Analysis of Alternating Hand Movement in Parkinson's Disease Patients

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Abstract. In Parkinson's disease the symptoms of motor disability predominate, generating consequences in their quality of life, psychological, social and economic stability. The Unified Parkinson's Disease Rating Scale is considered as a clinical evaluation method, that is a compendium of subjective interpretations. Alternatively a system called LEEPark is proposed, capable of quantifying the speed of the test of Alternating Hand Movement. The system uses Kinect V2 for data acquisition and features extraction, the results are stored in a database that is subjected to statistical analysis, grouped by degree of disease and by upper extremities. The analysis methods used were: ANOVA, linear regression and quantification of improvement, applied to data collected during 6 sessions from 6 patients: 4 with Parkinson's disease and 2 control subjects. The results showed contrasts in hand speed, being able to find significant differences between grade 1 and 2 of the disease. It was also possible to establish the decrease in speed as the degree of disease progresses and the percentage of improvement when comparing the effects of medication on the speed of the hands.

Keywords: Parkinson's Disease · Alternating hand movements · Kinect sensor · Medical application

1 Introduction

In the course of time, great technological advances have been evidenced in various areas of science. However, there are exceptions to this fact as is the case of neurodegenerative diseases. Currently, innovation in neurology has not been able

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to determine the origin, prevention and cure of several of its pathologies. Due to the growing affected population, most of which is elderly, medical research has focused on slowing the progression of these diseases and improving the living conditions of people who suffer from them [6,9]. This group of disorders represent progressive and chronic affections that compromise the central nervous system and therefore cognitive domains and motor performance. Among this classification is Parkinson's Disease (PD), the second neurogenerative condition that most affects the adult population after Alzheimer's [1,4,7,9]. Worldwide, more than 10 million people suffer from it. In Ecuador, the prevalence of PD ranges from 300 to 600 patients per 100,000 inhabitants; and, as in various studies, it is shown that the presence of the disease is more prevalent in people over 61 years of age, more commonly in men than in women [7,13].

PD arises at a gradual level with symptoms of motor disability which may vary by patient, however it generates significant limitations in his quality of life [15,16]. The majority of those who suffer it have a life expectancy of 15 years from its detection until death, as a result of causes derived from motor conditions: falls, fractures, infections, etc. [1,11].Its diagnosis is based merely on clinical fundamentals, even for an experienced neurologist, the detection of PD in its initial stages is a challenge since its presence in a patient cannot be assumed only by the manifestation of tremors [8,11]. Based on these complications, the medical community has established different methods to standardize the assessment including the commonly used Unified Parkinson's Disease Rating Scale (UPDRS) [12].

The UPDRS corresponds to a clinical method classified into three specific sections: mentation, behavior and mood; daily activities and motor examination. This evaluation, carried out throughout the subject's illness, gives indications of the history of the disease and the influence of the treatments used. However, this test is based on subjective interpretations and is therefore considered inaccurate [10,12]. In the motor section of the UPDRS there is an item called "Rapid alternating movements", an activity carried out with the purpose of evaluating the postural tremor of the hands and their performance before and after medication [12]. Is this exercise the motivation for the present proposal, which is focused on quantifying the speed of Alternating Hand Movements through the LeePark system, capable of recognising motions of hands in PD patients [14]. The aim is to expose a support tool for physicians with the goal of optimizing the UPDRS motor evaluation process and, consequently, eliminating the disadvantages of a subjective and imprecise assessment. The present implementation of said LeePark system, corresponds to a continuation of the work referenced in [14]. Nonetheless, this article makes reference to the recognition of the alternating movement of hands. The obtained data will be used for a population analysis regarding the degree of the disease, speed differentiation and evidence of PD progression in each limb, through an Analysis Of Variance (ANOVA) and Linear Regression [17].

2 Related Works

Different UPDRS assessment and analysis technologies or systems for PD patients have been developed to exclude the conventional clinical assessments used by physicians [2]. With these existing technologies, it is possible to achieve high assessment accuracy, monitor all stages of PD, and provide a much more accurate diagnosis. The systems closely related to our study are detailed below.

