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ОБРАБОТКА И АНАЛИЗ ЭЛЕКТРОНЕЙРОМИОГРАММ СРЕДСТВАМИ MAPLE

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PROCESSING AND ANALYSIS OF ELECTRONEUROMYOGRAMS WITH MAPLE TOOLS

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Аннотация. Статья посвящена методике компьютерной обработки и анализа сигналов электронейромиографии (ЭНМГ) в рамках известной системы компьютерной математики Maple. Проведен статистический и частотный анализ двух реальных записей электронейромиограмм для здорового человека и пациента с миопатией. Результаты обработки и анализа указывают на существенные различия двух ЭНМГ, которые можно рассматривать как диагностические признаки.

Ключевые слова: электронейромиография, обработка сигналов, статистический и частотный анализ, диагностические признаки

Abstract. The paper studies the methods of computer processing and analysis of signals of electroneuromyography (ENMG) within a known computer mathematics system Maple. Statistical and frequency analysis of two real records electroneuromyogram has been done for a healthy and for a patient with myopathy. The results of processing and analysis indicate substantial differences between these ENMG that can be considering as diagnostic features.

Key words: Electroneuromyography, signal processing, statistical and frequency analysis, diagnostic features

1. Introduction. Electroneuromyography (ENMG) is a method that uses surface electrical probes to obtain electrophysiological signals from nerves and muscles. This technique is developing from the late 1970s as an innovation of the American Academy of General Practice. ENMG provides a high level of diagnostic ability in the field of medicine. The focus of the modern ENMG seems to be concentered on the Computer-Aided ENMG [1].

2. Aim and tasks. The aim of paper is to demonstrate a power of a modern system of computer mathematics (Maple) as for processing and analysis of real electroneuromyograms (ENMG). In the framework of above-mentioned approach [1], we are going to present here:

a. Statistical analysis of real ENMG;
b. Fast Fourier analysis of ENMG;
c. Comparative analysis of normal and pathological ENMG;

3. Data and methods. The experimental data are borrowed from the electronic source [2]. Signals were recorded from 25mm concentric needle electrode placed in tibialis anterior muscle. First of patients has age 44 and no history of neuromuscular disease. Second has age 57 and myopathy due to long history of polymostis. Both records have the duration about 8 s. and the frequency of discretization (f_D) equal to 4 KHz. It corresponds to $N = 32768 = 2^{15}$ counts.

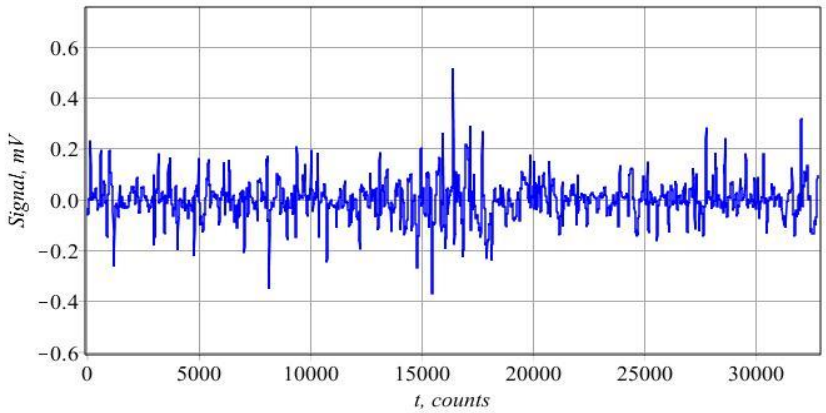


Fig.1. ENMG for healthy patient

Figures 1 and 2 present experimental data for both patients as discrete signals, Here (j+1)-count differs from j-count as “quant of time”:

$$t_{j+1} = t_j + \Delta t \quad j = 0,1,...,N \quad \text{and} \quad \Delta t = \frac{1}{f_D} = 0.00025\, s$$

