USING WAVELET FOR EARLY DETECTION OF PATHOLOGICAL TREMOR

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ABSTRACT

Tremor is a rhythmic, involuntary, oscillatory movement of body parts and is one of the most common movement disorders. New features and, as a consequence, new knowledge specific to Parkinson and normal tremor can be determined through time, frequency and statistical analysis. Some limitations of known methods used for the analysis of tremor time series, especially for patients who might have Parkinson tremor, are presented.

Early detection of pathological tremor (e.g. Parkinson) using wavelet coefficients is an essential goal of this research.

Index Terms**—** tremor, Parkinson's Disease, wavelet coefficients, early detection

1. INTRODUCTION

Older persons and a few other categories are affected by tremor. Persons with neuro-motor handicap or alcoholics are among them. Continuous stress or fatigue can induce tremor also to healthy persons.

There are several types of pathological tremor. The Parkinson disease is a resting tremor beginning distally in one arm at a 4 to 6 Hz frequency [1]. Currently there is no test which allows an early detection of Parkinson or other neurological diseases, which have the tremor as one of the symptoms.

Nowadays, different linear, nonlinear and statistical methods are being used to identify indicators for an early detection of Parkinson disease [2]-[4].

Using such methods on different time series representing Parkinson tremor we obtained results published in [5]-[9]. For example, the main nonlinear dynamic determinant is the Lyapunov exponent and it must be positive for a chaotic process. Using the CDA, Chaos Data Analyzer [10] software solution on the tremor signals of our database, we found that the Lyapunov exponent value varies between 0.05 and 0.92, depending on the analyzed signal [7]. We used NLyzer, Nonlinear Analysis in Real Time software solution as well [11], for identifying the nonlinear specific elements. Also, we obtained various values for the fractal dimension and various shapes for the auto-correlation function or attractors. For the patients with Normal tremor (NT), the fractal dimension varies from 1.14 to 2.25 and for the Parkinson patients Parkinson Disease (PD) and Suspicious Parkinson Disease (SPD) it varies from 0.02 to 1.02 [5]-[8].

The first goal of this research is the identification of new parameters/features of time series for a better pathological tremor classification. Early detection of Parkinson disease represent the final goal of the research, considering that the actual start of the disease is 15-20 years before the actual symptoms will appear and the diagnostic can be made beyond any doubts. An early detection of Parkinson disease could be possible based on new features. Also, better discrimination of normal and pathological tremor is one of our goals, especially the discrimination of various types of pathological tremor.

Developing new methods in order to extract new features that can help obtaining an early diagnostic of Parkinson tremor or other neurological disease (Essential tremor, Cerebellar tremor, Psychogenic tremor, Wilson's disease) is a challenge.

The new proposed approach in tremor time series analysis includes the wavelet transform, already used in processing other biological processes (EEG) or prediction of neurological disorder like epilepsy [12].

We used different forms of wavelet functions for analyzing the tremor time series (Parkinson, essential, normal), like Mexican Hat or Daubenchies 2, in order to obtain the most suitable series of wavelet coefficients.

Besides the monitoring of wavelet coefficients which can be considered as indicators of disease evolution, the goal of our research is to correlate these new parameters with the disease evolution.

2. DATA ACQUISITION

2.1. Subjects

Database with affected patients has been provided by Suceava Hospital (Neurology Clinic).

This dataset is composed of a range of biomedical tremor measurements from 82 people, 52 with Parkinson's disease (PD). Each column in the table is a particular tremor measure, and each row corresponds one of 2500 tremor recording from these individuals ("name" column). The main aim of the data is to discriminate healthy people from those with PD, according to "status" column which is set to 0 for healthy and 1 for PD or “Suspicious”. The data is in ASCII CSV format. The rows of the CSV file contain an instance corresponding to one tremor recording.

In this study, 28 PD (Parkinson’s Disease tremor), 24 SPD (“Suspicious” PD tremor), and 30 NT (Normal tremor) subjects were analyzed. All patients are suffering moderate to severe postural tremor. This postural tremor cannot be differentiated on clinical features (frequency, amplitude).