Dror et al. propose a non-invasive system with an Human Machine Interface (HCI) for the evaluation of motor activities according to the UPDRS scale such as hand movements (open-closed, pronation-supination and finger tapping), using a 3D depth sensor, similar to a Kinect v2. The data acquisition is obtained in 4 matrices of 986 by 274 pixels with a speed of 24 frames per second through a 3D camera based on Time of Flight (TOF) technology. The automatic classification between healthy and sick patients is carried out using machine learning techniques with the acquired data. For the final diagnosis, the manual action of the most unfavourable case is chosen, so if at least one of these actions presents PD, the patient will be classified as a person with Parkinson's disease [3].

AVIPARK: Web system for the evaluation and analysis of hand movements (finger tapping, hand opening - closing and pronation - supination), using artificial vision techniques with Kinect version 1 of people with EP based on the UPDRS scale. The interface allows to visualize statistical graphs with time values, repetitions and average speed of each movement of the left and right hands and fingers of each of the patients registered in the system, in order to evaluate in a quantitative way the evolution of the rehabilitation process, as well as to evaluate the effect of the different pharmacological treatments of the patient over time [8].

Ferraris et al. propose a low-cost HCI system for the automated evaluation of hand movements of a PD patient according to the UPDRS scale at home. This system is based on an RGB-Depth optical device and replicable software. The interface allows gestural interactions with visual feedback and allows the characterization of hand movements by the kinematic parameters of its trajectories. The correlation between selected parameters and UPDRS clinical patient performance scores is used to evaluate instances of new tasks using an automatic learning approach based on supervised classifiers [5].

LeePark: Web system capable of analysing hand movements in patients with PD with medication (Onstate) and without medication (Off state), using the Kinect v2 device based on the UPDRS scale to valuate finger tapping movements. The system measures the variations in the position of a patient, these displacements are interpreted as an increase in the intensity of the tremors. The application allows to visualize the acquired data or interpretations in a graphical interface. The difference of our proposal with the Leepark system is that it is mainly focused on quantifying the speed of alternating hand movement and in turn analyzing and inferring on the data collected with the ANOVA method, linear regression and quantification of improvement in patients with medicated and non-medicated PD [14].

3 Materials and Methods

The inclusion of technology to society suffering from PD seeks to incorporate tools, programs and applications that allow and facilitate the specialist to give a more accurate diagnosis, an appropriate therapy and, especially, to administer the required dose of medication. The study of alternating hand movements performed in this article is a continuation of LeePark project and is carried out in four phases: Acquisition, Processing, Visualization and Statistical Analysis, see Fig. 1.

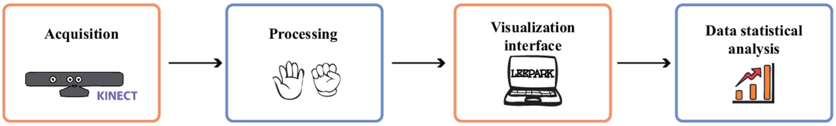

Fig. 1. Block diagram for detection of alternating hand movements using Kinect v2.

3.1 Acquisition

For the patients evaluation process, the system was applied in six subjects from 60 to 89 years of age from the Universidad del Adulto Mayor (UAM); four of them suffer from Parkinson's disease and two individuals are healthy. All participants signed a letter of informed consent to proceed with the examination, which was carried out when patients were on medication (ON status) or without medication (OFF status).

The exercise to be tested corresponded to the alternating movement of the hands where the subject opened and closed the hand repeatedly as fast as possible. The purpose was to count the number of repetitions performed by the patient in the time assigned by the specialist.

It is important to consider some parameters of the evaluation environment before testing such as height, distance between the patient and the device, posture and lighting as shown in Fig. 2.

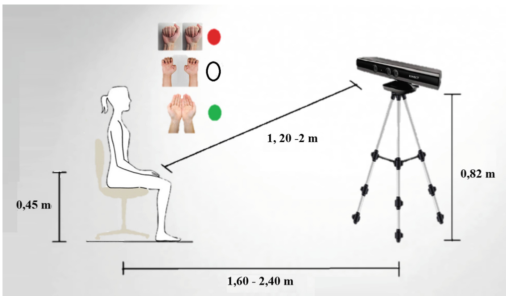

Fig. 2. Distances on scenario during testing.

In Table 1, the characteristics of the patients are presented in terms of age, sex and disease degree.

