Artificial Neural Network Applied like Qualifier of Symptoms in Patients with Parkinson's Disease by Evaluating the Movement of Upper-Limbs Activities

J. P. Bermeo, M. Huerta, M. Bravo, and A. Bermeo

Abstract

The Movement Disorder Society (MDS-UPDRS) defines characteristics to qualify various symptoms of PD, the present works propose to apply an Artificial Neural Network ANN to qualify symptoms based upon movement of upper-limbs activities. In this way, a system based on Arduino and Android mobile app were developed, where accelerometers are used to acquire and store the acceleration data from upper-limbs while PD patients were doing three activities: rest sitting, eating and brushing teeth, meanwhile their symptoms were classified by doctor between 0 (normal) to 4 (most severe impairment). After that, store data were processed and estimation on Power Spectral Density (PSD) was done, then this information and doctor's diagnosis were used into the ANN training to evaluate the symptoms in PD patients. For the ANN training was used back-propagation model and many ANN configurations, until get the best fit between inputs (processed data) and output (doctor's diagnosis). The results showed that trained ANN can be used like qualifier with a high degree of accuracy over the 90%, for the tests performed. Moreover, even though MSD-UPDRS allows to get an accurate diagnosis, there is not objective, so ANN could be fixed to be completely objective, being a great advantage with manual evaluation.

Keywords

Parkinson's disease • Artificial neural network MDS-UPDRS scale • Mobile apps • Power spectral density (PSD)

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1 Introduction

The "Paralisis Agitans" syndrome named the first time by James Parkinson in 1817, is a neurodegenerative disease caused by reduction of dopaminergic cells in the substantia nigra, however the most famous name is Parkinson Disease named by Jean-Martin Charcot [1]. Between 1 and 2% of population over 70 years are affecting by PD [2]; the tremor at rest, muscle stiffness, bradykinesia (slowness in voluntary and involuntary movements, but mainly difficulty to start and finish them), loss of postural reflexes and segmental cephalic tremor are the most common movement disorders.

In 1980, the Unified Parkinson's Disease Rating Scale UPDRS was developed, but the Movement Disorder Society (MDS) asked a revision about scale, resulting in the MDS-UPDRS scale [3], where start in 0 (normal) to 4 (most severe impairment).

The measurement process of MDS-UPDRS is large and complex, furthermore is subjective and potentially error prone, so there are a lot of methods and devices to evaluate the PD's motor symptoms. In [4] 3D visualization techniques are applied to monitoring and assessment of Parkinson's disease. The severity of symptoms had been assessed by Wii console [5], Kinetic sensor [6, 7], but the main problem is the weight in the first case because is a constraint for the free movement, and in the second case, the problem is a limited distance and the necessity of adequate light. A system based on Arduino and Android mobile App was developed in [8] to evaluate motor assessments. Neither all these approaches apply their measurements to evaluate the movement disorders of PD's patients in a MDS-UPDRS scale.

This paper takes advantages of Artificial Neural Networks ANN to classify a wide range of inputs, for this work, the inputs are processed signals measured by triaxial accelerometers from the system developed in [9], and ANN was trained with doctor's diagnosis such as output. The results showed a high accurate between ANN's output and diagnosis. The measures were taken form upper limbs in

L. Lhotska et al. (eds.), *World Congress on Medical Physics and Biomedical Engineering 2018*,
IFMBE Proceedings 68/2, https://doi.org/10.1007/978-981-10-9038-7_77

four activities of daily life such as lying rest, eating, rest sitting, and brushing teeth.

2 Methodology

For this work, begin with the training of ANN, after that the ANN is used to make diagnosis with measurement took and processed from acquisition system. The first step, to train ANN, is take measurement from system developed in [9], then data are processed to become in inputs to ANN, and doctor's diagnosis are the reference outputs. With inputs and reference outputs, ANN trains until get ANN's outputs are like reference outputs. ANN changes while training, so the last configuration is known as a "trained network", Fig. 1 show the process to train ANN.

The trained ANN could be applied to evaluate Parkinson's patients in a MDS-UPDRS scale. Figure 2 sketched what was described above.

In the next sections, every block is detailed.

2.1 Acquisition System

The acquisition system [9] has a digital accelerometer and gyroscope MPU-6050, Arduino Pro Mini, microSD module, HC-05 Bluetooth module and a Li-ion battery. The information is stored in CSV format in Android mobile device, information was sent by Bluetooth module from Arduino Pro Mini to Android mobile device. Figure 3 outlined block diagram of acquisition system.

