Entropy analysis as a significant diagnostic parameter for stimulation electromyography by means of wavelet-packet decomposition

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Анализ энтропии как значительный диагностический параметр для стимуляционной электромиографии посредством вейвлет-пакетного разложения

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Abstract: *the article analyzes a possibility to apply a processing method and analysis by means of wavelet packet while registering stimulus EMG muscle m.deltoideus of the patients with a normal state of musculoskeletal system and muscle syndromes - carpal tunnel syndrome, cubital tunnel syndrome and demyelinating polyneuropathy - is being considered.*

Аннотация: *в статье анализируется возможность применения метода обработки и анализа посредством вейвлет-пакетного разложения при регистрации ЕМГ сигнала мышцы m.deltoideus пациентов с нормальным состоянием скелетно-мышечной системы и патологическим синдромом мышц.*

Keywords: *stimulation electromyography, artifacts, wavelet packet analysis, entropy.*

Ключевые слова: *стимуляционная электромиография, артефакты, вейвлет-пакетный анализ, энтропия.*

One of the reasons hindering the analysis of the electromyographic (EMG) signal, is the presence of interferences (artefact), which can be divided into physical and physiological ones. Physical artifacts associated with the use of electrodes, amplifiers, filtration diagrams, as well as interference from mains interferences are usually eliminated by using hardware. The availability and the elimination of physiological artifacts as part of the EMG signals, is quite a challenge, since their number, as well as the amplitude and frequency range varies in a quite wide range [1, 2].

The use of electrical stimulation of the muscles with subsequent analysis of the parameters of evoked potentialslies in the heart of the stimulation electromyography. At that, the following artefacts (Figure 1) are added to the already marked physiological artefacts [3].

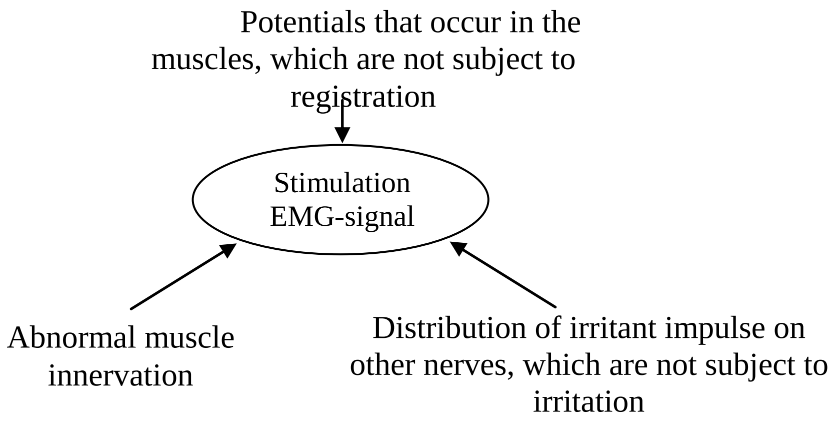

Fig. 1. Artefacts at stimulation EMG

hus, elimination of physiological artefacts in many cases requires the use of filtration schemes, whose cut-off frequencies should be defined at the lower frequency and high frequency, and order of filter, which determines the rate of decay, the level of nonlinear fluctuations and others.

Out of program methods to eliminate artifacts, the wavelet cleaning of signals based on nonstationarity of electrophysiological potentials is of great advantage in the optimum time-and-frequency localization of the tested signal.

The basic thing while working with wavelet transformation is the problem of choosing the most appropriate mother wavelet. Since there are no some sort of hard and fast rules, it is best to choose the wavelet so that it belongs to the same class of functions that the analyzed signal does. Daubechies functions (dB1) have been used as mother wavelet functions, which have been localized well in time and frequency [4].

Fig. 2-3 presents four levels of decomposition of EMG signals for the norm and considered set of diseases (for example, carpal tunnel syndrome), obtained via software in MATLAB environment. The original signal with the length of N = 256 points was selected for all studied diseases. As it is apparent from fig. 2-3, most acceptable levels of wavelet decomposition are levels 1 and 2, which do not distort the resolving capacity.

As for the wavelet packet decomposition, there is a possibility to obtain another numerical characteristics – the entropy values of coefficients in the nodes of the tree decomposition. Classical criteria based on minimum entropy are appliedto determine the optimal number of decomposition levels.

