

A Wearable Monitor for Movement Disorders in Parkinson's Disease

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Statement of Problem

- The complex and unpredictable nature of movement disorders in patients with Parkinson's disease (PD) presents a formidable challenge to developing effective measurement tools for assessing motor function.
- Current self-report methods, such as patient diaries, are less than optimal for tracking the variety of primary and secondary movement disorders in PD patients. These disorders can fluctuate uncontrollably as a result of long term drug treatment.
- The difficulty in accurately monitoring these movement disorders and medication states may impose a significant obstacle to properly managing interventions such as subthalamic DBS, which must be carefully adjusted during follow up.

Proposed Solution

- Recent advancements in wearable sensor and signal processing technologies have raised the prospects for an unobtrusive Personal Status Monitor (PSM) to automatically track:
 - the type and time course of specific primary and secondary movement disorders associated with PD (e.g. tremor, dyskinesia, bradykinesia);
 - the changes in the ON-OFF motor fluctuations related to anti-Parkinson's medication, and
 - the patient's physical mobility status (e.g. how often they walk, sit, stand, lie down, etc).

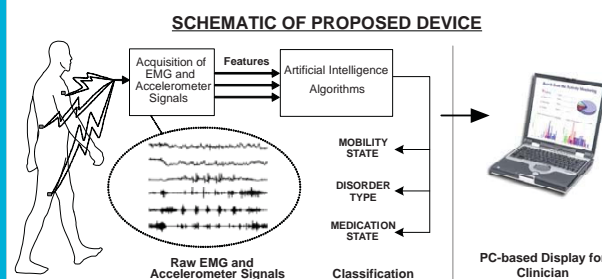


Figure 1: A schematic of the proposed PSM for identifying motor disorders, medication states, and mobility in patients with PD based on electromyographic (EMG) and accelerometer (ACC) signals recorded from the surface of the body. The wearable device will provide a continuous history and statistical summarization that can be made available to the clinician (right) to help manage drug/surgical interventions or develop new ones.

Description of Work to Date

HARDWARE

- We have been developing the underlying technologies needed to implement a PSM system based on electromyographic (EMG) and accelerometry (ACC) signals derived from hybrid body-worn sensors.
- Progress to date has included the development of portable (wired and wireless) data acquisition systems which can be adapted for use with the hybrid sensors. The system has been developed to deliver high-fidelity wireless data transmission, from the patient's home to the health care provider, in a manner similar to present-day Holter monitors or other Telemedicine approaches to health care.



Figure 2. (Left) Hardware developed by research team members to acquire and store up to 16-channels of EMG or ACC signals. Sensors are connected to a body-worn repeater (middle photo) which wirelessly transmits the data to a PC base station. Details of the surface EMG electrode innovation are seen in the callout. (Right) Prototype hybrid sensor combines EMG and ACC signal detection.

RESULTS

- Protocols were developed to acquire data from control subjects and PD patients with levodopa-induced motor complications. Recordings were made during "Peak On" and "Off" medication states while subjects performed a series of standardized motor assessment tasks derived from the CAPIT and UPDRS protocol.
- Examples of different EMG and ACC signal patterns (Fig. 3 left) and features (Fig. 3 right) from a control subject and a PD patient with levodopa-induced dyskinesia are shown. It is these visually apparent distinctions in the "Motor Image" that provide the basis for the likelihood of success of our approach.

