Quantifying Tremor Severity in Parkinson's and Essential Tremor Patients

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INTRODUCTION

Tremor can be defined as a rhythmic shaking and involuntary rhythmic movements of a body part. It could occur in healthy individuals, as so-called physiological tremor. The mechanism of tremor is still unknown. Tremor is composed of two oscillations, mechanical reflex and central neurogenic, which are superimposed on a background of irregular and involuntary fluctuations in muscle forces and displacements. In neurological patients, tremor is clinically described as rest (e.g., Parkinson's disease), postural and kinetic tremor (e.g., essential tremor).

In a clinical setting, tremor is characterized by the dominant frequency and its power spectral density. Rest tremor frequency is typically in the 3–6 Hz frequency range. The frequency of postural tremor is usually between 4 and 12 Hz. Kinetic tremor has a frequency between 2 and 7 Hz in most cases. There was also frequency dissociation effect that described the different frequency in the simultaneous tremor occurrence in different muscle groups. For example, one study using surface EMG electromyography identified that tremors occurring in arms and legs were 5.3 and 3.8 Hz respectively (O'Suilleabhain & Matsumoto, 1998). The findings above suggested a need to identify specific parameters to determine the oscillation among different types of tremor (i.e., resting and kinetic tremor) as well as among different body parts assessed based on their unique frequency characteristics and for diagnostic purposes.

Several sensors are available for evaluating the severity of tremor on patients of essential tremor and Parkinson's disease, including the accelerometer and gyroscope. Currently, however, the assessment is mostly based on subjective analysis, estimating the severity of tremor on a scale of 0-4, with 4 being high tremor and 0 no tremor. Although tremor can be estimated clinically, the non-stationary features and the difficulties related to a pure clinical evaluation (low inter-rater reliability) make the use of sensitive, reliable and stable sensors a necessary.

The overall goal of the current proposal was to develop and apply devices to quantify the severity of tremor in both patients of Parkinson's disease and essential tremor. These devices could be used conveniently in various contexts and across different diagnostic tasks.

MATERIALS AND METHODS

Deliverable by December:

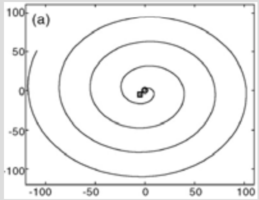
- Modify existing Shimmer LabVIEW program (vi) to record the sensor raw triaxial gyroscopic data into a text file, show power spectral density for each axis, show max peak value for each axis, and finally show tremor severity between 0-4
- Record preliminary results using the LabVIEW program
- Connect Shimmer via Bluetooth to a Bluetooth compatible laptop
- Order Digital Pen

•Deliverable by May:

- Apply Supervised Machine Learning Algorithm
- Apply RMS Algorithm
- Compare RMS method and Machine Learning Algorithm for accuracy and compare the two methods
- Measure tremor severity while tracing Archimedes spirals with digital pen
- Determine severity by measuring amplitude and frequency of tracing deviations
- Compare digital pen severity with gyro severity

DIGITAL PEN TRACING

- Use Digital pen on Anoto® patterned paper to trace an Archimedes Spiral
  - Write polar regression algorithms to determine
    - Physical deviations from the spiral curves
    - Velocities of the pen
    - Frequency of tremor
  - Compile results into a tremor rating scale
  - Output tremor severity on a 0-4 scale
  - Compare results with that from Shimmer Gyro



H. Wang et al. *Journal of Neuroscience Methods 171* (2008) p 266.

RMS METHOD

- For a set of finite values $\{x_1, x_2, \ldots, x_n\}$ the root mean square value is given by

$$x_{\mathrm{rms}} = \sqrt{\frac{x_1^2 + x_2^2 + \cdots + x_n^2}{n}}.$$

- The RMS value will be calculated over set time interval.
- The RMS value will update in real time and can be used for Deep Brain Scanning and related surgeries

