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Recent developments and trends for analyzing gait in Parkinson's Patients: A review

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Abstract— **Gait impairments are the foremost cause of morbidity in the Parkinson Patients. Due to the characteristics of these gaits varying enormously from normal gait to the freezing of gait, the analysis turns to be very difficult at clinical side. Analyzing gait using the instruments is one of the traditional method giving less accurate results. However, different algorithms and techniques have been implemented recently over the wearable sensor data to analyze, monitor or detect the gait in Parkinson patients. Therefore, the sole purpose of this research study is to explore different techniques used for analyzing gait in Parkinson patients.**

Index Terms— **Gait analysis, wearable sensors, signal processing, machine learning, deep learning.**

I. INTRODUCTION

As in modern era we want remedy for every disease. Disease is some kind of abnormality in human body and it can be caused by some external factors as well as some internal factors. Parkinson's disease is one of the neurological movement disorder in which neurons in the brain die or become impaired. Unfortunately, yet we have not found any cure for Parkinson's disease, except with treatment directed at improving symptoms. At the initial stage of disease the most obvious symptoms are shaking, rigidity, slowness of movement, difficulty in walking and gait.

Need of gait-analysis-systems has become critical and necessary in this era of stupendous technological advancements. There is a need to efficiently and automatically detect the gait that helps in differentiating between a normal subject and a Parkinson patient. In this regard, the researchers proposed different algorithms and techniques to analyse gait in Parkinson patients which are making a good progress at clinical side.

This paper is divided into V sections; Section II presents the wearable sensors for gait analysis, Section III describes the gait analysis using different techniques, Section IV comprises of conclusion. However, Section 5 gives directions for future work.

II. WEARABLE SENSORS FOR GAIT ANALYSIS

An accelerometer is the most widely used electromechanical device inertial sensor. It measures the changes in acceleration forces and its speed along its sensitive axis makes it satisfactory for data measuring motion status in the human gait. By affixing these accelerometers to the lower body, the velocity of the feet or legs during the gait can be determined in order to perform a gait analysis. A gyroscope is an angular position measuring sensor based on the principle of calculation of the rotational inertia, which can be applied to measure the angular velocity of the lower limb during walking and to determine the restructuring of the different gait phases. Mostly, while designing the wearable sensing system a gyroscope is often attached with an accelerometer to construct a complete inertial sensing system.

In comparison to a motion-capture system, accelerometers have certain limitations: they measure acceleration but perform poorly at computing the precise position because of the problems of integrating data with baseline drift. The readout of accelerometers is noisy and do not have very good dynamic range. The biasing may also differ with supply voltage and temperature, manifesting as an offset that results in inaccurate results

Force-plate sensors can be ingrained into footwear for ambulatory calculation of gait, allowing the capture and analysis of the gait over long periods of time and while the patient is in a natural (non-controlled) environment.

Different algorithms have been used over wearable sensors result to analyze, monitor or detect the Parkinson patients.

III. GAIT ANALYSIS USING DIFFERENT TECHNIQUES

Reference [1] shows that the researcher uses the sensors data and machine learning for the assessment of activities in Parkinson patients. In which, the subject carry Smartphone consisting of sensors that record the data of daily activities of Parkinson patients. For classification of data Human Activity Recognition (HAR) model, deep neural network (DNN) is used. But this research is unable to reveal more information regarding symmetry, power of stride length and even cannot predict fine grained activities of patient. In a research work carried out in [2] the researchers make a study on designing an intricacy reducing scheme that removes useless data and donate more quantization bits to more important parameters without reducing the performance. For that, the researchers use deep auto encoder and learn a non-linear dimensionality reduction scheme for accelerometer data measuring the gait of individuals with Parkinson's disease. This research is literally focused on discarding unimportant data and algorithms used for it. Reference [3] shows that the moments of 6 subjects are monitored and implemented support vector machine (SVM) classifier for differentiation between mild verses severe symptoms with an average accuracy of approximately 90% for quantitative tracking of disease progression. Several techniques based on wearable sensors such as accelerometer, gyroscope etc [4] placed on lower limbs to analyze gait parameters. Here the gait phase is detected in Parkinson patients both in OFF and ON levodopa conditions. Three algorithms are applied for this work which are based on

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threshold method and a novel Hidden Markova model approach. Around four inertial measurement units were placed on shanks and feet, and the walking tests are performed by patients. Finally, the goodness (G) of methods was evaluated through receiver operating characteristic. Results achieved in this research using machine learning are quite accurate as compared to other researches. The researchers in [5] motivate to global healthcare system to cope with better life expectancy and for that internet of things is most demanding. Real time data from patients' clothes connected with lightweight wearable sensors provides clinical database through mobile devices and fed into machine learning algorithms to detect severe conditions and vary medications on the basis of online observed physical deficits and estimate strategies to explore disease progression.

As the human grow older [6] the preponderance of neurodegenerative diseases is exponentially growing and Parkinson is most common among them. So the main aim of this study is to monitor severity of motor fluctuations in patients with Parkinson. With this regard, the focus is done on state of art in early detection of Parkinson symptom. Researchers used two classifiers instead of one which are Support Vector Machine (SVM) and Multilayer Perceptron (MLP). SVM provided best training accuracy and MLP gave better testing results than others. However, PD patients were monitored using Electromyography (EMG) and Electroencephalogram (EEG). The study provides good results but with complexity. Reference [7] provides the literature on wearable sensors and devices for analyzing human activities. Concluded that many lightweight, high performance wearable's devices will be available for monitoring a wide range of activities in future.

