Quantification of Parkinsonian Tremor and Essential Tremor Using a Novel Bluetooth-Integrated, Accelerometer-Based System

Caroline Kittle, Sai N. Nimmagadda, Eric Musselman, David Whisler
Department of Biomedical Engineering, Duke University – BME464L – Patrick Wolf, Ph.D

Abstract

The current clinical method of tremor diagnosis involves a visual assessment of tremor severity. Here we provide a Bluetooth-enabled, accelerometer based system to quantitatively assess tremor frequency and amplitude in real time. A graphical application for use by physicians during the diagnosis process also integrate the current clinometric UPDRS. After filtering and compensating for gravity, the the dominant frequency (DF) in four second windows of tremor was found using the Welch method to estimate the frequency content of the signal. Tremor amplitude was estimated via a double integration and filtering algorithm. Amplitude of tremor was found to have no effect on measured frequency and frequency of tremor was found to have no effect on displacement calculation. Frequency level was found to have a significant difference on accurate DF calculation (p=0.02), and amplitude of tremor was found to significantly affect the accuracy of displacement calculations (p=0.01). The proposed device offers accurate extrapolation of the DF within 0.5 Hz and tremor displacement calculation to within 2 mm.

Background

Parkinson's Disease (PD) and Essential Tremor (ET) are movement disorders causing tremor that affects more than 10 million Americans in total. Due to a lack of clear biological markers, a number of clinical diagnosis methods exist. The clinical standard for diagnosis of PD tremor is the Unified Parkinson's Disease Rating Scale (UPDRS), which is a longitudinal, qualitative assessment performed by a neurologist, with ET being diagnosed with similar scales. The goal of this system is to quantitatively assess tremor frequency and amplitude to using an accelerometer in the form of a wireless, wearable wrist device.

