The method of evaluation bioelectric activity of the brain in the study of electroencephalography

Sobko A., Kozyar V., Khudetskyy I., Antonova-Rafi Y.
Faculty of Biomedical Engineering
National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»
Kyiv, Ukraine
annasobko123@gmail.com

***Abstract* — a new method of processing the electroencephalogram signals (EEG) is proposed which reveals the characteristic signs of pathological activity of the brain based on computer processing of electroencephalographic data of patients with epilepsy for detection in the software environment MatLab. It has been shown that the bioactivity of the frequency rhythms of the brain varies with neuropathology and in a normal state, which makes it possible to automate the procedure for finding pathological sites on the EEG and to reduce the degree of subjectivity of the patient's brain neuronal evaluation. The article illustrates the work of the method on the example of treatment EEG records of 10 patients with epileptic attacks and in a state of rest. For each entry, percentages of alpha, beta, gamma and delta frequencies are calculated for total bioactivity.**

Keywords — electroencephalogram; epilepsy; Matlab; data processing.

I. Introduction

In the world, there are about 50 million people suffering from epilepsy. In Ukraine, according to statistics, about 25 thousand of them are children. According to doctors, every fifth or sixth child in his life tolerates paroxysmal condition, however, in 90% of cases, the epileptic reaction does not go into epilepsy and does not require treatment, but this requires medical observation and probable diagnosis.

There are different methods of diagnosis of epilepsy, however, electroencephalography is one of the main and the best at the moment. EEG is the basic method of diagnosis of epilepsy, which makes it possible to distinguish epilepsy from other diseases that are not related to the formation of a pathological discharge in the cerebral cortex. Patients with epilepsy often have changes in the nature of the brain waves, even in cases where the person is not currently experiencing an attack.

EEG is a process due to the activity of a huge number of generators, in this regard, the field created by them is very heterogeneous throughout the entire space of the brain and is variable in time. In this regard, variable potential differences arise between the two points of the brain, as well as between the brain and the tissues of the body remote from it, the registration of which is the task of electroencephalography.

In clinical electroencephalography, EEG is recorded with the help of located on the intact cover of the head and in some extracranial points of the electrodes. With such a registration system, the potentials generated by the brain are significantly distorted due to the effect of the cover of the brain and the peculiarities of the orientation of electric fields with different interposition of the electrodes. These changes are partly due to summation, averaging and weakening of potentials due to the surrounding brain of shunting properties of media [1].

At the beginning of the development of electroencephalography in physiologists there was a desire to evaluate the EEG with the help of objective quantitative indicators, to apply mathematical methods, and then to computer analysis already. Numerous studies have shown that the electrical potentials of individual brain neurons are closely related and accurately quantified with information processes.

Wavelet analysis methods decompose the electroencephalogram into the main frequency rhythms and calculate their numerical characteristics. The high-frequency part of the EEG is studied in more detail. It is divided into several components with good frequency localization, which their fundamental frequencies are located, the amplitude of the oscillations, the relative energy and other characteristics.

The visual method for evaluating electroencephalograms is the leading factor in the functional diagnosis of the state of the brain nowadays. However, this analysis and measurements with the help of a compass and a ruler are not sufficient to reveal the information contained in the complex picture of the brain biopotentials [2].

II. Database

The conduct of any EEG study requires the availability of a reliable data base. This database, collected at the Children's Hospital Boston, consists of EEG recordings from pediatric subjects with intractable seizures. Subjects were monitored for up to several days following withdrawal of anti-seizure medication in order to characterize their seizures and assess their candidacy for surgical intervention [3].

Recordings, grouped into 10 cases, were collected from 10 subjects (4 males, ages 11–18; and 6 females, ages 10–14). All signals were sampled at 256 samples per second with 16-bit

978-1-5386-2556-9/18/$31.00 ©2018 IEEE

resolution. The International 10-20 system of EEG electrode positions and nomenclature was used for these recordings.

Each case (chb01, chb02, etc.) contains 5 continuous .edf files from a single subject. All entries were cropped to a length of 30 seconds for the convenience of conducting the study.

TABLE I. DATABASE INFORMATION

Case	*Gender*	*Age*
chb01	F	11
chb02	M	11
chb03	F	14
chb04	M	22
chb05	F	14
chb06	F	10
chb07	F	12
chb08	M	16
chb09	F	10
chb10	M	18

For the analysis, the EEG sites were specifically selected. There are 5 records with and without attacks for each child. So, in general, the analysis was conducted on 100 sites of EEG (50 with epileptic attacks and 50 in the absence of them).

Appearance of EEG records at the onset and at rest of the patient chb01.

