

# Theoretical and experimental research on the development of an analysis system of the hand tremor movement for patients with Parkinson's disease

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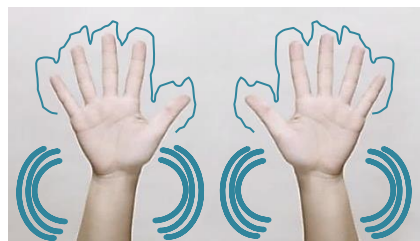
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**Abstract.** Theoretical studies indicate the existence of the tremor in the human body, normally physiological, barely visible, and which occurs when the upper limbs are stretch to the front or when very high precision is required in carrying out an activity. Different experimental researches seek the theoretical fundament of the tremor movements or, develop evaluating systems for this type of movement, and last but not least are creating systems for behavioural help for people who develop forms of tremor with effects on comfort. Thus, in the first part of the paper, the specific clinical tremor forms are analyzed, as well as the manifestation forms and the parameters quantifying methods of this movement form developed in the human body. In the second part of the work is reviewed the substantiation of the analysis models of tremor type oscillations. In the third part of this paper, the experimental setup developed is presented, focusing on finding the best behavioural help solution for patients with pathological tremors and presents some considerations related to the device constructive aspects. In the final part, the approach conclusions of developing an assistive system for patients with pathological tremors are presented, on the highlight of the parkinsonian tremor patients.

## 1. Introduction

The manifestations of tremor can be classified into several groups according to specific neurological characteristics. Thus, specialized studies [1] classify tremor status into: rest tremor, postural tremor, action tremor, kinetic tremor, intention tremor, and a type of tremor which involves customizing the actions, named tasks specific tremor.



**Figure 1.** The hand tremor

The first two types of tremor occur when the affected body part is not active and is supported to overcome gravitation, for example when the affected upper limbs are voluntarily held in a different position (stretched to the front) than the normal one (orthostatic position). The variants of action and

kinetic tremor are manifested in the case of voluntary or directed movements performed to evaluate various neurological examination tests (approaching and moving away the hand from the nose, etc.).

The other variants (intentional tremor and personalized task tremor, respectively) are characterized by an increase in tremor amplitude as the target is approached or are manifested during particular actions, such as writing. Besides, the same variants of tremor movement can be classified according to other criteria such as: state (normal or pathological), activation conditions (rest, postural, kinetic/intentional) and tremor frequency (setting limits of variation that divides the oscillation motion into low, medium, or high-frequency tremor) [2].

Among these forms, Parkinsonian tremor stands out due to the diversity of forms in which it can manifest (rest, postural or kinetic) or the low and medium frequency levels (3-7 Hz) of the oscillations during the action. Therefore, in order to perform a clinical evaluation of the different forms of tremor, it is necessary to identify in the first place the location of the tremor, its activation state and its frequency, and then to add the amplitude of movement.

Thus, this important feature of the oscillation-amplitude motion is taken into account for the evaluation of clinical forms and the creation of evaluation scales concerning this parameter. Clinical tremor assessment scales include the Fahn-Toulouse-Marin (FTM) scale, which assigns 0 to 4 points for tremor amplitude levels in different conditions and respectively 0 to 4 points for degrees of severity in daily activities. Unified Parkinson's Disease Rating Scale (UPDRS) [4] assigns 0 - 4 points for the pair of parameters amplitude and severity of rest and forms of postural or kinetic tremor. The ratings of the evaluation scale are on average proportional to the logarithm of the amplitude of the displacement as shown in the research [3].

The physiological variants of the tremor state were differentiated by identifying the basic and/or pathological forms and were indicated several different mechanisms to establish the origin of the tremor. In most research on this issue [5] several types of tremor-generating mechanisms are identified, such as:

- mechanical mechanism (each segment of the limbs involved or the entire upper or lower limb has a certain resonance frequency, which depends on the task to be performed);
- sensory reflex mechanisms or central oscillating mechanisms, as a group of oscillating neurons located in a specific structure of the brain or which are manifesting as a network or loop of several different structures.

