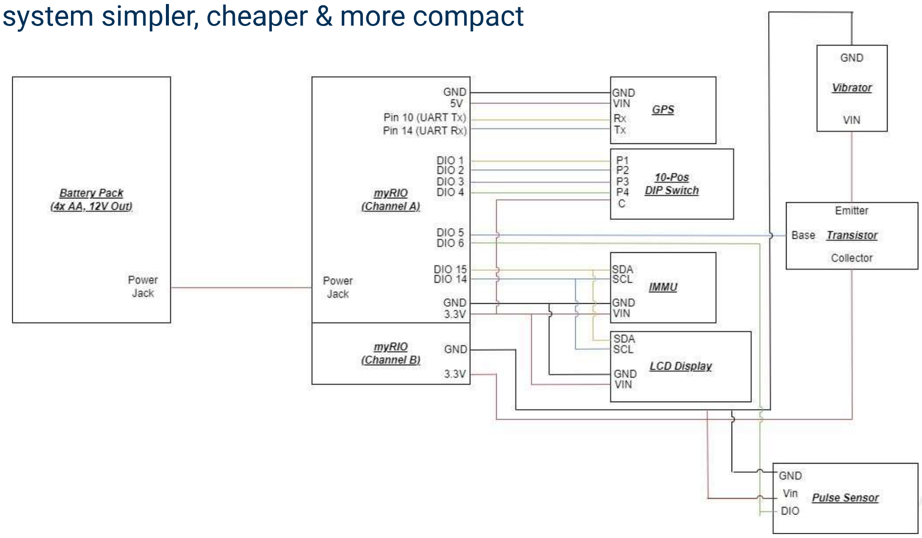
Power System/Control Theory

- All sensors powered through myRIO
  - Power/current within specs
  - Makes system simpler, cheaper & more compact



