Вісник Тернопільського національного технічного університету
https://doi.org/10.33108/visnyk_tntu
Scientific Journal of the Ternopil National Technical University
2024, № 1 (113) https://doi.org/10.33108/visnyk_tntu2024.01
ISSN 2522-4433. Web: ***visnyk.tntu.edu.ua***

UDC 004.021:004.422.8:616.853:517.57:519.21

METHOD AND SOFTWARE FOR PROCESSING DAILY EEG SIGNALS FOR DETECTION OF EPILEPTIC SEIZURES IN HUMANS

Mykola Khvostivskyi; Roman Boiko

Ternopil Ivan Puluj National Technical University, Ukraine

Summary. *A method, an algorithm and a software tool for processing daily EEG signals for computer electroencephalographic systems to detect the manifestation of epileptic seizures in humans have been developed. Mathematically, the daily EEG signal is presented as a random sequence of white Gaussian noise zones and additive mixtures of different-frequency harmonic components. Harmonic functions interpret the manifestations of epileptic seizures. The core of the method of processing daily EEG signals is a time-shifted window inter-covariance processing with multiple kernels in the form of different-frequency harmonic functions. Based on the method of window processing, an algorithm and a software tool for daily EEG signal processing with a graphical user interface using the MATLAB environment have been implemented. The developed software can be used as a component of computer EEG systems. The results of daily EEG signal processing using the software are displayed in the form of averaged products of covariance results (the value is measured in power units) within each processing window, which quantitatively reflect the time points of epileptic seizures in a person. Manifestations of epileptic seizures are reflected through the increase in the averaged values of the power of covariances in relation to observation intervals without corresponding manifestations of these seizures. To ensure the authorization of the process of determining the level of decision-making regarding the moments of epileptic seizures (exceeding the normal level), the threshold algorithm and the Neumann-Pearson statistical criterion were applied.*

Key words: *daily EEG signal, processing method, software tool, time-shift window, mutual covariance, harmonic functions of different frequencies, Neumann-Pearson criterion, computer EEG system, MATLAB.*

https://doi.org/10.33108/visnyk_tntu2024.01.119 *Received 04.01.2024*

Statement of the problem. Epilepsy is one of the most common chronic disorders of human brain functioning, which manifests itself through epileptic seizures and can lead to memory loss. According to the WHO, as of the beginning of 2023, the number of epileptic seizures in the world is approximately 50 million people. However, according to the conclusions of many specialists, these figures are underestimated, since many cases remain undiagnosed. Causes of epileptic seizures can be head injuries, excessive use of drugs and alcohol, stroke, diseases of the nervous system, and brain tumors.

In medical practice, electroencephalography is an effective informative method for detecting epileptic seizures in humans. This method provides registration of the total electrical activity of the brain in the form of EEG signals.

Studying human brain activity during the day using EEG signals makes it possible to detect manifestations of epileptic seizures, in particular, their intensity and duration, which can usually be missed.

Analysis of the well-known results of the research. The software tool in modern computer EEG systems is implemented on the methods of processing EEG signals for the detection of epileptic seizures in humans, in particular:

- the spectral method [1–3] provides a frequency analysis of EEG signals within a short observation time, which does not enable the study of daily signals for the fact of detecting epileptic manifestations and does not provide the process of determining the moments of time of these manifestations;

- the visual method [46] provides a visual study of the structure of long-term EEG signals for the detection of epileptic leads within short time observation zones;
- the morphological method [7] provides analysis of a short-term EEG signal in time space (amplitude, time), but does not work with daily realizations of signals;
- the correlation method [8] provides an analysis of relationships in the implementation of the EEG signal for a short period of time;
- the spectral-correlation method [9, 10] provides a study of the density of the distribution of power values of a short-term EEG signal in the frequency space;
- wavelet transformation [11, 12] provides decomposition of short-term implementations of the EEG signal into different frequency bands by decomposition of the wavelet packet of the 4th level and the process of calculating the entropy value of the signal within different frequency ranges when classifying the type of epileptic seizure, however, the process of determining the moments of time is not is carried out.

The Objective of the work. The development of an effective method for processing long-term EEG signals and a software tool for detecting epileptic manifestations based on a new mathematical model and a method for computer EEG systems to study the interdependence of variations in the signal structure in time space for the purpose of detecting manifestations of epileptic manifestations is an urgent task.

Mathematical model of daily EEG signals. During the manifestation of an epileptic seizure, the implementation of the EEG signal is dominated by harmonic oscillations within a certain frequency range $[f_1; f_2]$. The values of the lower and upper limits of the frequency range depend on the type of epileptic seizure (juvenile absence epilepsy – 2–4 Hz, Lennox-Gastaut syndrome – 1.5–2 Hz, idiopathic generalized epilepsy – 3–5 Hz).

