Review: The Application of Wearable Sensors on the Diagnosis and Monitoring of Parkinson’s Disease

Xun FU and Xiao-juan MO
Northwestern Polytechnical University, 127 West Youyi Road, Beilin District, Xi’an Shaanxi, P. R. China

*Corresponding author

Keywords: Parkinson’s disease, Wearable sensors.

Abstract. Due to the high speed development of wearable sensors technology, the approaches of health care have been revolutionized. Recently, more and more wearable sensors have been applied in the management of Parkinson’s disease (PD). This review concerns the use of wearable sensors on diagnosis and monitoring for PD patients. In this paper, we outline the current diagnosis situation of PD and existing problems and limitations, gather the information of concrete current applications and research status, review correlated data processing methods implicated, and conclude the limitations and challenges. Some strategies to overcome the limitations of wearable sensors application on PD patients are discussed.

Introduction

Parkinson’s disease (PD) is a degenerative neurological disorder characterized by postural instability, rigidity, reduced movement range, and tremor especially happens among old generation, now shows an increasing trend in younger generation. According to the estimation, the number of Parkinson’s patients is between 4.0 and 16.1 million and is predicted to be doubled until 2030 [1].

The deficiency of dopamine caused by degeneration of neurons in substantia nigra pars compacta is the primary biochemical abnormality in PD. Nowadays, the main treatment of Parkinson’s disease is based on augmentation or replacement of dopamine with the usage of biosynthetic precursor levodopa or other drugs that activate dopamine receptors. These therapies are often successful in alleviating the abnormal movements some times, but most patients eventually develop motor complications as a result [2], which includes wearing-off, the sudden loss of efficacy when dosing interval ends, dyskinesia and so on [3].

Current treatment is mainly pharmacological and focuses on relief of motor symptoms, but there are symptoms that do not respond to Parkinsonian drugs. One symptom that is frequently ineffective to the medicine is freezing of gait (FOG) [1].

Since levodopa has been found useful to the symptoms, especially akinesis of Parkinson’s disease (PD), it has been used in clinical routine. It is feasible to assess the disease- associated features, forming a sensible and useful approach to assist physicians to make therapeutic decisions. Nevertheless, the individual difference of the motor and non-motor features of the patients make these decisions complicated and subjective. In some cases, therapy may not only ameliorate PD symptoms, but might also lead to motor and non-motor complications. Hence, it is essential to acquire the valid and accurate information of patients’ real states to adopt the individualized and complex treatment [4].

More and more PD patients and physicians take advantage of the wearable devices to measure the disease-related features [5]. For example, sleep disturbance is one of the disabling symptoms of many PD patients. Researchers has established a wearable wrist monitor with tri-axial accelerometry and movements interpreted using simple algorithms used in sleep monitoring of PD patients [6]. Additionally, one wearable system (iCalm) has developed a combination of activity, skin conductance, temperature, and photoplethysmography on wrist and foot to help detect changes in autonomic activity combined [7]. The advances brought by the
The Importance and Application of Wearable Sensors for PD Diagnosis and Treatment

As the world’s population continues to increase, the situation obliges us to develop a more effective proposal for PD patients to meet the demand of larger and older populations [9].

There are a lot of limitations on current monitoring instruments. For examples, clinicians get the information of patients’ motor activity by asking them to recall past situations which are subjective to perceptual and recall bias. There is another approach of using patients’ diaries to get useful information, however, diaries may not be accurate due to patients’ consciousness are not definitely objective. People may not be aware of their own status [8]. Thus, a reliable quantitative tool for monitoring and evaluating the status of PD patients is valuable for daily clinical care of patients as well as providing objective basis for trials of new therapies [2].

What’s more, the medical conditions of patients are so complicated and huge that the aim of the extensive monitoring of a person’s health status should be realized. However, the discontinuous hospital monitoring only provides a simple supervision. So, considering the development of micro sensor technology makes it possible to apply a wearable system to monitor human health in a continuous way in daily life of PD patients. Long-term monitoring at home is a feasible option nowadays due to the existed technology both on battery, wearable sensors and communication technology [10]. Shyamal et al. have proposed preliminary results which indicated that wearable sensor is feasible to track longitudinal changes of PD patients in daily life [11].

Generally, gait analysis has been achieved by laboratory techniques that mainly use 3D-camera based systems, force plates or instrumented walkways specialized for PD patients. However, those systems is not capable of providing ambulatory parameters in daily life. With the development of wearable sensors, those parameters could be measured out of the laboratory, and some new parameters such as acceleration and vibration frequency, could be added to improve the assessment of gait [12].

Commonly, PD patients suffer from a high falling risk. Falls, a debilitating problem for PD patients, results in a diminished mobility, influence the quality of life. So, it is necessary to evaluate fall risk. Previously, assessment of fall risk relies on self-report and performance-based tests. Therefore, it may be insufficient to assess fall risk optimally. Recently, researchers have developed a study to determine whether metrics obtained from a small, body-fixed wearable sensors worn by PD patients continuously for 3 days, are capable for capturing fall risk. 110 patients were recruited to participate in this study, and 107 patients’ data were analyzed. After the correlated statistical analysis methods which were used to realize corresponding aims, the proposed results indicated that such sensor-based approach is able to identify the transition from non-faller to faller and that those metrics have the potential to enhance the assessment of fall risk. In the future, the approach may make a contribution to accomplish the earlier detection of fall risk and may reduce the loss and costs associated with falls [13].

