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

**Presentation @ Lawrence Berkeley National Laboratory -
May 21, 2015**

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Advanced Internet Technology
in the Interests of Society Laboratory



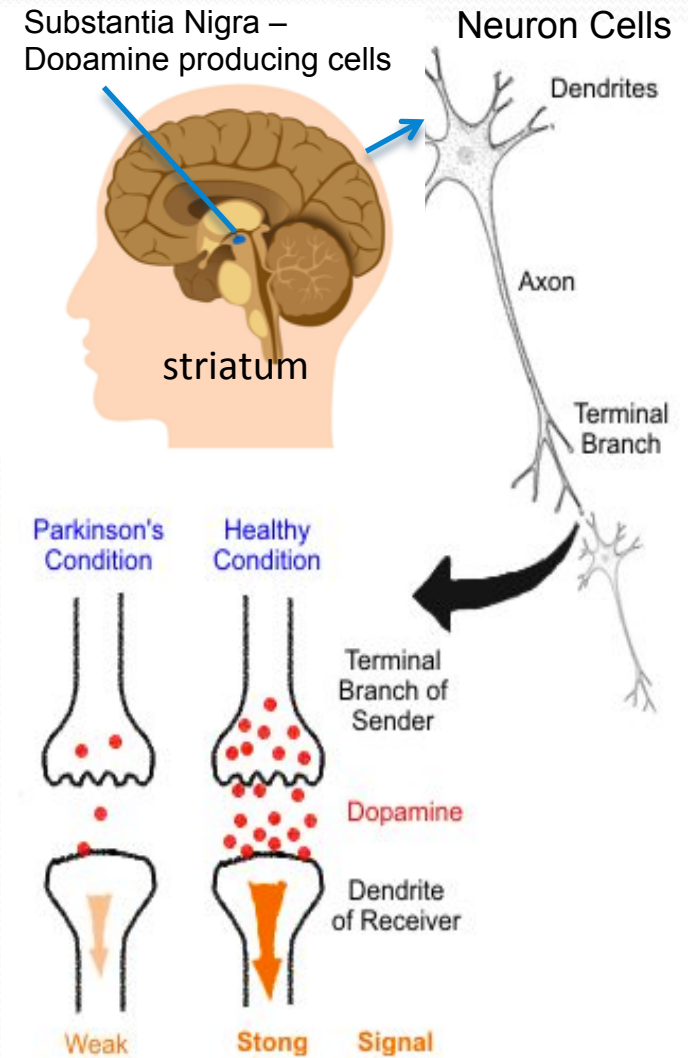
Agenda

- ✓ Background
- ✓ Project Objective
- ✓ Design Architecture
 - ✓ Hardware
 - ✓ Software
- ✓ Results
- ✓ Conclusion
- ✓ Future Works
- ✓ Questions



Background - What is PD?

- 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?