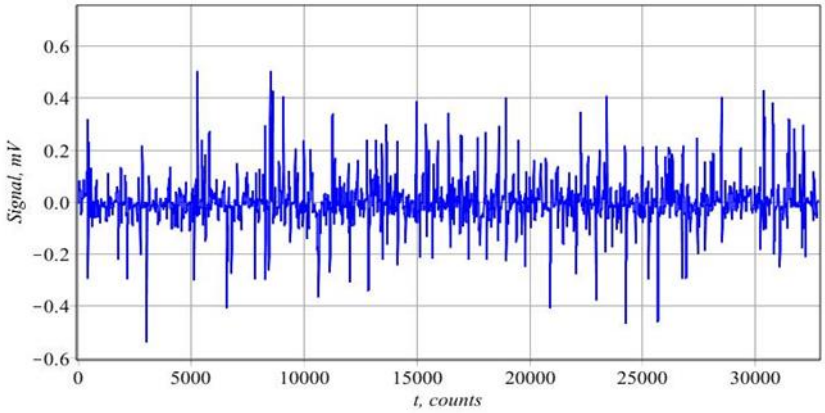
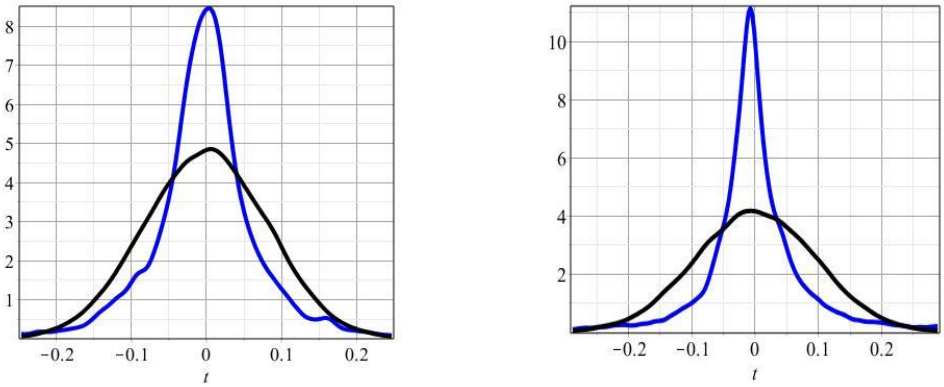


Fig.2. ENMG for patient with myopathy

The program tools of Maple 17 have been used for the processing and analysis of these prior data.

4. Statistical processing and analysis. The statistical processing has been done with program package “Statistics” (see Fig. 3).



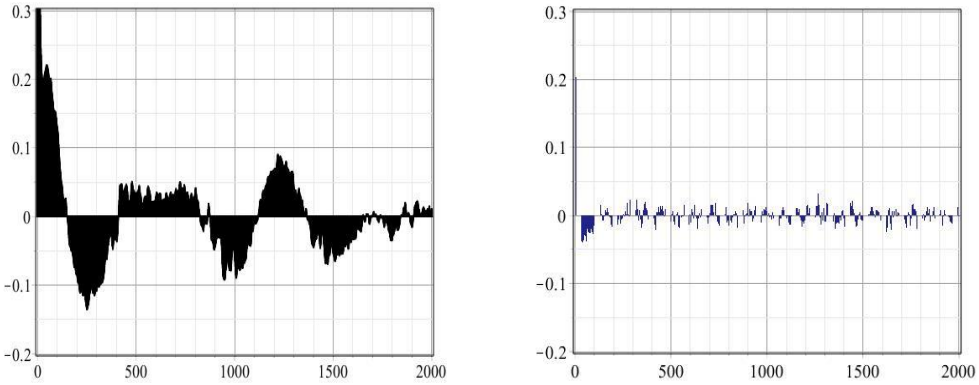
A B

Fig.3 Kernel density plots: A – for healthy patient, B – for patient with myopathy. Inferior lines show kernel density for hypothetical normal distributed analogs with the same means and standard deviations.

The analysis shows that the distributions are a bit like to normal Gaussian with mean value nearby zero. They have one mode coinciding with mean value moreover. It could testify about similarity, but the non-zero values of skewers and chiefly kurtosis reject such assumption.

The Fig.3 presents the kernel density plots for both signals and for hypothetical signals with the same mean mad standard deviations, but with normal distributions. The kernel density plots for both real ENMG are much sharper in comparison with the hypothetical normal distributed analogs.

Whereas the both kernel density plots are rather similar, the autocorrelation functions are quite different as for regarding moderate lags ($n = 2000$ counts). It is evident from Fig.4.



Fif.4. Autocorrelation functions of ENMG: A – for healthy patient, B – for patient with myopathy.

