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MEASUREMENT OF HANDWRITING TREMOR FOR DIAGNOSTIC PURPOSES

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Abstract − Spectral analysis of the tremor signals got from the movement of the writing hand is presented in this paper. Analysis of stylus position and velocity is made upon data collected from the computer system for handwriting analyses, developed in Institute of Precision and Biomedical Engineering Warsaw University of Technology. Volunteers drew the circles on the digitiser surface using electronic pen similar to a normal ballpoint pen. Presented analyses were obtained from the group of 31 participants aged from 21 to 60 with different spectral analysis results of tremor measurements. Some of analyses were chosen to show differences between person without troubles in handwriting and that one whose handwriting is not easily readable because of some troubles with motorical skills or some diseases with pathological tremor, for example Parkinson's disease. As a results of my research I presented the method to classify the spectrum analyses for characteristic tremor group using numerical parameters.

Keywords: handwriting process, motorical skills, tremor

1. INTRODUCTION

It is well known fact that some people have difficulty writing neatly and legibly. Some people, especially children, have big troubles with their handwriting and no one can read their notes. Teachers and psychologists tell them doing exercises to improve their manual skill. It is not effective method for all of them, because handwriting's problems sometimes appeared as results of various diseases and pathological changes in their organism. It is necessary to distinguish these patients from another negligent children.

There are two main groups of methods of studying human handwriting process. First, graphological methods (without patterns) are based on analysis of fragment of hand-written text. Second, tremor measurement methods (with pattern) are based on a draw created by following the trace. This research is based on method with pattern developed by author of this paper. I used the computer system for handwriting analyses, developed by me (in Institute of Precision and Biomedical Engineering Warsaw University of Technology) and my method to distinguish the tremor of human hands got from draw movements [6].

This tremor, so called kinematical tremor, may be physiological or pathological. Tremor was the subject of many studies [2], but in those works the tremor signals were got in other ways, using acceleration and force sensors [5], [4] or laser methods [1].

In my work I concentrated on analyse of handwriting process. I try to research if the tremor is present in hand movements of people with illegible handwriting.

I also try to distinguish differences between tremors caused by some diseases and some kind of disabilities.

2. MATERIALS AND METHODS

2.1. Procedure

31 volunteers aged between 21 and 60 with different motorical skills and participated in this study. The participants were seated at a stand of typical height, which contained the computer with the digitiser. The participants were asked to draw several times the circle (radius 60 millimetres) printed on the sheet of paper, which was put on the measurement surface. The trace, that participant followed, satisfied the criteria that the pen does not need to leave the surface during drawing and that the resulting measure contained at least 5500 samples. Participants wrote naturally with their dominant hand. There was no immediate visual feedback to the participants of their pen trace.

2.2 Apparatus

The data were collected using the computer system for diagnostic analysis of human handwriting, developed on Warsaw University of Technology in Institute of Precision and Biomedical Engineering by this article's author. The system recorded the X and Y co-ordinates of the stylus as it was moving across the digitiser surface. The data were sampled at the frequency of 100 Hz, at spatial resolution of 0.25 mm. The signals from pen were recorded and analysed using specially designed software.

2.2 Analysis methods

For each measurement point the system calculated the distance between the centre of theoretical circle printed on the pattern and the actual X-Y pen position. The difference between this distance and the radius of theoretical circle was called deviation. Deviations, calculated for each measurement points, were analysed by spectral methods to find a tremor. Difference between two successive deviations allowed me to calculate deviation velocity. The deviation's velocity was used as a filter to eliminate slow changing signals caused by form deviations (roundness etc.). To calculate power spectral density of deviation's velocity I used the Blackman - Tukey's method. I normalised values of the power spectrum by dividing them by the total signal energy, which was calculated as power spectrum integral.

3. RESULTS

3.1. Typical diagrams of spectral analyses

As a result of spectrum analysis of handwriting process I distinguished some characteristic groups of spectral analysis' results. In each group the spectrums have a characteristic shape with peaks on the same range of frequency. These effects may be caused by psychomotorical skill, diseases (for example Parkinson's disease), and by general psychophysical state of the organism (physiological tremor). I distinguished 3 characteristic groups of participants:

- control group – consist of persons without measuring tremor, with very good skill abilities,
- Parkinson's disease group – consist of patients with diagnosed Parkinson's disease, with characteristic visible tremor,
- physiological tremors group – consist of participants with physiological trembling.

