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Gait and tremor investigation using machine learning techniques for the diagnosis of Parkinson disease

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HIGHLIGHTS

- A novel approach has been proposed to diagnose PD using the gait analysis.
- Various gait features were extracted using the peak detection and pulse duration.
- An average accuracy of 92.7% is achieved for the diagnosis of Parkinson's disease from gait analysis.

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ABSTRACT

Parkinson's disease (PD) is a chronic and progressive movement disorder affecting patients in large numbers throughout the world. As PD progresses, the affected person is unable to control movement normally. Individuals affected by Parkinson's disease exhibit notable symptoms like gait impairments and tremor occurrences during different stages of the disease. In this paper a novel approach has been proposed to diagnose PD using the gait analysis, that consists of the gait cycle, which can be broken down into various phases and periods to determine normative and abnormal gait. Initially, the raw force data obtained from physionet database was filtered using a Chebyshev type II high pass filter with a cut-off frequency 0.8 Hz to remove noises arising from the changes in orientation of the subject's body and other factors during measurement. The filtered data was used for extracting various gait features using the peak detection and pulse duration measuring techniques. The threshold values of the gait detection algorithm were tuned to individual subjects. From the peak detection algorithm, various kinetic features including the heel and toe forces, and their normalized values were obtained. The pulse duration algorithm was developed to extract different temporal features including the stance and swing phases, and stride time. Tremor is a common symptom in PD. Tremor is an involuntary movement of body parts. At first the tremor may appear in a specific body part like an arm, leg or one side of the body and later it may spread to both sides . This rest tremor is a cardinal sign of PD. An average accuracy of 92.7% is achieved for the diagnosis of PD from gait analysis and tremor analysis is used for knowing the severity of PD.

1. Introduction

It can be inferred from [1] that, the VGRF analysis were done based on statistical and frequency parameters and conveyed that the use of summation force values may hide the details the VGRF signals want to convey. So the analysis of separate force values show a difference between the healthy and PD subjects. Also, they have mentioned that the power distribution over the foot varies for the PD and healthy subjects.

Heida, T. et al. [2], shows that there is a continual balance between rest tremor and its repression. Thus, the power shifts across low frequency values and the range citied as tremor frequency in correspondence to change in the motor actions such as resting posture, movement of the body part that experiences tremor and other voluntary actions. It can be inferred from the result if the pathological tremor is present or absent. A person is said to be unhealthy if he/she does not exhibit pathological tremor.

