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С. В. Калинчук, М. Р. Баязітов

ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ В РОБОТІ ЛІКУВАЛЬНО-ПРОФІЛАКТИЧНИХ ЗАКЛАДІВ

Розглянуто основні характеристики інформаційних технологій і зокрема телемедицини та стан телемедичної системи, яка на пілотному етапі обслуговує віддалені населені пункти у режимі консультування у реальному часі та ургентного медичного консультування. Наведено результати консультування хворих за п'ятимісячний термін роботи. Розглянуто концепцію розвитку інформаційних медичних технологій у країнах Євросоюзу й обговорено доцільність споріднення розвитку дистанційного навчання у межах «телемедичних» проектів.

Ключові слова: інформаційні медичні технології, телемедицина, дистанційне навчання.

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S. V. Kalinchuk, M. R. Bayazitov

INFORMATIONAL TECHNOLOGIES IN THE WORK OF MEDICAL HOSPITALS

Main characteristics of informational technologies with the emphasis on telemedical care as well as the general state of pilot telemedicine service for remote population have been analyzed. Thus, urgent and planned approaches to medical consultations were compared as well. The results on patient's consultations in the course of five month work have been reported. The conception on the development of hi-tech in medicine in Europe was delivered along with the discussion on the combined educational purposes of "telemedical" projects.

Key words: informational medical technologies, telemedicine, distant education.

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Krzysztof Kwiatos, Jacek Jakubowski, Marek Kuchta

MEASUREMENT AND SIGNAL PROCESSING OF HAND TREMOR

Military University of Technology, Warsaw, Poland

1. Introduction

Semantically tremor belongs to involuntary movements and in early periods of disease may be considered as a physiological. Similar kind of tremor is found in over fifty percent of healthy populations. Tremor constitutes one of the most important symptoms of neurological disorders. However, its objective assessment is very difficult (Barbeau 1984). The methods used for objectivisation require application of such devices as Schottky photodetectors, piezoelectric detectors or kymographs. The best results are achieved with the use of spectral analysis. To meet requirements of objective tremor measurement the Institute of Fundamental Electronics of Military University of Technology, Warsaw, Poland, designed a measurement set consisting of acceleration transducers, preamplifiers and multichannel A/D converter, plugged into the ISA slot of a microcomputer (Fig. 1). The set includes a special software (Pakszys et al. 1990, Pakszys et al. 1997).

The software for tremor signals measurement, digital data processing and display of results was prepared in DASYLab software environment from DASYTEC GmbH from Germany. Readings and analysing results can be displayed graphically and/or numerically. The acquired data and processing results can also be saved to the files so that they can be retrieved for further processing with the use of more sophisticated analysis i.e. in Matlab environment (Bobrowicz et al. 1999).

2. Method

The used method for the daily tremor profile investigations were aimed at:

1. Determination of the daily profile of tremors among the patients not treated up to now.
2. Determination of the pharmacodynamic effect of used drugs, among the treated patients.
3. Correction of the used drugs or their doses, if it necessarily.
4. Investigations of the treatment progress.

The investigations comprised the group of 49 patients volunteers (30 male and 19 female) aged from 40 to 75 years. They were informed and after acceptance of the protocol of investigations by sign, the patients were able to undertake the daily tremor profile investigations. The patients come from outpatients of neurologic polyclinic. Their feeling of tremor of hands of upper arms as one of the most important symptoms was the reason of medical treatment. Investigations were carried out among the patients presented tremor as an important sign and disease symptom which distributed their living conditions.

