Assessment of Degree of Severity of Parkinson’s Disease using Gait Signal Envelope

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Abstract

Neurological disorders disrupt the daily activity of many human beings. Recent survey has shown that Parkinson’s disease is more predominant in the present scenario in the age group of 65 and above. Using appropriate sensors gait signals are obtained from both normal and pathological subjects. Such signals are processed to determine start time of a stride and envelope of gait signal. Further two different methods are implemented using gait envelope to determine the degree of severity of Parkinson’s disease in pathological subjects in comparison with normal.

Keywords: Envelope, Gait Signal, Parkinson’s disease, Severity, Start Time

I. INTRODUCTION

Present worldwide survey shows that around 1% of people older than 60 years and above suffer from Parkinson’s disease and majority of them develop several speech impairments [1]. Parkinson’s disease is one of the chronic neural disorders which affect the people over the worldwide. PD symptoms include tremor, rigidity and loss of muscle control in general, as well as cognitive impairment [2]-[3]. This is a progressive disease with a slow progressive rate and gradually results in severe disability in terms of walking ability, speech and in handling of day to day routine activities [4]. Computer-aided diagnosis system for the automatic evaluation of Parkinson’s disease may provide useful information to the medical practitioner to make more accurate diagnosis and monitoring of PD patients and it can also help them to evaluate the severity level of disease periodically [5]. Gait is one of the behavioral biometrics and is defined as the manner of walking [6]. It may be considered as an effective tool to identify a person. Freezing of Gait (FOG) occurs quite commonly among persons with advanced Parkinson’s disease [7]. Few researches have discussed how to distinguish normal pressure hydrocephalus and Parkinson’s disease [8] and other researchers have proposed methods to determine the contribution of abnormal leg muscle activation to freezing in patients with Parkinson’s disease [9].

II. METHODOLOGY

Normal and pathological subjects are allowed to walk on level ground at their usual pace for two minutes. Under each foot, eight sensors are placed. These sensors measure vertical ground reaction force as a function of time. The output of total sixteen sensors are digitized and recorded at 100 samples per second. The sum of eight sensor output for each foot is calculated and included in the data. This signal database is available in physionet and is used for the current study.

Initially, ten numbers of healthy and normal persons are identified and they are treated as control subjects. The data of these subjects is used to create the reference values. The analysis is repeated for pathological subjects and compared with that of normal subjects to identify the level of severity of Parkinson’s disease. In each case of normal/ pathological subjects, one hundred and twenty seconds of walking/gait data is chosen. This consists of approximately 12000 samples, with sampling rate of 100 samples per second. In this data, first one thousand samples and last one thousand samples are removed. Starting thousand samples are eliminated since those samples may be appearing in the transition phase of rest to normal walking. The last thousand samples are eliminated since they represent transition period between normal walking to rest. After removal of these two thousand samples, intermediate ten thousand samples are considered for the data analysis. Such ten thousand samples are further divided into ten groups, each consisting of one thousand samples.

The analysis is carried out using two methods. In the first method, start time of each step is calculated and using this information envelope is determined for both normal and pathological subjects. Comparing the normal and pathological subjects’ envelope, degree of severity is assessed. In the second method, after calculating envelope, standard deviation is obtained for each subject. Depending upon the values of standard deviation, severity is assessed for pathological subjects in comparison with the normal. A. Method 1

For start time detection, either left foot or on right foot samples may be chosen. Since both of them yield similar results, in the present work, analysis is carried out using left foot samples. For each subject, data representing sum of the 8 sensor outputs of left foot is considered and is normalized by dividing it by maximum value. One group of thousand samples is considered. Such
signal frame is shown in Fig. 1. From the beginning, a set of three consecutive samples are chosen and checked if first sample value is above 0.1. If yes, then the sample is discarded and next set is considered. This process is repeated until a set consisting of three samples is found in which amplitude of first sample is less than 0.1. Once a set is found, then all the samples in the set are checked to find whether the amplitude of the consecutive samples is in the increasing order. If the previous condition is satisfied, then the first point is considered as start point of a step, otherwise next three samples are considered to find out whether they are in the increasing order. After finding start point, immediate null point is found by locating a set of three successive points, whose values are very close to zero. This process is continued to find all the start points of a group. The same is depicted in Fig 2. Each group of thousand samples of a subject is processed in sequential manner to determine start point of every step.