The experimental implementation of the daily EEG signal is shown in Fig. 2 (database resource from the website http://www.physionet.org was used). Data of EEG signals from this database were also used in works [13, 14].

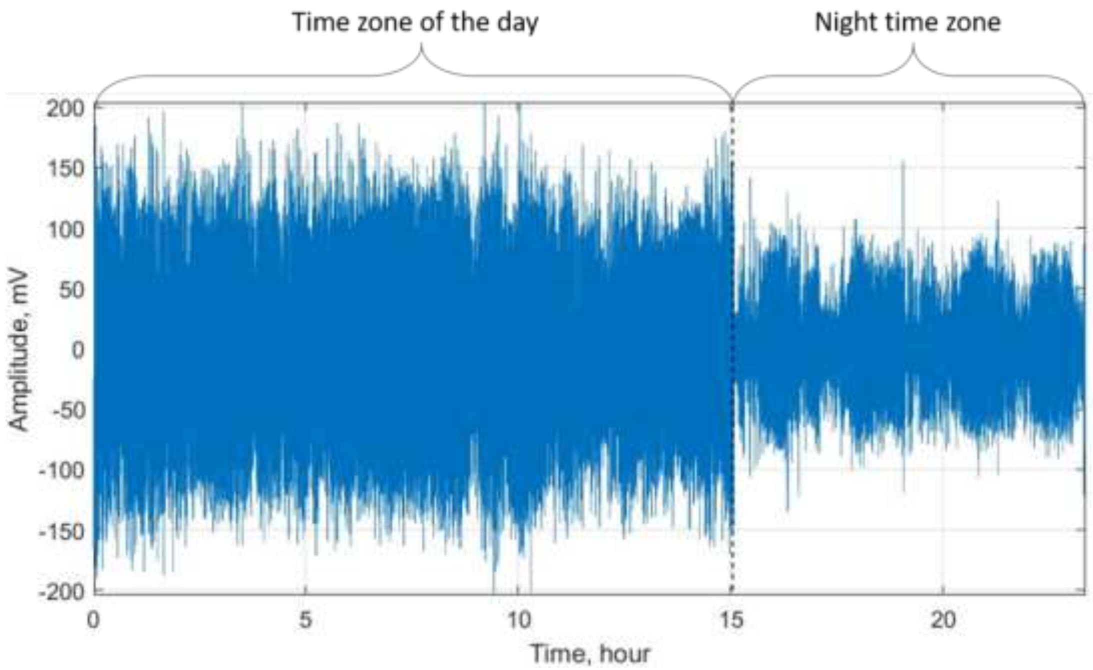

Figure 1. Experimental realization of daily EEG signal

Pre-selected short time fragments from the daily EEG signal (Fig. 1) from the daily implementation without the manifestation of an epileptic seizure and during the seizure are shown in Fig. 2–3.

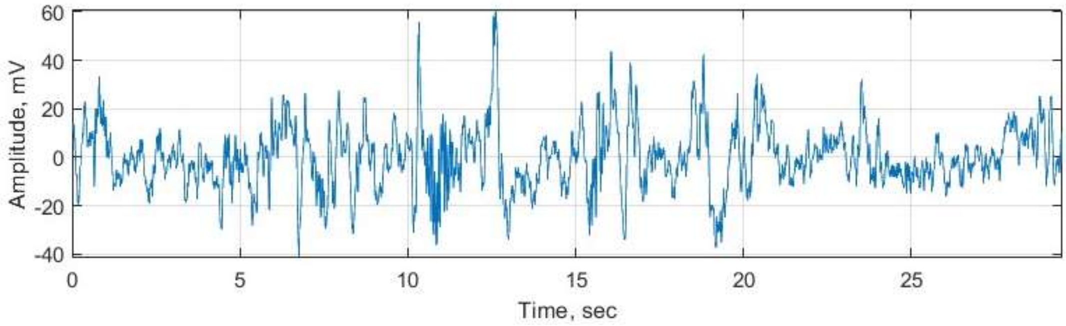

Figure 2. A fragment of the EEG signal without the manifestation of an epileptic seizure