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During deep brain stimulation, electrical signals are passed to the regions in the brain that causes tremor. Hence, when deep brain stimulated, there is a shift in the frequency range of the power spectral density. Vrutangkumar V. Shah et al. [3] suggests that high amplitude of input signals for deep brain stimulation has a more prominent effect in reducing the tremor. This is because the tremor components in the low frequency regions will experience a considerable loss in their equivalent gain. It also indicates the non-linear relation of tremor and the amplitude of frequency stimulation. Daryl Chang et al. [4] suggested the importance of machine learning in increasing the efficiency and accuracy of diagnosing the Parkinson's Disease. The center of pressure was used a characteristic to distinguish the subjects as normal or Parkinson's Disease affected person. A detailed probe into the Support Vector Machine (SVM) algorithm and the implications of regression was carried out. Sachin Shetty et al. [5] have successfully classified the Parkinson's Disease from other neuro-degenerative disease by applying a Gaussian RBF based kernel with an SVM classifier. They have achieved a good accuracy of Parkinson's over other disease and thus, this technique of using a SVM classifier has a good potential to differentiate Parkinson's from normal and other neuro-degenerative disease. Shyam V. Perumal et al. [6] have used the wearable sensors to develop a gait monitoring system for patients with Parkinson's disease. Their aim was to distinguish between PD and healthy subjects by identifying the most significant feature. The statistical analysis of variance test using the Linear Discriminant Analysis (LDA) algorithm to differentiate the subjects based on the values of mean and pattern classification. Thus achieving a better classification accuracy rate for distinct set of gait features like stance, swing phase and step distance. Manish Dubey et al. [7] used mean coefficient of variation, mean sum of variation and mean standard deviation and mean max of GRF as features and self organizing map has been used for classification. A person is said to be unhealthy if he/she exhibit pathological tremor. P.S. Motto and J.W. Judy [8] proposed the use micro machined probes for performing the surgical procedure. Hence, when the deep brain is stimulated, there is a shift in the frequency range of the power spectral density. Vrutangkumar V. Shah et al. [3] suggest that high amplitude of input signals for deep brain stimulation has a more prominent effect in reducing the tremor. This is because the tremor components in the low frequency regions will experience a considerable loss in their equivalent gain. It also indicates the non linear relation of tremor and the amplitude of frequency stimulation. O. Bazgir et al. [9] tested the correctness of the Unified Parkinson's Disease Rating Scale(UPDRS). Daryl Chang et al. [4] suggested the importance of machine learning in increasing the efficiency and accuracy of diagnosing Parkinson disease. The center of pressure is used as an attribute to distinguish normal person from Parkinson affected person. Human gait is analyzed under three heading namely kinematics, kinetics, and electromyography (EMG) by Pei-Hao Chen et al. [10]. A. Samàa et al. [11] used the signals from triaxial accelerometer and by using machine learning algorithm to diagnose the bradykinesia severity. Tucker et al. [12] used remote data mining based methodology to differentiate between "on" and "off" medication states among PD patients using low-cost, non-wearable sensor hardware. Data miner module is prepared using association rule mining algorithm and classification is done by using partial decision tree by Exarchos T.P. et al. [13]. N. Tahir et al. [14] used gait parameters features for classifying gait input using support vector machine and artificial neural network. Frenkel Toledo et al. [15] used stride-to-stride variability of gait timing to diagnose Parkinson disease. Amende et al. [16] quantified spatial and temporal indices of gait dynamics in a mouse model of Parkinson disease and Huntington disease. Spatiotemporal variables, kinematic differences and kinetic differences are used to diagnose Parkinson disease [17]. Gait dysfunction in Parkinson affected patients is analyzed with a help of kinematics and kinetics with systematic manipulations of dopaminergic status and attention [18]. Shenkman et al. [19] used Range of Motion (ROM) extremities measured from goniometer, ROM of the spine measured from functional axial rotation test ,motion during reaching determined by 3-dimensional motion analysis, followed by multivariable analysis of variance is used to diagnose Parkinson disease. Mirek E. et al. [20] utilized Vicon 3-d system to register three dimensional motion analysis. Get up and go test method is explored by Mathias S. et al. [21] to diagnose PD. Morris M. et al. [22] investigated stride length cadence relation in gait hypokinesia and the effect of levodopa medication on footstep pattern. Post B. et al. [23] explored the prognostic factors for the progression of Parkinson disease. Gelb D.J. et al. [24] suggested three levels of diagnostic buoyancy, which are differentiated namely definite, probable and possible.

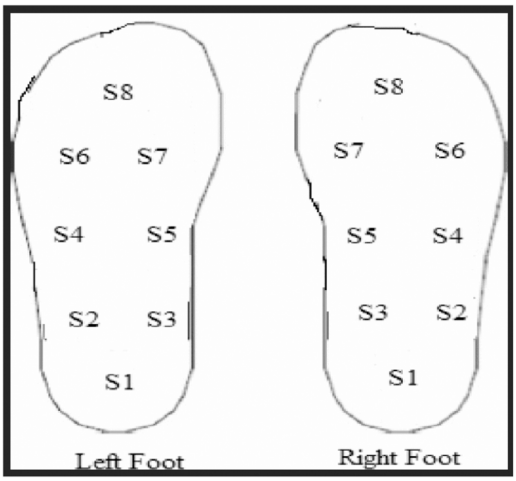

Fig. 1. Position of force sensors in the calculation of VGRF.

2. Materials and methods

2.1. Material

The Database of vertical ground reaction force (VGRF) was utilized from a public dataset maintained by Physionet. The data consists of 279 gait recordings from 93 patients with idiopathic Parkinson's Disease (PD) and 73 healthy controls, sampled at a rate of 100 Hz. To reduce the influence of subject's body weight on the force, the force values were normalized to the percentage of their body weight. During data collection, 8 sensors were placed underneath each of the subject's feet, as lying approximately at the following (X, Y) coordinates measured as a person is comfortably standing with both legs parallel to each other. For each subject, measurements of the vertical ground reaction force (VGRF) in Newton's were recorded as they walked at their usual, self-selected pace for approximately 2 min on level ground. Thus, each datum consists of 16 VGRF time series, as well as an additional 2 time series representing the aggregate force under each foot. For the tremor analysis, data from the Physionet database was utilized, resulting from the experiments conducted on 16 patients with PD. The patients were under minimum medications at the time of study to induce tremor and the data were recorded for a time period of 60 s (depending on the duration of tremor occurrence in subjects) and sampled at 100 Hz (see Fig. 1).

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