The information measured from triaxial accelerometers, has a sampling frequency of 14 Hz, for each test 450 samples were used to data processing, information is registered by sensor in Arduino device and data is sent to personal computer by Bluetooth in CSV format. Figure 4 shows acceleration of each axes and the module received from acquisition systems for one Parkinson disease's patient X

2.2 Data Processing

The ANNs are sensitive to variations of amplitude and time displacement [10], so the data should be processed before introduced to ANN. To generate invariance to time displacements, the module of the Fast Fourier Transform FFT [11] and Welch's power spectral density estimate [12] are used.

The FFT is applied to acceleration, and Welch's power spectral density is applied to displacement. The acceleration's integral is equal to velocity, and velocity's integral is the displacement [13]. For each integral, interpolation is applied to evaluate the middle point, its mean that N original points will become $2 * N - 1$ points for first integral and $2 * (2 * N - 1) - 1$ points for second integral, so for $N = 450$ acceleration's points there are 1797 displacement's points. Figure 5 shows calculated displacement for each axes and module.

The accelerometers measure the gravity, furthermore a constant velocity could be affect the estimation of

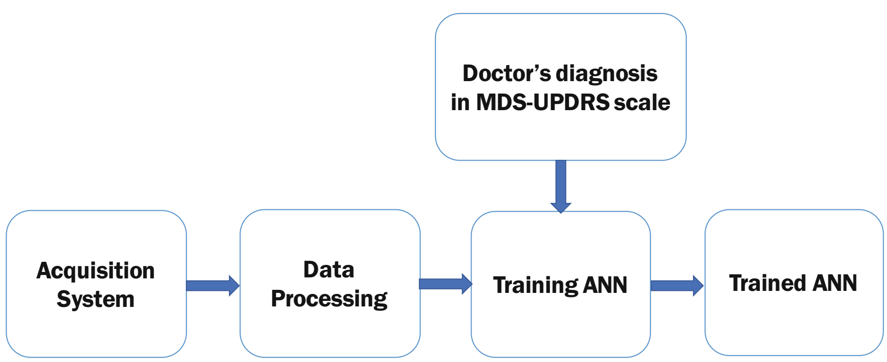

Fig. 1 Flow chart of the artificial neural network (ANN) training process

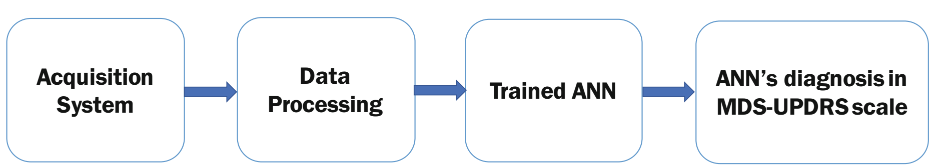

Fig. 2 Trained ANN applied like evaluator

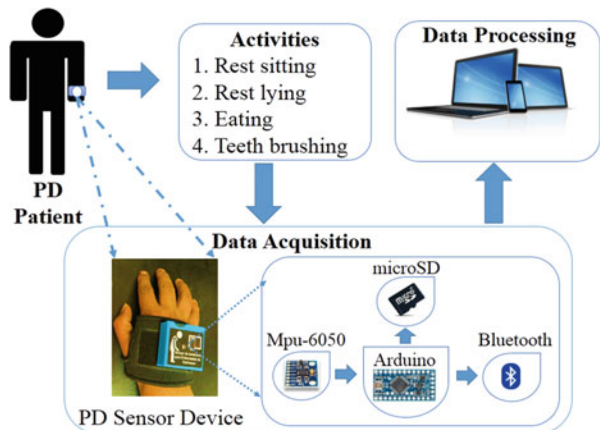

Fig. 3 Block diagram of acquisition system [9]