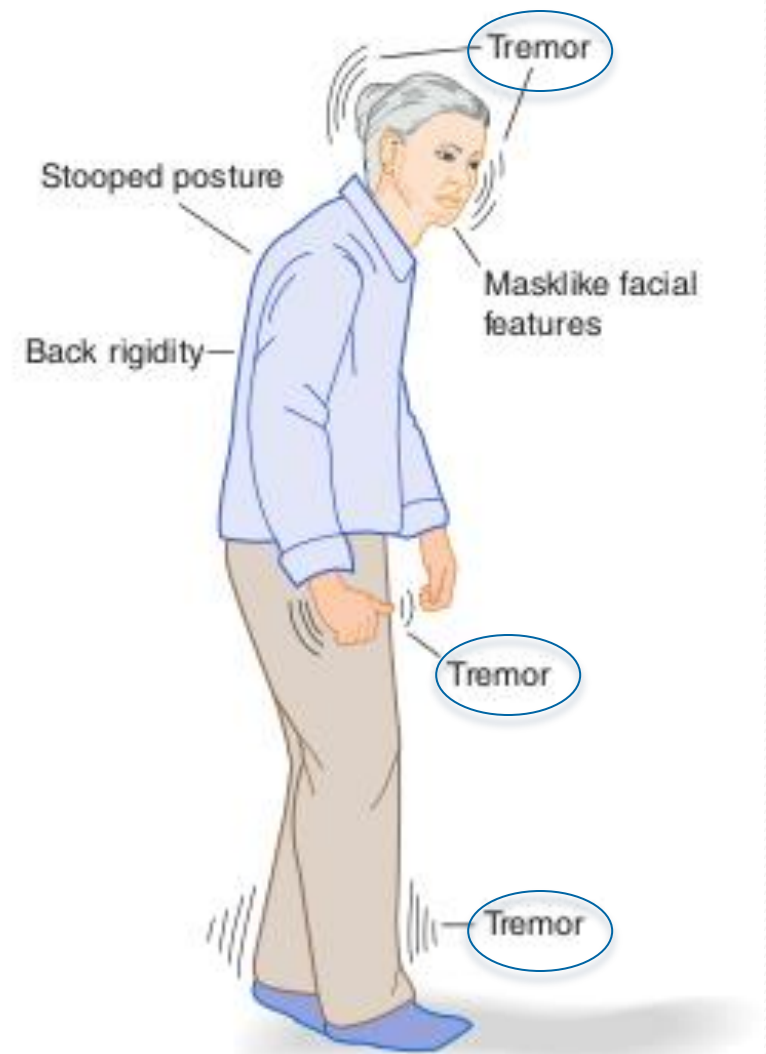


- Over **6 million** people in the world suffer from different stages of PD
 - Each year as many as 60,000 new PD cases of PD are diagnosed in the U.S.
 - Affecting up to a million people in the U.S.
 - 14th top cause of death in the U.S.
- In addition to mental & emotional cost, the annual **economic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



Background - Tremor Characteristics



- 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)



For example, hand tremor at rest may have a movement frequency of 4 Hz

Background

Diagnosis and Treatment



- 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



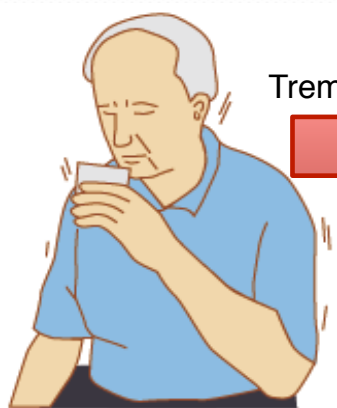
- Develop a **tracking device** to aid the clinicians in making better, objective decisions about health care outcomes of patients suffering with PD
- Our focus is to monitor **hand tremor**
 - Is the tremor being reduced?
 - Is the prescribed medicine effective?



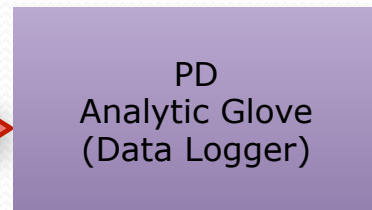
Long Term monitoring of frequency and intensity of hand tremor during On/Off periods → optimizing patient-specific therapy; resulting in improvement of patient care and quality of life!

