Continuous At-Home Monitoring of Tremor in Patients with Parkinson’s Disease

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Abstract. Accurate assessment of tremor in patients with movement disorders is crucial for optimizing therapy and clinical trials. Current practice for assessment of motor symptoms is based on a brief clinical evaluation. However, these evaluations are limited due to fluctuations in symptoms during the day. With rapid advances in micro-electro-mechanical systems, inertial sensors have successfully been used to monitor patients’ movement mainly in clinics. In this study, we used inertial sensors to track tremor in patients with Parkinson’s disease at home. We show that objective measures calculated from inertial sensors can successfully track tremor fluctuations caused by dose cycles during normal daily activities.

1 Introduction

Many adults and children are affected by neurological problems that impair their motor function. Parkinson’s disease (PD) is the second most common neurodegenerative movement disorders. It afflicts 0.34–1 million people in the United States [1]. The motor symptoms of PD include rigidity, freezing in place, slowed movements, tremor, difficulty in initiation and small steps, as well as postural instability. People with PD often have a rest tremor with a frequency 4–8 Hz [2]. The current practice for assessment of motor symptoms is a brief clinical evaluation using clinical rating scales. However, these rating scales are subjective, momentary, coarse and fail to capture subtle changes in patient’s motor state which varies continuously throughout the day [3, 4]. Continuous and objective measurements of a patient’s daily physical activities can be used to study the degree of motor impairment, activity fluctuation during the day, and to assess the effect of different treatments and therapies.

Technological advances in low-power microelectronics and micro-electro-mechanical systems (MEMS) sensors have led some research groups to use inertia sensors to track movement in patients with movement disorders. Several studies have recently shown that some motor symptoms of Parkinson’s disease, and particularly tremor, can be measured accurately with inertial sensors [5–8]. However, these studies have been conducted in a laboratory setting or during a clinical assessment with prescribed activities. The value of these brief assessments during prescribed activities are limited because of the significant fluctuation in patients’ motor state throughout the day.

A few earlier studies to measure movement for long periods of time utilized activity monitors such as actigraphs. These actigraphs monitor patient’s rest/activity cycles and provide a measure of how frequently the acceleration exceeds a threshold per time interval. Unfortunately, these activity monitors provide no information on the type or intensity of movement and cannot discern regular activities from movement disorder symptoms such as tremor. Van Someren \textit{et al.} described an actigraph designed primarily for long-term evaluation to discriminate tremor from other movement of PD patients [9]. The device incorporated an accelerometer with only one degree of freedom. This approach is confounded by the effects of gravity. An earlier study with activity monitors was conducted by Hilten \textit{et al.} when they recorded activity over six days from nine patients and ten healthy controls [10]. This study was followed by a larger study with 69 PD patients and 59 healthy controls. They found a significant correlation between diurnal motor activity measures and Unified Parkinson’s Disease Rating Scale (UPDRS) total score.
They also found the activity monitoring to be useful for evaluating the influence of resting tremor, hypokinesia, and rigidity on motor activity [11].

One of the limitations of the brief clinical assessments is that they cannot be used to track daily fluctuations or measure how tremor responds to medication. Almost none of the prior long-term monitoring studies have recorded the times of medication intake to study the effect of dose cycles on motor fluctuations. In this study, we use wearable and unobtrusive devices with inertial sensors to continuously monitor tremor fluctuation and to study dose cycles in patients with PD at home during normal daily activities.

2 Methods

Ten subjects with PD and six age-matched controls were recruited from the Parkinson’s disease clinic at Oregon Health and Science University for a three day study (Table 1).

<table>
<thead>
<tr>
<th>Number</th>
<th>Age±σ</th>
<th>Duration±σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD Subjects</td>
<td>10</td>
<td>63.6 ± 9.0</td>
</tr>
<tr>
<td>Control Subjects</td>
<td>6</td>
<td>64.0 ± 9.0</td>
</tr>
</tbody>
</table>

Tab. 1: Summary of subjects monitored in the study. Ten PD subjects including 7 males and 3 females. Six controls participated in the study; 1 male and 5 females.