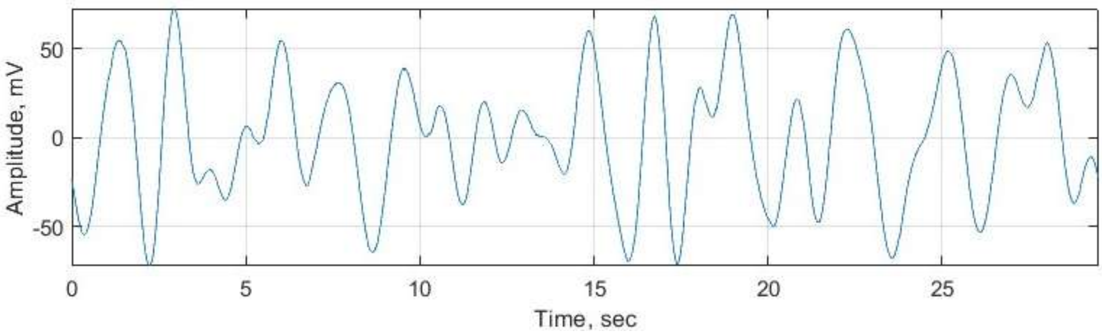

Figure 3. A fragment of the EEG signal with the manifestation of an epileptic seizure

Based on the Fourier transformation of selected fragments of EEG signal implementations (Fig. 2–3), it was established that during the period of epileptic seizure (manifestation of juvenile absence epilepsy), the dominance of components in the frequency range of 2–4 Hz is observed, in contrast to the implementation of EEG signals without manifestations of an epileptic seizure.

It is assumed that the implementation of the EEG signal in the time zone without the manifestation of epileptic seizures is an approximation based on the structure of white Gaussian noise, and in the zone of manifestation it is an approximation to a set of different-frequency harmonic components. Under this assumption, the structure of the daily EEG signal is presented structurally in Fig. 4.

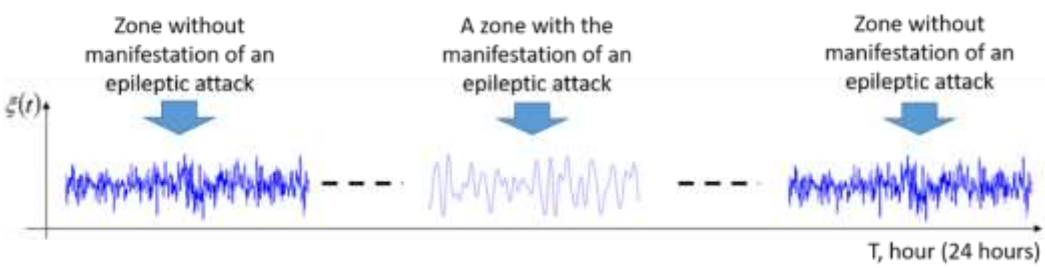

Figure 4. Temporal structure of the daily EEG signal with zones of manifestation and without manifestations of epileptic seizures

Under this assumption (Fig. 3), the mathematical model of the daily EEG signal is presented in the form of a random sequence of k-th white Gaussian noise zones $n_1(t),\ldots,n_k(t)$ and additive mixtures of n-th different-frequency f_n harmonic components $\sum_{n=1,N} s(A_n, f_n, t)$ (modernization of work model [13, 14]):

$$\xi(t) = n_1(t) \cup \sum_{n=1,N} s(A_n, f_n, t) \cup n_2(t) \ldots \cup \sum_{n=1,N} s(A_n, f_n, t) \cup n_k(t) \tag{1}$$

where $n_k(t)$ – the k-th zone of the EEG signal without the manifestation of an epileptic seizure in the form of white Gaussian noise;
N – the number of harmonic components that are formed during the period of epileptic seizures;
$s(A_n, f_n, t)$ – zone of the EEG signal during the manifestation of an epileptic seizure in the form of a set of additive components of different frequencies f_n and amplitudes A_n:

$$s(A_n, f_n, t) = A_n \sin(2\pi f_n t),\ t \in \mathrm{R} \tag{2}$$

where A_n – amplitude level of the harmonic component (for all components A=1);
f_n – the range of n-th frequencies of the harmonic component, which are generated under the influence of epileptic seizures.

The alternation of $\sum_{n=1,N} s(A_n, f_n, t)$ and $n_k(t)$ zones is a random sequence without any a priori determinations.

The number of zones in the structure of the daily EEG signal with and without manifestations can be the k-th number, therefore expression (3) is rewritten in a more compact form through sets, in particular their union:

$$\xi(t) = \bigcup_{k=1}^{K} \left(n_k(t) \cup \theta_k \cdot \sum_{n=1,N} s(A_n, f_n, t) \right),\ t \in \mathrm{R} \tag{3}$$

where $n_k(t)$ – the k-th zone of the EEG signal without the manifestation of an epileptic seizure;
θ_k – unknown parameter that takes the value ($\theta_k \in \{0,1\}$):

- θ_k =1 (k-th zone of manifestation of an epileptic seizure);
- θ_k =0 (k-th zone without manifestation of an epileptic seizure).