They were being invited for observations and investigations day after day from 8.00 to 13.00 or from 13.00 to 18.00. Every investigations started

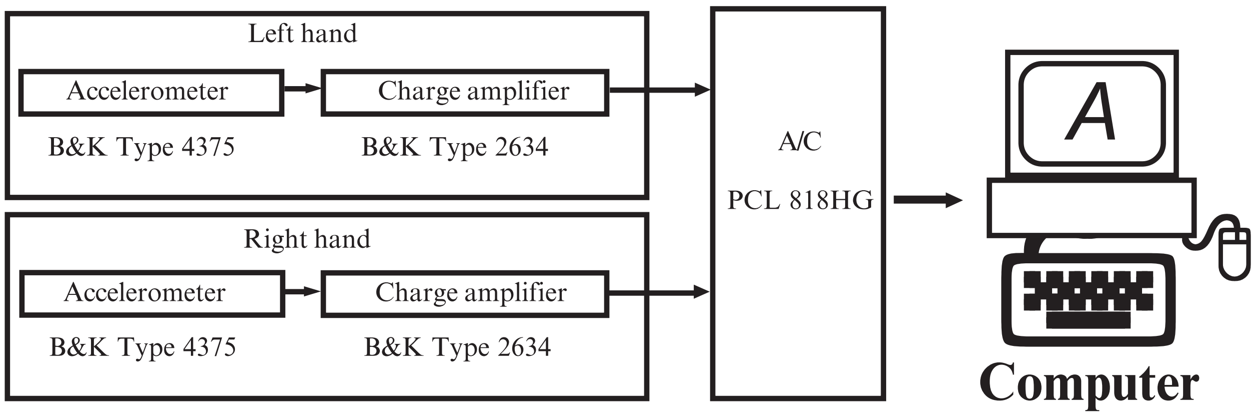

Fig. 1. Measurement set

before ingestion of morning dose of drugs or were performed among the patients with tremor not treated up to now. Among investigated group 49 patients were:

— 15 persons with physiological tremor;
— 14 persons with essential tremor;
— 20 persons with parkinsonian syndrome and P. D.

Accelerometers were placed on nail plate, middle fingers both side hands. After short time of adaptation, after arterial pressure and heart rate rhythm normalized to own personal value, the tremor investigations were started 8 times by 10 sec.

The daily tremor profile was performed in sitting position on the arm-chair as a:

1. resting tremor of hands;
2. positional tremor of hands with supported forearms;
3. positional tremor of hold out of upper arms.

The obtained measurement results (time series of accelerometer's signals) were saved on a disk in ASCII format. A disk could be simply attached to patients treatment card. Moreover, during the measurement the following values are displayed on the computer monitor:

— root-mean-square value of acceleration signal;
— correlation function of both hands;
— power spectrum of tremor (Fig. 2);
— power of acceleration signal;
— mean power of tremor

$$P_{dr} = \frac{1}{T}\int_0^T |a(t)v(t)|dt$$

were: a(t) — acceleration, v(t) — velocity, T — time of observation,

— signal energy (in fixed period of time).

Moreover, the saved signals were analysed with the use of more advanced methods i.e. time-frequency analysis (Fig. 3) or blind identification.

Obtained results lead to following conclusions:

1. Usefulness of the proposed method in clinical and experimental medicine.

2. The undertaken investigations indicate the validity of the proposed method for determination of tremorolytic and tremorogenic effects of applied drugs, as pharmacodynamic effect.

3. Spectrum of pathological and physiological tremor have different shape.

4. Energy of pathological tremor is more higher than energy of physiological tremor.

5. In advanced stages of extrapyramidal disease predominates a single frequency of tremor different by different patients.

3. Possibilities of using higher-order statistics in blind system identification of hand tremor

3.1. Discussion of the problem

Consider the linear system identification problem: the received discrete-time signal $y(n)$ is a linear process corrupted by additive noise, i. e.:

$$y(n) = \sum_k h(k)u(n-k) + g(n) \qquad (1)$$

The model is depicted in Fig. 4. If we have access to input $u(n)$ and some knowledge of the properties of noise $g(n)$, we can use conventional techniques i.e. cross-correlation based to reconstruct $h(n)$, the impulse response of the system. However, in many "real world" problems and in the analysis of tremor particularly we do not have access to the input $u(n)$ but there is still the need to estimate the impulse response. This problem is known as blind system identification. For the problem to be well-posed some assumption must be taken. The input is unknown, but is assumed to be stationary, non-Gaussian, independent and identically distributed (the so called i. i. d). Writing (1) in terms of 2nd order statistics (autocorrelation sequence $c_{2y}(k)$ and power spectrum $S_{2x}(f)$ we have:

$$c_{2y}(k) = c_{2u}(0)\sum_n h^*(n)h(n+k) \qquad (2)$$

$$S_{2y}(f) = c_{2u}(0)|H(f)|^2 \cdot \qquad (3)$$

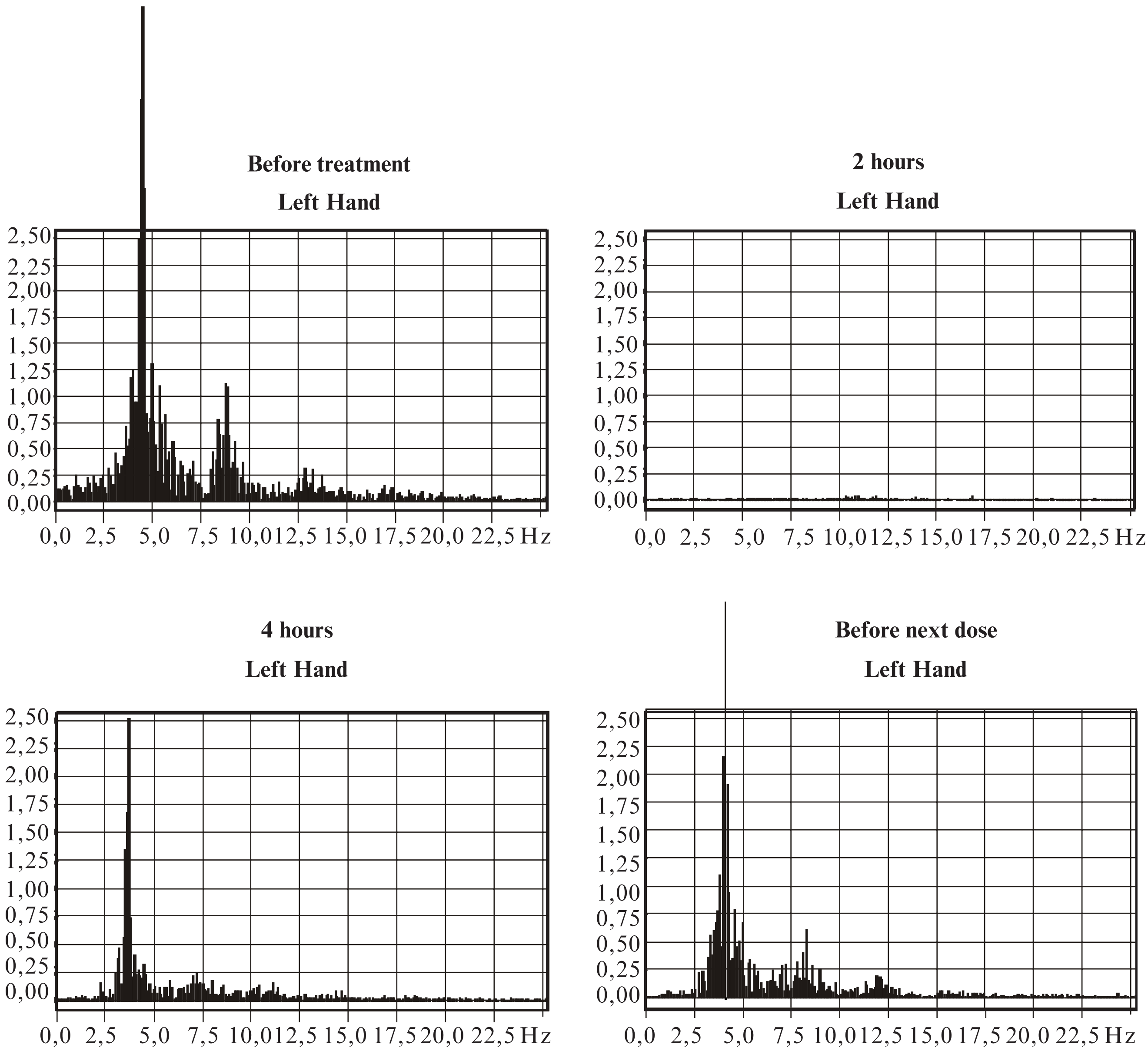

Fig. 2. Daily profile of parkinsonian tremor and pharmacodynamic drug effects. Patient A. R., male, 61 years, diagnosed as: vasogenic parkinsonism

