PD Analytics: A Wearable Device to Monitor & Quantify Motor Dysfunction in Patients with Parkinson's Disease

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Agenda

- Background
- Project Objective
- Design Architecture
  - Hardware
  - Software
- Results
- Conclusion
- Future Works
- Questions
A progressive neurodegenerative movement disorder

Other neurodegenerative disorders include Alzheimer’s & Huntington’s disease (causing dementia)

PD results in disorder of neuron cells in brain which produce dopamine

Under the influence of dopamine, (neurotransmitter) signals from the striatum regulate all forms of movement
Background - What Are PD’s Impacts?

- Over 6 million people in the world suffer from different stages of PD
  - Each year as many as 60,000 new PD cases are diagnosed in the U.S.
  - Affecting up to a million people in the U.S.
  - 14th top cause of death in the U.S.

- In addition to mental & emotional cost, the annual economic impact of Parkinson’s disease in the United States is estimated to be around $10.8 billion
Background - Symptoms (Motor System Disorders)

- Rigid muscles
- Impaired posture and balance
- Loss of automatic movements
- Speech and writing disability
- Slowed movement
- Tremor
Tremor is characterized clinically by involuntary, rhythmic and alternating movements of one or more body parts.

Parkinson's disease harbors many different tremors:

- Vary according to the circumstances under which they occur, the body part that is involved and the frequency & intensity at which the tremor occurs.

Tremor frequency can vary from low (4–5 Hz) to high (8–10 Hz).
Diagnosis and treatment of neurodegenerative diseases (PD) are very critical in today's health systems. Patient monitoring has not played a key role. Treatments may be ambiguous and inaccurate.
Ambiguous Diagnosis ....

- Doctor: “How do you feel today?”
- Patient: “Feel lousy Doc.!”
- Doctor: “Take THREE Pramipexole (Mirapex) capsules & TWO Selegiline HCL everyday!”
- Patient: “Can Mirapex cause skin cancer?”
- Doctor: “Yup!”
- Patient: “Ok Doc.”
- Doctor: “See you in 6 months!”

“Better medication management for Parkinson's would be a god-send.” - Nancy Moon, wife of a PD patient, CA
Our Project Objective

- Develop a **tracking device** to aid the clinicians in making better, objective decisions about health care outcomes of patients suffering with PD
- Our focus is to monitor **hand tremor**
  - Is the tremor being reduced?
  - Is the prescribed medicine effective?

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**Long Term monitoring of frequency and intensity of hand tremor during On/Off periods** → optimizing patient-specific therapy; resulting in improvement of patient care and quality of life!
System Architecture
PD Analytics Glove + Software

Tremor

PD Analytic Glove (Data Logger)
Designed by SSU in 2014

Multi-dimensional, Anonymous Tremor Data

DMV Software
Proposed to be completed in this project

PD Analysis
Design Methodology

- **Long Term Patient Monitoring**
  - Hand Tremor Monitoring
  - Sleep Deprivation
  - Activity Monitoring

- **Laboratory Testing**
  - Hand Tremor Characterization

- **Patient Awareness**
  - Enabling patients to be involved in their own health

- **Nerve Stimulation**
  - Transcutaneous electrical nerve stimulation
  - Using multi-lead TENS
**Core Hardware Design**

**Components**
- Wrist brace
- Digital IMU 6DOF
- Microcontroller- Arduino
- SD card
- 2 Batteries (500 mAh)
- Slide Switch

**Total Cost is under $100**
Motion Detection Sensor-
6DoF IMU

- Inertial Measurement Unit (IMU) – combination of Accelerometer and Gyroscope sensors
  - A single PCB with an accel. (motion) and gyro (rotation)
  - Specifications: Accel:±2, 4, 8, 16g Gyro:±2000 (deg./sec angular velocity); I2C Interface

DXL345 accelerometer and the ITG-3200 MEMS gyro

Detecting six degrees of freedom
PD Analytics Software

- Software was developed in MATLAB R2014a (GUI-Based)
- Provides user-friendly interaction for doctors
- Signal processing with different statistical tools
- GUI features
  - Displays motion in (x, y, z) with two options:
    - Raw Data
    - Acceleration and Angular Velocity
  - Estimates dominant frequency in each axis
  - Estimates displacement in each axis
  - Determines RMS, Max. and Min. amplitude of tremor
  - Option to enable filtering using moving average
PD Software
Matlab - Based

Prototype Device

Raw Data Signal
- Scaling
- Calculating Frequency of Tremor
  - Fast Fourier Transform (FFT)
- Calculating Amplitude of Tremor
  - Butterworth Filter
- Acceleration Signal
  - Integrator
  - Velocity Signal
    - Butterworth Filter
    - Integrator
    - Filtered Velocity Signal
- Amplitude (mm)