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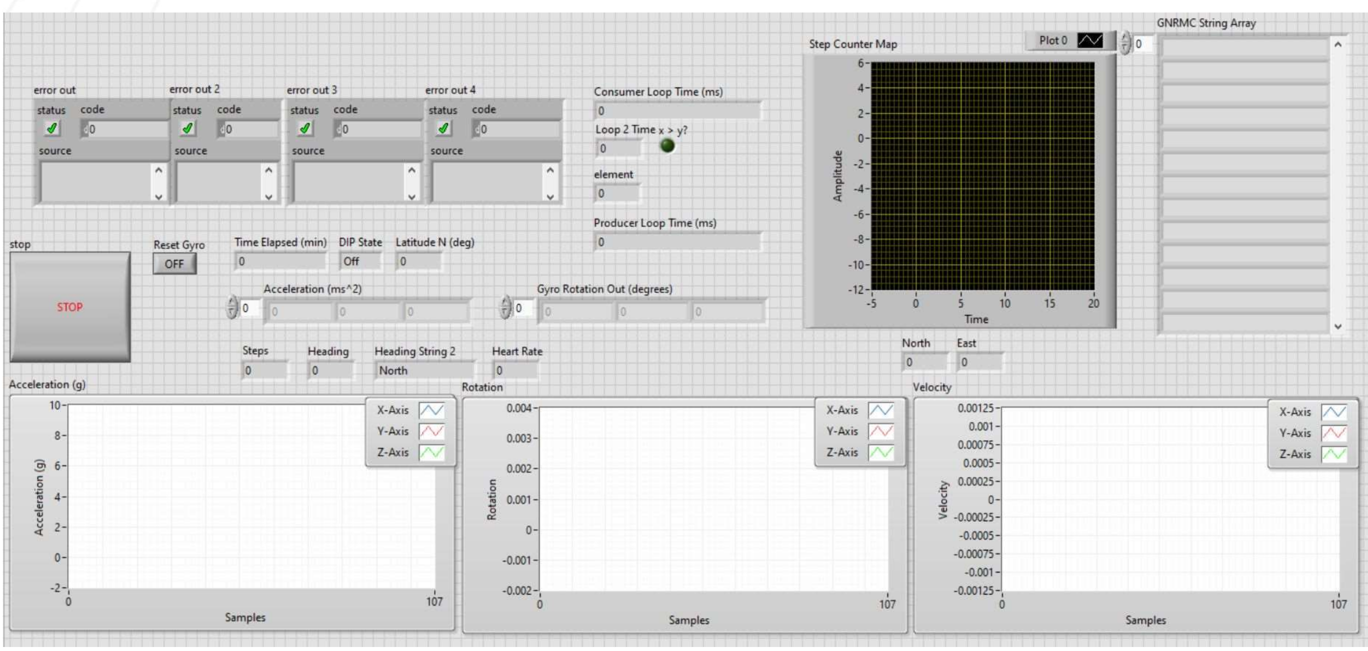
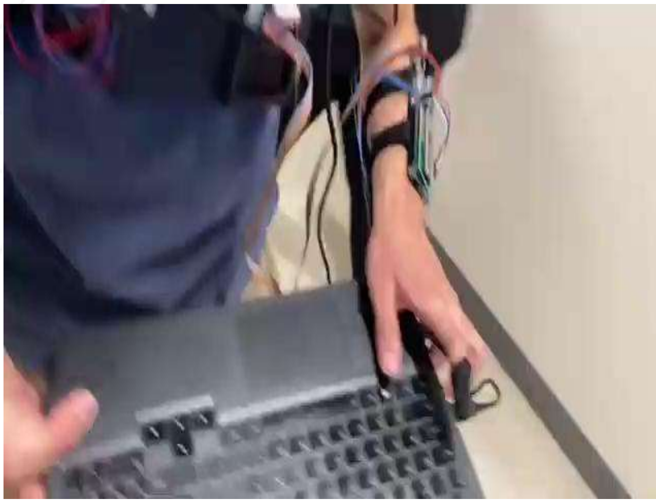
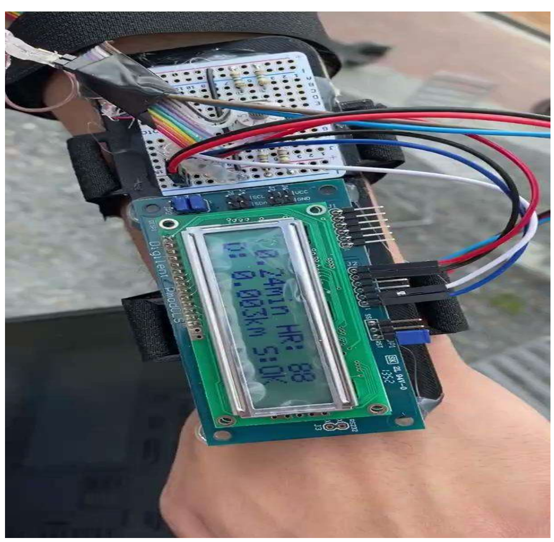
Demo



Record Demonstration (Labview interface connected)



Stand-alone Deployment demonstration



Results - Pulse Sensor

Inactive Pulse Monitoring results

Time elapse	Pulse Sensor Count Trial 1	Pulse Sensor Count Trial 2	Manual Count Trial 1	Manual Count Trial 2
60 seconds	73	71	74	71
10 seconds	12	13	12	13

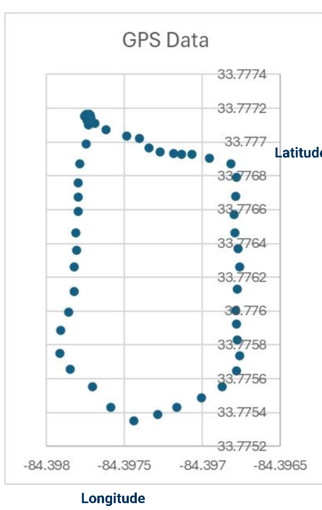
Active (arm waving) Pulse Monitoring results

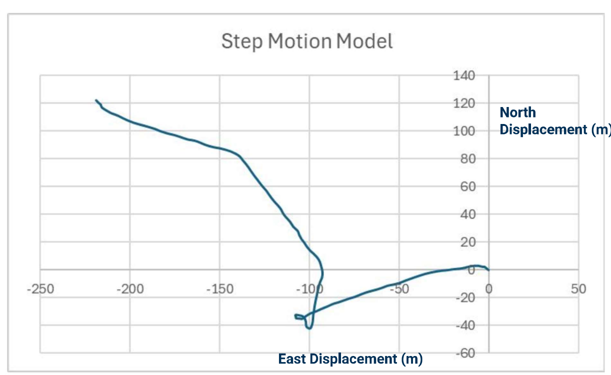
Time elapse	Pulse Sensor Pulse Count Trial 1	Pulse Sensor Pulse Count Trial 2	Manual Pulse Count Trial 1	Manual Pulse Count Trial 2
60 seconds	94	92	83	87
10 seconds	17	19	15	16

