Improved Spiral Test Using Digitized Graphics Tablet for Monitoring Parkinson's Disease

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Improved spiral test using digitized graphics tablet for monitoring Parkinson's disease

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ABSTRACT

The monitoring of the progression of Parkinson's disease (PD) is held on frequently in the clinic and an inconvenient and time-consuming process since PD is generally observed mostly in elderly people whose physical visits to the clinic are troublesome, and the physical examinations must be performed by trained medical staff. Besides, from the machine learning perspective, building a generalizable non-invasive PD diagnosis and monitoring decision support system requires enough number of training samples collected from PD patients at regular intervals. Therefore, self-administered and non-invasive telemonitoring applications that enable the PD patients to collect data at home and transmit it over the internet to a dedicated server have recently become popular. In addition to these, the use of computer systems to collect data from subjects enables the researchers to develop various tests which cannot be easily performed with paper and pencil. In this study, considering that PD affects the handwriting motor abilities of patients, we collected handwriting samples of PD patients who have admitted to the Department of Neurology in Cerrahpaşa Faculty of Medicine, Istanbul University via a graphics tablet which was used in many biomedical studies before like cancer imaging, influence of stress on servical myelopathy, and brain imaging. In addition to the static spiral drawing test (SST) which can also be performed traditionally with pencil and paper, we propose a new test called dynamic spiral test (DST) which, unlike SST, can only be performed with the use of electronic equipments such as a tablet and a computer. We present the comparative results of SST and DST, and show that handwriting samples collected with a computerized system can be used to build generalizable PD telemonitoring systems.

Keywords: Telemonitoring, e-health, motor system features, computer-aided data collection.

1. INTRODUCTION

The monitoring of the Parkinson's Disease (PD) at regular intervals is a costly and inconvenient process because it is difficult for patients and their carers to come to clinic in the advanced stages of the disease, and performing the physical examinations requires trained medical staff. On the other hand, frequent monitoring of PD symptoms with telemonitoring applications helps the researchers and medical doctors to observe the effects of the administrated treatment and ease the early intervention (Tsanas et al., 2009). Besides, from the machine learning perspective, collection of sufficient amount of data with telemonitoring applications can be very useful to build generalizable and reliable decision support systems. Therefore, self-administeredandnon-invasivetelemonitoringapplicationsthatenable the PD patients to collect data at home and transmit it over the internet to a dedicated server have recently become popular (Tsanas et al., 2010; Little et al., 2009).

PD impairs the motor system abilities like speech, handwriting, and walking (Jankovic, 2007; De Rick et al., 1997; Chaudhuri et al., 2006; Little et al., 2009). In this study, considering that PD affects the handwriting skills of patients, we propose a new handwriting test called dynamic spiral test (DST) which, unlike traditional Static Spiral Test (SST) applied with paper and pencil, can only be performed with the use of a computer. We present the comparative results of DST and show that it can be used along with the traditional tests in telemonitoring applications.

PD causes disorders like illegibility and micrographia in handwriting of the patients due to tremor. Therefore, the handwriting samples have been widely used for PD diagnosis in the literature for developing a non-invasive diagnosis system. In the recent years, digital tablets have been used to collect handwriting samples of the patients. The handwriting samples used usually in these studies are continuous. In one of the studies, continuous 'llllllll' writings with different lengths were drawn by control subjects and PD patients (Van Gemmertet al., 2003), and the analysis of the resultant drawings showed that PD subjects were not able to draw the requested text above the length 1.5 centimeters. Also the writing speed and acceleration of PD patients are much slower than the healthy ones(Van Gemmertet al., 1999; Unlu et al., 2006; Aly et al., 2007; Wang et al., 2008). Hence, in this study, we collected the handwriting samples of the PD patients who have admitted to the Department of Neurology in Cerrahpaşa Faculty of Medicine, Istanbul University and control subjects using a graphics tablet – Wacom Cintiq 12WX (Hahne et al., 2009) – which was used in many biomedical studies like cancer imaging (Kushkia et al., 2011), influence of stress on servical myelopathy (Takahashi et al., 2013), writing difficulties of children with dysgraphia (Avila-Garcia et al., 2008), brain imaging (Pinzera et al., 2012), bone porosity (Britz et al., 2010) and geometry (Britz et al., 2009). The use of the graphics tablet for data collection enables the researchers to develop various tests and obtain different kinds of information which cannot be easily performed and obtained with paper and pencil.