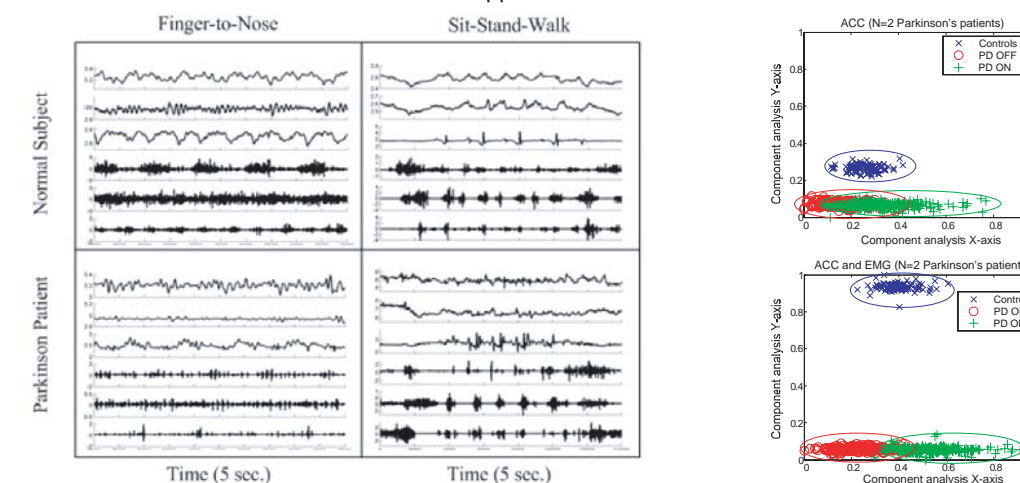


Figure 3. (Left) Traces from 3 channels each of EMG and ACC signals taken during two standardized motor assessment tasks: a Finger-to-Nose test, and a Sit-Stand-Walk test. Data are from an upper limb for the Finger-to-Nose task and a lower limb for the Sit-Stand-Walk test for a control subject and a PD patient with moderately severe dyskinesia; (Right) Results from Principal Component Analysis of the data demonstrating the greater separation of ON-Off medication states (approximately 400% increase) when both EMG and ACC data are included in the analysis. Separation of data points are highlighted by ellipses.

Proposed Work

- We have proposed a **hierarchical plan** to advance algorithm/software development for 3 activity stages :
 - Stage 1:** pre-planned, well-specified motor assessment tasks (as described in our Work-to-Date above);
 - Stage 2:** normal daily activities (e.g. sitting, standing, walking) that are constrained to specified times without overlap (i.e.;"Singular activities");
 - Stage 3:** normal daily activities which are performed extemporaneously (i.e.;"Free-form activities").
- We will develop trainable AI Algorithms to identify the various medication/movement disorder/mobility states from extracted signal features. The tools will include:
 - Multiple Artificial Neural Networks (ANNs)** based on results from a previous project (NIDRR Project No H133G020108) for a wearable sensor system to automatically track activities of daily living in patients with stroke.
 - Rule-Based System (RBS)** for identifying the most likely mapping of states to temporal epochs.
 - Iterative Correlation Analysis** for resolving identification problems due to the simultaneous presence of motor abnormalities and/or extraneous motor activities. This analysis is based on our previous work on the automatic decomposition of intramuscular EMG signals into motor unit action potential trains (NASA Grant 99E192; NICHD-NCMRR BRP Grant 1R24HD38585).

- An IPUS Blackboard architectural model of our own design (Nawab and Lesser, *Symbolic and Knowledge-Based Signal Processing*, 1992) will integrate the diverse AI techniques proposed above into a single PSM system (Figure 4).

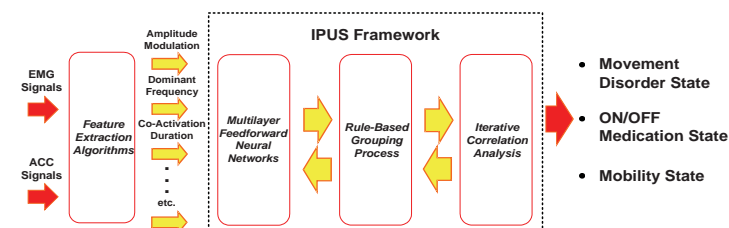


Figure 4. Schematic of the proposed AI analysis tools and blackboard architecture of the PSM.

- The PSM system will be designed to ensure that its algorithms are trained with respect to a representative population of PD patients that does not necessarily include any of the actual users of the completed system.
- Preliminary PSM development will be followed by a performance evaluation phase to ensure that performance converges to 85% sensitivity and specificity with the use of no more than 4 hybrid sensors. This degree of accuracy was specified based on previous successes with a monitoring system for functional activities in stroke patients (NIDRR Proj. No. 133G020108).

- The PSM will produce a report providing a complete history of patient mobility, occurrence of specific movement disorders, and fluctuations due to anti-Parkinson's medication (Figure 5).

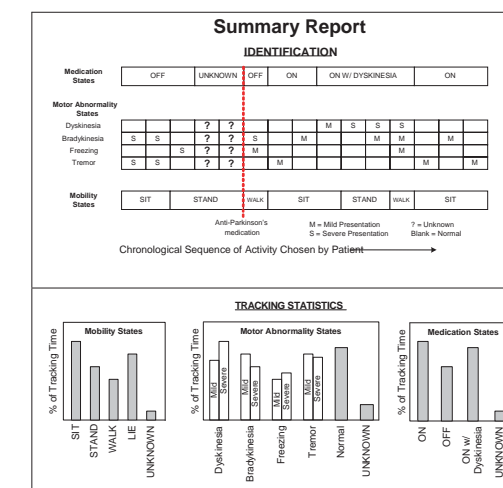


Figure 5. Example of a Summary Report derived from the proposed PSM.