Method of processing daily EEG signals. Therefore, the method of processing the daily EEG signal should detect time zones with manifestations of epileptic seizures (Fig. 2) by detecting the set of harmonic components $\sum_{n=1,N} s(A_n, f_n, t)$ of the range $f_n = [f_1; f_2]$ depending on the type of epileptic seizure.

Taking into account that the daily implementation of the EEG signal in the database is a numerical data array of a large volume and requires a powerful computing resource, it is therefore proposed to process the EEG signal data within the limits of a sliding window with a discrete step (Fig. 5).

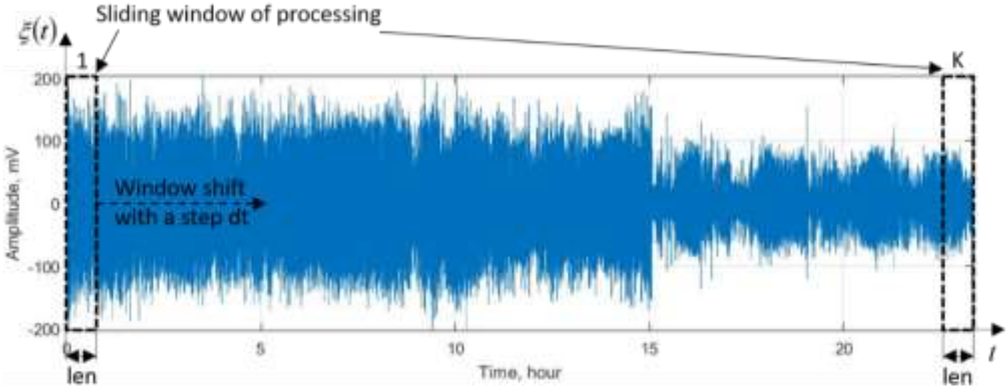

Figure 5. Realization of the daily EEG signal with sliding processing window

Selection of the k-th sliding window for processing the EEG signal fragment $\xi_k(t)$ within the time interval *len* is provided by the indicator function $\chi_{D_k}(t)$ of the time duration D_k according to the expression:

$$\xi_k(t) = \xi(t) \cdot \chi_{D_k}(t),\ t \in \mathrm{R}\ , \tag{4}$$

where $\chi_{D_k}(t) = \begin{cases} 1, if & t \in D_k \\ 0, if & t \notin D_k \end{cases}$ – an indicator function that forms the time domain of the k-th sliding window of EEG signal processing in a time interval D_m .

$D_k = [k \cdot dt, k \cdot dt + len)$ – the time interval of the k-th processing window (Fig. 5), $dt = const$ – shift step.

The minimum length of the sliding window len for daily EEG signal processing should be 1 minute, taking into account the recommendations of neurophysiology experts. Since arbitrary variations in the realization of the EEG signal within 1 minute are considered as pathological signs.

Window processing of the EEG signal is implemented using the intercovariance method with multiple kernels in the form of different-frequency harmonic functions of the $[f_1; f_2]$ frequency range depending on the type of epileptic seizure detection.

Window intercovariance processing operates with the centered values of the EEG signal in order to determine the quantitative measure of similarity of the variations of the EEG signal values with centered sets of n-th harmonic components within k-th sliding processing windows:

$$\hat{b}_{nk}(u) = \frac{1}{T}\sum_{t \in \mathrm{R}} \overset{0}{s}_n(A, f, t)\overset{0}{\xi}_k(t-u),\ n = \overline{1, N}\ ,\ t \in \mathrm{R}\ ,\ f = [f_{\min}, f_{\max}] \tag{5}$$

where f – frequency range of the core (harmonic components with frequencies $[f_{\min}, f_{\max}]$) mutual covariance processing;

$\overset{0}{s}_n(A, f, t)$ – the centered kernel of mutual covariance processing (harmonic component of frequency range $f = [f_1; f_2]$ with amplitude level *A*);
N – the number of mutual covariance processing cores;
$\overset{0}{\xi}_m(t-u)$ – shifted by the u-centered implementation of the EEG signal within the k-th sliding processing window.

