A Noval Method for Gait And Tremor Quantification In Parkinson’s Disease Patients

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Abstract: Tremor and gait disturbances are one of the key features in Parkinson’s Disease. There is an unmet need to evaluate the complex motor disturbances, especially tremor, gait and balance disturbances, that manifest and progress with the duration of disease. Till date there exists no validated system which can quantify gait and tremor, the values of which can be used clinically to assess patients. To analyze the tremor, we used MEMS based triaxial accelerometers attachable to the region of interest, mainly knuckles. And for gait assessment, we used snug fit shoes attached with switches at prefixed points. Data was collected and analyzed offline in MATLAB. With this instrument we were able to successfully measure gait and tremor in the patients. Standardization with complete removal of human intervention in this whole process of assessment must be studied further.

1. Introduction

Parkinson disease (PD), the second most common neurodegenerative disorder that affects approximately 2% of the population around 60 years of age, is primarily characterized by motor symptoms like akinesia, rigidity, resting tremor and postural instability. The secondary symptoms (dopamine-non-responsive symptoms) include Cognitive impairment often seen as a decline in intellectual functioning, Mood disorders (panic attacks, depression, anxiety and a variety of impulse control disorders), sleep disturbances (insomnia, vivid dreaming, REM Sleep Disorder, where individuals act out their dreams and RLS), orthostatic hypotension, constipation, hypophonia and slurred speech, reduced gastric motility, unexplained pains, numbness, tingling, drooling and loss of smell and visual contrast. However, the presentation of the disorder, response to treatment and the non-motor symptoms/comorbidities is heterogeneous.

Parkinson’s disease occurs when neurons that produce dopamine in the brain, predominantly in Substantia Nigra Pars Compacta (SNPC), a part of brain’s Basal Ganglia, degenerate. The degenerated cells have Lewy Body (Protein Alpha-Synuclein) depositions in them. Lewy bodies are recognized as pathological markers for this disease. All the symptoms of PD result from the loss of dopamine secreting (dopaminergic) cells and subsequent loss of neuromelanin in the pars compacta region of the substantia nigra. This leads to disruption in the normal direct and indirect motor pathways responsible for the movements. This is the
underlying reason for most motor and non-motor symptoms, which manifests as the disease condition progresses.

Tremor and gait disturbances are one of the key features in PD. Tremor can be defined as an involuntary rhythmic, asymmetric muscular activity, affecting chin, lips, head, hands, legs vocal cord or entire body of the patients. It exists while the patient is resting or while performing various tasks. Gait disorders in these Parkinson’s patients are a major cause of comorbidities. The major kinds of gait disturbances in PD patients range from festination to freezing. Rigidity results in reduced arm swing which in turn results in reduced balance. The patients are also presented with stooped posture and flexed knees. All of these considerably impair the patient’s quality of life (7).

There is an unmet need to evaluate the complex motor disturbances that manifest and progress with the duration of disease. Till date there exists no validated system that can quantify gait and tremor, the values of which can be used clinically to assess patients.

For analyzing tremor in PD patients, the neuro-physician, relies on the visual observation of the patients and rates the symptoms on the certified scales, while the patient performs several suitably designed activities. The diagnosis usually depends on the expertise of the physician which can be biased. To overcome such situations, we proposed a novel advance sensor-based technique to quantify tremor and gait parameters.

2. Materials and Methods:

2.1 Materials:

**Tremor:** To analyze the tremor, we used MEMS based triaxial accelerometers attachable to the region of interest, mainly knuckles. The MEMS based accelerometers are having the advantage of being light in weight and can also provide analogue/digital outputs. In the present project, we used analogue accelerometers. The three analogue signals obtained from the sensor has been connected to a microcontroller. 2 accelerometers were used bilaterally, which require 6 channels. These signals are provided to a controller which is preprogrammed to acquire the data. This data is transferred to laptop or PC and store it for further analysis. In our study, we performed offline analysis of the data using MATLAB.

**Gait:** For analyzing gait, we used tight shoes fitted with 4 switches as shown in the figure. The switches provide digital output, through which we can identify the different phases of gait pertaining to time like stance, swing, single support double support. Each shoe is also attached to an accelerometer, to measure the other gait related other parameters. As the subject is walking, the switch output and the accelerometer output are accessed and transmitted through Bluetooth to be stored in laptop for further analysis.

Gait cycle starts when one foot is on the ground and ends when the same foot touches the ground again. Few gait parameters which are of interest are mentioned below:
- Single leg support: one leg is in the air and the other on the ground during the gait cycle.
- Double leg support: both feet are on the ground.
- Swing phase: the foot is lifted off the ground and swings in the air. Its displaced from its original position.
Stance phase: this is when foot remains on the ground.

Gait velocity = meters travelled / time elapsed
step length = meters travelled / step count
step duration = time elapsed / step count

2.2 Data Collection:

Parkinson’s Disease patients attending Department of Neurology, Nizam’s Institute of Medical Sciences, are included in the study after obtaining signatures on the written informed consent form. They were analyzed in both off (no medication) state and on (on medication) state for both tremor and gait. The differences were documented as text files which were further analyzed in MATLAB. The UPDRS scale has been used as a measure for PD for comparison purposes.

2.3 Analysis:

Tremor analysis:

The obtained signal is high pass filtered to remove the DC offset associated with the sensor. It was double integrated, and the obtained signal was analyzed to identify the tremor frequency in X, Y and Z axes, which gives us numerical data in amplitude and frequency of displacement from center.
Gait Analysis:

In the gait analysis, the switch outputs are used to sense the different phases of gait like strike, flat foot and swing initiation. The set of switches assembled on both the shoes give us the timing parameters. Data from the accelerometer is used to quantify the step height, length, velocity and acceleration/deceleration timings.

3. Results:

On limited subjects the analysis has been done, and the instrument is providing data in a satisfactory manner which needs to be validated and standardized for further clinical use by the clinician. The parameters obtained were correlated with the clinically administered scales while the subject is on and off the anti-Parkinson’s medication. The results were also comparable to the literature available as of date.

4. Conclusion:

With this proposed instrument, we were successfully able to measure gait and tremor quantitatively. We expect to further improve this system to fit the current unmet need that demands the quantitative assessment of these parameter which would help in better diagnosis and hence aid in development of appropriate treatment methods. Also, this can be used to analyze other kinds of tremors and gait related disorders quantitatively, after appropriate validation, apart from those pertaining to Parkinson’s disease. The analysis can further help in development of gait rehabilitative devices or as a reminder to take medication, when the effects are wearing off. Also, the tremor device can be used intraoperatively while stimulation the patient at various currents to select the best fit electrode in DBS. We hope to provide a cost-effective gait and tremor related labs which will provide data instantaneously. Standardization with complete removal of human intervention in this whole process of assessment must be studied further.

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