As it shown in various studies, the tremor associated with Parkinson disease (PD) is one of the most widely studied and the second most common pathological tremor, with prevalence of 102-190 cases per 100,000 population in Western countries. Age at disease onset is usually after 60 and incidence increases with advancing age. [6]

Resting tremor is present in 80% of patients with autopsy-proven PD. Asymmetrical onset of tremor is commonly observed, and tremor onset may be coincident with other parkinsonian symptoms of rigidity and slowness of movement (bradykinesia). As PD progresses the severity of tremor may diminish, but the tremor is accentuated by performing mental tasks or contralateral voluntary movements and during ambulation. In a sample of PD patients, resting tremor may be inhibited by voluntary movement and up to 20% of PD patients also exhibit postural or kinetic tremor". [7]

## **2. Theoretical aspects of tremor mathematical model and software applications**

For fundamental research studies, especially in the field of tremor level assessment, a series of mathematical models have been developed based on the study of oscillations. A first differential nonlinear model is constructed as a Van der Pol oscillator [8] defined by equation (1) in which  $p$  represents the position coordinate (as a function of time), and  $\mu \geq 0$  is a scalar parameter indicating the nonlinearity and the degree depreciation.

$$p'' - \mu(1 - p^2)p' + p = 0 \quad (1)$$

The parameter  $\mu$  is calculated according to the equation (2) where  $F$  = the rate of emotional arousal, and  $I$  = inhibition rate. The parameter  $\mu$  can take zero values ( $\mu = 0$ ), when the excitation rate is equal

to the inhibition rate (simple harmonic oscillator) or non-zero values ( $\mu \neq 0$ ), where equation (1) is transformed into equation (3) by entering the parameter  $b$ .

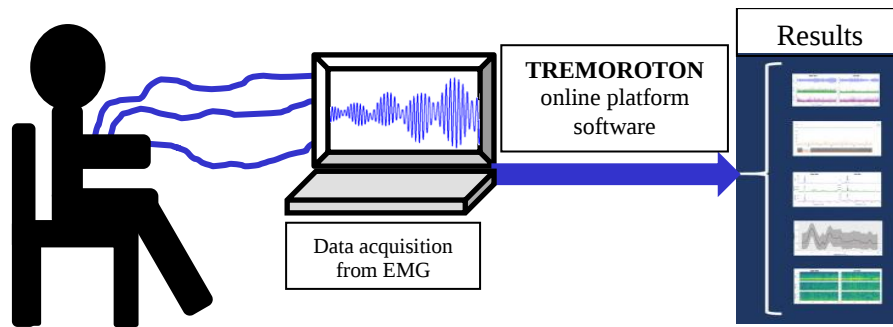
$$\mu = \frac{F}{I} - 1 \quad (2)$$

$$p'' + bp' + p = 0 \quad (3)$$

As is mentioned in [8] "the coefficient  $b$  is interpreted as damping (with  $b < 0$  corresponding to anti-damping behaviour where solutions gain energy over time). In the case of the Van der Pol equation,  $b$  is replaced by a nonlinear term which is negative when  $|p| < 1$  and positive when  $|p| > 1$ ."

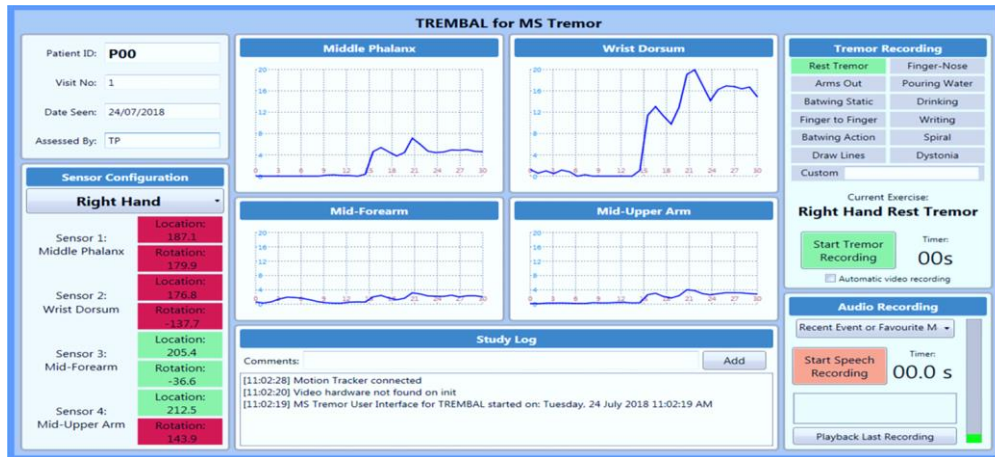
Based on this tremor motion oscillation model and along with other approaches that take into account the Deep Brain Stimulation (DBS) process, open-source platforms have been developed with applications for calculating the parameters needed to be evaluated in different forms of tremors.