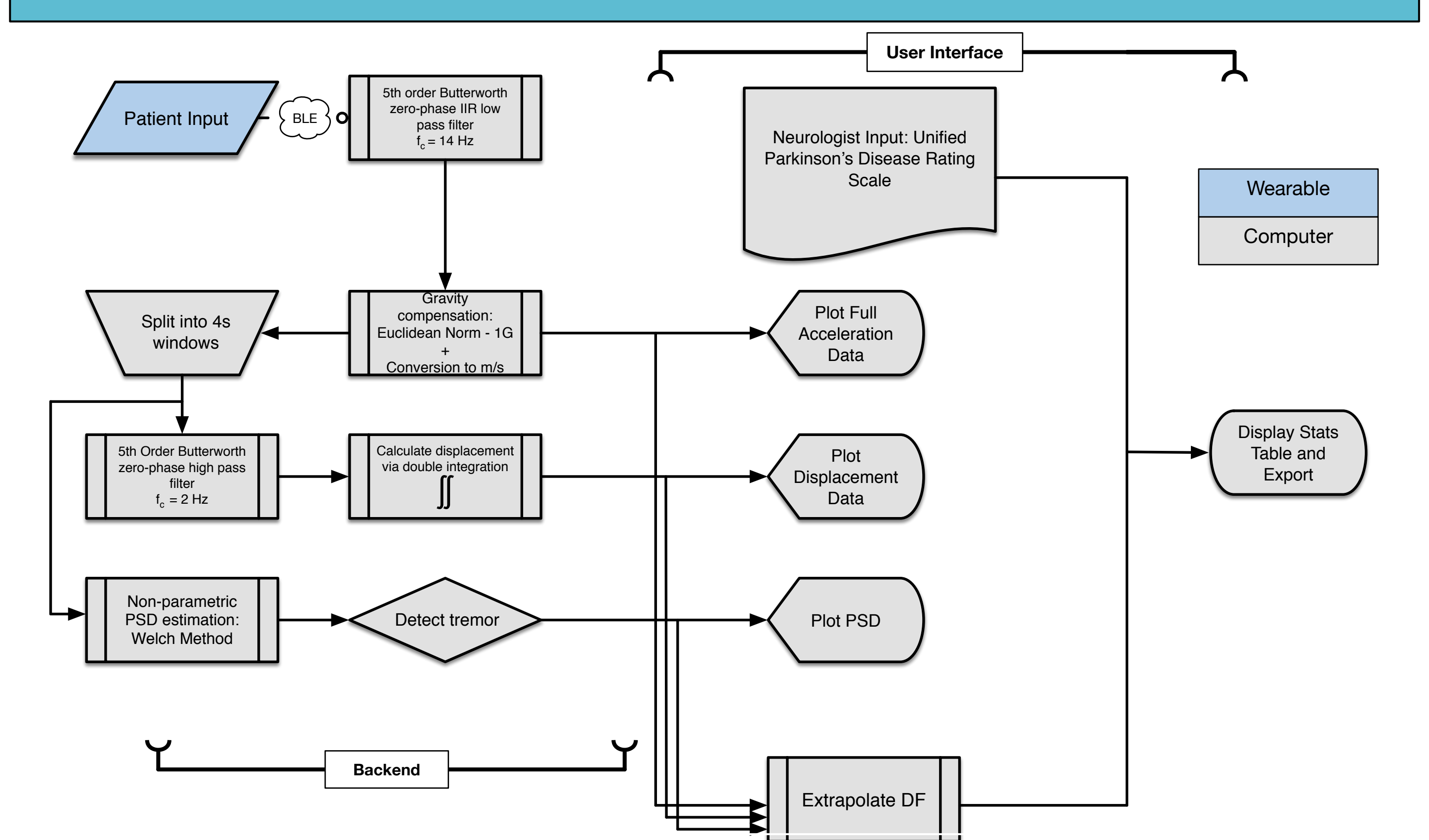

Figure 1: Block diagram of algorithm

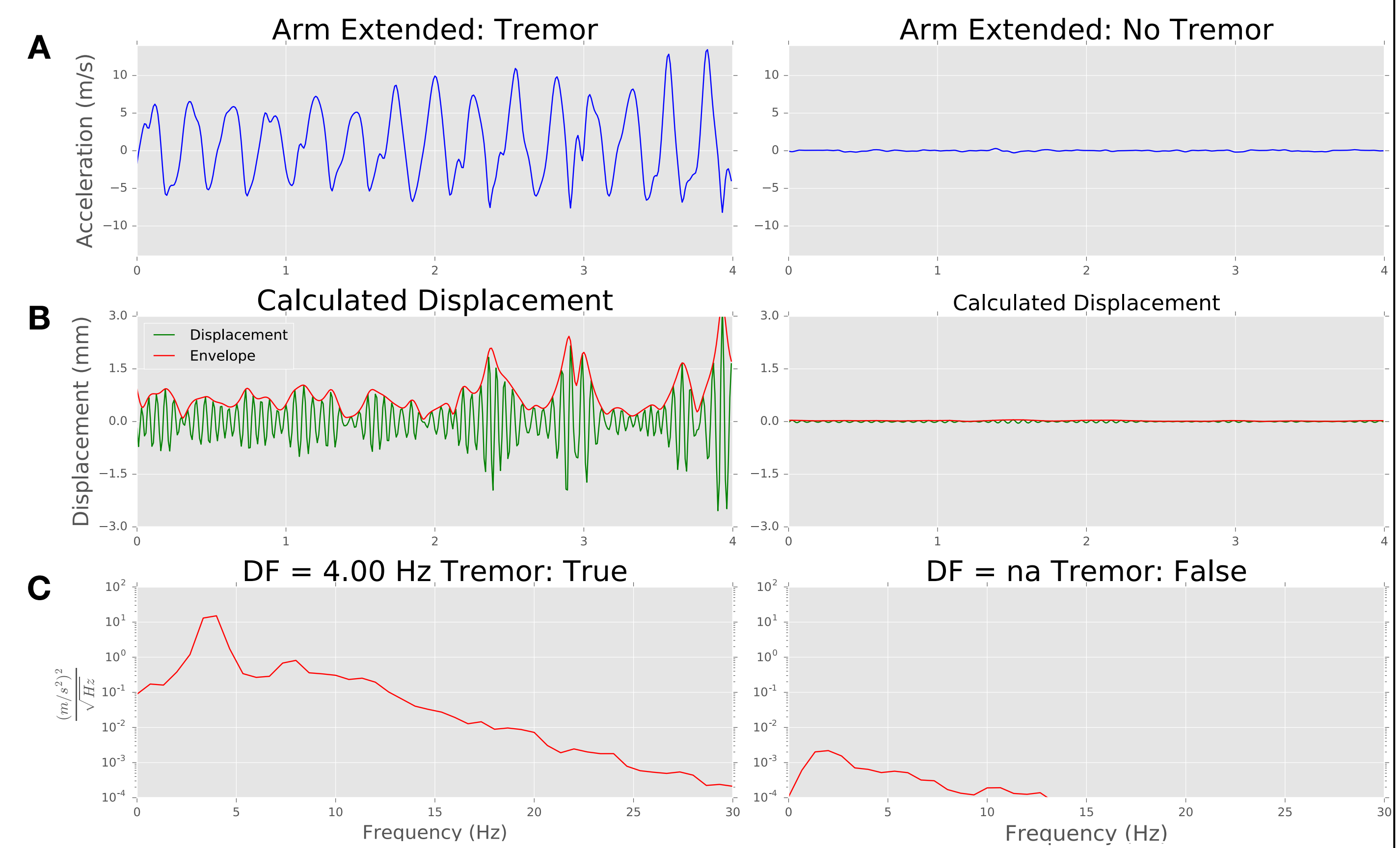

Figure 2: Sample analysis of signals with and without tremor
(A) Filtered, gravity compensated acceleration signal of subject with tremor (left) and no tremor (right). **(B)** Calculation of displacement using double integration method. **(C)** Power spectral density of

