MEASUREMENT OF TREMOR USING DIGITIZING TABLETS

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***Abstract* – Tremor is the most common movement disorder. The assessment of tremor is in general carried out in a very subjective way. This paper aims to review and explain the use of digitizing graphic tablets for a precise measure of tremor. First it is explained why a accurate measure of tremor is important. Then some topics are discussed: (I) the influence of tablet specifications, (II) the acquisition and pre-processing of the data, (III) the reasons for using specific drawing tasks, and finally (IV) how to quantify the tremor.**

***Keywords* – Digitizing graphic tablet; Drawing; Movement disorders; Spectral analysis; Spirographs; Tremor.**

I. INTRODUCTION

Tremor, a rhythmic, involuntary oscillatory movement of body parts, is the most common movement disorder [1]. A common method employed for evaluation of patients with pathological tremor is the execution of drawing tasks. In this exam patients are instructed to make some drawings (i.e. Archimedes spirals, squares) and the result is subjectively rated using clinical scales simply by looking at the drawing. Though very simple, this approach fails in providing precise measures of tremor amplitude and frequency, which are of great interest for the clinician.

This precision can be easily achieved using a digitalizing tablet for acquisition of the drawings. A digitizing tablet (Fig. 1) is a very simple mechanism that keeps track of the position of a pen. The data provided by the tablet can be stored in an ordinary computer and it is suitable for most signal analysis techniques.

Fig. 1. A digitizing tablet.

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Another common way for precise detection of tremor is by means of accelerometry, however, digitalizing tablets has been revealing itself as a better method for clinical environments due to its simplicity and low cost [2].

A. The importance of frequency-amplitude information

More than 10 distinct types of pathological tremor have been identified [3] and each one of them has different frequency-amplitude characteristics. For example, Spieker [4] found the frequency bandwidth for three pathological tremors:

- Cerebelar Tremor: 1.5 - 4 Hz
- Essential Tremor: 4 - 12 Hz
- Parkinsonian Tremor: 3 - 8 Hz

So, if a clinician has access to the frequency information of the patient's tremor, he/she would have one additional tool for improving his/her diagnosis just by looking at the typical bandwidths of tremor syndromes.

In addition to the bandwidths, each one of tremor pathologies has its own way of altering amplitude-frequency characteristic during the progress of the disease. Monitoring this kind of information is of great importance in the treatment of tremor pathologies.

II. THE USE OF TABLETS FOR TREMOR DETECTION

Following are some important considerations that are necessary to carry out a tremor measurement by means of a digitizing tremor.

A. Tablet especifications

A digitizing tablet has under its writing surface a set of parallel horizontal wires covered by a set of vertical parallel wires. The pen emits an electromagnetic field that excites the wires in the neighborhood permitting the tablet to calculate the pen position. The larger the number of wires per unit of area is, the larger the resolution of the tablet is. The resolution of the tablet is important to decide whether it is capable of acquiring a specific kind of tremor. For example, if it is desirable to detect physiologic tremor (amplitude below 0.5 mm [5]) with a resolution of 0.01 mm the tablet must have at least 100 wires per mm, which in commercial values is equivalent to 2520 Lines per Inch (LPI). Tablets with 3048 LPI can be easily found commercially. Actually, a tablet that is capable of detecting physiologic tremor can detect any other kind of tremor because the physiologic tremor is the one that presents the smallest amplitude.

Another desirable specification for digitizing tablets that will be used to detect tremor is the sensitivity of the pressure. Modern tablets can measure how much force is applied on the pen while a person is drawing. This feature is important

in studies with tremor because pressure is a mechanism naturally employed by humans to damp tremor [6]. It has been reported that subjects that apply less pressure in their drawings accentuate the oscillation of limbs during the drawing activity [7]. So, the measure of pressure is relevant information for tremor quantification.

B. Acquisition and pre-processing

Data acquisition through digitalizing tablets, in contrast to acceleromets, is very simple, i.e., it does not require any pre-amplification or externals analog-to-digital converters. Basically, all that is necessary is to connect the tablet to a computer and run a program to store the set of coordinates provided by it. Considering that the highest tremor frequency is about 13 Hz, a minimum acquisition rate is of 26 Hz, as required by Nyquist Theorem. In order to avoid any alias effect, 50 Hz is a commonly used value.

After the data are collected some pre-processing may be done. As mentioned before the upper tremor frequency is about 13 Hz, so a low-pass filter with cut-off frequency of 13 Hz can help to eliminate high frequency noise without changing the main characteristics of the signal. Voluntary drawing movements have very low frequencies, generally less than 1.0 Hz. So, if voluntary movement is not desirable, a high-pass filter with cut-off frequency of about 1.0 Hz could be used. These pre-processing techniques can help isolate tremor from unwanted movements and noise.