System Architecture

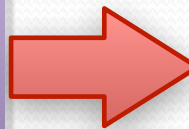
PD Analytics Glove + Software



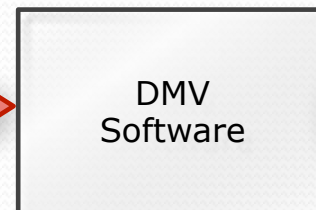
Tremor



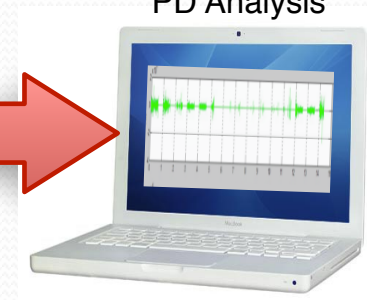
Designed by SSU in 2014



Multi-
dimensional,
Anonymous
Tremor Data



Proposed to be completed
in this project



Long Term Patient Monitoring

- Hand Tremor Monitoring
- Sleep Deprivation
- Activity Monitoring

Laboratory Testing

- Hand Tremor Characterization

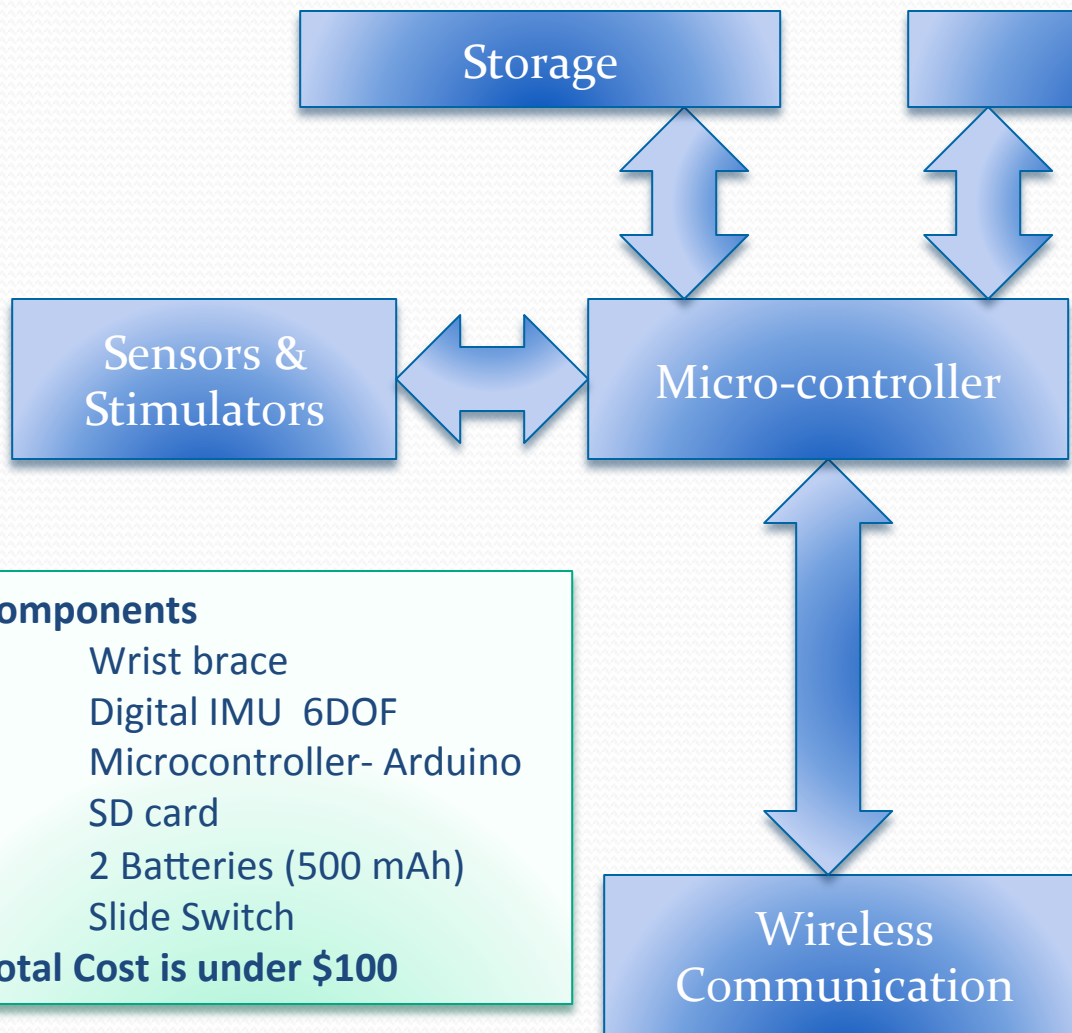
Patient Awareness

- Enabling patients to be involved in their own health

Nerve Stimulation

- Transcutaneous electrical nerve stimulation
- Using multi-lead TENS