Fig.4a allows observing three full oscillations at least with average period about 575 counts and amplitude $r \approx 0.085$. Such period corresponds to main frequency close to 7 Hz taking into account $f_D = 4000$ Hz. Let us evaluate the Student factor for $r \approx 0.085$ and $n = 2000$ as:

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \qquad (1)$$

It gives: $t \approx 3.81$. This estimation is greater than well-known critical values of Student factor on the standard levels of 0.05. 0.02 and even 0.01 (

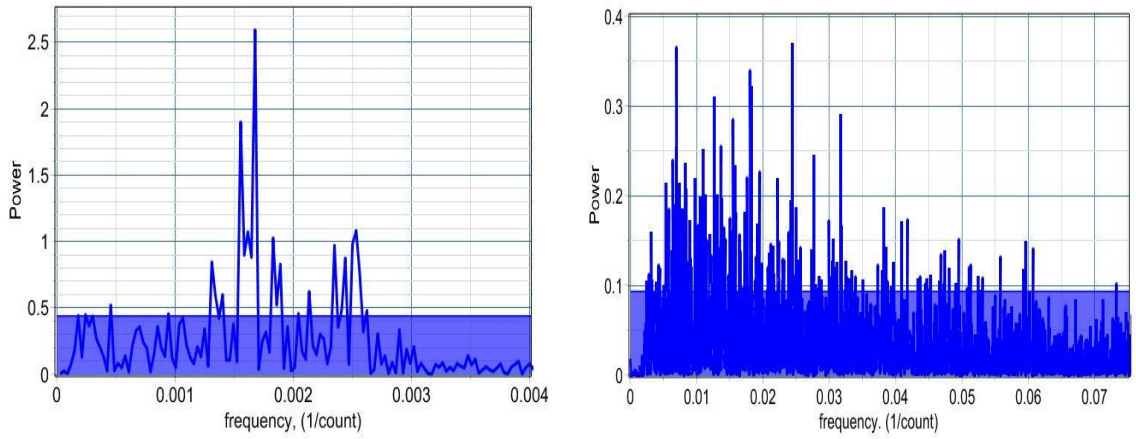
$t_{cr} = 1.96, 2.33, 2{,}58$ respectively). Therefore, the autocorrelation is statistically significant and this ENMG securely includes the petty oscillation component with low frequency about 7 Hz.

We observe opposite situation on the Fig.4b. The autocorrelation function is typical for random signals without any autocorrelation. Evidently, that correlation coefficient not exceeds $r \le 0.025$ and Student factor does not be greater then: $t \approx 1.12$. It is less then $t_{cr} = 1.96$ (at $\alpha = 0.05$) and since is statistically insignificant. Low-frequencies oscillations are not detectable in this case.

5. Fourier analysis. We practiced the fast Fourier transformation (FFT) to both ENMG. The sets of Fourier magnitudes were considered as random vectors and their standard deviations have been determined statistically. It permits us to found the universal thresholds of noises for both Fourier spectrums by method [3]. Such a threshold is defined as:

$$T = s_d \cdot \sqrt{2 \cdot \ln(N)} \qquad (2)$$

here s_d is corresponding standard deviation and $N = 32768 = 2^{15}$.



A B

Fig.5 Fourier spectrums of ENMG on the background of the noises thresholds: A – for healthy patient, B – for patient with myopathy.

Now we can to present the Fourier spectrums of both ENMG on the backgrounds of their noises thresholds. The Fig.5 is allowing these comparisons visually. The main energy of signal is concentered within narrow range of frequencies (from 5 to 10 Hz) with maxima about 6.5 Hz as it shows the Fig 5a. The rest part of Fourier magnitudes are disqualified by the noise threshold. The main frequency (about 6.6 Hz) reasonably corresponds with the same (about 7 Hz) evaluating above from autocorrelation function.

The energy of spectrum is stretched within much wider range for patient with myopathy: from 13 up 240 Hz . We cannot to select sole main frequency inside this diapason also. These observations confirm the above conclusion about absence of low-frequency oscillations in this case. The twice-larger noise threshold for patient with myopathy underlines the above statement regarding to randomness of ENMG components.

6. Conclusions. Thus, the spectral results of Fig.5 are in good agreement with statistical conclusions of Fig.4. Let us to collect the main results of analysis into following points:

a. The kernel density plots are similar for both ENMG. The distribution of signals components are different of normal Gaussian mainly because high kurtosis, whereas the mode of those coincides with mean value like for Gaussian.
b. The auto correlation functions are quite different for both ENMG. The healthy patient demonstrates the corellogram with clearly detectable oscillations, whereas the patient with myopathy has the practically random corellogram (Fig.4).
c. Important divergence shows also de-noised Fourier spectra. If the main frequencies range is narrow for healthy patient (5-10 Hz) with one main frequency 6.6 Hz, then this range is much wider (13-240 Hz) and without one main frequency as for patient with myopathy. This last has the twice-larger threshold of noises moreover.

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