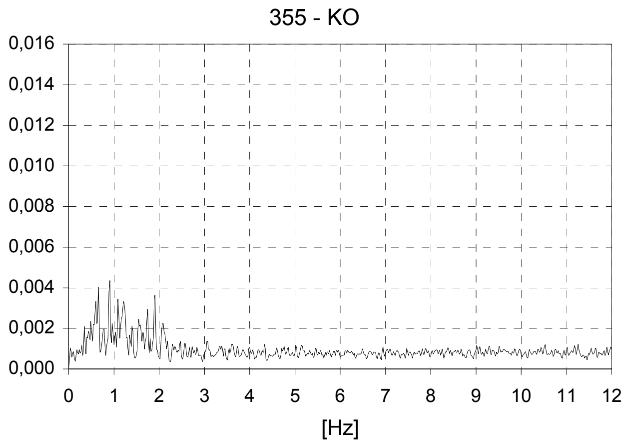

Fig. 1. Power spectrum of a person from the control group

For each group differences in the shape of the curves of power spectrum density are visible and significant. The examples of spectrum analyses for each group are shown below.

Power spectral density of deviations of 21-year-old female subject with spectrum typical for persons with good psychomotorical skills, without tremor is shown on fig.1. This spectrum has higher level of the signal in the range of frequencies typical for heartbeats and physiological blood flow. It is typical diagram for persons from the control group.

Example of a typical spectrum adequate to pathological tremor is shown on fig. 2. It is obtained from the 60-year-old man with diagnosed Parkinson's disease. This diagram contains relatively high peak at higher frequencies, in the range from 4 to 8 Hz.