This paper is organized as follows: Section 2 presents the data acquisition and the handwriting ability tests that have been applied in the content of this study. Section 3 presents the comparative analyses of the proposed DST. We conclude in Section 4.

2. MATERIALS AND METHODS

2.1. Data Acquisition

Handwriting dataset was constructed using Wacom Cintiq 12WX graphics (Hahne et al., 2009) shown in Figure 1. It is basically a graphics tablet and LCD monitor rolled into one. It enables to display a PC's screen on its monitor and only interacts with digitized pens. The tablet is generally used for drawing and designing the artwork projects. Therefore, accurate and sensitive sketches can be made with it. The main difference between a portable and a graphics tablet is that a number of values like x-y-z coordinates and pressure during the writing can be obtained with a digital pen via the API functions of the device. Also, this graphics tablet's sampling rate is superior to the other portable tablets. These were the most important factors in building our handwriting dataset with a digitized graphics tablet. Special software was designed for recording handwriting drawings and testing the coordination of the PD patients using the recordings. The software uses API functions of the device and was developed in C# platform which can be run on Windows systems.

Figure 1.Digitized Graphics Tablet (Hahne et al., 2009)

2.2. Handwriting Ability Tests

The patients were asked to make drawings to be used in coordination tests using the developed software. Unlike the traditional tests conducted with pencil and paper, the patient's digitized handwriting gives some digital features which are x-y-z coordinates, the pressure applied to the screen, stylus grip angle and the time consumed to complete the drawing task. This available data enables the researches to build quality, reliable, and objective computerized decision support systems for the diagnosis of several diseases with symptoms affecting the hand.

In this study, there are three different kinds of tests developed for the data collection via graphics tablet. The first one is the Static Spiral Test (SST) which is frequently used for clinical research in the literature for different purposes like determining motor performance (Wang et al., 2008), measuring tremor (Pullman, 1998) and diagnosing PD (Saunders et al., 2008). In this test, three wound Archimedean spirals appears on the graphics tablet using the software and patients were asked to retrace the same spiral as much as they can using the digital pen. During the test, the features which are mentioned above and the other data to specify the patient are recorded to the database. Figure 2 shows SST of two PD patients who has been ranked as the best and worst by the neurologists that work in the Department of Neurology in Cerrahpaşa Faculty of Medicine, Istanbul University.
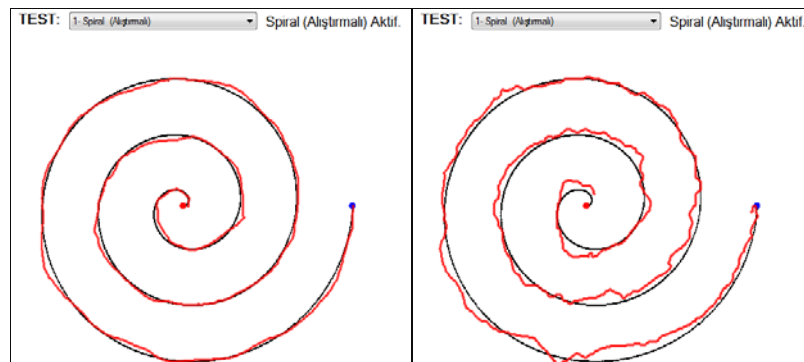

Figure 2.SST drawings of the PD patients that got the **(left)** highest score **(right)** lowest score from the neurologists

The second test is the Dynamic Spiral Test (DST). Unlike SST, Archimedean spiral just appears and disappears in certain time intervals, in other words the Archimedean spiral blinks. This forces the patient to keep the pattern in mind and continue to draw. The purpose of this test is to determine the change in patient's drawing performance and pause times since it is more difficult to retrace the Archimedean spiral in this case. As a result of this test, it is observed that most of