![Fig. 1: One frame of normalized signal of control subject](image1)

![Fig. 2: Start time values](image2)

Once the start points of each group are found, envelope of each group of data is determined. Consider the position of a start point and select another point at an interval of seventy points from that start point. Seventy points are chosen so that it amounts to more than half of sampling rate. Then the sample value which is maximum in the selected interval is determined. This procedure is continued in a group of thousand samples and envelope of that group is determined. Same process is followed for all the ten groups in the consecutive manner to determine the envelope of control subject. Both the signal and its envelope are indicated in Fig. 3 and 4 respectively.

**B. Method 2**

After determining the envelope of control subjects individually, standard deviation value of each segment of all ten control subjects is obtained. Then average of standard deviation values of all individuals are calculated block wise. Using this value, signal plot has been established and is considered as reference plot while determining the degree of severity of Parkinson’s disease with respect to individual pathological subject.
III. RESULTS AND DISCUSSION

A. Method 1

Control subject signal envelopes are obtained for all the ten cases of normal subjects and average value is calculated by considering individual segment wise. Average value of envelope of control subject signals is indicated in the Fig. 5. That has been considered as reference envelope signal while distinguishing the severity of the Parkinson’s disease among pathological subjects.

The envelope of individual pathological subject is determined by following the same procedure as that of control subject signals and individual pathological subject envelope has been compared with average value of envelope of control subject to estimate the degree of severity of Parkinson’s disease associated with individual pathological subject in comparison with the
normal subjects. Fig. 6 shows four waveforms. Blue colored waveform is indicating average value of envelope of control subject signal (reference signal). Other waveforms indicated with different colors are very close to reference signal. That indicates mild degree of severity.

![Plot of mild degree pathological subjects envelope signals along with reference signal](image1)

Fig. 6: Plot of mild degree pathological subjects envelope signals along with reference signal

Fig. 7 shows four waveforms. Blue colored waveform is indicating average value of envelope of control subject signal (reference signal). Other waveforms indicated with different colors are slightly shifted away from the reference signal. That indicates moderate degree of severity.

![Plot of moderate degree pathological subjects envelope signals along with reference signal](image2)

Fig. 7: Plot of moderate degree pathological subjects envelope signals along with reference signal

Fig. 8 shows three waveforms. Blue colored waveform is indicating average value of envelope of control subject signal (reference signal). Other waveforms indicated with different colors are scattered away from the reference signal. That indicates severe degree of Parkinson’s disease.

![Plot of severe degree pathological subjects envelope signals along with reference signal](image3)

Fig. 8: Plot of severe degree pathological subjects envelope signals along with reference signal

**B. Method 2**

Average of standard deviation values of envelope of controls subjects is indicated in Fig. 9.
Fig. 9: Average value of standard deviation of envelope of control subject signals

Fig. 10 shows four waveforms. Blue colored waveform indicates average value of standard deviation of envelope of control subject signal (reference signal). Other standard deviation waveforms indicated with different colors are very close to reference signal. That indicates mild degree of severity.

Fig. 10: Plot of standard deviation of envelope signals of mild degree pathological subjects along with reference signal

Fig. 11 shows four waveforms. Blue colored waveform indicates average value of standard deviation of envelope of control subject signal (reference signal). Other standard deviation waveforms indicated with different colors are slightly away from the reference signal. That indicates moderate degree of severity.

Fig. 11: Plot of standard deviation of envelope signals of moderate degree pathological subjects along with reference signal

Fig. 12 shows three waveforms. Blue colored waveform indicates average value of standard deviation of envelope of control subject signal (reference signal). Other standard deviation waveforms indicated with different colors are far away from the reference signal. That indicates severe degree of Parkinson’s disease.
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CONCLUSION

Present work may be helping the medical practitioner to speed up his diagnosis process regarding the degree of severity of Parkinson’s disease, once it is predicted in a patient. After medical practitioner starts treating the patient, periodical monitoring may be required to diagnose the degree of severity in the patient. In such cases the above work can be used as a tool to speed up the diagnosis process.

REFERENCES