In accordance with the described properties of entropy for the signals to be submitted in the form of orthogonal expansions, the following expression for the entropy of the signal S is true:

$$E(S) = \sum_i E(s_i) \qquad (1),$$

Where, s_i - is coefficients of signal S expansion on the orthonormal basis.

The following expressions are given for the four types of entropy considering the expansion coefficients on the orthonormal basis [5, 6]:

- Non normalized Shannon entropy

$$E(S) = -\sum_i s_i^2 \log_2(s_i^2) \qquad (2),$$

Concentration according to normpat $1 \leq p < 2$

$$E(S) = |s_i|^p = \|s\|_p^p \qquad (3),$$

or $E(S) = \sqrt[1/p]{\sum_i s_i^p}$

- log ‘energy’ entropy

$$E(S) = \sum_i \log_2(s_i^2) \qquad (4),$$

- Entropy “SURE”

$$E(S) = \sqrt{2\ln(N\log_2(N))} \qquad (5),$$

Where N – is the number of counts.

Entropy values o fvarious types during the EMG signal decomposition for the considered set of diseases are given in Table 1.

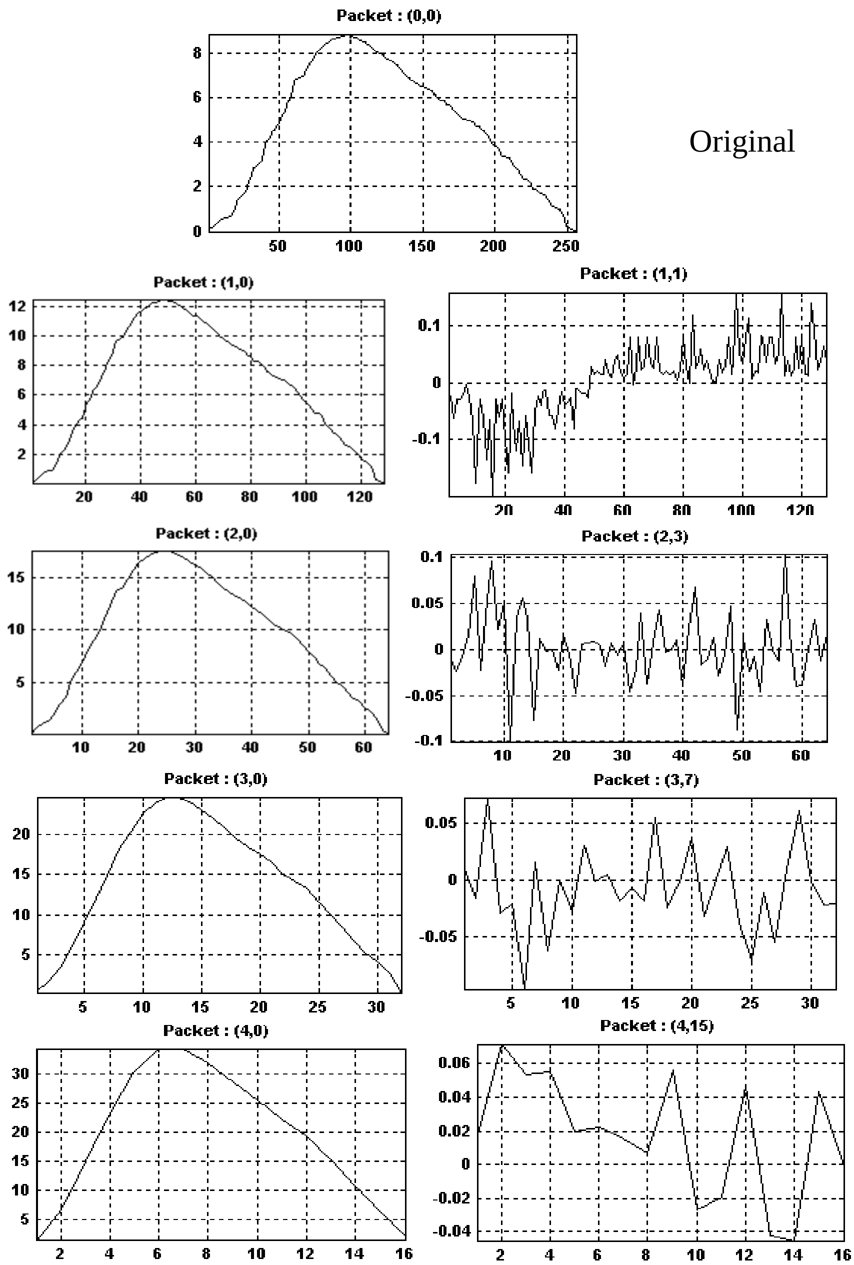

Fig. 2. Levels of decomposition signals for the normal state of the studied muscle