Table 1. Patient data.

Patient	Age	PD	Gender	Disease degree
P1	82	Yes	Male	3
P2	72	Yes	Female	3
P3	83	Yes	Female	2
P4	87	Yes	Male	1
P5	89	No	Female	–
P6	62	No	Female	–

3.2 Processing

During the opening and closing hand movements, the system used the KinectPv2 Processing library, which detects the change of state of the hands (opening and closing) to a person within the measuring range.

The state of the hands is represented by a circle, where if the hands are closed, the circumference is red, while when the hands are open, the circumference turns green. However, when the hands are not in the correct position, the circumference turns white indicating that the hands are out of place.

The results are stored in a database using MySQL server, the PHP is used for connection and interaction with the database using web server XAMPP (version 3.2.2).

3.3 Visualization Interface

Over the visualization interface, as shown in Fig. 3, the user can access to the historical data of the evaluations recorded by session, which can be consulted by patient and by date. The information of each subject is visualized through dynamic graphs composed by the speeds of exercise execution in ON and in OFF state.

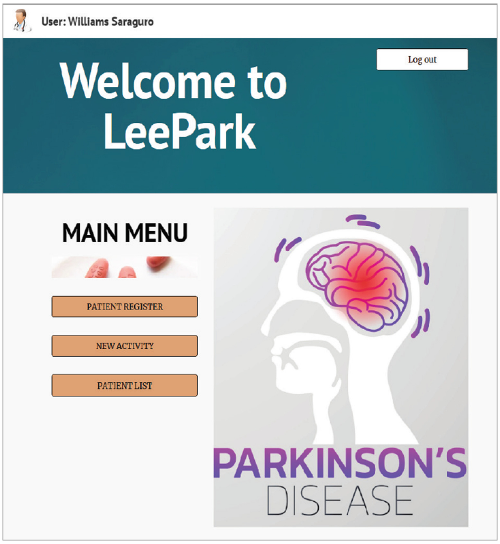

Fig. 3. LEEPARK system registration interface [14].

3.4 Data Statistical Analysis

In order to carry out a proper interpretation of the obtained results, different statistical and mathematical techniques were used. The first analyses correspond to population comparisons through ANOVA and Linear Regression; with the first one, a relationship hypothesis is tested to determine significant differences between groups that have been classified by disease degree; in the second case, thanks to the linear adjustment, the progression of PD in each extremity is evidenced. Finally, in order to demonstrate the evolution of each patient, a percentage representation is established.

4 Results

The database collected from the LeePark system is subjected to statistical analysis with the objective of quantifying the state of each patient and of the total sample, grouping them by degree of disease (Grade 0 to Grade 3) and by their upper limbs (right and left). The methods used were: ANOVA with a 95% confidence interval, linear regression and quantification of improvement; the first method is used to determine differences in velocities between the degrees of disease and between the upper limbs, the second method establishes the progress of the disease and the third method stipulates the level of improvement in each patient.

For the first calculation the patients in Off state were grouped and labeled according to their PD degree, where healthy patients were classified as Degree 0. Four groups of patients were established (Degree 0 to Degree 3), to which

ANOVA was calculated, under the null hypothesis that there is no difference in velocities during the alternating movement of the hands test between PD degrees. Its result of F (73.55) > critical value (3.10) rejects the null hypothesis, accepting the alternative hypothesis that at least one of the groups differs in speed with respect to the rest, the results of the calculation are shown in Table 2.

Table 2. ANOVA of speeds between the degrees of disease.

Origin of variations	Squares sum	Freedom degrees	Squares average	F	Probability	Critical value for F
Between groups	1379.77	3	459.92	73.55	5.59E–11	3.10
Within groups	125.06	20	6.25			
Total	1504.83	23				

The ANOVA calculation was repeated for the following groupings: Degree 0 – Degree 1, Degree 1 – Degree 2 and Degree 2 – Degree 3, in order to determine how much difference exists between consecutive groups. The result of the calculation determined that there are no significant speed differences between the groups: Degree 0 – Degree 1 and Degree 2 – Degree 3. While the grouping Degree 1 – Degree 2 evidenced a high differentiation due to the fact that F (59.68) > Critical value (4.96).