the patients continued drawing but nearly all of them lost the pattern. Consequently, their performance on retracing the Archimedean spiral was worse than the one in SST (Figure 3).
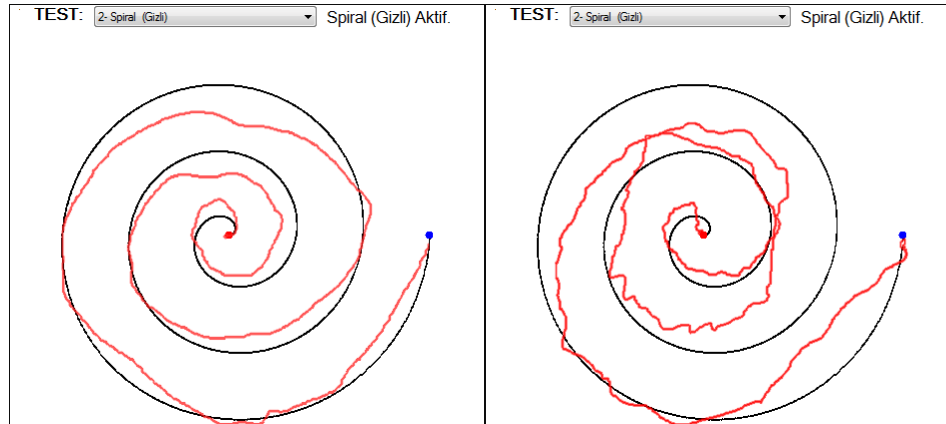

Figure 3.DST drawings of the PD patients that got the (left) highest score (right) lowest score from the neurologists

3. EXPERIMENTAL RESULTS

The SST and DST recordings of 25 PD patients and 15 control subjects are analyzed based on speed and acceleration of their drawings. For each spiral drawing, we compute the distance between two consecutive samples (*x* and *y* coordinates at time *t* and at time *t*+1) to obtain the instantaneous velocity, *V*, of the pen at time *t* during the drawing (Eq.1).

$$V_t = \sqrt{(x_t - x_{t-1})^2 + (y_t - y_{t-1})^2}$$ Eq. 1

Velocity varies during the drawing for both SST and DST tests. Especially in DST, blinking of the spiral may cause more confusion for the patients and therefore leads to instantaneous slowing down or speeding up during the drawing. For example, if the subject has difficulty recalling the spiral pattern when it shortly disappears from the tablet, the velocity can change dramatically. Therefore, we examine the change in velocity, which is known as the acceleration. Instantaneous acceleration, *A*, at time *t* is calculated as in (Eq. 2).

$$A_t = V_t - V_{t-1}$$ Eq. 2

Figure 6 shows the acceleration results of SST and DST drawings of a PD patient, where the recordings were of different durations (SST took longer for the patient to complete and thus has more samples).
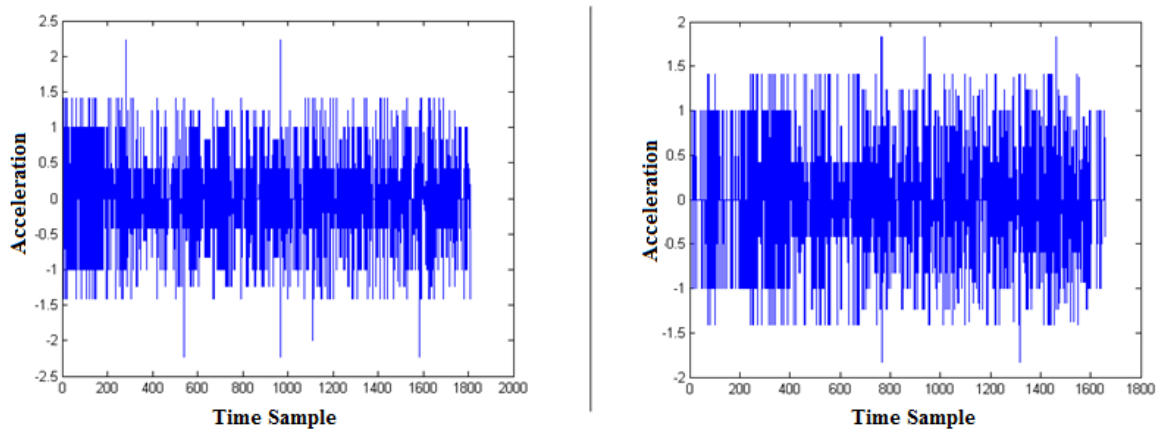