These applications include: the online platform for tremor analysis that uses the "R" language-called "TREMOROTON". To validate this application, the researchers compared using an intraclass correlation coefficient, the tremor frequency estimate obtained with Tremoroton, with the results obtained from commercially available software, obtained from a sample of 20 patients (10 with essential tremor and 10 with Parkinson's diagnosis). The experimental system (figure 2) of this research was based on the analysis of the activity recorded with an accelerometer and electromyographic sensors (EMG) positioned on the arm muscles. [9]



**Figure 2.** The TREMOROTON software platform

Another experimental structure developed with a software application that supports the analysis of tremor movements is TREMBAL, a system "that quantifies tremor using electromagnetic motion tracking sensors with four sensors (trakSTAR), a remote control and a standard notebook computer with custom software" (figure 3). [10]



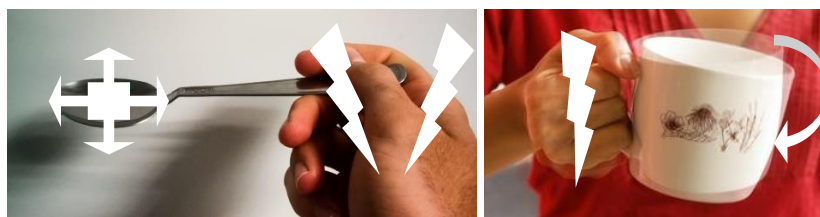
**Figure 3.** The graphical user interface of the TREMBAL software application

In order to make these systems for assessing and measuring the level of tremor more practical in terms of use in experimental research, mobile software applications have been developed for tablet or smartphone devices [11]. Thus, the researchers developed "a novel open-source mobile app for tremor quantification TREMOR12", offering "a low-cost tremor quantification method only for research purposes and algorithm development, and may help to improve treatment evaluation". [12] The TREMOR12 application was developed in Xcode 7 using the Swift version programming language. 2.0 and through it, 4 parameters can be extracted, with 3D representation.

These parameters are: acceleration, rotation angle, rotation speed and gravitational acceleration, the first three parameters providing values of quantification of tremor, and the fourth can be used to calculate a standardized 3D space to make comparisons between measurements. The TREMOR12 application together with the TREMOR 12P version (data processing mode) runs on iPhone and iPod Touch and requires iOS8 or a newer version. Although not yet a certified and widely used application, it is a useful tool for further research that can be further developed.

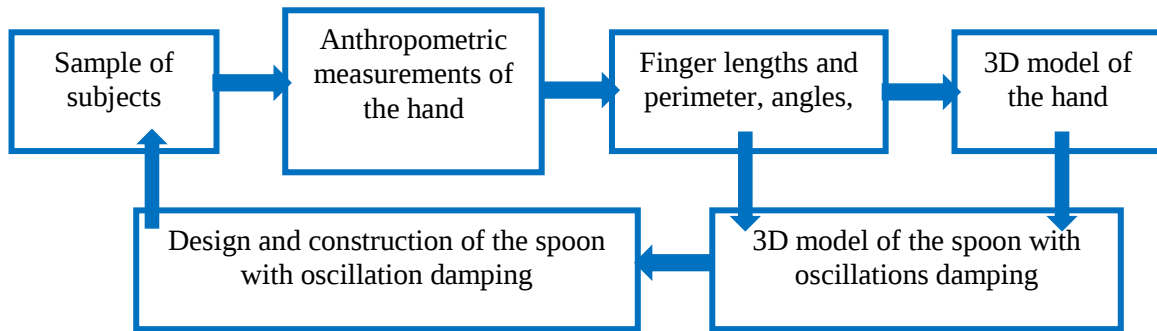
### 3. Experimental setup

There is also an important aspect of research on tremor-type movements, in addition to evaluations and measurements of kinematic and dynamic parameters. It is about the identification of solutions to help patients with this pathological form, to be able to carry out daily personal or professional maintenance activities, providing them solutions to increase and improve postural comfort.



**Figure 4.** The handling of objects in case of tremor

These devices are addressed primarily to patients with a tremor in the upper limbs and who have to perform actions to handle various objects in the ambient environment (figure 4).



