A Finger-Worn Sensor Network for Monitoring the Real-World Performance of Stroke Survivors

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***Abstract*—During rehabilitation therapies, stroke survivors may demonstrate improvements in clinical settings that do not translate to improved performance in real-world settings. Wrist-worn accelerometers show potential for monitoring real-world performance, but mainly capture gross-arm movements. In this abstract, we introduce a body networked system composed of two low-power, miniaturized finger-worn accelerometers – capable of capturing both gross-arm and fine-hand movements – that can wirelessly communicate with a smartphone. The system demonstrated usability over 19 hours when streaming data in real-time. We believe this system will enable further research into the assessment of patients' real-world performance and the application of remote therapies.**

I. Introduction

About 75% of patients who survive a stroke develop upper-limb motor impairments on their affected side, which can significantly impact their capabilities when performing activities of daily living [1]. Stroke survivors may show improved movement capacity via rehabilitation in the clinic, but this improved capacity does not always result in improved performance in non-clinical settings [2]. Wrist-worn accelerometers have gathered great interest for their potential utility in monitoring real-world upper-limb performance but have been criticized for their inability to accurately capture finger and hand movements [3].

In this abstract, we introduce a body networked system consisting of two ultra-low power, ultra-miniaturized, finger-worn accelerometers that can store and wirelessly transmit captured data to a smartphone. Finger-worn accelerometers can track both gross-arm and fine-hand movements with minimal intrusion. We show that the system can collect real-time data from patients, which enables further research into assessing the real-world performance of stroke survivors.

II. Materials and Methods

Our system is a body sensor network consisting of a single Android phone and two finger-worn accelerometers. Each sensor independently communicates with the phone via Bluetooth Low Energy (BLE) and has a sampling rate of 50Hz. The finger-worn sensors consist of a three-axis accelerometer, a 140mAh rechargeable battery, a micro-SD card, and an ultra-low power 32-bit microprocessor in a waterproof case. This network uses a star topology, with the smartphone aggregating data as the master node, and the sensors collecting data as the slave nodes (see Figure 1a).

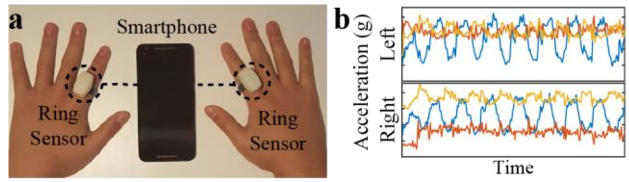

Figure 1. a) The proposed system. Each ring sensor sends data to the smartphone via Bluetooth Low Energy. b) An acceleration time series (open and closed fist) streamed from the sensor to the phone.

To test the lifespan of the system and the success rate of retrieving the data via BLE communication, the system was left to run until a component ran out of battery. The success rate of data retrieval was calculated based on how many data points we theoretically expected the phone to receive versus how many data points were actually received. We repeated this test 3 times to account for potential variability.

III. Results and Conclusions

Figure 1b shows acceleration in all three axes from both sensors while the wearer's hands are being repeatedly closed and opened. When the system ran until a component lost power, the phone always ran out of battery first and was therefore the lifespan bottleneck. The system lasted for an average of over 19 hours, with an average of 23% battery remaining for the sensors. The packet retrieval rate was greater than 99.9%. These results show that the system is capable of live-streaming data about users' movements throughout an entire day, with the system being recharged at night while users sleep. We believe that our system enables further research opportunities, such as automatic performance assessment in free-living environments and interventions that encourage the use of the affected limb.

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