Subjects were continuously monitored at home over a 9 hour period while performing their normal daily activities.

Fig. 1: Example of an inertial sensor used in this study.

Inertial data were collected with five SHIMMER devices (Real Time Technologies, Dublin, Ireland) attached to both wrists, ankles and the trunk of each subject. An example of device worn on the wrist is shown in Fig. 1. The Shimmer contains triaxial accelerometers to measure the acceleration of motion in addition to gravity and triaxial gyroscopes to measure the rotational velocity. Each of the six channels of inertial was highpass filtered with a 0.1 Hz cutoff frequency to eliminate drift in the acceleration and rotational rates. Fig. 2 shows a five minute segment of a total rotational rate of the inertial device worn on the wrist of a control (a) and PD (b) subject. Based on the orthogonality of the gyroscope channels, the total rotational rate was calculated as follows

\[ |\omega(t)| = \sqrt{\omega_x^2(t) + \omega_y^2(t) + \omega_z^2(t)} \]

(1)

where \(\omega_x^2(t)\), \(\omega_y^2(t)\), and \(\omega_z^2(t)\) are the instantaneous power of the rotational rate of the gyroscope \(x\), \(y\), and \(z\) axes, respectively.

A time-frequency analysis (spectrogram) was performed for each of the three channels of
rotational data. The power spectral densities were estimated with a modified periodogram. Each 30 second segment was multiplied with a Blackman data window. Fig. 3(b) shows two spectrograms of the rotational rate from a device that was worn on the wrist of a control subject (top) and a PD subject (bottom). The triaxial gyroscope data were combined additively to display how the signal power of the total rotational rates were distributed across time and frequency.

Our inertial measure of tremor was calculated as a ratio of the rate of the power of total rotation within frequency range of 4–8 Hz to the power of total rotation within frequency range of 0.1–8 Hz. Our tremor index was calculated as

\[ T = \frac{\omega_p^2}{\omega_t^2} \]  

where \( \omega_p^2 \) and \( \omega_t^2 \) are the power of total rotation within frequency ranges of 4–8 Hz and 0.1–8 Hz, respectively.

3 Results

One of the objectives of this study was to determine if inertial monitoring can detect changes in motor fluctuations due to oral medication. We compared tremor measures 30 minutes prior to medication and 120 minutes after medication averaged across all dose cycles recorded during the 2 day study period. Results show that the average value of tremor measures in PD patients are elevated as compared to about 30 minutes after medication intake as seen in Fig. 3(a). The top panel of Fig. 3(a) shows no tremor fluctuations as expected for a control.

Another objective of this study was to determine if inertial devices can monitor tremor throughout the day. We compared the continuous measure of tremor in patients and controls. Results show that tremor measures are elevated in PD subjects as compared to the controls. The spectrogram in the bottom panel in Fig. 3(b) shows strong tremor within 4–6 Hz for about one hour centered about the medication intake time. Three patients had clear trend of high-frequency tremor. The tremor was easily detected from all of the five devices. These three patients had much higher tremor indices during all of the non-movement tasks than the other PD and controls subjects.
4 Conclusion

Objective measures calculated from inertial sensors can be used to monitor tremor in patients with Parkinson’s disease at home during normal daily activities. The results support the prior evidence in the literature that tremor in Parkinson’s disease patients can be accurately assessed with inertial sensors. Using time-frequency analysis, significant differences were detected between the patients and controls. Results also show that continuous monitoring tracks tremor fluctuations caused by dose cycles regardless of the activities that subjects perform. Our measure of tremor correlated with medication intake times. The assessment of motor symptom severity and fluctuation can be of great help in the evaluation of new therapies for Parkinson’s disease.

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References