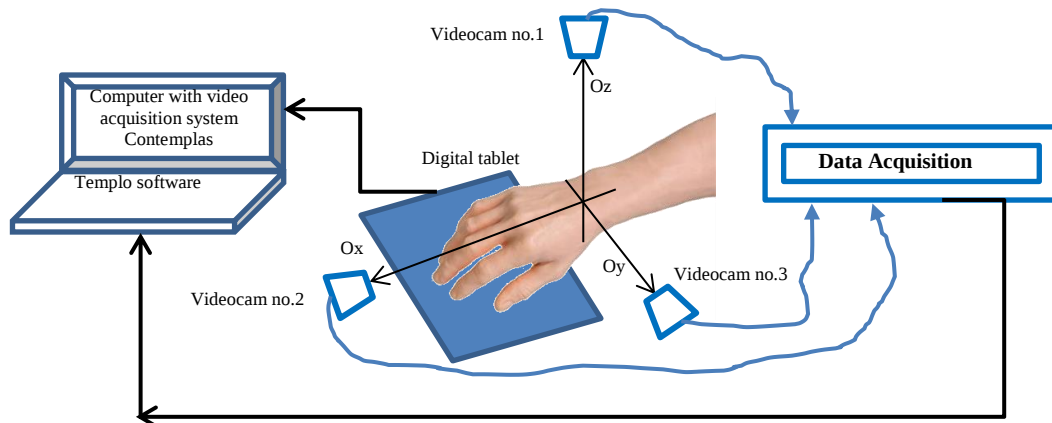
**Figure 5.** Block diagram to develop an attenuation system (spoon) of tremor movement in the hand

The movements due to the tremor can take place in vertical or horizontal direction regardless of how the object is caught, but the effects are the same because the object is becoming an oscillating exciter that amplifies the movement both in frequency and amplitude.

Therefore, instruments containing damping systems for these tremor oscillations are useful for patients with such manifestations. As such, the design and construction of such systems require in the first stage, an assessment of the anthropometric dimensions of the sample of subjects for which a tremor attenuation system is developed.

These measurements are part of the procedure for developing an attenuation system (spoon), for these movements (figure 5) and respectively for the overall analysis of the tremor-type movements at the level of the upper limbs.

The tremor-type motion analysis system developed in this research is based on image acquisition from a system (Contemplas), consisting of 3 high-speed video cameras (250 frames/sec), which synchronously captures images in three different directions for as then they are processed with the help of the Templo software application (figure 6).



**Figure 6.** Block diagram to record the hand movements in tremor

The obtained images are synchronized and processed to identify the parameters of the tremor movement (frequency, amplitude) and also to determine the direction and the way of the movements in parallel with the use of the online application [13] for the 2D recording of tremor movement on a digital tablet with a touchscreen, as a path displayed on the touch screen.

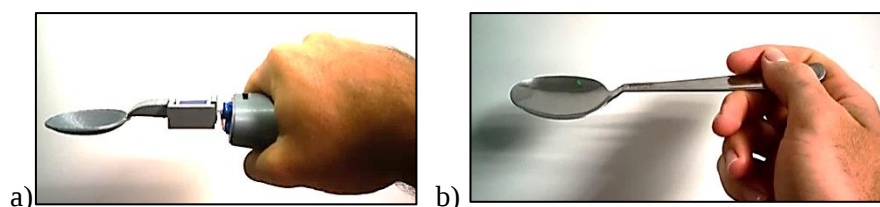
#### 4. Results and conclusions

The analysis procedure is designed to contain several work steps to be able to verify the initial hypotheses. Thus, the recordings on the video system were made in three stages of work, namely:

- recording the tremor movements without any attenuation device and comparing with the routes recorded on the digital tablet, then,
- in the second stage the subjects are recorded holding a regular spoon in their hand (video image acquisition) and respectively
- the third stage in which the subjects are recorded with the video cameras but also on the tablet, holding in their hand the tremor attenuation system, spoon with damping (figure 7a).

Following the construction of this experimental setup, the development of the image acquisition activity and the correlation with the routes recorded on the touchscreen tablet, a series of aspects were found that will determine changes and optimizations of the activity modules (positioning of video cameras, constructive modification of the system damping, modification of the spoon-grip system with damping, etc.).

The need for a calibration stage of the video cameras about the activity space and a resizing of the actuation systems of the cushioning structure in the spoon in order to obtain an ergonomic and accessible variant for patients was also identified.



**Figure 7.** Grip modification of the damping spoon system (a), in relation to the usual catching (b)

The configuration thus made requires a large volume of image acquisition and processing, for which the experimental system is provided with a memory hard-drive dedicated to these operations, to avoid loading the computer and reduce the working speed. Preliminary results of the use of this analysis system lead us to the conclusion that through a development and diversification of records, the information that can be obtained leads to the improvement of manoeuvring aid systems (figure 7) for patients with Parkinson's tremor.

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## **6. Acknowledgments**

In these experiments we've developed the investigations with equipment from Applied Optometry and Medical Engineering Laboratories and the research is part of Ștefania-Gabriela Bortă's student diploma project works that was funded by the Transilvania University of Brasov.