The mean disease duration (time for disease to install), age and sex of PD patients were compared with the SPD or NT in Table 1.

Table 1. Data-size, age, gender, and disease duration distribution of PD, SPD, and NT subjects.

	PD	SPD	NT
Number of patients	28	24	30
Mean age (years)	64.54	63.24	64.52
(range in years)	(40-90)	(27-94)	(24-86)
Gender (male/female)	18/10	16/8	19/11
Mean disease duration (years)	16,4	15,3	

Notice in Table 1 that the mean age of PD, SPD and NT populations is similar, but the age ranges are different. This could be considered as an indicator that the PD starts years before actual diagnosis.

2.2. Tremor recording

The tremor time series were acquired using an accelerometer sensor from a Wii™ console, connected via Bluetooth™ to a PC. The data were analyzed using an application implemented in Visual C 2010 Professional.

The Wii™ Remote known as the Wiimote™, is the primary controller for Nintendo's Wii console. A main feature of the Wii Remote is its motion sensing capability, which allows the user to interact with and manipulate items on screen via gesture recognition and pointing through the use of accelerometer and optical sensor technology [13].

We chose to use a computer game device, the Nintendo, as a simple accelerometer wireless. We consider that Wii Remote Nintendo may be an attractive tool as an accelerometer for monitoring of tremor by physicians and laboratory technicians. The Wii Remote contains an accelerometer that has a range of ±3 G, which is sufficient for tremor recording [14], [15].

Nintendo has three-axes: x - lateral, y - anteroposterior, and z - vertical. The device records both acceleration induced by hand movement and the component of gravitational force. If the controller is rotated, the gravity accelerometer affects the values on the x, y, and z axes.

This system using a Wii Remote is capable of analyzing frequency and estimated amplitude of tremor between 3 - 15 Hz (N tremor is between 5 - 12 Hz, and PD tremor is between 4-6 Hz). The Wii Remote and PC are connected by Bluetooth - Human Interface Device Profile. The tremor analyzing program was developed using Visual C 2010 Professional. The acceleration sampling period was set at 10 ms in the Nintendo.

In Fig. 1 are presented the two time series for N tremor and PD tremor, for the case x (lateral) = 0, y (anteroposterior) = 0, and z (vertical) =1 (equilibrium state).

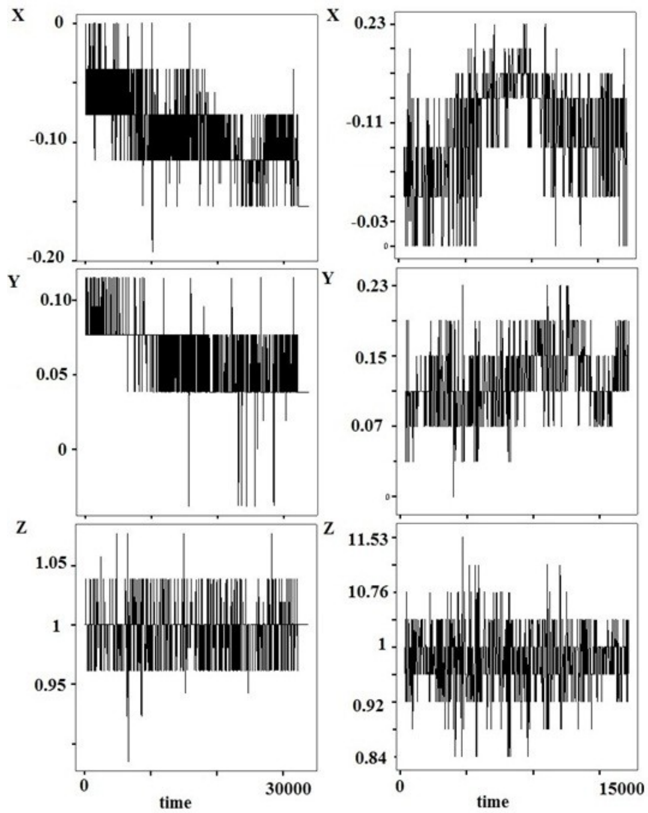


Fig. 1. Time series for NT (first column) and PD tremor (second column), for the equilibrium state.