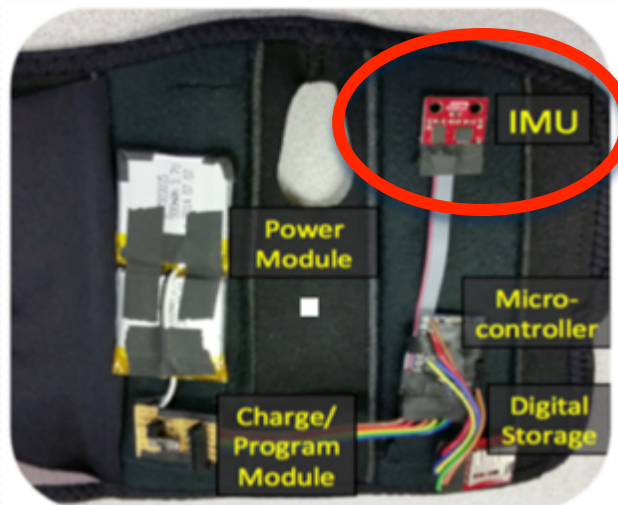
Core Hardware Design



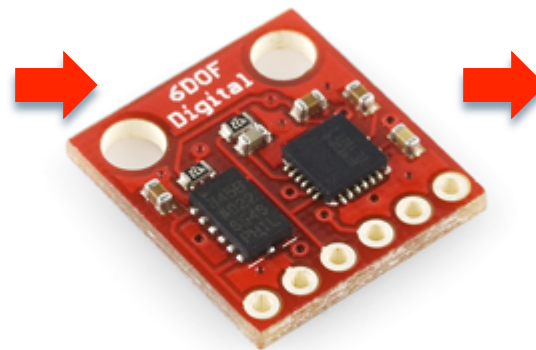
- Components**
- Wrist brace
 - Digital IMU 6DOF
 - Microcontroller- Arduino
 - SD card
 - 2 Batteries (500 mAh)
 - Slide Switch
- Total Cost is under \$100**

Motion Detection Sensor- 6DoF IMU

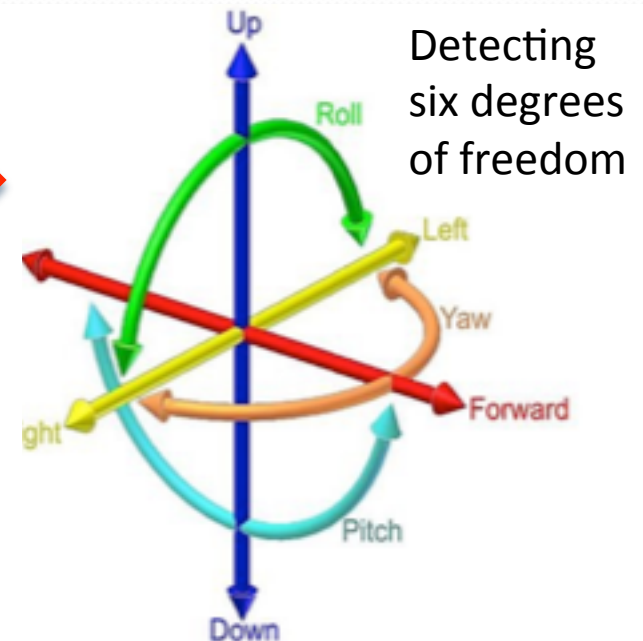
- Inertial Measurement Unit (IMU) – combination of Accelerometer and Gyroscope sensors
 - A single PCB with an accel. (motion) and gyro (rotation)
 - Specifications: Accel: $\pm 2, 4, 8, 16g$ Gyro: ± 2000 (deg./ sec angular velocity); I2C Interface



IMU



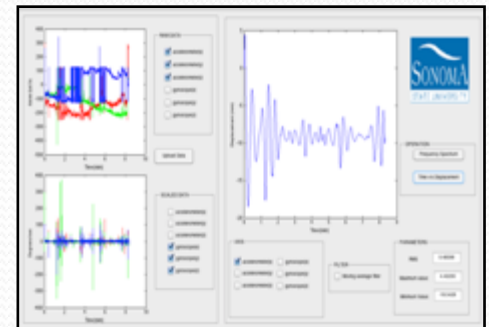
DXL345 accelerometer
and the ITG-3200
MEMS gyro



