הפקולטה להנדסת חשמל ומחשבים ע"ש אנדרו וארנה ויטרבי

Work in Progress

SIPL

Signal and Image Processing Lab

TECHNION Israel Institute of Technology

Foot Gestures Recognition for Controlling a 3D-Printed Prosthetic Hand

Sammy Apsel and Da-el Klang, Supervised by Shunit Polinsky

Introduction

- Motivation: Helping and improving an amputee's quality of life.
- Current solutions are expensive and do not fit every amputee.
- In out project, we research low-cost solutions for controlling 3D-printed prosthetic hand.

A prosthetic, robotic arm

Goals

- Classify and estimate foot gestures:
  - False-positive errors must be minimized.
- Implement the system with low-cost hardware:
  - 2 BNO055's IMU's
  - Raspberry Pi Model 3B

Challenges

- Train classification algorithm with limited training data.
- Classify between the gestures and other human activities.
- Generalize the algorithm for different users, without re-training the classification algorithm.

Placement of Sensors

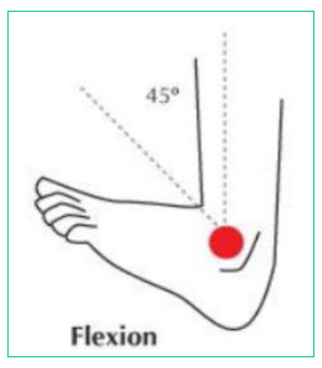
- Sensors are placed as described in picture and strapped on tightly.
- Using these locations, we're able to calculate the ankle orientation.

The foot gestures

- We chose 6 gesture to analyze:
  - Linear Slide Forward
  - Linear Slide Right
  - Linear Tap
  - Rotating Slide Right
  - Rotating Tap
  - Rotating Reverse Tap
- These gestures are supposed to be simple.
- Differences between users (e.g.: gestures performance time, anatomical leg structure) must be taken into account.

Calibration Procedure

- Sensors-to-world calibration in order to read accurate orientation of each IMU:
  - Accelerometer
  - Gyroscope
  - Magnetometer
  - Each sensors samples its orientation to the world: q_{world}^{sensor}

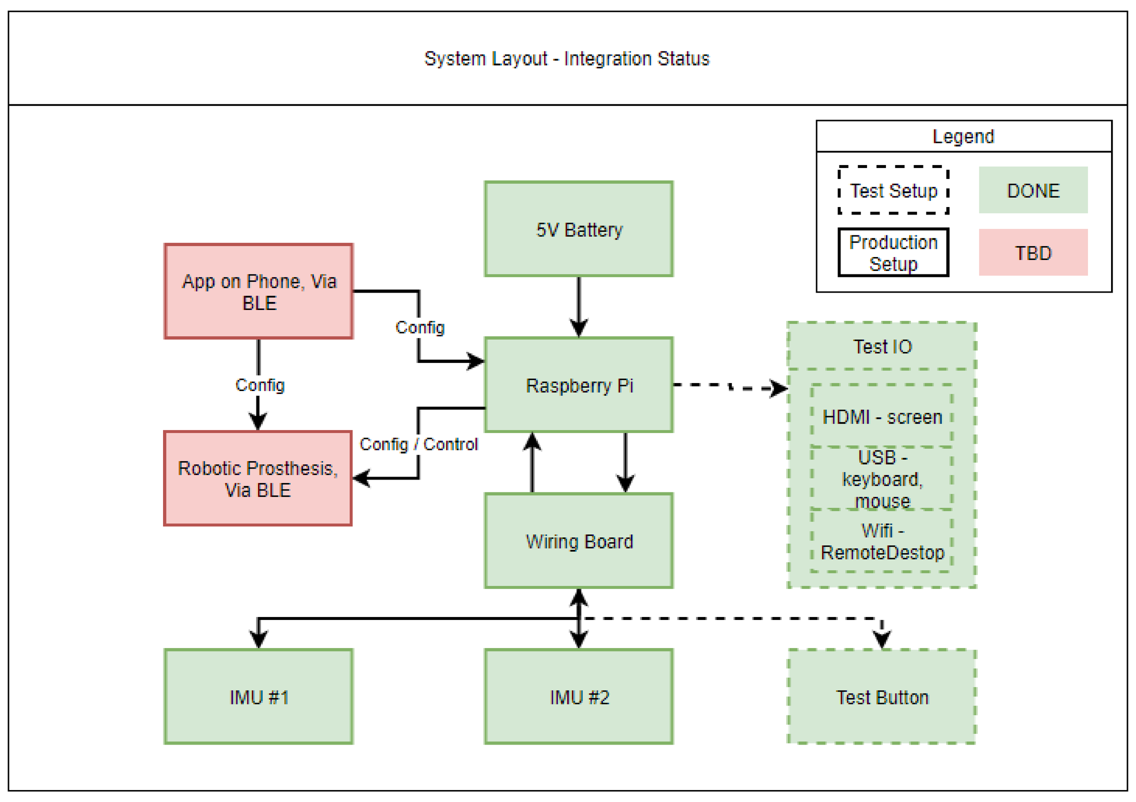


- Sensors-to-Segment calibration in order generalize the algorithm for different users anatomy:
  - sample standing and flexing sensor reading to calculate the relevant calibration quaternion:
    - Sample: $\begin{cases} q_w^{Sfoot}(standing) \\ q_w^{Sfoot}(flexing) \end{cases}$ and find the foot orientation w.r.t world: q_{world}^{foot}
    - Calculate sensor orientation to body segments:
$$\begin{cases} q_{sensor_1}^{foot} = \left(q_{world}^{sensor_1}\right)^* \cdot q_{world}^{foot}, \\ q_{sensor_2}^{shank} = \left(q_{world}^{sensor_2}\right)^* \cdot q_{world}^{sensor_1} \cdot q_{sensor_1}^{foot} \end{cases}$$
    - For each real-time sample, we can use this calibration to find the ankle orientation: $q_{shank}^{foot} = \left(q_{sensor_2}^{shank}\right)^* \cdot \left(q_{world}^{sensor_2}\right)^* \cdot q_{world}^{sensor_1} \cdot q_{sensor_1}^{foot}$
  - This calibration should hold as long as the sensors attached to same spot.

Pre-Processing

- The system samples the sensors at 40 Hz
  - Human movements are upper bound by 12 Hz
- Due to the low sample rate, a simple averaging is used as LPF.
- The calibration quaternions are used to transfer sensor acceleration to world coordinates.

Integrated System Layout



- The system will sample the IMUs for its orientation, and process the data in the computing module - Raspberry Pi.
- The computing module will classify and decide the relevant response.
- The decision will be transmitted via Bluetooth to the prothesis.
- Further customization may be possible with an app on the user's phone.

Future Work

- Fine-tuning pre-processing flow.
- Considering state machine implementation for final decision.
- Adjust the algorithm for real-time processing.
- Bridging between the system and the robotic hand.

Current Challenges

- Optimizing pre-processing to select more significant data for the classification input.
- Selecting and optimizing the classification algorithm.
- Sampling reliable database for training and testing.

References

- [1] Qifan Zhou et al.: "Design and Implementation of Foot-Mounted Inertial Sensor Based Wearable Electronic Device for Game Play Application"(2016)
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- [3] Yamen Saraiji et al.: "MetaArms:Body Remapping Using Feet-Controlled Artificial Arms"(2018)

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