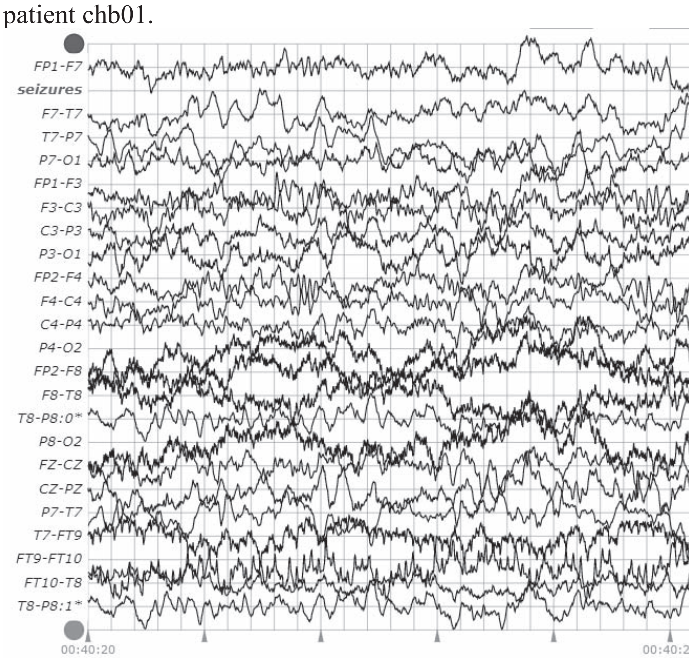

Fig. 1. Example of EEG recording in the absence of an attack

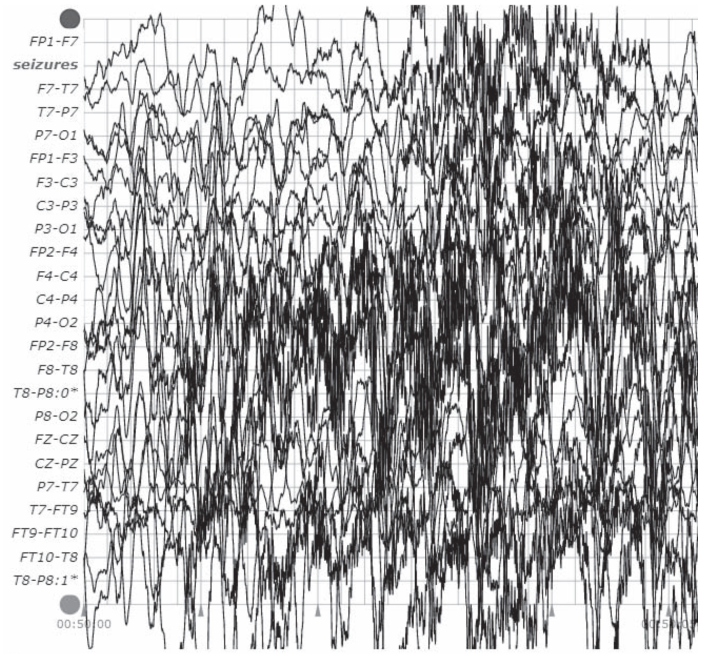

Fig. 2. Example of an EEG recording with an epileptic attack of the same patient

III. THE ALGORITHM OF THE METHOD

Modern software provides a wide range of EEG processing methods. At the first stage, various frequency characteristics can be calculated for the electroencephalographic signal. Their location is regulated by the following parameters, such as length and shift of epochs, filter smoothing and correction windows. For each calculated frequency response, generalized spectral indices can be found in the given frequency ranges (in standard ranges: delta, theta, alpha, beta).

Various EEG indicators across the set of registered assignments may serve as the starting material for topographic mapping - a visual representation of the distribution of values of the selected scalable scores on a multi-color scale. The mapping can be played within the given analysis period or in the selected range by the epoch in which the EEG record is broken. Topography visualization can take place in three forms: one card, a series of cards and an animated series of cards (animation). Saved card indexes can be subject to statistical analysis [1].

Well-known spectral and coherent analyzes are classic methods of processing EEG. If the spectral analysis allows to judge the presence of certain EEG rhythms in this wave process and their individual expression, then the coherent analysis provides an opportunity to estimate the spatial and temporal parameters of the investigated process. Thus, the spectral and coherent analysis of the EEG harmoniously complements each other [2].

There are also auxiliary methods, such as: correlation analysis with the deduction of auto and cross-correlation functions (according to a given example and at a given epoch); mathematical transformation of EEG - filtration, smoothing;

segment analysis related to the marking of EEG stationary areas, the evaluation of inter-segment synchronism and the classification of dominant topographic patterns [3,4].

Analyzing a large number of new methods of computer processing of EEG, it is clear that almost all of them are focused on the extraordinary increase in the informational possibilities of the method of electroencephalography, and not on the reduction of the subjectivity of its evaluation.