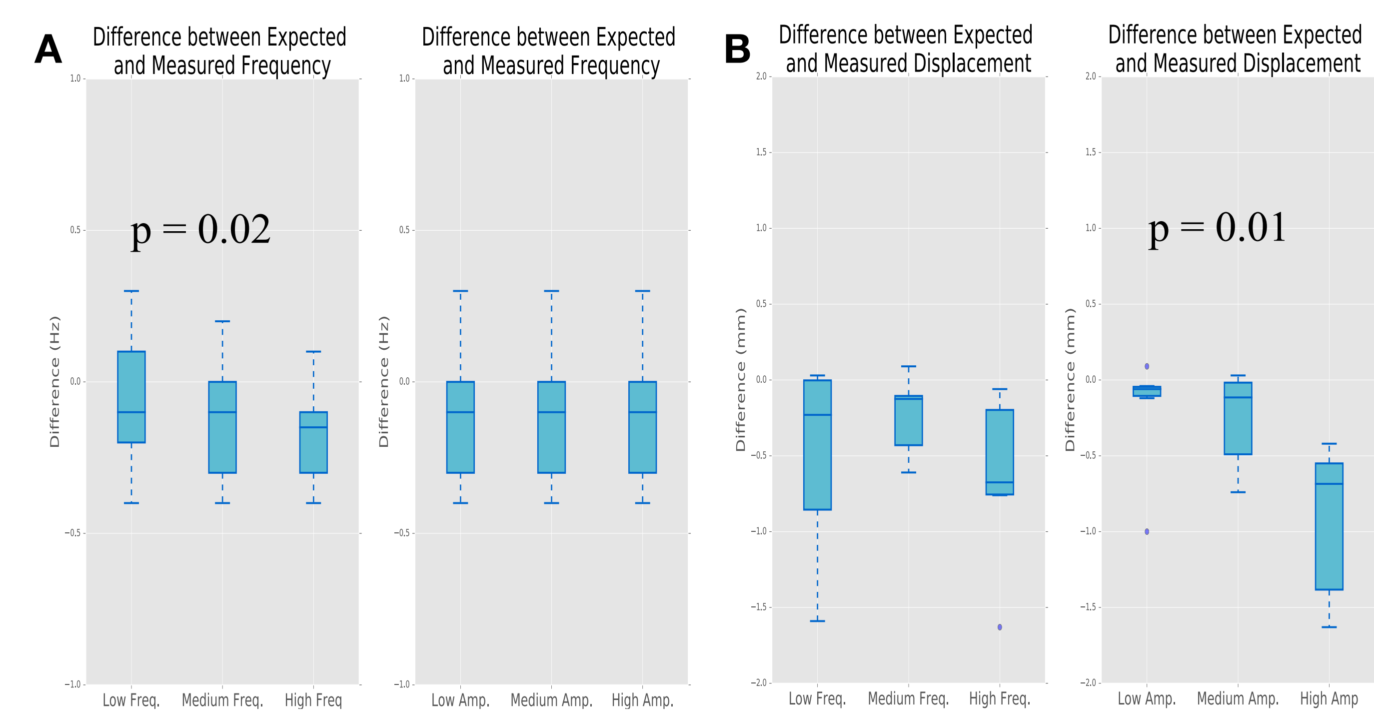

Figure 3: Effect of frequency and amplitude on device accuracy
(A) Difference between expected and calculated frequencies. **(B)** Difference between expected and calculated displacements. Freq. Ranges as follows: low:[2-5.4 Hz], medium:[5.6-9 Hz], high:[9-13 Hz].