Graphical User Interface (GUI)
Raw Data (Accelerometer)

\[ |X_{\text{max}}| = 4.7 \text{Hz} \]

Frequency calculation in each axis using FFT (\(Y=\text{fft}(X);\) vector \(X\))
Design Methodology

Algorithm Outcome:
Tremor Severity
Scale 0-5

PD Tracker

Kinematic movements & postures assessment:
Sitting, Standing, Walking

Parkinson's Disease Analytics

Department of Engineering Science (EE) - Learning Electrical Engineering in Small Classes and Through Student-Centered Projects
Test Methodology

- Data collected from 5 patients at different stages of PD - aging between 55-75
  - All volunteers from Parkinson's Support Group of Sonoma County
- Measurements were taken in three different positions
  - Sitting, Standing, and Walking
- Established a Scale Factor (between 0-5) for each patient indicating the severity of the tremor, 5 being the worst
- All measurements were taken during ON time
- Total measurement time for each test was limited to 10 minutes (600 sec. of data)
- Collection sampling rate was set to 50 msec.
## Test Results – Determining the Dominant Axis

<table>
<thead>
<tr>
<th>Position</th>
<th>Frequency</th>
<th>Amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accelerometer axis</td>
<td>Gyroscope axis</td>
</tr>
<tr>
<td>Sitting</td>
<td>X-axis</td>
<td>X-axis</td>
</tr>
<tr>
<td>Standing</td>
<td>Y-axis</td>
<td>Y-axis</td>
</tr>
<tr>
<td>Walking</td>
<td>Y-axis</td>
<td>Y-axis</td>
</tr>
</tbody>
</table>

**DOMINATE axis for measuring frequency & amplitude in different positions**
# Test Results – Maximum Change of Axis

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>SENSOR</th>
<th>POSITION WITH MAXIMUM VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>FREQUENCY</td>
<td>ACCELEROMETER</td>
<td>STANDING</td>
</tr>
<tr>
<td></td>
<td>GYROSCOPE</td>
<td>WALKING</td>
</tr>
<tr>
<td>AMPLITUDE</td>
<td>ACCELEROMETER</td>
<td>STANDING</td>
</tr>
<tr>
<td></td>
<td>GYROSCOPE</td>
<td>WALKING</td>
</tr>
</tbody>
</table>

Maximum axis changes in terms of frequency and amplitude
## Test Results – The Scale Factor

<table>
<thead>
<tr>
<th>PATIENT</th>
<th>FREQUENCY in hertz</th>
<th>AMPLITUDE in mm</th>
<th>SCALE FACTOR (SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PATIENT 1</td>
<td>4.54</td>
<td>16.20 mm</td>
<td>5</td>
</tr>
<tr>
<td>PATIENT 2</td>
<td>3.2</td>
<td>1.03 mm</td>
<td>2</td>
</tr>
<tr>
<td>PATIENT 3</td>
<td>2.350</td>
<td>2.39 mm</td>
<td>3</td>
</tr>
<tr>
<td>PATIENT 4</td>
<td>2.117</td>
<td>3.448 mm</td>
<td>3</td>
</tr>
<tr>
<td>PATIENT 5</td>
<td>3.7</td>
<td>3.2 mm</td>
<td>3</td>
</tr>
<tr>
<td>HEALTHY VOLUNTEER</td>
<td>0.05</td>
<td>0.2 mm</td>
<td>0</td>
</tr>
</tbody>
</table>

\[
SF = \sqrt{\alpha \cdot V^2 + \beta \cdot f^2}
\]
Future Design Extensions

- Nerve Stimulation
- Mass Storage
- Display
- Power
- Core Design
- Comm.
- Clinical Testing
- Patient Awareness
- Long Term Patient Monitoring

Department of Engineering Science (EE) - Learning Electrical Engineering in Small Classes and Through Student-Centered Projects
Future Design Extensions – What is Next?

Redesign the core hardware:
- smaller, lower-power, faster data storage
- use higher resolution sensor
- remove noise
- add ON/OFF LED
- change the glove
- hardware signal processing
- adding embedded RF

More clinical testing: $$

Improve communication protocol:
- Add low-power & low-range BT
- Ability to automatically download the data

Algorithm Outcome:
Tremor Severity Scale 0-5

Kinematic movements & postures assessment:
- Sitting
- Standing
- Walking
Data Analysis & Software:
Adding more features:
• better visualization: adding zooming capability, show status activity, show sampling rate, & more
• improving data analysis,
• removing noise - better filters, App development
Meet the Development Team....

Janene Grippi*, Campbell Smith, Luis Reyes, Faiza Qadri, Farid Farahmand

Sonoma State University, Department of Engineering Science & Department of Kinesiology*
7. Delano, Brian Parise, Georgia Tech Research Institute (GTRI)
Finally....

Thank you!
Any Questions?