The accelerometer built into Wii Remote (Nintendo) measures gravitational and non-gravitational acceleration, and results of this paper suggest that Nintendo will be useful for measurement and analysis of tremor using the methodologies described in [14], [15].

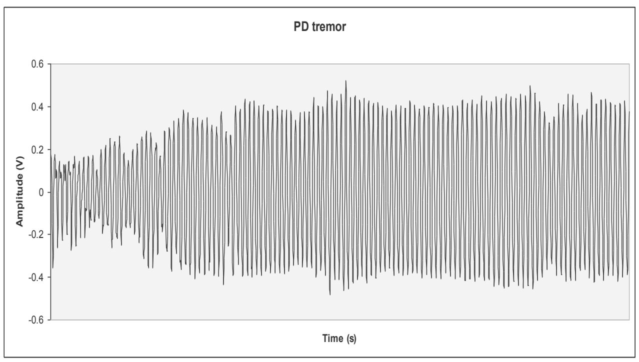
3. DATA ANALYSIS METHODS

Using linear, nonlinear and statistical methods we analyzed a database which contains both Parkinson and normal tremor time series. Actually this evaluation of median filter is performed to avoid misdiagnosis, which might be provoked by filtering. Filter was applied in order to remove the noise embedded in analyzed time series.

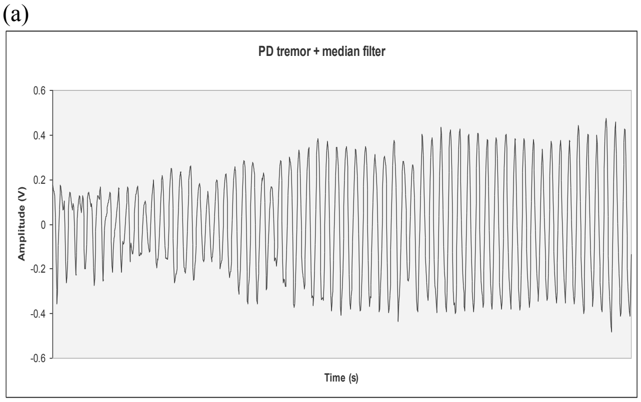
3.1. Median filtering

Median filtering was used to remove noise from time series representing different types of tremor. The principle of this filtering method is based on replacing each sample with the median of its neighbor samples. Using the function y = *medfilt1(x, n)* in MATLAB R2009b [16], we applied a 1-dimensional filter of order n to vector x. The filter's order indicates the size of the filtering window. Vector x is the tremor time series which will be filtered.

For filtering, the neighbor samples have different weights, which means that the current sample will have as new value the weighted average of neighboring samples. Fig. 2 illustrates the tremor time series filtered using the described method.



(a)



(b)

Fig. 2. PD tremor signal, first 2000 samples (a), PD tremor signal obtained by median filtering, first 2000 samples (b)

Number of neighbor samples considered for filtering is depending on the filtering window size, 20 in our case. This parameter can be optimized by minimizing the square mean error. In our case the value of filtering weight was 0.8.

3.2. Using wavelet for discriminating tremor spikes

In the past years, researchers in signal processing have developed wavelet methods for the multiscale representation and analysis of biomedical signals. Wavelet tools differ from the traditional Fourier techniques by the way in which they localize the information in the time-frequency plane. In biomedical engineering, the spectrum of applications of wavelet transform has been large (analysis of the more usual physiological signals such as the Electrocardiogram (ECG), or Electroencephalogram (EEG), the very recent imaging modalities: Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) [17] – [20].

From biomedical signals point of view, the interest information's are often a combination of features that are well localized temporally or spatially (e.g. small oscillations, transients oscillation, and "spike" in tremor signals). This requires the use of wavelet, because is the most versatile analysis method in handling events that can be at opposite extremes in term of their time-frequency localization.