C. Drawing tasks

Some common tasks used in the measurement of tremor are writing and Archimedean Spirals. Handwriting is a good test as it is a very natural task to almost all patients, however it has the inconvenience of generating voluntary movements with frequencies closer to the low frequencies of tremor making data analyses more difficult. Archimedean Spirals (Fig. 2a) are by far the most used drawing task. Its form can be described by (1),

$$R = a \cdot \theta \tag{1}$$

where

R - Radius on the polar coordinate system.

a - Constant that controls the distance between sucessive turnings of the spiral.

θ - Angle on the polar coordinate system.

When one is drawing an increasing radius spiral, the distal arm joint movement decreases and the proximal arm joint movement increases [8], this is helpful to identify the tremulous arm part. This observation can be made only if the spiral has a minimum external radius. Typically, spirals with three or four turns and external radius of 10 cm are used. Examples of spiral drawings for healthy subjects and patients with tremor are shown in Figs. 2b and 2c respectively.

During the drawing, the patient has to maintain, whenever possible, the pen over the surface of the tablet all the time. However, people with severe tremor may be unable to carry out this.

In the past when the patient lifted the pen off the tablet surface the signal was discontinued. Modern tablets can now keep track of the pen movement even when the pen is a few centimeters from its surface. This feature permits that even subjects who cannot draw continually could be examined without extra considerations.

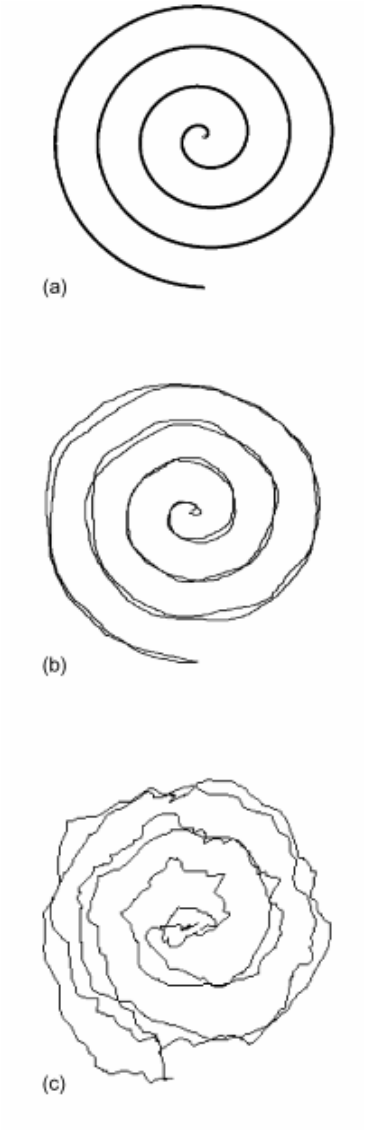

Fig. 2. (a) Template of an Archimedean Spiral; (b) Spiral drawing of a healthy subject; (c) Spiral drawing of a patient with tremor (from [8]).

D. Tremor quantification

Because of its oscillatory characteristic, tremor is well suited to spectral analysis, which is the most popular method of tremor quantification [9]. Spectral analysis is used to reveal the distribution of the signal power through the frequency spectrum (an example is depicted in Fig. 3). Most spectral analysis techniques are based on the Fast Fourier Transform (FFT), an inexpensive computational implementation of the Fourier Transform. However, FFT shows some problems while applied to tremor signal because it assumes stationarity. So, to provide a more accurate

measure of tremor other supplement techniques may be used such as Wavelet Analysis [10] and Adaptive Fourier Modeling [8].

Spectral analysis can also be applied on the first and second derivatives of the signal (velocity and acceleration respectively). Numerical differentiation accentuates the higher frequencies components of the signal, highlighting tremor in the spectrum. However, standard differentiating algorithms increase the total noise in the data producing a considerable error. Thus, it is necessary to use an algorithm that smoothes the data, such as Kernel Estimators [11] and Least Square Procedures [12], while differentiating.

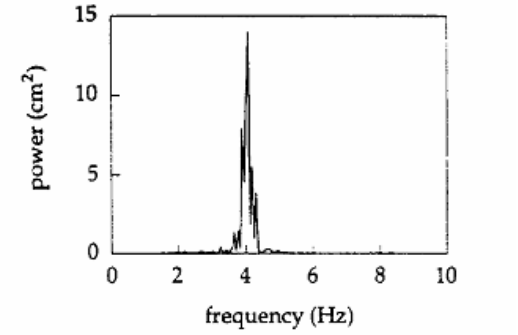

Fig. 3. Power spectral density of a signal detected by a digitizing tablet from a patient with Parkinsonian tremor (from [9]).

III. CONCLUSIONS

The use of digitizing tablets seems to be a very good mechanism to measure tremor. It can provide a much more accurate data from tremor than other traditional methods for drawing evaluation, which only subjectively rate the tremor as normal, mild, moderate and severe. In addition, digitizing tablets are much cheaper and simpler to use than other methods such as accelerometers and gyroscopes. Due to these advantages, these tables are now a promising mechanism to objectively measure tremor.

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BIOGRAPHY

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