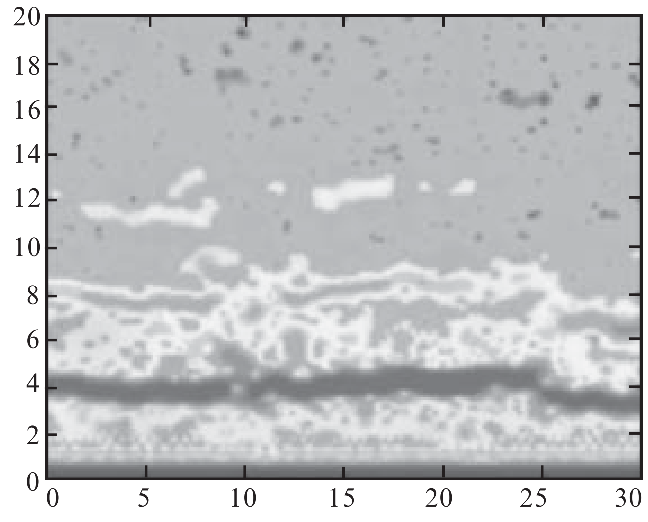

Fig. 3. Spectrogram (STFT) of tremor signal. Patient A. R. male, 61 years

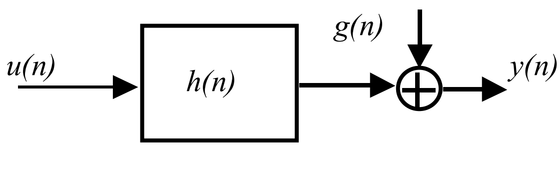

Fig. 4. A single channel model of a system

Note that they do not carry any information about the phase of the system. When the 2nd order output statistics are used, one may obtain only the spectrally equivalent minimum phase part of it. The underlying reason is that they are unaffected by all-pass factors, and as such are "phase-blind" sequences. To recover a general non-minimum phase model of hand tremor one need phase sensitive higher-order statistics — cumulants and polyspectra. The relationship with equation (1) is described by (Brillinger and Rosenblatt (1967)):

$$c_{ky}\left(m_1,\ldots,m_{k-1}\right)= \\ = c_{ku}\left(0,0,\ldots,0\right)\sum_n h(n)h(n+1)\ldots h(n+m_{k-1}) \qquad (4)$$

$$S_{ky}(f_1,\ldots f_{k-1})= \\ = c_{ku}(0,0,\ldots,0)H(f_1)\ldots H(f_{k-1})H\left(\sum_{n=1}^{k-1} f_n\right), \qquad (5)$$

where c_{ky}, c_{ku} denotes respectively the output and input k-th order cumulants (for zero lag called sometimes skewness γ_{3u} and curtosis γ_{4u}), S_{ky} *is* the output k-th order spectrum. The above statistics do contain the information about the phase of the system and there are several interesting algorithms for both parametric (e.g. Swami and Mendel (1990)) and non-parametric (e.g. Pan and Nikias (1988)) estimation of non-minimum phase system based on them.

Besides, there are two very useful properties of higher-order statistics: a) all cumulants c_{yk} for $k>2$ of any kind of Gaussian process y are zero, be they coloured or white (it also holds for symmetrically distributed random processes in third-order statistic) and b) the cumulant of two statistically independent random processes equals the sum of the cumulants of the individual ones. These properties are of paramount importance when the acceleration based methods and A/D converters are used because the quantization noise is assumed to be symmetrically distributed and we can then suppress the effect of additive noise when the signal is non-Gaussian.