To evaluate the n-th results of mutual covariance processing of $\hat{b}_{nk}(u)$ EEG signals within the k-th sliding window of processing, an estimate of the product of the averaged processing results for the frequencies of the n-th frequencies was used:

$$\widehat{Y}_k(t) = \left| \prod_{n=1}^{N} \left(M_u \{ b_{nk}(u) \} \right) \right|, \; u = \overline{0, U_{\max}}, \tag{6}$$

where $M_u\{\bullet\}$ – the averaging operator by the shift of the quantity *u*;
$U_{\max}$ – maximum time shift.

The generalized sequence of daily EEG signal processing is shown in Fig. 6.

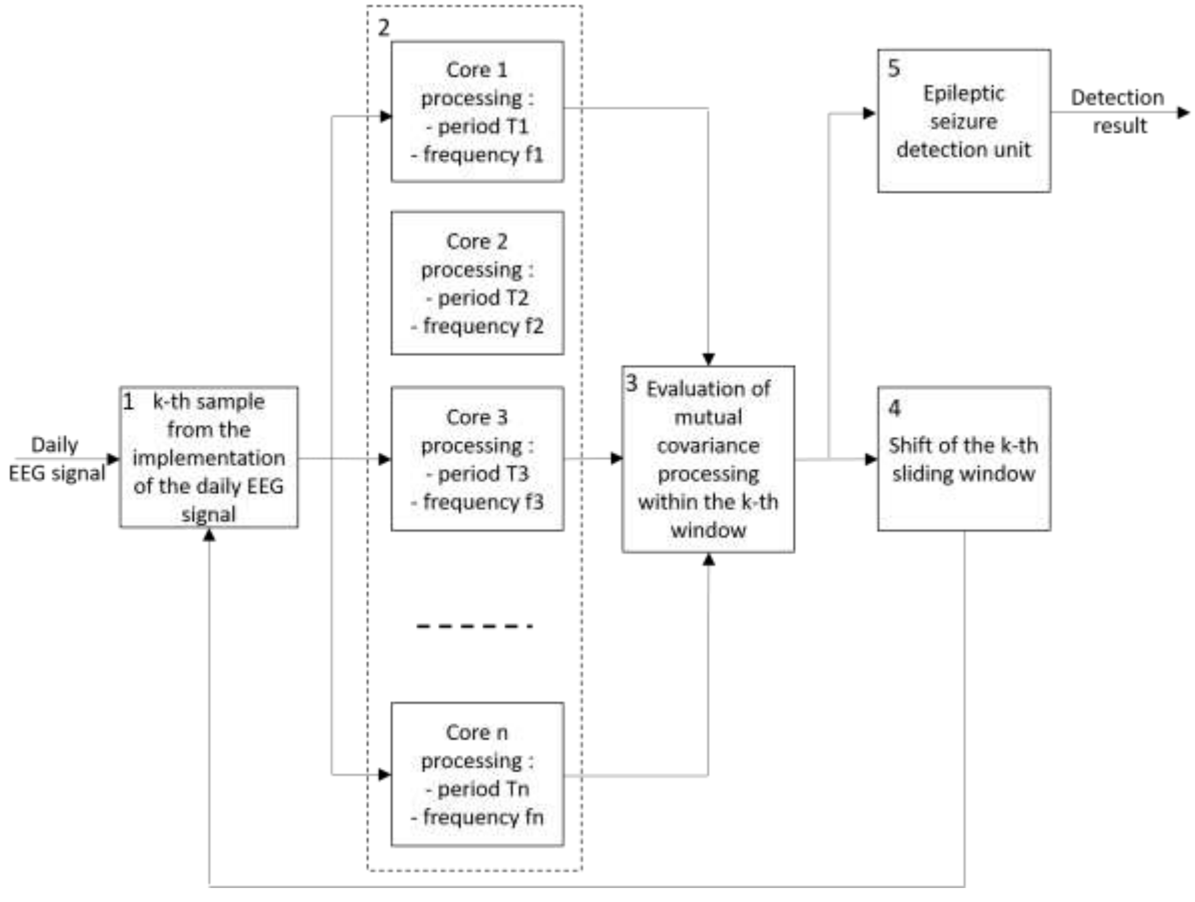

Figure 6. A generalized sequence of window mutual covariance processing of the daily EEG signal

The proposed method of processing the daily EEG signal makes it possible to develop the core of the computer EEG system software, namely the EEG signal processing algorithm for determining the moments of epileptic seizure manifestations.

Algorithm for processing daily EEG signals. The algorithm for processing the daily EEG signal to detect epileptic seizures is shown in Fig. 7.