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

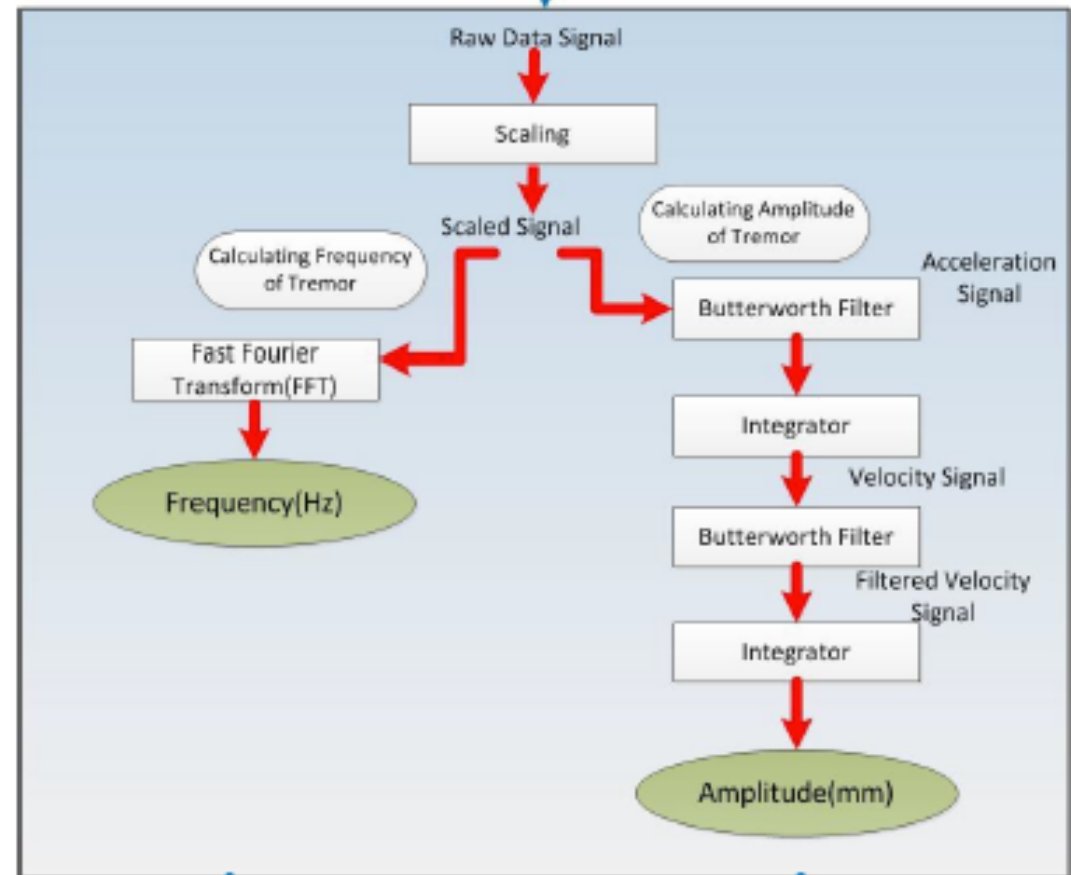
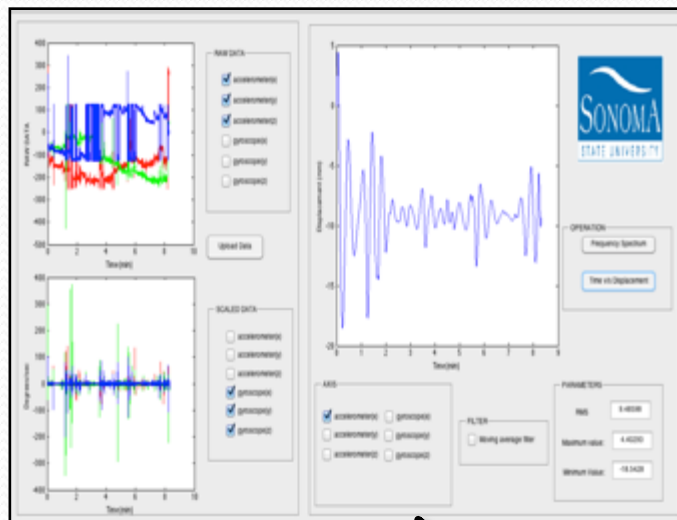