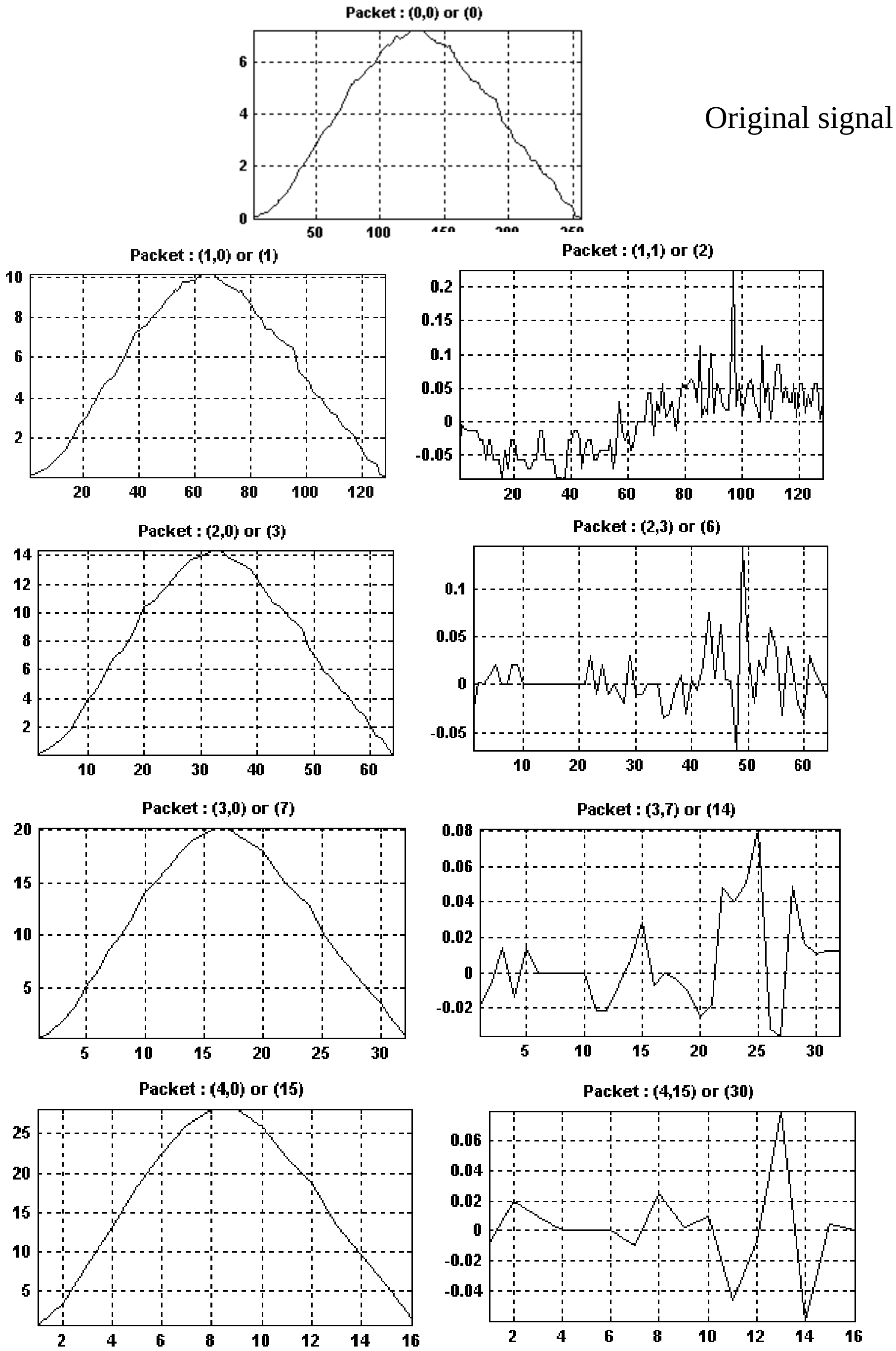

Fig. 3. Levels of decomposition signals for carpal tunnel syndrome of the studied muscle