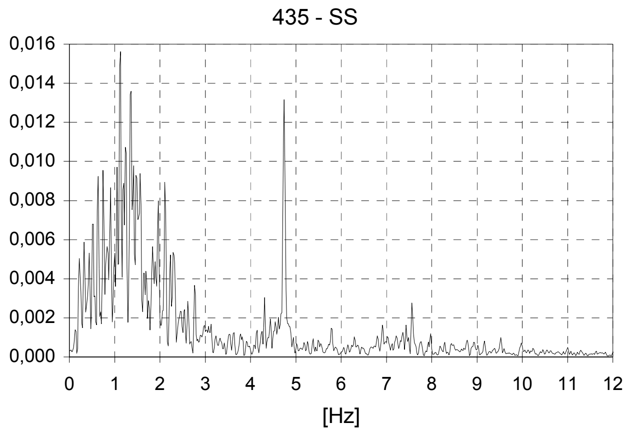

Fig. 2. Power spectrum of a patient with Parkinson's disease

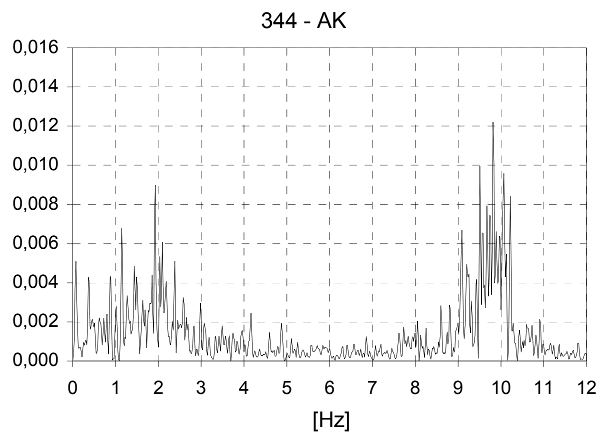

Fig. 3. Power spectrum of a person with physiological tremor

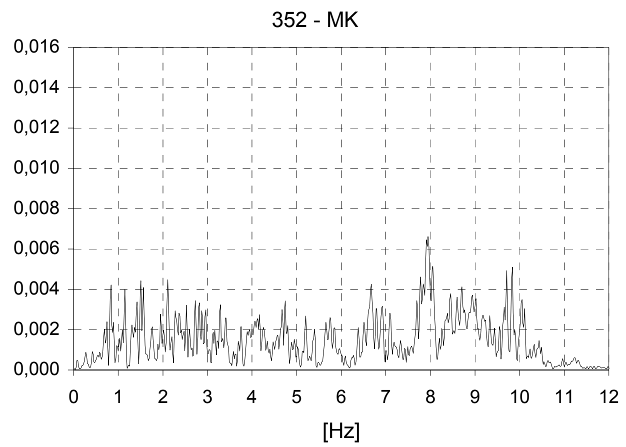

Fig. 4. Power spectrum with of a person with wide spread range of tremor

Two different results of spectrum analyse of two, 21-year-old, students with significant values on higher frequencies, especially in the range from 8 Hz to 12 Hz are shown on fig. 3. and fig. 4. The tremor in this range (8 - 12Hz) was defined in [3] as a physiological tremor. Person coded as AK (fig. 3.) was tired after physical effort. He suffers from the pain of his right hand.

Person coded as MK (fig. 4.) has wide spread range of tremor. I don't know the reason of that effect, because neurologist never examined that person before, but I noticed that he was all trembling during the test.

3.2. Classification method

The diagram-based diagnosis is not objective and non comfortable method for medical purposes, so in my work I am trying to find numerical parameters to distinguish patients with pathological kinds of tremor.

First of all I divided full spectrum range to a few smaller ranges. This division was based on observation of power spectrum analysis charts, like shown above. For every range the sum of spectrum values was calculated and divided by width of the range. I analysed data in the following ranges: 0 – 0,6 Hz, 0,6 –2,5 Hz, 2,5 – 4 Hz, 4 – 6 Hz, 6 – 8 Hz, 8 – 12 Hz, 12 – 20 Hz and 20 – 50 Hz. Some of these ranges are useful to distinguish the chosen groups of participate, as described above.

The power spectral analyses obtained from 14 persons from control group, 14 persons with physiological tremor and 3 patients with pathological tremor caused by Parkinson's disease are presented on the next charts.

Because analysis is made upon 8 different ranges, each person's result values can be shown as a point in 8 - dimensional attribute space. Such space cannot be shown on two-dimensional diagrams, so I choose some planes of projection to find best ones. Each plane of projection of attribute space shows correlation between average tremor values in two ranges.

The correlation between tremor in frequency ranges from 2.5Hz to 4Hz and from 8 to 12Hz is shown on fig. 5. This chart shows that Parkinson's disease tremor doesn't mark off in 2.5 – 4 Hz range. Persons with Parkinson's disease cannot be distinguished from the non-pathological control group based on values calculated in this range.

Parkinson's disease tremor shown on fig. 6. is bigger than tremor of the control group, but not for everyone. It means that the chosen groups, especially the control group and Parkinson's disease group, can not be divided using the vales of power spectrum from the range 4 - 6 Hz.

The chart of tremor in frequency range from 6 to 8 Hz is shown on fig. 7. In this range persons from control group have average value of spectrum below 1000. Pathological tremor is much bigger. Both groups have small average value of spectrum in the frequency range between 8 and 12 Hz. This range is adequate for physiological tremor, so the group with physiological tremor is above 1000. This plane of projection of attribute space seems to be the best to divide the chosen groups, but for now analysed group with Parkinson's disease tremor is too small to make it sure.