Results - Standalone Deployment

- GPS Results matched out well with actual route (±10m per point)
- Initial step motion model didn't work at all - Due to compass issue

Actual Map





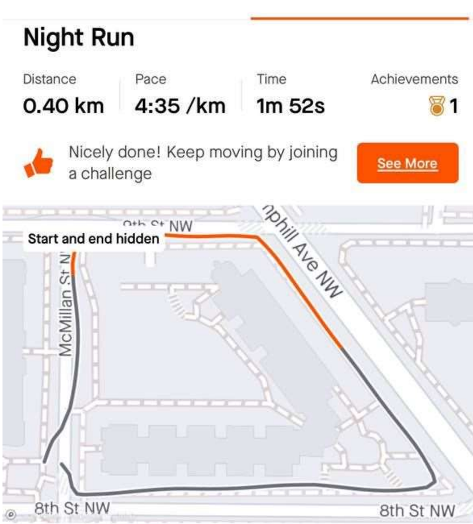
Actual Dist: 555.6m
Step Counter Dist: 375.2m

Results - GPS Issues

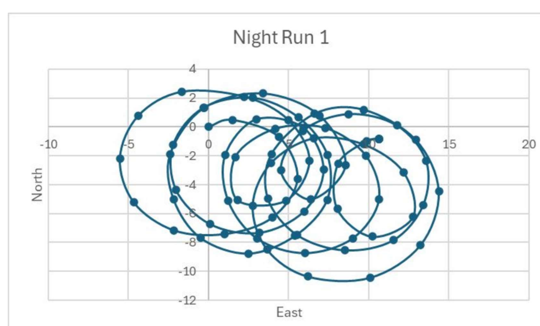
- GPS eventually stopped working, only gave data very sporadically
- Tried:
    - Switching myRIO
    - Changing UART Serial parameters (*eg. baud rate, timeout*) & implementation (*eg. constant vs varying bytes read buffer closing serial port after every read*)
    - Switching wiring & power

Step Counter Run Test 1

Strava Record

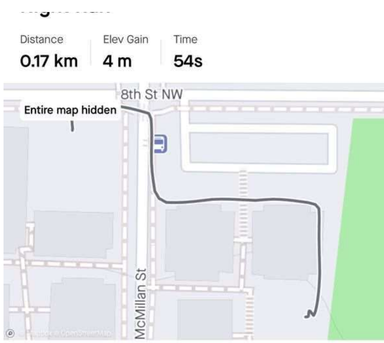


Step Counter



Step Counter Run Test 2

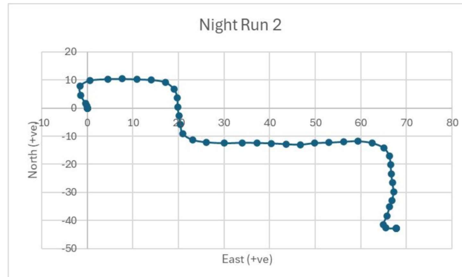
Strava Record

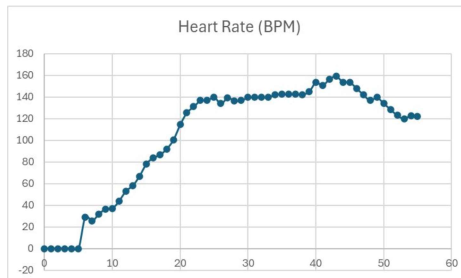


Average heart rate:139 to 178 bpm for same speed and age group (20-24)