The wavelet transform is a multidimensional analysis method, taking into account both time and frequencies dynamics of analyzed time series.

The tremor spikes are considered as an important early indicator of Parkinson disease. For a better detection of these spikes a suitable wavelet function must be chosen. The characteristics of the chosen wavelet function must be similar with those of analyzed time series. As a consequence, the tremor time series will be represented by a series of wavelet coefficients. For the tremor spikes the wavelet coefficients will have higher values, where the amplitude is high. The analysis method used has been described in [11].

After applying the wavelet transform the relevant samples from analyzed time series will be emphasized, while the rest of samples are reduced or even completely eliminated (i.e. noise). As a consequence, after using the median filtering and the wavelet transform the resulted time series will be more accurate.

This approach consists of the following steps:

- the wavelet coefficients are calculated for different scales; the wavelet coefficients are used to discriminate high amplitude tremor signals (tremor spikes) from small oscillations, or transients oscillation; this is possible due to the fact that the wavelet coefficients are higher for tremor spikes than for artifacts, when using certain scales of mother-wavelet function;
- an additional criteria that has been introduced for algorithm tuning, in order to avoid detection errors is the energy normalized value of wavelet coefficients;
- first, a linear combination of weighted wavelet transforms is applied on tremor signals; second, the square of normalized power is being calculated.

Success of detection is totally dependent on the chosen mother-wavelet function. Considering that the wavelet coefficients' values reflect the amount of similarity between functions of wavelet base, two functions were selected.

The purpose of future analysis is to check the sensitivity and specificity of detection for the two types of wavelet functions used.

4. RESULTS

The selected functions, Mexican Hat and Daubenchies 2, are similar with the high amplitude tremor signals. The signals were tested for analysis scales of 2, 10 and 32. The presented results are only for 3 subjects (N, PD and SPD tremor), but for all subjects in our database we obtain the same results.

The thresholds were chosen after evaluating the effect of analysis scales on the normalized powers corresponding to wavelet coefficients. For comparison, the wavelet transform based on Mexican Hat wavelet functions has been applied to time series representing normal tremor NT (a), PD tremor (b) and suspect of PD tremor (c) in Fig. 3.

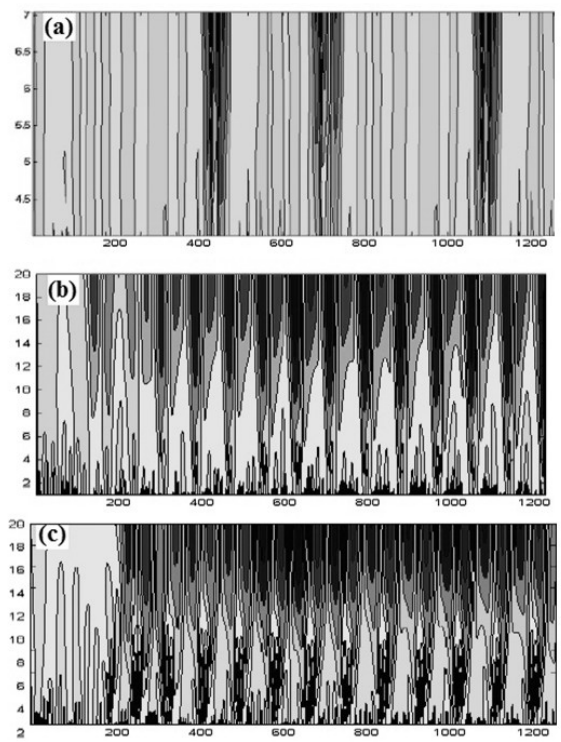


Fig. 3. Wavelet coefficients applied on Normal tremor (a), PD tremor (b), and SPD tremor (c), using Mexican Hat wavelet.

In Fig. 3 (a, b, c) are represented the wavelet coefficients for the N, PD and SPD tremor signals (first 1200 samples).