A new ANOVA calculation was applied between the right and left hand speeds, considering only patients diagnosed with PD. The result from Table 3 indicated that there is no difference in the velocities of the two limbs, as F (0.14) < Critical value (5.99).

Table 3. ANOVA of speeds between the upper limbs.

Origin of variations	Squares sum	Freedom degrees	Squares average	F	Probability	Critical value for F
Between groups	8	1	8	0.14	0.72	5.99
Within groups	332.33	6	55.39			
Total	340.33	7				

Although no difference in velocity between the extremities was demonstrated, Fig. 4 illustrates the average velocities during each patient's 6 sessions, grouped by degree of disease and demarcating data from the right and left extremities. Figure 5 also show the application of lineal regression to the data, which show a decay of speed in each limb as the degree of disease progresses.

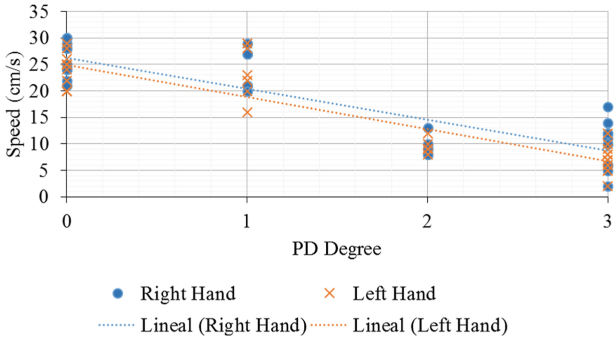

Fig. 4. Lineal regression of the upper limbs.

Figure 5 shows the percentage improvement of each limb in PD patients, comparing the average velocities during the 6 sessions between Off and On states. Patients 1, 2 and 3 show significant improvements over 20%, while patient 4 (Degree1) has the lowest improvement in the group, 8.28% in the right hand and 15.84% in the left hand. The data shows that the percentage does not depend on the degree of disease, nor is it exclusive of gender or age; a more exhaustive and complete analysis would make it possible to know the incidence of the drugs in the progress of improvement.

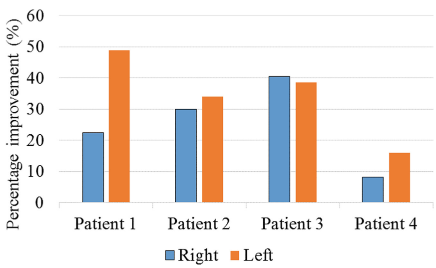

Fig. 5. Percentage improvement of each limb in PD patients.

5 Conclusions

The LEEPark system made it possible to quantify the speed of the alternating movement of the hands. The collected data was subjected to a population analysis on the degree of disease, speed differentiation and evidence of PD progression in each limb; through: ANOVA, Linear Regression and calculation of the difference of speeds, without medication and with medication of the patients, thus achieving that the physician evaluates in a quantitative way the progress of the disease. The system is a medical tool that optimizes the motor evaluation within the UPDRS.

The applied statistical analysis allowed to quantify with more precision the differences between the groupings of the sample, excluding the subjective opinion and standardizing the results. Given that in Ecuador there are 229 cases of PD registered according to the National Institute of Statistics and Censuses, a sample of 68 patients is calculated for measurement with the system and subsequent analysis, under a 95% confidence level and a 10% margin of error.

The results of the ANOVA calculations determined that the alternating hand movement test does not allow differentiation of motor speeds between the upper extremities (right or left), but can be used to differentiate the first signs and stages of PD, being able to find significant differences between Degree 1 and 2 disease.

Linear regression to the velocity distribution of all patients showed that there is a relationship between the degree of disease and the speed of alternating hand movement. The speed decreases as the degree of PD advances, although its values tend to increase in each patient during each session.

It was also possible to compare the velocities between the Off and On states of patients with PD, the results are part of the indicators of the effectiveness of medication in their body, as well as a quantitative result from medical history.

The system is intended to implement a module for statistical analysis with the results, as well as to realte the processing and calculation of the Finger Tapping test, previously performed in the LeePark system. It is hoped to achieve concise and accurate results that will allow further automation of the UPDRS quantitative motor analysis.

Ethical Statement. All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Comité de Ética de Investigación en Seres Humanos USFQ (2019-011E).

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