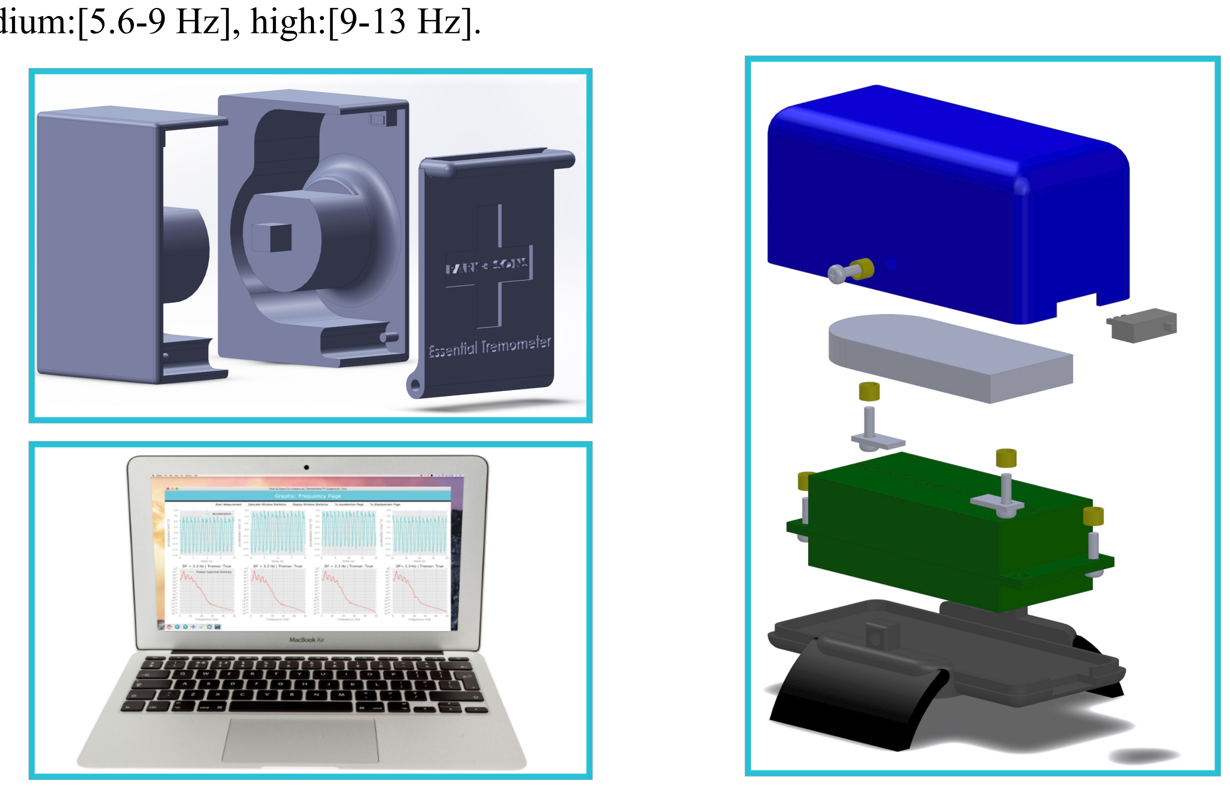

Figure 4: The Essential Tremometer Diagnostic System
(A) Encasing and holding platform. **(B)** Accompanying software **(C)** Wearable.

Conclusions & Next Steps

- After testing, the device was proven to be able to measure the DF of tremor to within 0.5 Hz and to calculate tremor displacement to within 2 mm.
- Different frequency levels were shown to have a significant effect on the accuracy of DF determination.
  - Increasing the sampling rate of the accelerometer (currently100 Hz) to improve the PSD estimation using the Welch method.
  - In order to improve the sampling rate, a Bluetooth chip with a higher rate of data transmission would need to be used.
- Amplitude has a significant effect on accuracy of displacement calculation.
  - Potentially due to inaccuracy in the test method which uses a 60 fps camera to record the device to find the actual displacement.
- A microcontroller with integrated Bluetooth capability could improve power consumption and data transmission speeds.
- Future iterations of the device could use more accurate sensors, such as a 9 DOF inertial motion unit
  - This would allow for a better compensation for gravity using the quaternion approach.

Acknowledgments

We would like to thank Dr. Wolf and Mark Draelos for their guidance and insight throughout this process. Special thanks to Matt Brown for materials and providing a a sinusoid generator.

Jankovic, J., and J. D. Frost. "Quantitative Assessment of Parkinsonian and Essential Tremor: Clinical Application of Triaxial Accelerometry." *Neurology* 31.10 (1981): 1235. Web.

Manzanera, Octavio Martinez, Jan Willem Elting, Johannes H. Van Der Hoeven, and Natasha M. Maurits. "Tremor Detection Using Parametric and Non-Parametric Spectral Estimation Methods: A Comparison with Clinical Assessment." *Plos One* 11.6 (2016): n. pag. Web.

Thenganatt, Mary Ann, and Elan D Louis. "Distinguishing Essential Tremor from Parkinson's Disease: Bedside Tests and Laboratory Evaluations." *Expert review of neurotherapeutics* 12.6 (2012): 687–696. *PMC*. Web. 8 Dec. 2016.

"Statistics on Parkinson's." *Statistics on Parkinson's - Parkinson's Disease Foundation (PDF)*. N.p., n.d. Web. 08 Dec. 2016.