To summarise, the blind system identification with the use of higher-order statistics is possible if a hand tremor acceleration signal is non-Gaussian and linear. If it is not linear one can use nonlinear models also based on higher-order statistics (e.g. Volterra system).

3.2. Testing procedure

To test the data for non-Gaussianity and linearity we have used the procedure developed by Hinich (Hinich (1982)). The basic idea is that if the third-order cumulant of a process is zero, then its bispectrum and bicoherence bic_{3y}:

$$bic_{3y} = \frac{S_{3y}(f_1,f_2)}{S_{2y}(f_1)S_{2y}(f_2)S_{2y}(f_1+f_2)} \qquad (6)$$

are also zero. If the bispectrum is not zero, then the process is non-Gaussian. If the process is linear and non-Gaussian then combining (5) for k=2 and k=3 with (6) we have that the magnitude of bicoherence should be a non-zero constant:

$$bic_{3y} = \frac{\gamma_{3u}H(f_1)H(f_2)H^*(f_1+f_2)}{\sqrt{\gamma_{2u}\left|H(f_1+f_2)\right|^2\gamma_{2u}\left|H(f_1)\right|^2\gamma_{2u}\left|H(f_2)\right|^2}} = \\ = \frac{\gamma_{3u}H(f_1)H(f_2)H^*(f_1+f_2)}{\gamma_{2u}^{3/2}\left|H(f_1)H(f_2)H(f_1+f_2)\right|} = \frac{\gamma_{3u}}{\gamma_{2u}^{3/2}}e^{j\theta(f_1,f_2)} = \\ = \lambda_0 e^{j\theta(f_1,f_2)} \qquad (7)$$

The test result for non-Gaussianity is reported as probability of false alarm, the so called PFA, i. e., the probability that one will be wrong in assuming that the data have a non-zero bispectrum. If this value is small, say 0.05, we accept the assumption of non-zero bispectrum which means that the data are non-Gaussian. Care must be taken if the PFA is high since it means that the process is symmetrically distributed and may be Gaussian but does not have to be.

The test result for linearity is achieved by comparison of two inter-quartile ranges of a test statistic — theoretical and estimated ones. If the estimated value is much larger or much smaller than the theoretical value, the linearity assumption should be rejected. In this paper we accept linearity hypothesis if the inter-quartile ratio lies between 1/2 and 2.

3.3. Results and conclusions

Time series of hand tremor have been collected by light-weight piezoresistive accelerometers and a simple data acquisition system. During recordings subjects were sittings comfortably with forearms supported. Their hands were slightly raised. The sensors were fixed on subjects' fingers, one on each hand. The acceleration signals were digitised with a rate of 100 Hz. The length of each record was 10 s so that 1024 data points were obtained. The time series have been normalised to unity variance and zero mean. The data set consisting of 15 time series of physiological, 14 time series of parkinsonian and 4 time series of essential tremor was used in testing.

The results of testing for Gaussianity are depicted in Fig. 5a whereas for linearity in Fig. 5b. Physiological, parkinsonian and essential tremor generally appear to be non-Gaussian with no strong evidences of non-linearities, so that the higher-order statistics seem to be very useful in the blind system identification of them. As an example of this kind of analysis we present parameters of 2nd order AR parkinsonian and essential tremor models obtained respectively when the 2nd order (Fig. 6a) and the 3rd order (Fig. 6b) statistics were used. Note the ability of the latter to separate the diseases on the a(1)-a(2) AR parameter plane.

