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A Wireless Sensor Interface for the Quantification of Tremor Using Off the Shelf Components

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Abstract- *Deep brain stimulation (DBS) surgery involves placing an electrode in the subthalamic nucleus to suppress the motor symptoms, such as tremor, of patients with Parkinson's disease (PD). Currently physicians use the standard Unified Parkinson's Disease Rating Scale (UPDRS) to describe the tremor intraoperatively and post operatively. This scale involves subjective anchor-based observations by the clinical expert.*

In this study, a wireless accelerometer system is presented that was built from off the shelf components to objectively quantify tremor scores. The system consists of a Teensy 3.1 microcontroller and two 3-axis accelerometers. It wirelessly transmits the readings through a Bluetooth module. The data is received by a custom C++ program that parses and transmits the data.

The system is used to record data from patients with PD during and after DBS surgery. We show example data recorded from several PD patients and study the correlation of sensor readings with the DBS ON and OFF states. We provide initial data showing that such a system can be effectively used in the clinic for the objective quantification of motor symptoms of PD patients.

I. Introduction

Parkinson's disease (PD) is a neurodegenerative disease with a broad spectrum of motor and non-motor symptoms. It affects patients with a variety of motor symptoms including bradykinesia, dyskinesia, impaired posture, and tremor. Physicians can use observations from clinic appointments to determine how to titrate the medicine for optimal results [1].

Currently, the main method of describing the tremor is using the Unified Parkinson's Disease Rating Scale (UPDRS). This scale involves subjective anchor based observations made by a clinical expert. It is a 30 minute test that consists of a several questions from 4 different categories. Each question is answered from 0-4 (0=normal, 1=slight, 2=mild, 3=moderate, 4=severe). The UPDRS scale has received an update in 2008 that addresses some problems with the original scale, but still contains inherent problems that arise from using human observations as the main measurement tool [2]. These problems include both variations in scores by different raters as well as only using a small temporal resolution of ~30 minutes to determine severity.

With the advances in technology bringing down cost, miniaturizing the hardware, and increasing the performance of microcontrollers and sensors, several groups have been advocating the use of wearable sensors as a feasible diagnostic tool. There have been studies that look to quantify tremor based on features from sEMG [3], gyroscopes [4], and accelerometers [5]. The issues with many sEMG systems are that they are not feasible for long term use and require large expensive equipment. Other systems have issues with having an excessive number of sensors or too many wires. This can prove to be difficult for patients to quickly and easily put on the system. The aim of our system is to provide a wireless accelerometer system built from affordable, commercially available components to quantify tremor in the clinical setting.

II. Methods

A. Measurement Hardware

The system consists of a 72 MHz Teensy 3.1 microcontroller with a Cortex-M4 core that digitizes two GY-61 3-axis accelerometers with an ADXL335 chip with 10bit A/D resolution and 100Hz sampling frequency.

The system wirelessly transmits the readings through an HC-05 Bluetooth module (BT) with a CC2541 chip at a baud rate of 115200. The data is received by a custom C++ program made on Visual Studio 2013 that reads the incoming BT data from the virtual COM port. It looks for a full packet and makes sure the terminator character is at the end. It then forwards the

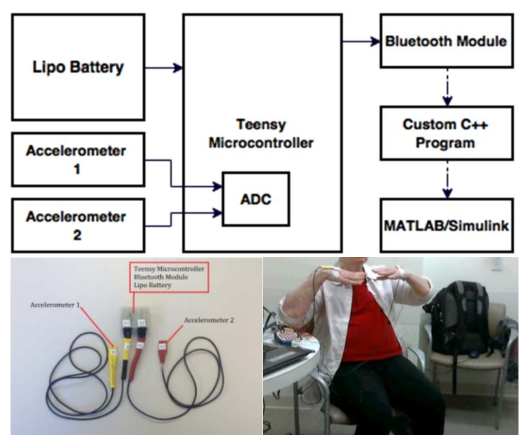

Fig. 1. Top: A schematic diagram of the system. The two 3-axis accelerometers were connected to 6 digital input pins. The Bluetooth module was connected to the RX and TX pins of the Teensy. The solid lines indicate physical connections and the dotted lines indicate either wireless or virtual connections. Bottom left: Wireless accelerometer system. The two accelerometers are attached to the either hands. Inside the custom 3D printed enclosure is the microcontroller, Bluetooth module, and battery. The accelerometer sensors are connected to the microcontroller through a modified Hyperthin HDMI cable that terminates in matching 5pin JST plug and connector. Bottom right: Patient wearing the system and doing the lateral postural tremor task in the clinic.