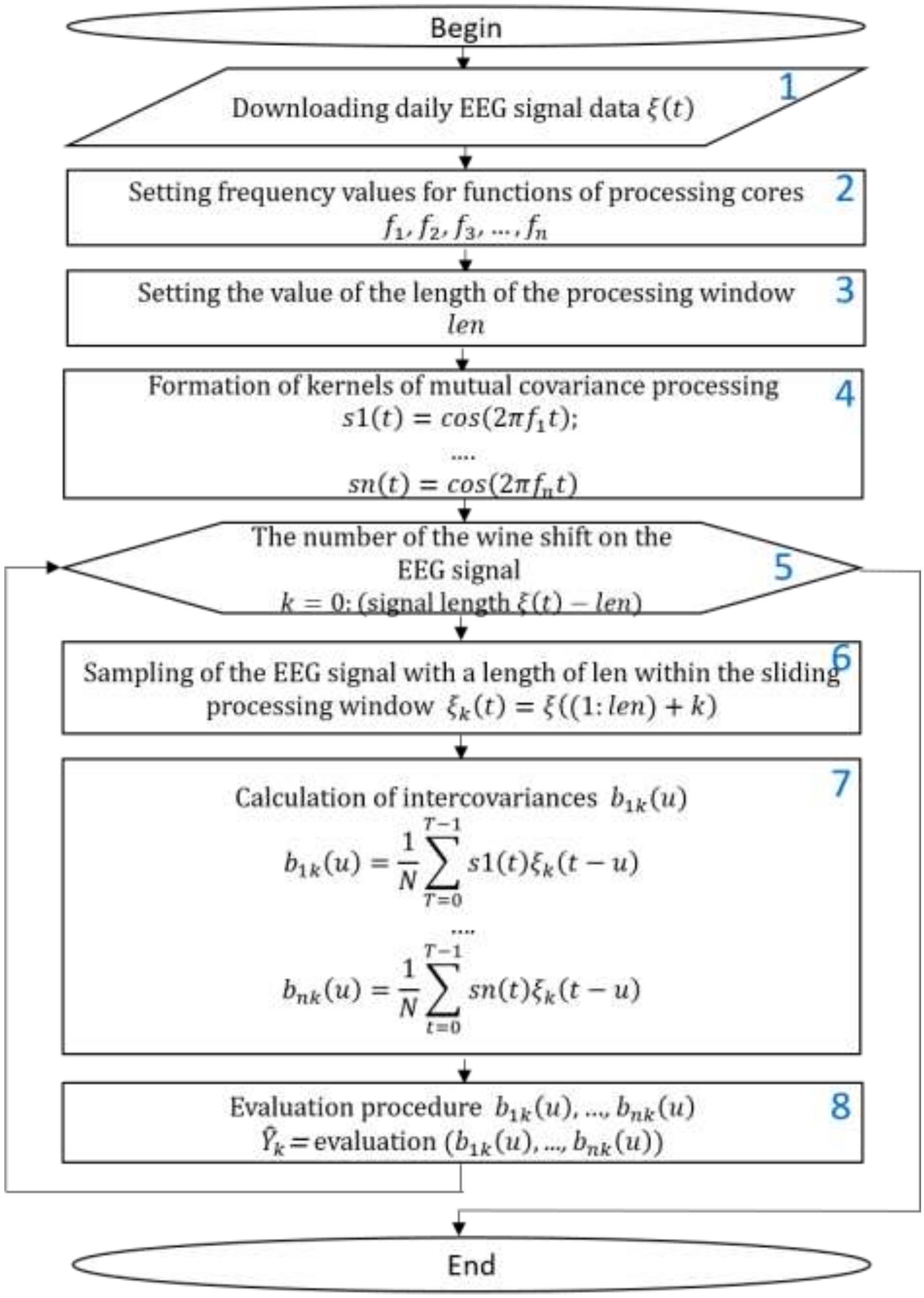

Figure 7. Algorithm of window mutual covariance processing of the daily EEG signal for detecting the moments of epileptic seizures

The algorithm of window mutual covariance processing of the daily EEG signal (Fig. 7) makes it possible to develop a suitable software tool for computer EEG systems.

Software and results of daily EEG signal processing. Using the algorithm (Fig. 7), a software tool with a graphical user interface was developed on the MATLAB platform and its GUIDE utility (Fig. 8). The software is configured to detect epileptic seizures in the range from 2 Hz to 4 Hz.