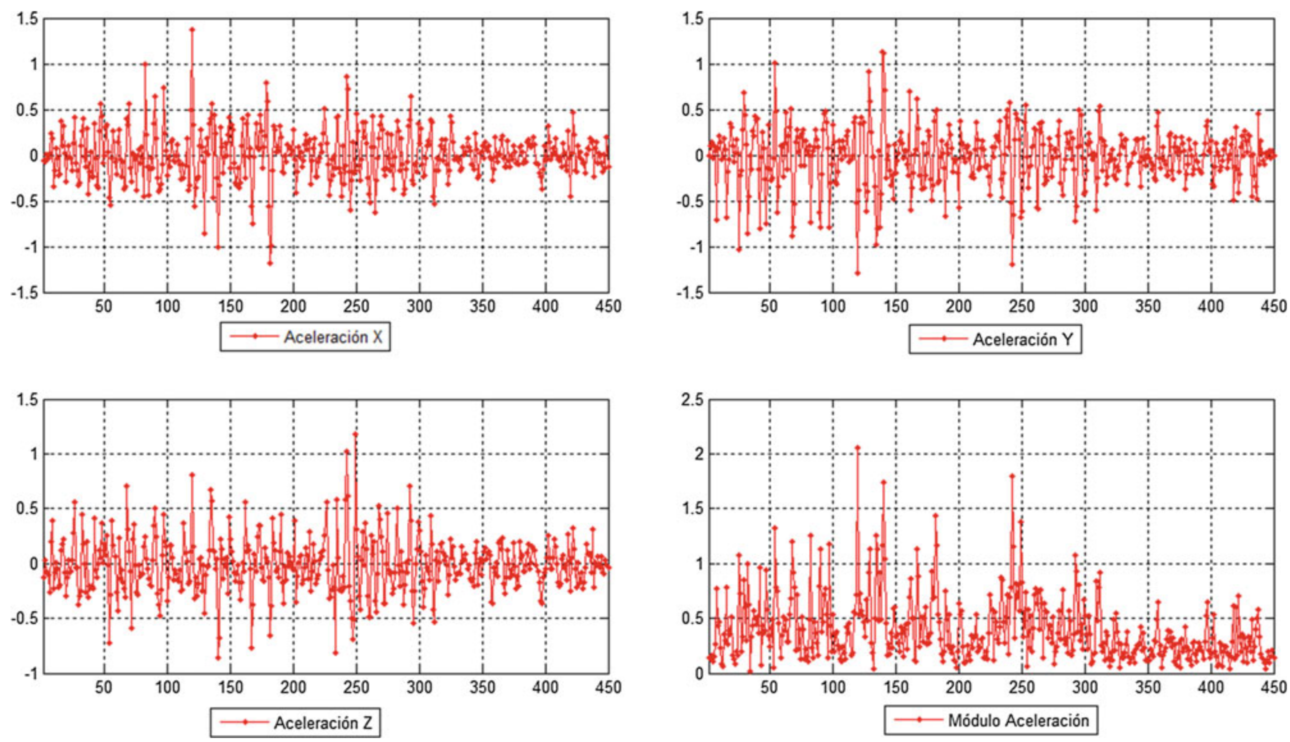

Fig. 4 Acceleration measured from triaxial accelerometers

displacement, so before each integral, a digital high pass filter was applied to eliminate frequencies below 0.5 Hz, Matlab's functions [14] were used to get this aim. Figure 6 shows the Fast Fourier Transform of acceleration and Welch's power spectral density estimated from displacement.

2.3 Artificial Neural Network ANN

The ANN's has several applications like pattern recognition [15], sales forecasting [16], evaluation of health index of power transformers [17], and others. In this paper ANN was used like evaluator for patients with PD.

After data processing, information can be entered to ANN to start the training. Some configurations were tried, at the end, the ANN with the best results, had three layers, 357 inputs, thirty neurons in hidden layer and one output; logsig function to hidden layer and lineal function to last layer. The ANN is sketched in the next Fig. 7.

With the trained ANN, in the Fig. 8 a comparative between net's output and doctor's diagnosis is showed. There is a high equivalence between both diagnoses, its