Table 1. Entropy values for different decomposition values

Norm

m	Shannon	Norm (p=1)	Log energy	SURE
1	2,35	6,16	-8,63E+02	-1,27E+02
2	0,52	1,80	-5,28E+02	-6,39E+01
3	0,25	0,90	-2,64E+02	-3,20E+01
4	0,15	0,54	-1,20E+02	-1,60E+01
5	0,05	0,19	-7,32E+01	-7,99E+00

Carpal tunnel syndrome

m	Shannon	Norm (p=1)	Log energy	SURE
1	1,72	5,27	-8,45E+02	-1,28E+02
2	0,31	1,14	-1,15E+03	-6,39E+01
3	0,14	0,60	-4,95E+02	-3,20E+01
4	0,08	0,28	-3,30E+02	-1,60E+01
5	0,59	0,19	-1,31E+02	-7,99E+00

Cubital tunnel syndrome

m	Shannon	Norm (p=1)	Log energy	SURE
1	2,13	9,23	-7,34E+02	-1,24E+02
2	0,64	3,09	-5,51E+02	-6,08E+01
3	0,64	1,70	-2,56E+02	-3,14E+01
4	0,56	1,15	-1,15E+02	-1,57E+01
5	0,38	0,66	-5,65E+01	-7,83E+00

Demyelinating polyneuropathy

m	Shannon	Norm (p=1)	Log energy	SURE
1	2,96	7,26	-6,83E+02	-1,27E+02
2	0,52	1,77	-8,52E+02	-6,39E+01
3	0,25	0,82	-6,09E+02	-3,20E+01
4	0,14	0,51	-1,10E+02	-1,60E+01
5	0,08	0,26	-1,16E+02	-7,99E+00

It can also be concluded from the outcomes of the analysis that the entropy decreases much more slowly after the first resolution level (m =1) than in the range from the 2nd to the 5th level. The same conclusion can be drawn from the nature of entropy reduction, shown in Figure 4.

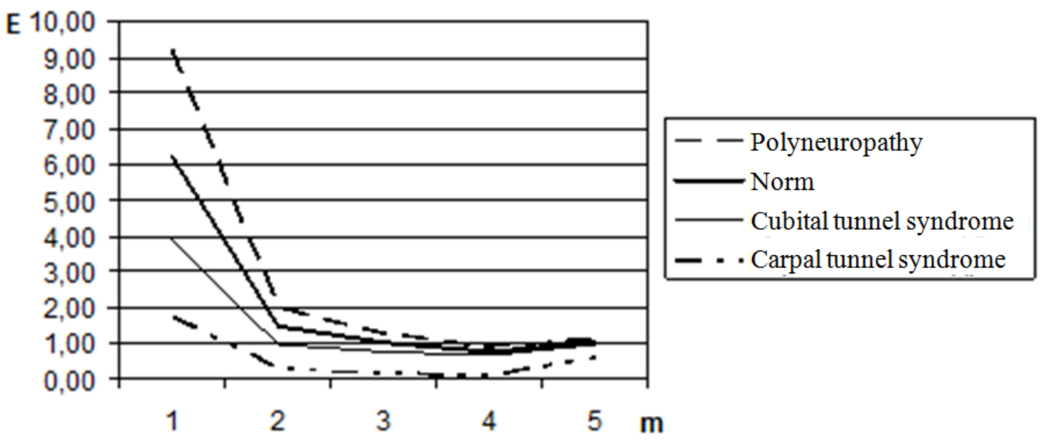

Fig. 4. Entropy values for the norm and muscle diseases

Thus, a selection of the optimal number of decomposition levels of orthogonal wavelet transformation based on the resolution of the studied signals and the minimum entropy levels of permission has been conducted to consider the array of muscular diseases for the studied muscle. The difference of entropy values of packet wavelet coefficients is even more significant than that for statistical characteristics, so it may also have a diagnostic significance.

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