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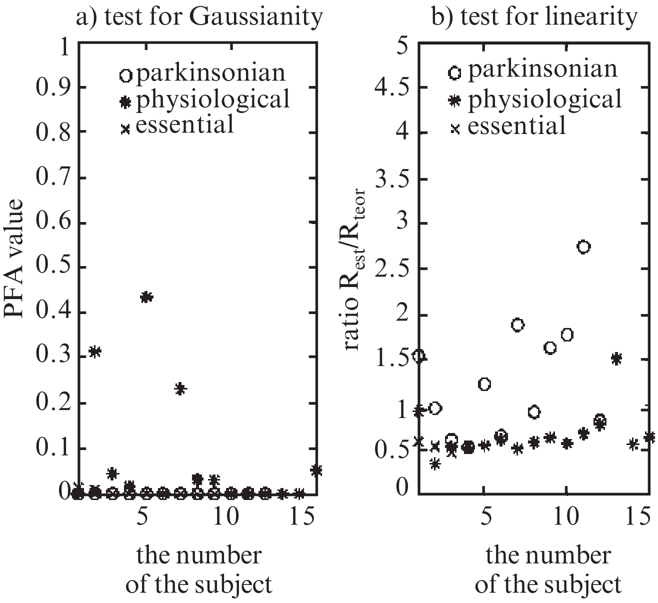

Fig. 5. Results of the test for non-Gaussianity and linearity

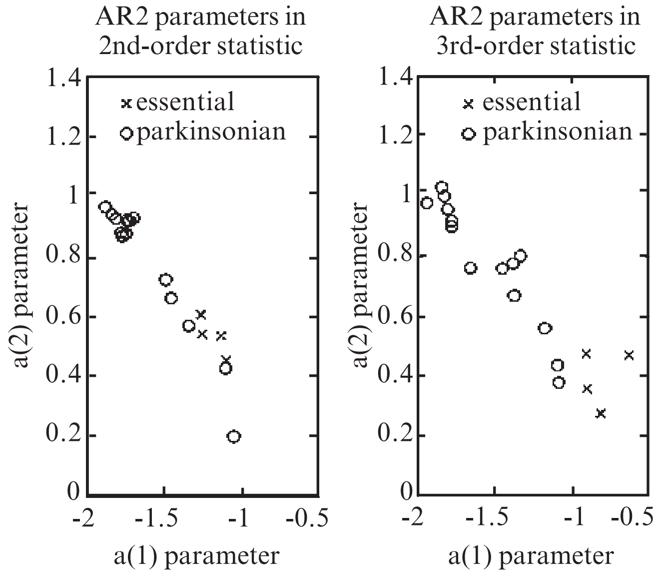

Fig. 6. Parameters of the 2[nd] order AR hand tremor models obtained with the use of the 2[nd] and 3[rd] order statistics

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К. Квятос, Я. Якубовський, М. Кухта
ВИМІРЮВАННЯ І ОБРОБКА СИГНАЛУ ТРЕМОРУ КІНЦІВОК

У роботі подано загальний опис діагностичного методу для аналізу патологічного тремору кінцівок людини разом з інструментальними та технічними засобами. Система вимірювання грунтується на п'єзоелектричних акселерометрах. Їх сигнали виходу передаються через підсилювачі заряду до входу карти конвертора A/C, діючої як комп'ютерний інтерфейс. Спеціально розроблене програмне забезпечення здатне визначати кілька параметрів сигналів тремору як діагностичних при хворобах нервової системи.

Подано можливості застосування статистики вищого порядку в моделюванні ручних часових серій тремору. Були проведені початкові випробування для фундаментальних властивостей серій часу. Результати дозволяють зробити вибір відповідної моделі, а також знайти методи його ототожнення.

Ключові слова: тремор людських кінцівок, часові серії.

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K. Kwiatos, J. Jakubowski, M. Kuchta
MEASUREMENT AND SIGNAL PROCESSING OF HAND TREMOR

In this paper, a general description of diagnostic method for analysing pathological tremors of human limbs is presented along with hardware and software tools. Measurement system is based on piezoelectric accelerometers. Their output signals are transmitted through charge amplifiers to the input of A/C converter card acting as a computer interface. Specially designed software is capable of determining several parameters of tremor signals as diagnostic parameters in diseases of nervous system.

The possibilities of the application of higher-order statistics in modelling of hand tremor time series have been presented. Initial tests for fundamental properties of time series, i. e. gaussianity and linearity have been conducted. The results enable the choice of the proper model as well as the methods of its identification.

Key words: tremors of human limbs, time series.