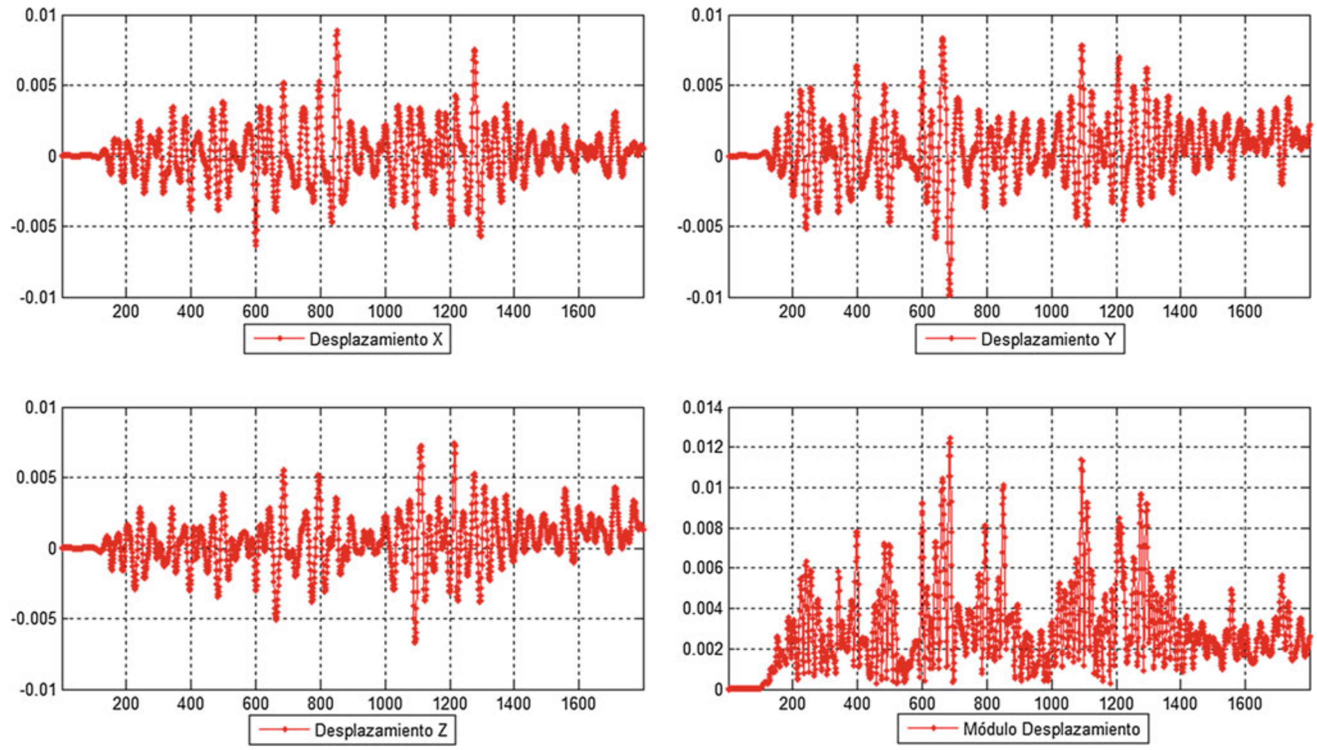

Fig. 5 Displacement calculated from twice integrated acceleration

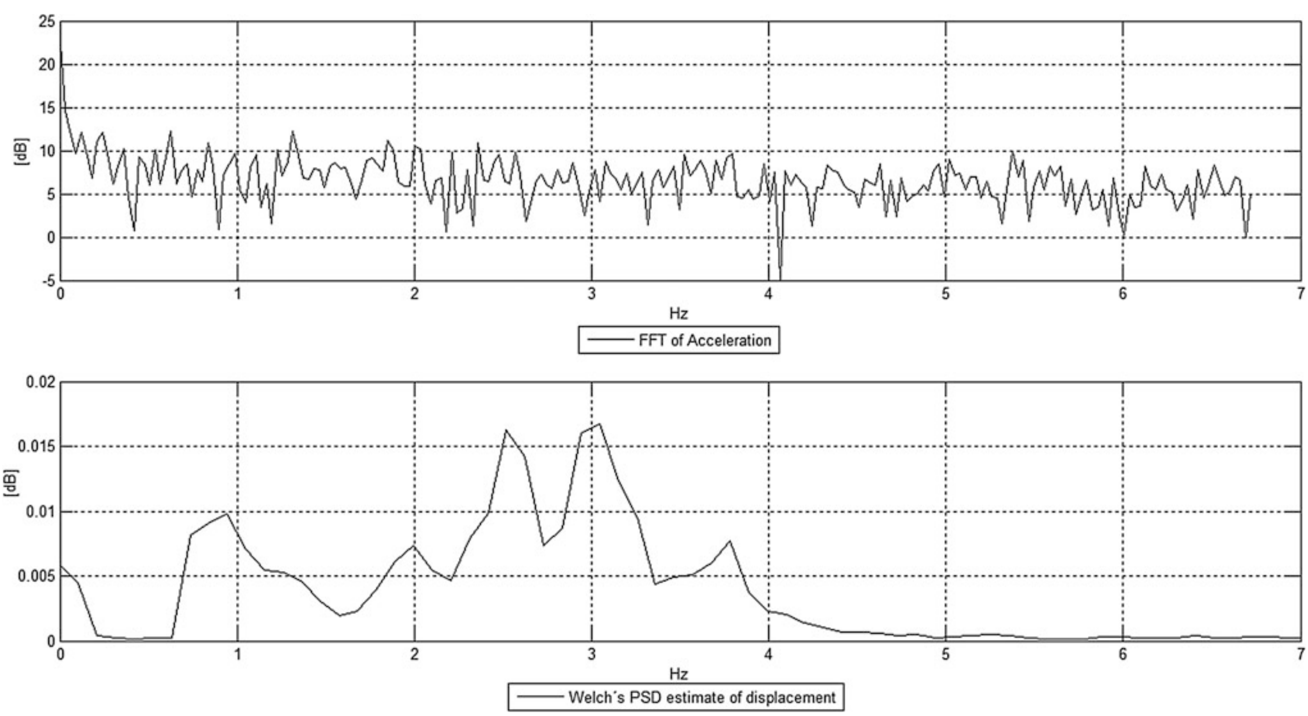

Fig. 6 FFT and Welch's PSD estimate

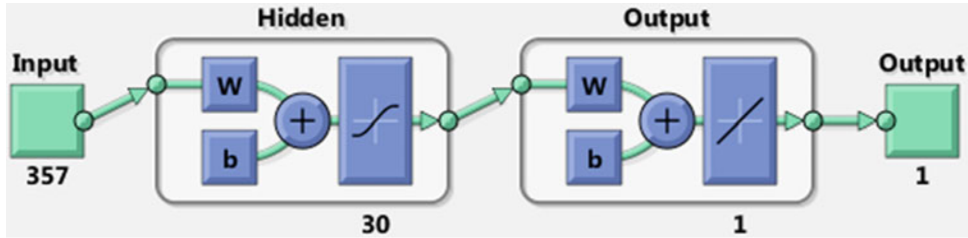

Fig. 7 ANN's scheme

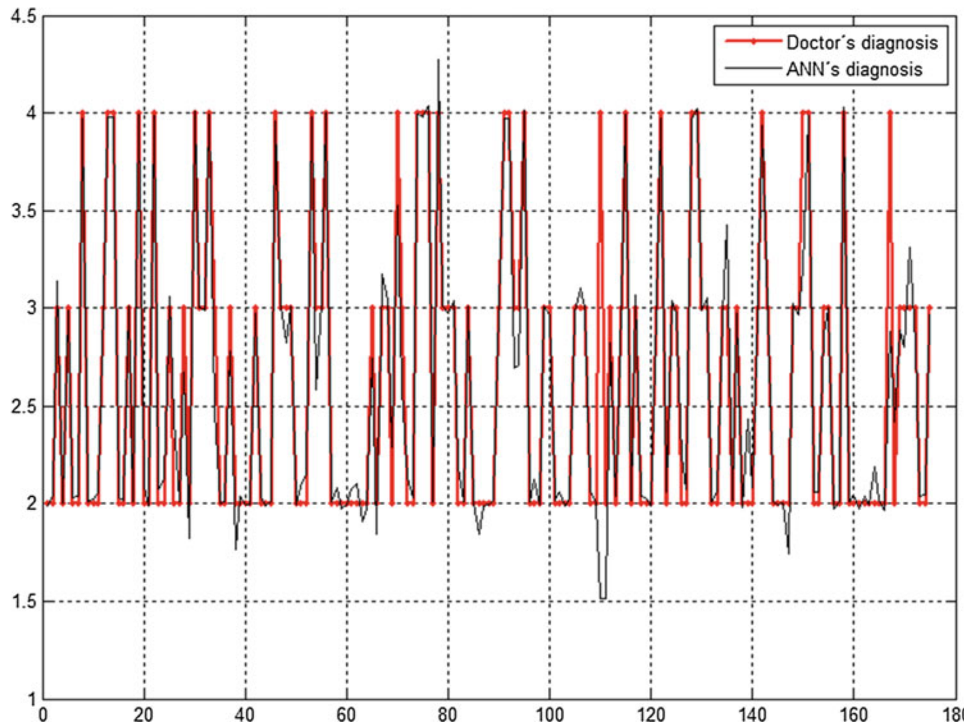

Fig. 8 Comparative between ANN and Doctor's diagnosis

mean, the ANN have a good performance to make an estimation in a MDS-UPDRS scale, with over 90% of success.

3 Conclusions

This method evaluates the patients in shorter time than traditional method, so it should have less inconveniences to doctor and patients, furthermore this tool is objective without the subjective influence of evaluator.

At least thirty minutes are needed to evaluate PD's patients in a MDS-UPDRS scale [3], with the equipment and software claimed in this work, the evaluation time is rough ten minutes, and this is a big advantage in the process. Furthermore, the high level of certainty (>90%), shows that ANN could be used to diagnosis.

The inputs for ANN must be processed to eliminate invariance like to displacement in time or others, so the FFT and Welch's PSD estimate are good tools to get this aim.

Acknowledgements The authors gratefully acknowledge the support of the Project named "*SISMO-NEURO: Análisis del Movimiento Corporal en Enfermedades Neurológicas*" (*Analysis of the body movement in neurological diseases*) of Universidad Politécnica Salesiana from Ecuador.

Conflict of Interest Statement The authors have no conflict of interest.

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