We consider it to be effective to use the method of calculating the biological activity of the brain in the EEG post processing, which allows the neurophysiologist to provide information that complements and clarifies the visual, and, to a certain extent, a subjective evaluation of the EEG. The method is based on the distribution of electroencephalography waves on components of different frequencies (alpha, beta, theta, etc.) and the calculation of the bioactivity of each rhythm (under the calculation of bioactivity is the calculation of the integral of the resulting curve for each frequency).

Electric oscillations recorded in the electroencephalogram (EEG), differ in frequency, duration, amplitude and shape. There are four main types of EEG rhythms.

Alpha rhythm is a regular rhythm of a sinusoidal form, with a frequency of 8-13 Hz (oscillations in 1s) and amplitude of 20-80 μV (microvolt). The alpha rhythm is recorded when biopotentials are diverted from all areas of the cerebral cortex, but more permanently from the occipital and parietal regions. Alpha rhythm is registered in a person in conditions of physical and mental rest, necessarily with closed eyes and no external stimuli.

The beta-rhythm has a vibration frequency of 14-35 Hz. This rhythm is low-amplitude: only 10-30 microvolts. It can be recorded by withdrawing potentials from any areas of the cerebral cortex, but more pronounced in the frontal lobes.

Theta rhythm has a frequency of 4-7 Hz, its amplitude is 100-150 μV. It is observed in a state of shallow sleep, with oxygen starvation of the body, with moderate in depth anesthesia.

The delta rhythm is characterized by slow potential oscillations with a frequency of 0.5-3 Hz, its amplitude is high: 250-300 μV, it can reach up to 1000 μV. It is found when biopotentials are diverted from all areas of the cerebral cortex, during deep sleep, and also during anesthesia. In children under 7, the delta rhythm can also be recorded in the waking state.

Separation of components of different frequencies is planned using a spreadsheet wavelet. The wavelet-decomposition of the EEG signal into separate frequency bands allows them to be considered independently of each other and enables to study the frequency and other properties of each component.

We will use Meyer's orthogonal wavelet ‘dmey’. It has a carrier at the interval [0,101] and a central frequency Fr = 0,6634 Hz. The choice of this wavelet is due to the good localization of the frequency spectra of the signal components. The fact is that this wavelet has the widest frequency spectrum among orthogonal wavelets with a compact carrier. In it, in equal degrees, the frequencies present in a rather large vicinity of its central frequency of 0,6634 Hz are presented. That is why it gives a good timing of the signal to the components corresponding to certain frequency bands [5].

It is enough to decompose the EEG signal to the 6th level. In this case, the elements of the signal with frequencies in the range from 0 to 4 Hz (delta rhythm) will be represented by the approximation coefficients A6. For wavelet decomposition of a signal fragment up to 6th level, we use the following MATLAB command:

```
[c,l] = wavedec (Fragment,6,'dmey').
```

We get the structure [c, l], which contains the set of wavelet coefficients {D1, D2, ..., D6, A6}, where D1, D2, ..., D6 are the coefficients of the parts and A6 are the approximating coefficients as a result. The restoration of the original signal is carried out in sequence in reverse order. If we apply the recovery procedure to only one set of coefficients, when all the other coefficients consist of zeros, we get the signal part corresponding to one set of coefficients. We call such a part a signal component.

The components of the signal, reconstructed only by the part coefficients D1, D2, ..., D6, will be called high-frequency signals and will be denoted RecD1, RecD2, ..., RecD6, respectively. For example, RecD2 is a signal component reconstructed from the following set of wavelet coefficients: {0, D2, 0, 0, 0, 0, 0}, where 0 denotes an array of zeros. Similarly, low-frequency components RecA1, RecA2, ..., RecA6 are obtained by reconstructing only one set of approximating coefficients. The MatLab Wavelet Toolbox has a function ‘wrcoef’, which allows to restore both high-frequency and low-frequency components of the signal according to the previously obtained structure [c, l] of the wavelet coefficients {D1, D2, ..., Dn, An}. Then the fragment of our signal decomposes into the sum of the following components:

Fragment = RecD1 + RecD2 + RecD3 + RecD4 + RecD5 + RecD6 + RecA6.