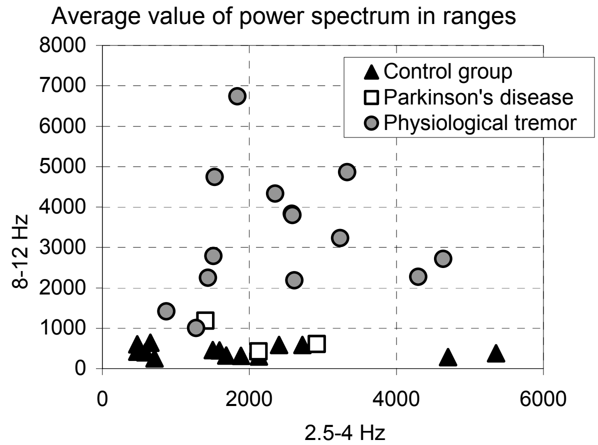

Fig. 5. Dependencies between the groups in chosen ranges

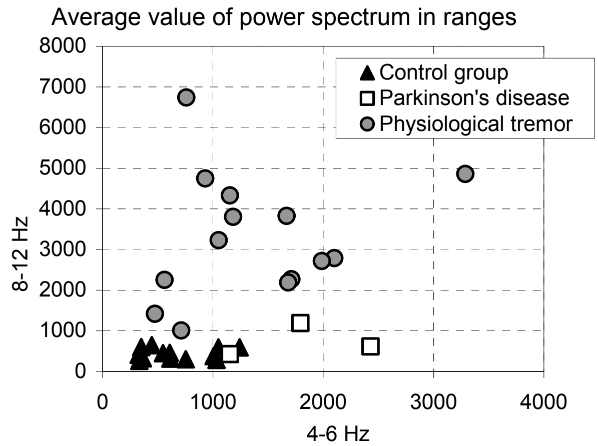

Fig. 6. Dependencies between the groups in chosen ranges

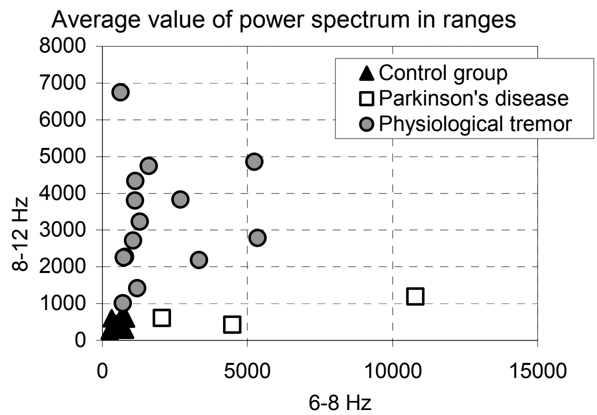

Fig. 7. Dependencies between the groups in chosen ranges

The chart on fig. 7 shows us another important thing: group of persons with physiological tremor can be divided into two different groups because of high values in both of ranges. The main boundary value is about 1000 - the same as between control group and persons with Parkinson's disease.

Aggregated values of average spectrum level in four chosen frequency ranges are shown on the table below, but because of small number of tests those values should be considered only as an example.

TABLE I. Value of power spectrum calculated in chosen ranges for specified groups

Freq.	Group	Min	Max	Avg
2.5-4Hz	Control group	475	5 357	1 920
	Physiological tremor	869	4 638	2 435
	Parkinson's disease	1 403	2 917	2 149
4-6 Hz	Control group	329	1 242	645
	Physiological tremor	477	3 290	1 377
	Parkinson's disease	1 157	2 430	1 794
6-8 Hz	Control group	251	816	517
	Physiological tremor	631	5 347	1 919
	Parkinson's disease	2 047	10 784	5 769
8-12 Hz	Control group	257	644	430
	Physiological tremor	1 008	6 742	3 299
	Parkinson's disease	427	1 191	744

The lower limits of power spectrum values are the highest for Parkinson's disease in all frequency ranges except 8-12Hz. It agrees with observation of power spectrum charts – there is only wide peak of physiological tremor in this range (fig. 3) so average level counted from these values is much bigger.

Fact that for every range aggregated values of the control group are several times smaller than in other groups is very promising for diagnostic purpose.

The values shown in the table I are the first step to find an universal index of tremor kind. Such index is needed for medical diagnostics.

4. CONCLUSION

As it was shown on examples above, the computer system and the method lead to good results in detection of physiological and pathological tremor.

I can distinguish a few types of tremor adequate to psychophysical state of organism, psychomotorical skills, moving co-ordination or some diseases.

The power density spectrum analysis of handwriting process is a good method for the tremor detection. For diagnostic purposes it requires definition of some numerical parameters.

Classification method based on analysis of attribute space gives promising results. It can be used to distinguish different kind of tremors, but to do it with high reliability I need to get much more measurements of patients with pathological tremors.

The method is non-invasive, is safe for patient and very simple to carry out. It is very comfortable, especially for children examination and can be used for early diagnosis of some diseases.

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