Step Counter

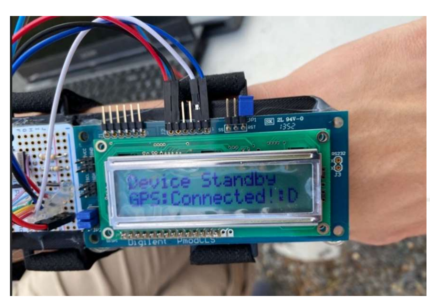
Distance Recorded: 125.6m



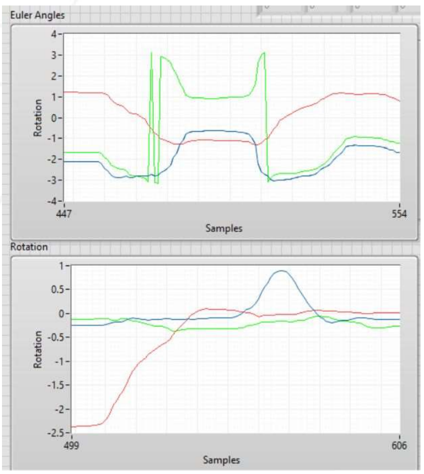


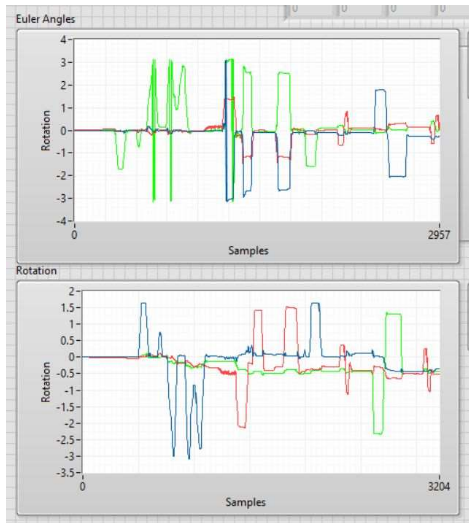
Discussion - Performance Evaluation

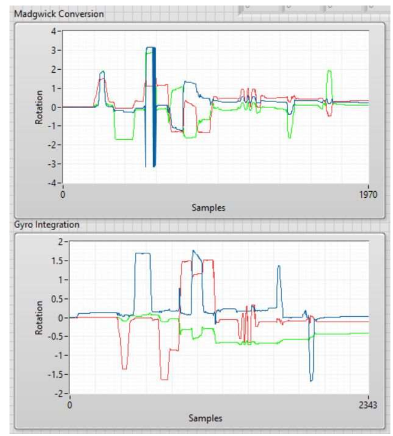
- Pulse Rate
  - Accurate under ideal, static conditions
  - Noisy under real-world conditions (eg. varying light intensity, moving)
- Step Counter
  - Matches overall route only, unable to track position accurately + significant drift over time
- GPS Tracking
  - Some error (±10m) due to inherent sensor limitations, but otherwise accurate
- Other Subsystems
  - Vibrator - Able to buzz when user set heart-rate exceeded
  - LCD Display - Able to display key stats



Madgwick Tests







Challenges

- Hardware
  - **Magnetometer** - Both IMMU and standalone CMPS2 had erroneous readings which couldn't be cleared by resetting; suspect interference from surrounding sensors
    - Integrated AK09916 was very unstable + outputted data in Big Endian
  - **IMMU** - Inadequate quality to do accurate INS/AHRS, faced issues with I2C implementation
  - **Pulse Sensor** - Sensitive to movement and external light - tends to not be accurate when running
  - **GPS** - Failed during the testing phase; unlikely to be UART, connection or software issues. Also did not work in standalone deployment

- Software
  - **Libraries** - Hard to Labview libraries for common sensor fusion
  - **IMMU technical data** - No support for DMP, internal I2C bus unclear
  - **Deployment** - GPS and Pulse sensor refused to work on standalone version, along with

- Filter Algorithms
  - **Madgwick -** Very unstable (Labview), plus doesn't work well for non-static applications
  - **Kalman Filters** (EKF, UKF, etc.) - Unavailable as libraries for INS motion models, did not have sufficient time to implement

Conclusion

- Goals & Progress
  - Fitness tracker with minimal function was created
  - Gained experience on implementing position/pose tracking, Labview and system integration
  - Unsuccessful due to sensor failure and inaccuracy issues, plus complexity of system

- Future Work
  - IMMU
    - Fix magnetometer heading issues
    - Create EKF that uses 9 axis IMMU + GPS
  - Pulse Sensor
    - Design tight-fit full inclusive pulse monitor mount
    - Get more robust sensor
  - GPS
    - Fix/replace, integrate into EKF
  - Deployment
    - Do on a C++/Python system instead (eg. ESP32, rPi)

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