PD Software Matlab - Based



Prototype Device

.txt file



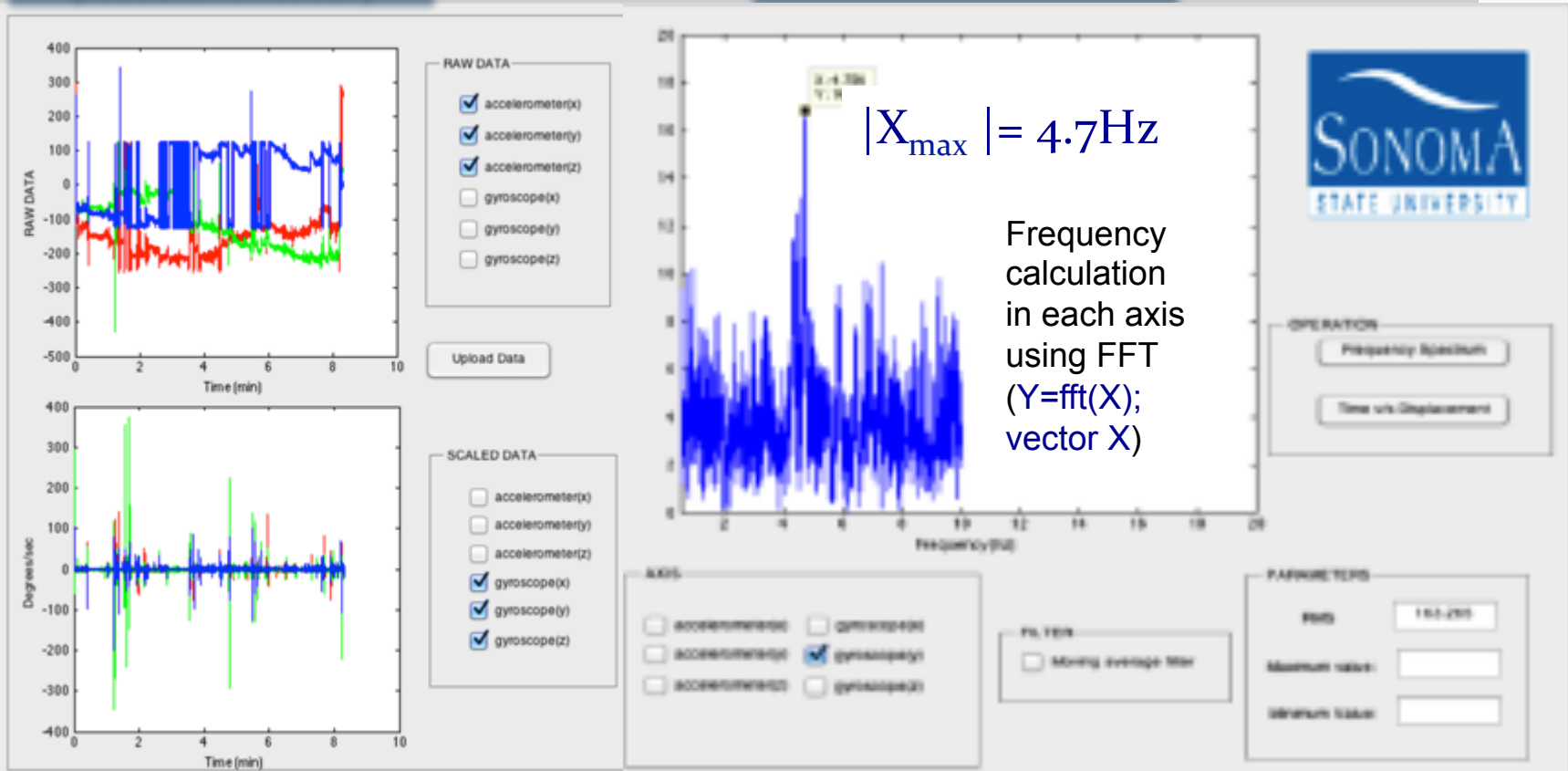
Graphical User Interface(GUI)

PD Software Visualization



Raw Data
(Accelerometer)

Results



Raw Data (Gyro)

