Classifying and Estimating Tremor Frequency via Inertial Measurement Unit

Zachary R. Miller[1,], and Chad G. Rose[2]*

[1] Undergraduate Student, Department of Mechanical Engineering, Auburn University
[2] Assistant Professor, Department of Mechanical Engineering, Auburn University

Tremor can generally be defined as involuntary, chaotic twitching motions of various parts of the body, usually caused by neurological impairments [1]. The presence of tremor in the hands and fingers specifically can negatively impact a patient's ability to perform daily tasks such as writing, eating, typing, etc., greatly decreasing the patient's quality of life. Mechanical, non-invasive solutions have been proposed to address the limitations of pharmacological and surgical tremor solutions. One commercially available solution, known as the Readi-Steadi®, uses passive, constant damping elements across the whole hand to suppress tremor [2]. Unfortunately, this also suppresses any desired motion, which can unintentionally impede the wearer.

To remedy this over-suppression of movement, a more active solution should be considered. An active tremor solution should utilize a closed feedback loop to detect when tremor is occurring, and then to apply the suppressing effect only when needed. However, such suppression devices must be able to detect when a tremor is happening for active control methods to be viable. The objective of this research is to design a device to accurately study the motion of the index finger to determine and differentiate between voluntary motion and involuntary tremor. It is commonly accepted that most voluntary motion occurs between 1 and 3 Hz, while tremor typically occurs from 3 and 12 Hz [3]. These cutoffs can be used to sufficiently differentiate between tremor and voluntary movement. Validation of this device relies upon achieving similar tremor behavior in the frequency domain as prior research [4]. The device, shown in Fig. 1, uses two inertial measurement units (IMUs), which are attached to the proximal interphalangeal (PIP) joint and the distal interphalangeal (DIP) joint respectively to report translational acceleration data of the left index finger in three dimensions.

The subject's hand is inserted into the glove and placed on a flat surface with the ulnar side of the wrist facing down. The subject then begins flexing and extending their index finger at a constant rate for 20 seconds. The two IMUs interface with a Raspberry Pi Pico microcontroller through a multiplexer using the Inter-Integrated Circuit (I2C) communication protocol. The microcontroller receives translational acceleration measurements from the IMUs using a C++ script through the Arduino IDE, which is then stored in a .csv file by sending the data over a serial connection using PuTTY. The .csv file is processed through a MATLAB script that first calculates the magnitude of the acceleration data which is then processed through a Fast Fourier Transform algorithm to plot the finger's motion in the frequency domain to observe the frequencies present within the motion. The tremor motion is then plotted in both the continuous time domain and the frequency domain, shown in Fig. 2.

Fig. 1 Tremor measurement device with the (a) IMUs, (b) Raspberry Pi Pico and (c) multiplex.

*Corresponding author: zrm0014@auburn.edu

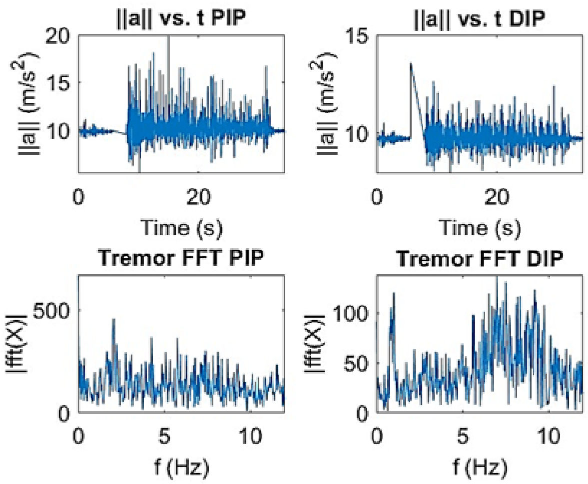

Fig. 2. Tremor acceleration data plotted against time (top) and in the frequency domain (bottom) of the PIP and DIP joints.

The acceleration readings show that the IMU oscillates about 9.81 m/s^2, meaning that the acceleration due to Earth's gravity was the dominant force acting on the IMUs. The frequency readings show that the PIP joint primarily experienced frequencies at 2.1 Hz, 4.3 Hz, and 5.8 Hz. Similarly, the DIP experienced frequencies primarily at 0.5 Hz, 6.5 Hz, and 8.6 Hz. The results show that classifying tremor based upon the frequencies present in the motion is a viable solution. However, some modifications should be made to the device to improve the accuracy of the measurements. The device can then be implemented alongside something like a soft hand exoskeleton to actively suppress tremor.

Statement of Research Advisor

Zachary's project was self-motivated, and the work was carried out largely independently. This is a new research area for my group, and addresses a challenge in all wearable robotics, but a particularly challenging issue in wearables for actively compensating tremor – how can a robot best understand and predict what a person intends to do. In this preliminary work, Zachary and I developed greater experience with new measurement modalities and this application area, and I am excited to have Zachary continuing in this research area for his M.S. work in my group.

- Chad G. Rose, Department of Mechanical Engineering, Samuel Ginn College of Engineering

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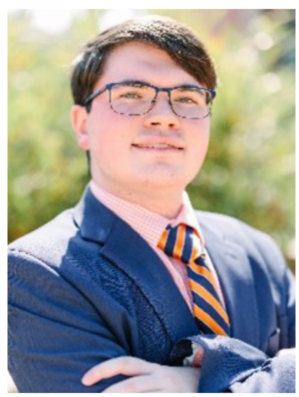
Authors Biography



Zachary R. Miller is a senior-year student pursuing a B.S. in Mechanical Engineering at Auburn University. Following graduation, he will be pursuing a M.S. in Mechanical Engineering at Auburn University working as a Graduate Research Assistant under Dr. Chad G. Rose in the Wearable and Bio-Robotics Lab.

Chad G. Rose, Ph.D. is an Assistant Professor in the Department of Mechanical Engineering and directs the Wearable and Bio-Robotics (WeBR) Lab. Dr. Rose holds a B.S. in Mechanical Engineering from Auburn University and an M.S. and Ph.D. in Mechanical Engineering from Rice University. His research focuses on the design and control of robots to rehabilitate, assist, or augment motor and sensory function.