MACHINE LEARNING ALGORITHM

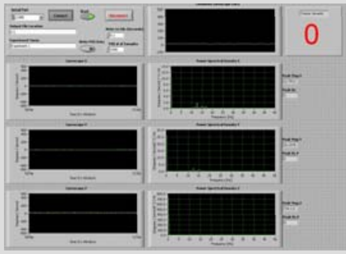
- Use features like frequencies, amplitudes extracted from tri-axial gyroscope data as input features
- Apply Supervised Learning Algorithm
- Annotate data observing patients with tremor of different severity
- Train Machine Learning Algorithm with annotated data
- Test algorithm on unclassified data
- Measure severity (from 0 to 4)
- Learn the severity from annotated data

BUDGET

item	item #	US$	Total
wrist strap	SH-STRAP-002	$16.34	$16.34
gyro module	SH-GYR-KIT-002	$200.19	$216.53
Shimmer base board	SH-SHIM-KIT-004	$271.00	$487.53
USB Reader/Charger	SH-DUAL-KIT-001	$230.15	$717.68
AZiO BTD211 Bluetooth USB 2.0 dongle	N82E16833340019	$11.99	$729.67
Customs Processing Charge (estimate)		$25.00	$754.67
Digital Pen & software (estimate)	AHHM-2111	$299.00	$1,053.67
Shipping: newegg		$5.99	$1,059.66
Shipping: shimmer (estimate)		$40.00	$1,099.66
Total			$1,099.66

PRELIMINARY RESULTS

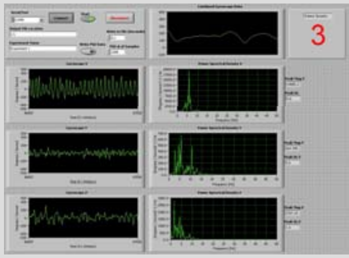
Two screenshots of our custom LabVIEW program are shown on the right. The upper screenshot shows gyroscope and PSD data from someone without tremor (value of 0 shown in upper right). The lower screenshot shows someone with hand tremor (value of 3 shown in upper right).



Custom Labview program showing a normal person's values (score=0)

Custom LabVIEW program Features:

- Displays 3-axis gyroscope data in real time
- Displays Power Spectral Density (PSD) for each axis in real time
- Records 3-axis and PSD to a text file up to 200 Hz
- Option to select file location, file write rate, and window of samples for PSD
- Option to not write PSD values to file for saving space.
- Calculates the max peak in real time, which shows the predominate frequency for each axis
- Shows the magnitude of the max peak in real time for each axis
- Combines all 3 axis on upper right chart showing unified gyroscope data
- Displays a value between 0-4 showing tremor severity (still in progress)



Custom Labview program showing hand tremor values (score = 3)

ROLES

- Heidi: Background research on tremors and clinical assessment tools, Dr. Jamie Mark communication, IRB.
- Nathan: Component selection, parts list, budget, Digital Pen algorithmic data analysis, Bluetooth communication, Dr. Carlson communication
- Conrad: Frontend and backend for LabVIEW GUI, component selection, apply RMS method to raw gyroscope data to compute severity of tremor on the fly
- Selina: Apply machine learning algorithm on raw gyroscopic data to compute the severity of tremor

References:

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- O'Suilleabhain, P. E., & Matsumoto, J. (1998). Time-frequency analysis of tremors. *Brain, 121*, 2127-2134.
- A. Salarian, H. Russmann, F.J.G. Vinterhoets, P.R. Burkhard, Y. Blanc, C. Dehollain, K. Aminian. "An Ambulatory System to Quantify Bradykinesia and Tremor in Parkinson's Disease," Proceeds of the IV annual IEEE Conference on Information Technology Applications in Biomedicine, UK, p35-38, 2003.
- H. Wang et al. "Journal of Neuroscience Methods" *171* (2008) 264-270.

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