The black and dark grey areas correspond to high values of these coefficients. Notice that for PD and SPD tremor signals the high value coefficients are located between 200 and 1200 samples. The number of spikes within this region is more than 10. For the N tremor signal the number of spikes is smaller, but roughly with the same distribution over the analyzed samples.

A clear discrimination between N, and PD tremor using Continuous Wavelet Transform (CWT) can be observed in Fig. 4.

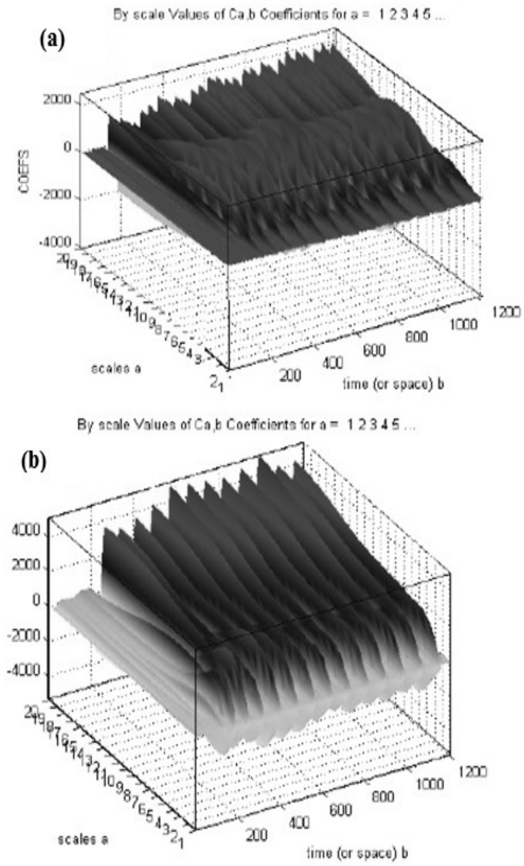


Fig. 4. Continuous Wavelet Transform (CWT) applied on normal tremor N tremor (a) and PD tremor (b), using Mexican Hat wavelet

In Fig. 4 the 3D representations clearly emphasize the presence of spikes in tremor signals (first 1200 samples). Also, notice the correlation between selected scale a and spikes amplitude (z axis). The spikes corresponding to N tremor have lower amplitude than those corresponding to PD tremor.

5. DISCUSSION AND CONCLUSIONS

We used a low-cost and easy to use system for analysis of tremor (Wii Remote).

Linear, nonlinear and statistical methods are not suitable for an early detection of Parkinson disease. Considering different types of tremor signals, including from patients considered to be suspect of Parkinson disease, it has been observed that there are strong similarities between the PD tremor signals and suspect PD tremor signals after applying the wavelet transform.

However, further studies are necessary to ensure that the appropriate wavelet functions family and scales are chosen. It can be considered also the use of wavelet transform as a starting point in developing a screening system for early detection of PD.

The chosen scale proved to have high relevance when discriminating between tremor “spikes” and low frequency components. With the increasing of scale, the discrimination becomes less performing. As a consequence, for normal tremor, the scale a=5 is most suitable.

For PD and suspect PD time series, the best discrimination between low and high frequency components is achieved when using a scale of a=15.

The type of mother-wavelet function is influencing the detection quality. The detection properties of Wavelet Transform have also been used advantageously for pathological tremor signals processing tasks. In this paper, one example is the detection of tremor "spikes" recordings of PD or "suspicious" PD patients.

A future direction of our research assumes that, after a 6 month period, the same patients (especially the suspect PD) will be subject to investigation by acquiring again their tremor signals using a Wii Remote System and a new system based on Xbox 360 Technologies for tremor analysis.

The same analysis procedure will be followed and the new set of wavelet coefficients (using different forms of wavelet functions, like Chwi Wang spline, Mayer, or Morlet) will be compared with the previous set.

The results encourage us to develop a classifier using RNA or an expert system for early identification of Parkinson's disease, using the discriminatory "power" of Wavelet Coefficients.

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For further information on database structure please contact Dr. Oana Geman (geman@eed.usv.ro).

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