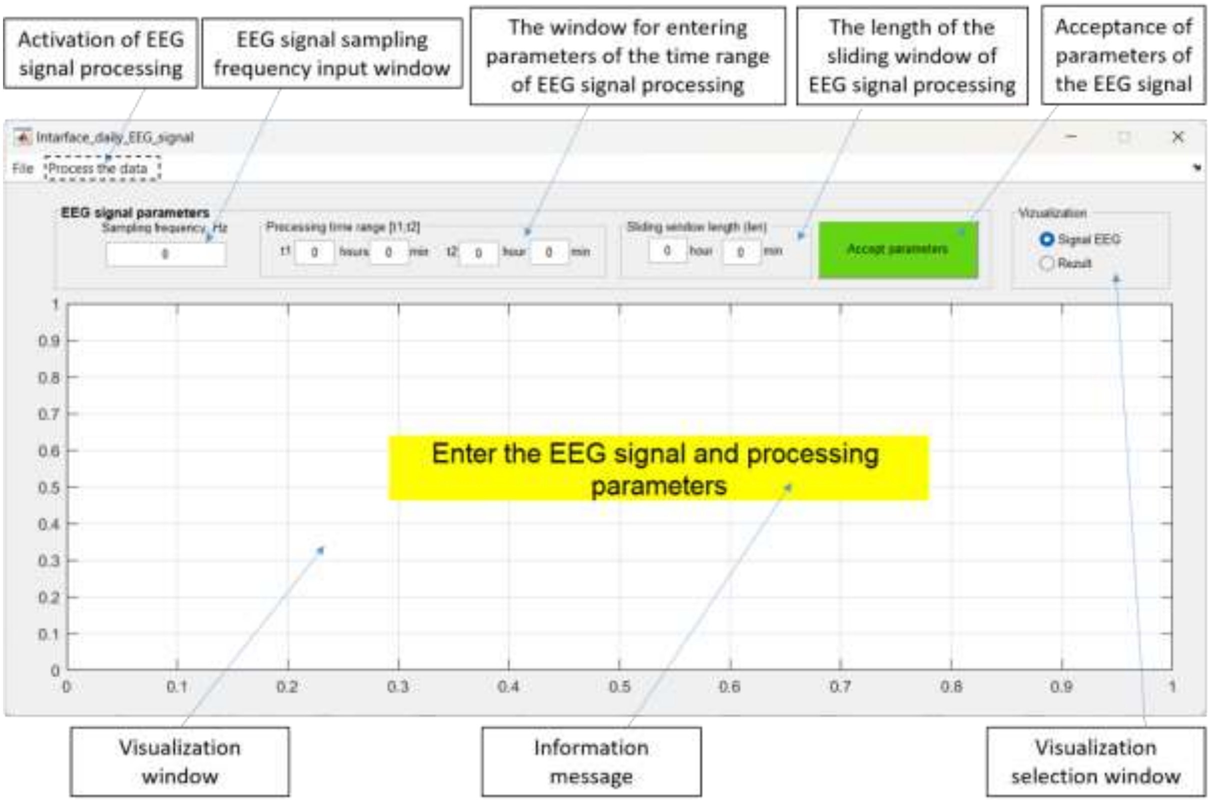

Figure 8. General view of the daily EEG signal processing software

The result of loaded daily EEG signal with activated parameters and processing parameters is shown in Fig. 9.

