Long-term Wearable Sensor Suite for Real-World Biomechanical Tracking in Prosthetics

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***Abstract*—This work presents a suite of sensors configured to optimize long-term motion reconstruction and indoor/outdoor localization using wearable sensors. The system was designed to enable improved real-world biomechanical analysis in persons with amputation. We will present the design of the system, its data logging architecture, and hopefully the first recorded data sets.**

Keywords—wearable sensor, prosthetics, biomechanics

I. Introduction

Real-world tracking is of great interest in biomechanics, but research to date has focused overwhelmingly on simple measures such as step counts or all-inclusive analyses based on big-data approaches. Neither of these methods yields sufficiently detailed analysis to enable decisions about biomechanical superiority of some interventions over others. Our team is developing a method that tracks a person's movement across all locations, indoors and out, and analyzes intervention-related changes only in the most frequently-repeated circumstances. Here we extend the previous method, based solely on foot-mounted movement sensors, to include a wider array of movement, biomechanical, and environmental sensors chosen to optimize this type of analysis. The goal is to enable sound scientific comparison of different interventions based solely on data from everyday life. The specific focus is on prosthetic foot-ankle systems with different classes of features.

II. Methods

A. Sensor Suite

The sensor system consists of one high-accuracy inertial measurement unit (IMU) mounted on the prosthetic shank; three wired low-power IMUs, on the prosthetic-side foot, shank and thigh; one Bluetooth low-power IMU on the intact-side foot; a real-time kinematic global positioning system (RTK-GPS) receiver; environmental sensors for air temperature, pressure and humidity; and a Bluetooth-enabled prosthetic pylon load cell. These data are sampled and synchronized by a Raspberry Pi Zero W (RPi) and logged to its integrated microSD card.

B. Data Logging Architecture

We use Robot Operating System (ROS) as the central coordinating software. ROS enables time-stamped synchronous logging of multiple sensors' data in a common file, while managing these sensors as independent program nodes within a Linux environment. By periodic communication with each sensor, error detection and power management based on subject's activity level are implemented. This architecture has relatively high computational overhead, but offers modularity, robustness to individual sensor failure and a standardized file format.

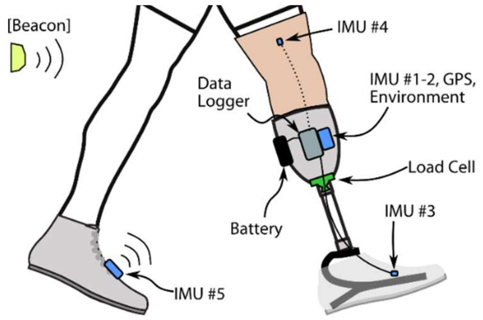

Fig 1: The sensor system will include 3-5 IMUs, GPS, environmental sensors, Bluetooth for location beacons, and a pylon load cell. These improved sensors will enable better movement reconstruction and gait analysis.

C. Reconstruction and Analysis

Movement reconstruction is done using Pedestrian Dead Reckoning (PDR) techniques [1] fused with RTK-GPS data using a Kalman Smoother [2]. Environmental sensors, GPS data and open-source maps are used to determine elevation changes and indoor/outdoor periods. Movement paths are clustered based on location, direction and overlap of multiple movement bouts to identify the most frequent paths. Biomechanical variables such as stride length, stride width and prosthetic socket load are characterized statistically for each cluster of frequent paths and compared across intervention conditions [2].

III. Results

We do not have any results yet, but we will show the sensor suite, debate its merits and demerits, and discuss any data we have recorded by the time of the conference.

References

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This work was supported in part by DOD grant W81XWH-19-2-0024.