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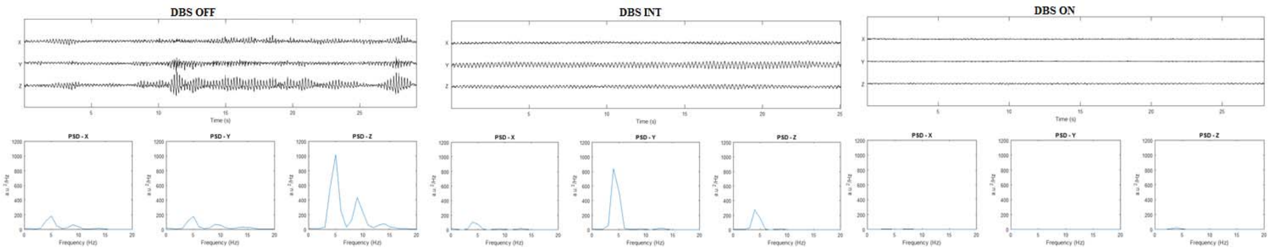

Fig. 2. Raw accelerometer data as well as power spectrum density (PSD) estimates using 1 second Hanning windows with 50% overlap from postural tremor test are shown. The left is with the DBS electrode OFF (0 V, physician rated UPDRS sub score 3), middle is with DBS electrode at an INTERMEDIATE level (2.0 V, physician rated UPDRS sub score 2), and the right is with the DBS electrode ON (3.1 V, physician rated UPDRS sub score 1+).

packet to the local machine through UDP. The system was powered by an 850 mAH Lipo battery. This was able to continuously run for ~19 hours before needing a charge.

B. *Experimental Design*

We collected data from patients with PD in the Parkinson's Disease Center and Movement Disorders Clinic at Baylor College of Medicine Medical Center. The two accelerometers were attached to either of the patient's hands. The patients were then asked to do 3 tests to determine: forward postural tremor, lateral postural tremor, and kinetic tremor. The patients did these tests a total of 3 times. The first time with the stimulation at their usual setting, the second time with the stimulation at a lower setting, and the final time with the stimulation turned completely off. Each patient took approximately 15 minutes to go through the whole exam.

We recorded all accelerometer data along with video using a custom model we developed in MATLAB/Simulink (The MathWorks Inc, Natick, Massachusetts). This model runs in soft real-time and receives the accelerometer data from the UDP port and displays the signal waveform. The patients were recorded during these tests using a Logitech c270 webcam that was synchronized with the rest of the data by capturing the frame number along with the accelerometer data.

III. Results

The patient's data was segmented into 3 different parts (one for each task). The raw accelerometer data from one of the tasks from a patient are shown in figure 2. We also show the power spectrum density (PSD) estimates of the accelerometer data under the 3 DBS conditions (ON, INTERMEDIATE, OFF). It is clear that a tremor is illustrated in the PSD estimates for OFF and INTERMEDIATE with strong peak around ~ 5 Hz and harmonics at frequencies multiple of 5 Hz due to non-sinusoidal waveform. We note our observation is within the range of PD tremor band which was reported in the 3-7 Hz range [6]. We can also see a higher power in the tremor when the DBS electrode is OFF, followed by INTERMEDIATE, followed by ON. This reinforces the UPDRS sub scores given by the physician.

IV. Conclusions

This study shows a system that will allow objective, accurate information on the existence and severity of tremor as a tool to supplement clinical observations. It can objectively measure both frequency and amplitude of tremor. This will allow physicians to identify meaningful differences in tremor severity that would be difficult to pick up with human observations. This system can easily be added to the current diagnosis procedure.

Future work should include further miniaturization and improvement of battery life of the hardware in order to allow for long term continuous recording. The dynamic temporal tremor data from long term recording can be analyzed and processed by computers and physicians to offer highly personal treatment plans as well as offer insight on how motor symptoms change over time in regards to stim ON and OFF states.

References

[1] S. Patel, H. Park, P. Bonato, L. Chan and M. Rodgers, "A review of wearable sensors and systems with application in rehabilitation", *Journal of NeuroEngineering and Rehabilitation*, vol. 9, no. 1, p. 21, 2012.

[2] C. Goetz, B. Tilley, S. Shaftman, G. Stebbins, S. Fahn, P. Martinez-Martin, W. Poewe, C. Sampaio, M. Stern, R. Dodel, B. Dubois, R. Holloway, J. Jankovic, J. Kulisevsky, A. Lang, A. Lees, S. Leurgans, P. LeWitt, D. Nyenhuis, C. Olanow, O. Rascol, A. Schrag, J. Teresi, J. van Hilten and N. LaPelle, "Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): Scale presentation and clinimetric testing results", Movement Disorders, vol. 23, no. 15, pp. 2129-2170, 2008.

[3] M. Bacher, E. Scholz and H. Diener, "24 Hour continuous tremor quantification based on EMG recording", Electroencephalography and Clinical Neurophysiology, vol. 72, no. 2, pp. 176-183, 1989.

[4] A. Salarian, H. Russmann, C. Wider, P. Burkhard, F. Vingerhoets and K. Aminian, "Quantification of Tremor and Bradykinesia in Parkinson's Disease Using a Novel Ambulatory Monitoring System", IEEE Transactions on Biomedical Engineering, vol. 54, no. 2, pp. 313-322, 2007.

[5] J. Hoff, A. v/d Plas, E. Wagemans and J. van Hilten, "Accelerometric assessment of levodopa-induced dyskinesias in Parkinson's disease", *Movement Disorders*, vol. 16, no. 1, pp. 58-61, 2001.

[6] D. Hobson, "Clinical Manifestations of Parkinson's Disease and Parkinsonism", Can J Neurol Sci., vol. 30, no. 1, pp. S2-S9, 2003.