Data Analysis

Design Methodology



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



Position	Frequency		Amplitude	
	Accelerometer axis	Gyroscope axis	Accelerometer axis	Gyroscope axis
Sitting	X-axis	X-axis	Y-axis	Y-axis
Standing	Y-axis	Y-axis	Z-axis	Z-axis
Walking	Y-axis	Y-axis	Z-axis	X-axis

DOMINATE axis for measuring frequency & amplitude in different positions

Test Results – Maximum Change of Axis



PARAMETERS	SENSOR	POSITION WITH MAXIMUM VALUES
FREQUENCY	ACCELEROMETER	STANDING
	GYROSCOPE	WALKING
AMPLITUDE	ACCELEROMETER	STANDING
	GYROSCOPE	WALKING

Maximum axis changes in terms of frequency and amplitude

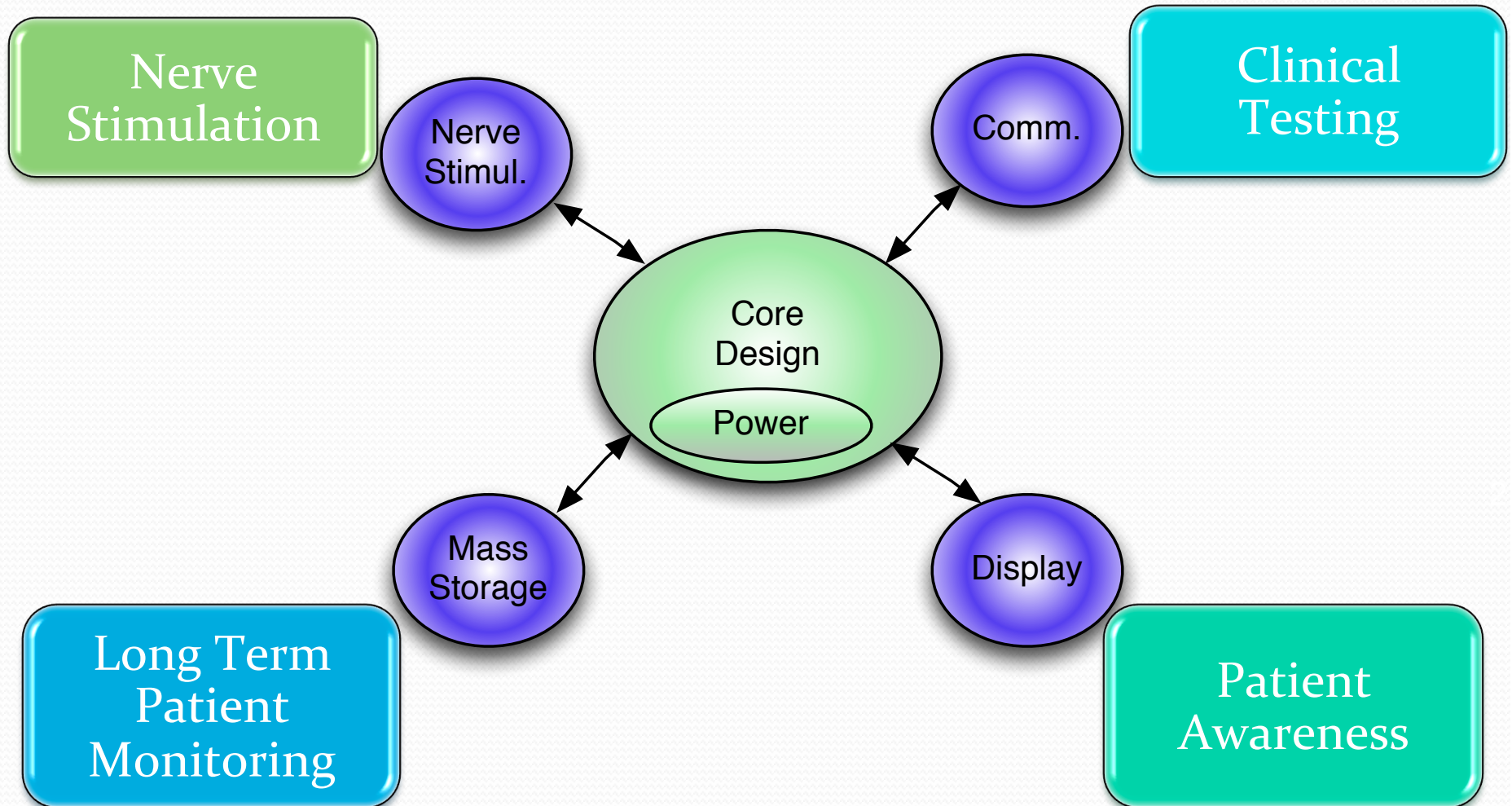
Test Results – The Scale Factor



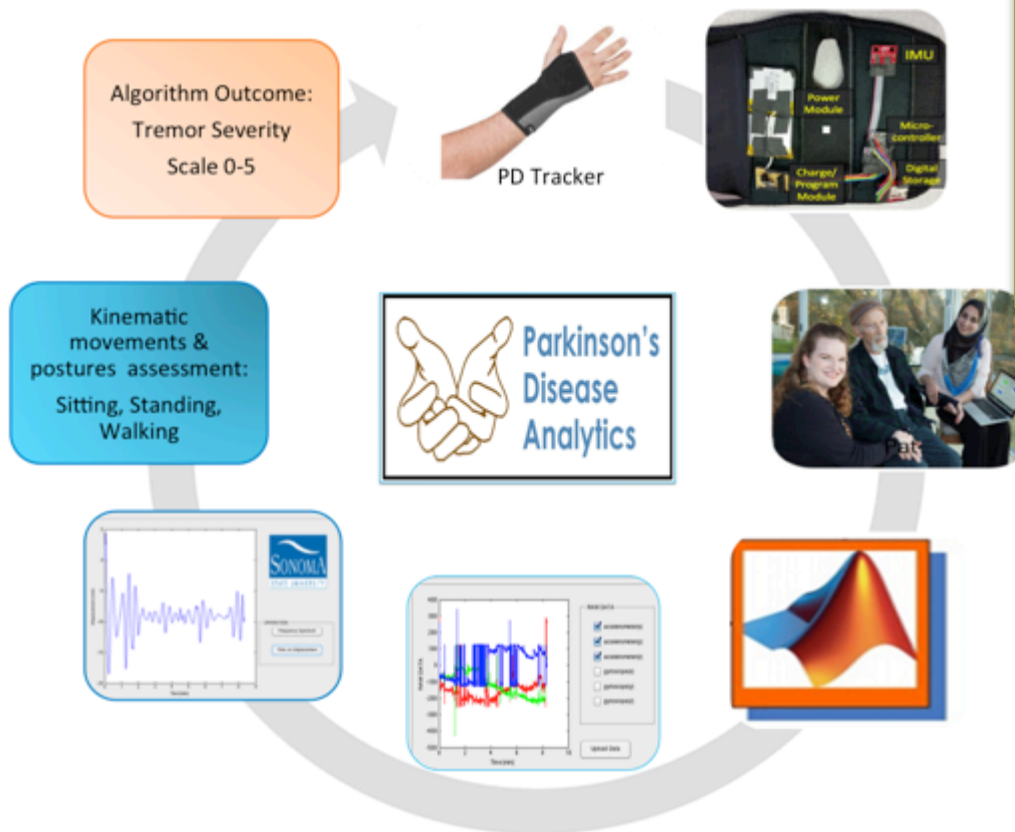
PATIENT	FREQUENCY in hertz	AMPLITUDE in mm	SCALE FACTOR (SF)
PATIENT 1	4.54	16.20 mm	5
PATIENT 2	3.2	1.03 mm	2
PATIENT 3	2.350	2.39 mm	3
PATIENT 4	2.117	3.448 mm	3
PATIENT 5	3.7	3.2 mm	3
HEALTHY VOLUNTEER	0.05	0.2 mm	0

$$SF = \sqrt{\alpha \cdot V^2 + \beta \cdot f^2}$$

Future Design Extensions



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

Future Design Extensions – What is Next?

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...



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Faiza Qadri, Farid Farahmand

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Kinesiology*



References



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Finally....



Thank you!
Any Questions?