A treadmill based study [8] is proposed to detect if people with Parkinson can use real time feedback (RTFB) of step length and back angle to improve gait and posture. However, this research can further be enhanced in order to find the long-term effects of this RTFB paradigm. Reference [9] represented a sensor system that quantifies three symptoms of PD i.e. rigidity, bradykinesia and tremor. The work is done in two phases, first phase access whether data can be correlate to clinician's severity score using supervised Machine Learning (ML) models and the second phase detects that both sensor system distinguish difference before and after Deep Brain Simulation (DBS) optimization, and an average accuracy of 90.9% was achieved by MLP. In the Columbia University, a fully portable instrumented footwear named SOLESOUND is developed that is capable of recording gait parameters and acknowledge action-related audio tactile feedback. Eventually the performance of SOLESOUND [10] under two calibrations strategies, subject-specific and generic are measured. With subject-specific calibration the results were more accurate. Hence the device has potential to be used as quantitative gait analysis tool.

A novel multivariate method for analyzing gait is proposed in [11] using gait influence diagrams (GIDs). Here a particular case Weiner-Akaike-granger-Schweder influences measures known as 'Extended granger causality analysis' is used. GIDS are graphs with arrows indicating those influences that are significantly from healthy one and Parkinson patients. Reference [12] shows that abnormal gait patterns are detected of Parkinson patients. Data is collected from sensors located at 16 different positions on right and left foot. Extracting parameters based on summation of sensors output of each foot T-test and receiver operating characteristic (ROC) curve techniques are used to check performance of time and frequency features. Reference [13] shows that researchers use PHYSIONET dataset and applied statistical analysis of variance (ANOVA) test to differentiate subjects based on values of mean and pattern classification using linear discrimination analysis (LDA) algorithm. Better classification accuracy rate in step distance, stance and swing phases were achieved. Smart insole is developed in [14] to access long term chronic conditions like Parkinson. It consists of thirty-two piezo sensors, one tri-axial accelerometer, temperature sensors and force sensors to switch insole ON and OFF. Reference [15] shows that the researcher analyzes the freezing of gait and distinguish its severity in Parkinson patient. According to his research work analysis, Parkinson symptoms is one of the leading problem. Freezing of gait is a temporal interruption that lasts for a short duration in which feels like their feet are glued to the ground and because of which they are unable to move despite of concerted effort. The frequent problem found in PD patients is freezing of gait which increases with the span of time. The result of freezing of gait (FOG) results in falls and head injuries which increases the mortality rate. Researchers in [16] used deep learning model and achieved 90% for geometric mean between sensitivity and specificity and compared state of art methods which are unable to give 83% accuracy for same metric.

According to [17], FOG detection is performed using deep learning and signal processing techniques. Wearable unit is placed around waist. Though the approach achieved comparable to results of state of art is 88.6% and 78% sensitivity and specificity respectively. As gait signal is actually a movement signal [18] which can be obtained from the force sensitive resistor placed under foot. Left and right stride and left swing signals are selected, frequency spectra and power spectral density of signals are obtained. For classification Artificial Neural Network (ANN), SVM and Naive Bayes classifiers are used. Researchers in [19] developed cloud Unified Parkinson Disease Rating Scale (UPDRS) app for assessment of motor symptoms of Parkinson's disease. This research work successfully achieved high quality data collection and reduction of test duration. Three different problems are addresses [20], first classification of Parkinson patients' verses healthy control, access neurological state of PD patients using UPDRS score and the prediction of a modified version of Frenchay dysarthria assessment (M-FDA). Deep learning methodology is adopted in [21] and its aim is to overcome some of the limitations present in a typical deep learning framework, for that spectral domain pre-processing is used before the data. Reference [22] shows that abstract information obtained by wearable sensors is translated to context related expert features based on deep convolution neural networks. Unstable behavior [23] is analyzed using deep convolution neural network. Framework is composed of two parts; 1) Human skeleton divided into five joint groups, 2) Encoded representations are labelled using an automatic labelling method and evaluated using deep learning. Large number of studies focused on using wearable sensors to analyze freezing of gait and falls. This exploration review describes the operation of inertial sensors for FOG and falls in Parkinson's disease. However, [24] remarks that mostly sample size is minute, subjects are predicted to be at initial stages of disease, protocols are laboratory based and algorithms are not efficient. The good assessment of PD would only result from better inticipation among researchers, aligning data gathering protocols and exchanging dataset. Reference [25] shows the literature survey provided on gait assessment and authors concluded that gait detection through use of wearable's need algorithm fusion approach to measurement culminating in ability to better detect and classify falls. Reference [26] defines new set of features to improve performance of previous methods for FOG detection. They showed energy based algorithms are highly independent on gait pattern and their freezing on back to track postures of patients. Reference [27] aims to document rehabilitation in Parkinson patients after hydrotherapy session considering 2D and 3D underwater and on-land gait monitoring. Reference [28] introduced robotic assisted gait training for Parkinson patients. Three-month follow-up clinical trial left significant improvements. Adoptive logic network using Sural ENG as an input [29] is robust method for controlled stimulation timing for foot drop correction. Reference [30] proved that deep learning performed well with respect to accuracy than other machine learning algorithms by at least 4.6%. Hence deep learning is a propitious method.

IV. Conclusion

As Parkinson is a progressive disease for that the gait analysis is very important. Gait is the manner of walking. It is a peculiarity that may easily helps in detection of Parkinson patient.

Therefore, this research was focused on the survey of different techniques used for accurate and precise detection of gait that aids in differentiating between Parkinson patient and control subject.

V. Future Work

In future we will do the training of input features with the help of latest training algorithms. These features will be trained using deep learning to give robust output and making system more accurate to deal with large dataset and give more accurate results

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