The calculations showed that the frequency spectra of the signal components are well localized and the resulting components represent the main ranges [3] of the EEG: RecA6 is the Delta rhythm (0-4 Hz), RecD6 - Theta rhythm (4-8 Hz), RecD5 - Alpha-rhythm (8-16 Hz), RecD4 - Beta-rhythm (16-31 Hz). MatLab commands:

```
xa6 = wrcoef ('a', dec, struct,'dmey', 6);
xd6 = wrcoef ('d', dec, struct,'dmey', 6);
xd5 = wrcoef ('d', dec, struct,'dmey', 5);
xd4 = wrcoef ('d', dec, struct,'dmey', 4);
```

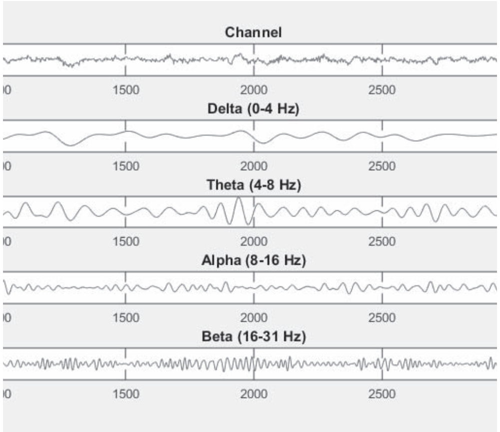

Fig. 3. View of the Matlab window after the wavelet decay of the signal.

After separating the main rhythms, it is necessary to calculate the bioelectric activity of each rhythm. To do this, the integral curves were calculated.

It was decided to group alpha with beta rhythms and theta with delta rhythms. The percentage value for each group, calculated for the total bioelectric activity of the signal. If the total bioelectric activity is equal to 100%, then the components of other rhythms are calculated in proportion:

Sum=sum(BioActivity);
l=100*(delta+teta)/Sum;
m=100*(alfa+beta)/Sum;

IV. Results and discussion

The software product has processed EEG data of 10 patients (100 records). The following mean values of the bioelectric activity of the rhythms for an attack and an intermediate state are obtained.

TABLE II. Bioelectric activity of the rhythms with attack

Case	Bioelectric activity,%	
	Alpha + Beta	*Theta + Delta*
chb01	60,30	39,69
chb02	61,64	38,35
chb03	57,91	42,08
chb04	57,73	42,26
chb05	64,94	35,05
chb06	61,62	38,37
chb07	63,69	36,30
chb08	56,38	48,61
chb09	54,89	47,10
chb10	55,46	48,53

As can be seen from the data obtained, the alpha + beta activity in the rest of patients has an average of 59.46% in the range of 54.89 ... 63.69%. Theta + delta activity is respectively 41.63% in the range of 35.05 ... 48.61%.

TABLE III. Bioelectric activity of the rhythms without attack

Case	Bioelectric activity,%	
	Alpha + Beta	*Theta + Delta*
chb01	68,46	31,53
chb02	69,78	30,21
chb03	69,59	30,40
chb04	71,80	28,19
chb05	67,62	32,37
chb06	67,70	32,29
chb07	67,07	32,92
chb08	56,99	42,00
chb09	54,70	45,29
chb10	59,60	40,39

As can be seen from the data obtained, alpha+beta activity in patients with epileptic seizure has an average of 65.33% in the range of 54.70 to 69.78%. Theta + delta activity is respectively 34.55% in the range of 28.19 ... 45.29%.

V. Conclusions

On the basis of the developed EEG processing method, a software product was created in the MatLab environment. By processing the EEG record database method during an epileptic attack and in a state of rest, it was possible to detect the dependence of the value of the change in bioelectric activity. The results show that there is an addiction in the comparison of EEG records that contain an attack and those that do not exist: during an attack, the percentage of delta and theta of rhythms increases, while the manifestation of alpha and beta rhythms decreases in compared to records that do not contain epileptic seizures. The revealed dependencies give a clear understanding that the processes of the brain result in a change in the activity of the frequency rhythms. Thus, a sharp increase in the manifestation of rapid rhythms detects the presence of pathology in the recording.

References

[1] A. Mecler, “Application of the apparatus of nonlinear analysis of dynamic systems for processing EEG”, Actual problems of modern mathematics: scientific notes, 2004, pp. 112-140.

[2] V. Vorobyev, Theory and practice of wavelet transformation, Military University of Communication, 1999. - p. 204.

[3] A. Goldberger, L. Amaral, L.Glass, J. Hausdorff, P. Ivanov, R. Mark, PhysioBank, PhysioToolkit, and PhysioNet: Components of a New Research Resource for Complex Physiologic Signals. Circulation 101(23): e215-e220 [Circulation Electronic Pages; http://circ.ahajournals.org/cgi/content/full/101/23/e215]; 2000 (June 13).

[4] A. Shoeb, J. Guttag. Application of Machine Learning to Epileptic Seizure Onset Detection. 27th International Conference on Machine Learning (ICML), June 21-24, 2010, Haifa, Israel.

[5] A. Shoeb, H. Edwards, J. Connolly, B. Bourgeois, S. Ted Treves, J. Guttag. Patient-Specific Seizure Onset Detection. Epilepsy and Behavior. August 2004, 5(4): pp.483-498.