Wearable sensor techniques enable clinicians monitor motor functions of PD patients timely [2]. As wearable devices make it possible to measure the motor function out of hospital, having the potential to monitor PD symptoms at home and community settings [3].

Signal Processing Methods

Many exhaustive reviews have focused on presenting the importance to use wearable sensors to assist health monitoring. Meanwhile, data processing is also important while considering real time analysis of sensor data. Several works have been done that some researchers have presented the vital sign parameters which can be measured to evaluate and monitor the concrete status of individuals [14].
In health monitoring systems, data analysis plays a role in extracting information from the low-level sensor data and transform them to the high-level knowledge representation. Consequently, current health monitoring systems have put more attention to the technique of data processing to obtain much more beneficial information [14].

The techniques of data processing which are applied to wearable sensor data are not uniform. The data mining approach consists of three steps: a) data preprocessing; b) feature extraction and selection; and c) modeling data learning the input features (considering expert knowledge and metadata). These three steps accomplish the tasks of detection, prediction, and decision making [14].

Among methods of modeling data learning the input features, the widely used algorithms are indicated as follows [14].

**Support Vector Machine**

Support Vector Machine is one of the dominant statistical learning methods which is capable of classifying undiscovered information [15]. Health parameters including ECG, HR, etc. are often considered when using SVM. Researchers have applied SVM to discover the arrhythmia in ECG signals. And the results show that the SVM method performs better with polynomial kernel compared with other kernels [14]. Moreover, some researchers implemented SVM classifier to estimate the severity of tremor, bradykinesia and dyskinesia from accelerometer data features [3].

**Neural Networks**

Neural Networks, the widely used method for classification and prediction, is an artificial intelligent approach [14]. Neural networks were able to assess the severity of Levodopa-induced dyskinesia (LID) and to differentiate voluntary movements from LID [16]. Keijsers et al. used static neural networks to track dyskinesia by analyzing the signals acquired from accelerometer sensors worn by PD patients [17].

**Decision Trees**

The decision tree is a reliable and effective method which provides an efficient representation of rule classification [18]. Using this method, the most active features will be found for initial splitting the input data by creating a tree-like model. Usually, decision tree methods are restricted by the space of constructed features. Therefore, it is not recognizable to detect the information out of constricted features. Moreover, decision tree methods are not generally applied to numerous and complicated data due to the efficiency of the method will be affected by the number of features [14].

**Limitations and Prospective Developing**

There are some shortcomings of the existing technology. For example, the obtrusiveness of some systems is such that difficulties are encountered in donning and doffing the technique. There still exist limitations if one intends to deploy the systems in the home setting, such as the “lifespan” of the systems (i.e. how long the system can under working without requiring that one recharges or replaces the battery) [8].

Additionally, many wearable systems have heavily focused on the monitoring of motor symptoms of PD patients. The monitoring of non-motor symptoms cannot be neglected. Sources of disability often arise from non-motor deficits (i.e. depression, fatigue, anxiety). Unfortunately, monitoring non-motor symptoms mainly relied on measurements in laboratory. So, a urgent need for monitoring non-motor symptoms with unobtrusive systems in home and community settings should be resolved [19].

One issue related to the home use of wearable sensor systems for healthcare is the difference between acceptance of such systems in out-of-the-lab environments compared to in-the-lab environments. Systems designed for home use obtain high scores when they are assessed in the lab. But the acceptance rates are lower than in-the-lab environments. Usually, difficulties appear
when adopting the systems in lab conditions at the user’s home. Among the series of factors, social, emotional, and environmental factors play a critical role in the adoption and use of healthcare system in the home environments [1].

Take the developed wearable systems into account, most of them are not compatible with each other. In this case, there would exist problems in combining data collected by systems made by different manufactures [19].

Also, there is a question concerning how the data generated by those healthcare system should be used [4]. Patients may concern about how they could protect collected data. One promising approach has been proposed that the collected data should be included into patient-controlled [5].

Moreover, the collection and interpretation of data must lead to reasonable results, which implies some reporting matters. Therefore, users including PD patients, clinicians, therapists, and health care providers have to analyze the data thoroughly. Individual user should be provided with unambiguous instructions for analyzing the data. Now, the technology systems have been capable of measuring numerous clinically relevant parameters accurately, but the data collected is so significant that a research is required to condense the collected information and extract the target parameters for individual patient due to the treatment goals are different to each other [4].

The next generation of wearable sensors technology may be facilitated by the lateralization of their design, fabrication and distribution [9]. Though the use of some current devices is limited to controlled settings, the development of battery technology will enlarge the application of wearable sensors from limited hospital to home and community environments. Additionally, the innovative methods for data processing are being developed to decrease computational load [20]. The continuous development in wearable sensor would better serve PD patients and help improve their life quality.

References