Figure 6.Instantaneous acceleration of the drawing of a PD patient for the tests
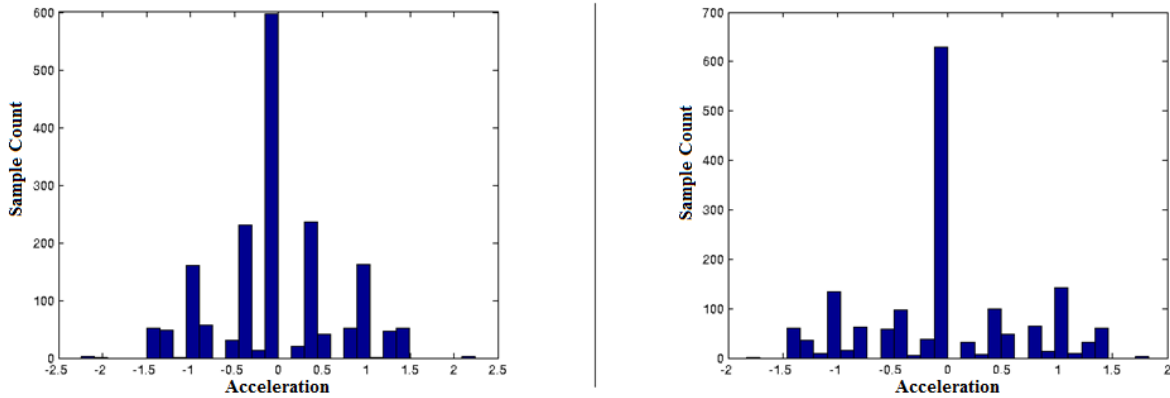(left) SST and (right) DST

Figure 7.Acceleration histograms for the drawings given in Figure 6
(left) SST and (right) DST

As the number of sampling points varies between SST and DST, histograms of the instantaneous accelerations were used for comparing SST and DST of a subject. Specifically, acceleration values were divided into sample counts (very small and very large values were truncated).The histogram counts were converted to percentages by dividing by the total number of sample points in the recording. Dissimilarity of (SST and DST) Acceleration Histograms, *DAH*, for each subject is calculated by computing the L2 norm of the histogram differences (Eq 3).

$$DAH = \left\| H_{SST} - H_{DST} \right\| = \sum_{i=1}^{10} \left(H_{SST}(i) - H_{DST}(i) \right)^2 \qquad \text{Eq. 3}$$

The closer these *DAH* dissimilarity values are to zero, the subject's SST and DST drawings are more similar to each other with respect to acceleration, indicating that the subject can handle SST and DST equally well/unwell. The control subjects are expected to show similar performances in SST and DST. In Figure 8, the *DAH* scores of PD patients and control subjects are shown. The difference of *DAH* scores of control subjects and PD patients is found to be statistically significant (*p*-value <0.002).
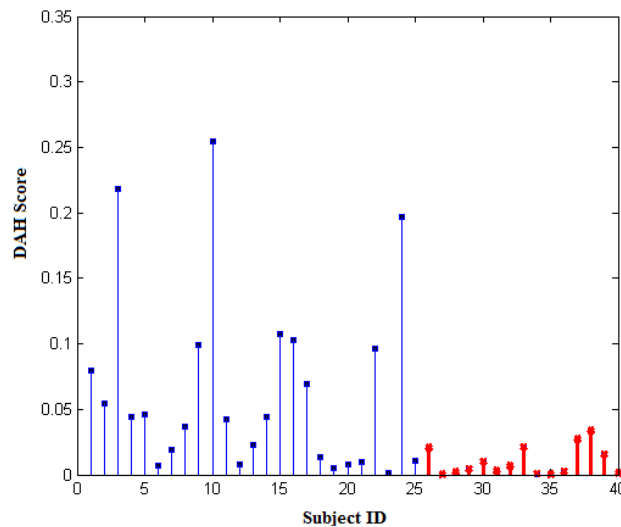

Figure 8. Difference of accelerations for SST and DST tests for each patient
(blue) PD patients and (red) healthy control subjects

4. CONCLUSION

Parkinson's Disease (PD) affects the motor features of patients like speech, handwriting, and walking. In this study, we propose a new handwriting test called dynamic spiral test (DST) which, unlike traditional Static Spiral Test (SST) applied with paper and pencil, can only be performed with the use of a computer. We use a graphics tablet to collect the handwriting samples of subjects to develop a novel test. We applied the static and dynamic spiral tests to PD patients and healthy control subjects. The analysis on the obtained drawing tests demonstrates that the acceleration of SST is statistically closer to that of DST for control subjects when compared to the PD patients. It can be concluded that the SST and DST tests can be applied together in order to measure the cortical and motor performance of the subjects and can find use in diagnosis and telemonitoring applications of PD and some other similar neuropathological conditions.

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