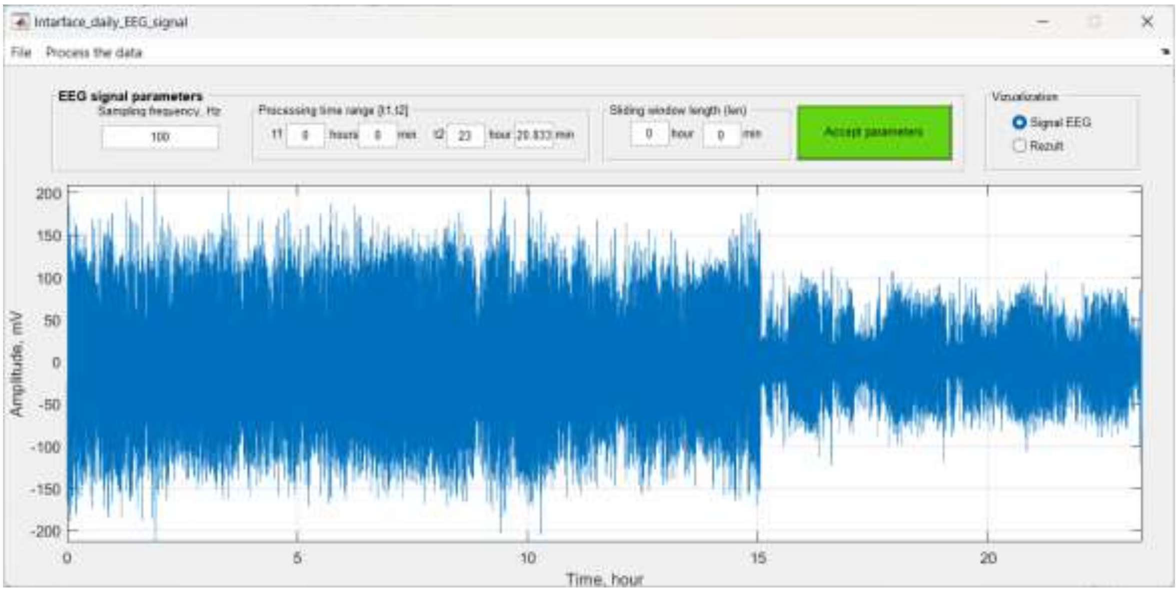

Figure 9. The result of visualization of the daily EEG signal when using the developed software

The result of processing a daily EEG signal lasting 23 hours. 20.833 min. with the sampling frequency f=100 Hz, the length of the sliding processing window len=2 min is shown in Fig. 10 in the form of estimates of the averaged products of covariances.

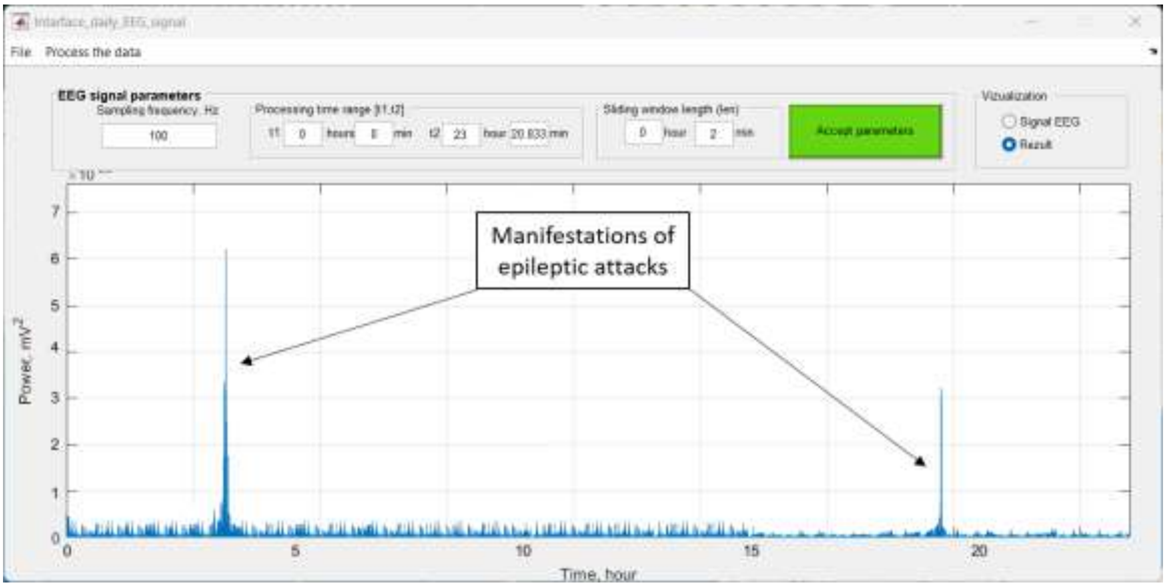

Figure 10. The result of daily EEG signal processing

Fig. 10 shows that at specific moments of time epileptic seizures are observed by means of an increase in the values of the average power of the covariance $\widehat{Y}_m(t)$ in relation to time intervals without the occurrence of seizures.

The threshold device q will be responsible for the process of automated detection of manifestations of epileptic seizures and decision-making regarding their presence. The threshold device functions according to the expression:

$$A(t)=\begin{cases}0, if \ \ \widehat{Y}_k(t)<q\\ 1, f \ \ \widehat{Y}_k(t)\geq q\end{cases}, \qquad t\in \mathrm{R} \tag{7}$$

where q – decision threshold.

$A(t)$ – the function of the patient's state, which takes the value 0 or 1 at a certain time t (0 – no manifestation of an epileptic seizure, 1 – manifestation of an epileptic seizure).

According to expression (7), the threshold device in case of detection of an epileptic seizure ($\widehat{Y}_m(t)\geq q$) will generate 1 at the output, and in the absence of an seizure it will generate 0. To determine the level of decision-making, the Bayesian concept of likelihood ratios and the Neumann-Pearson statistical test are applied. The specified criterion makes it possible to determine the threshold level with an a priori value of the probability of an error in the decision made (for medicine, $p_f=\{0{,}001; 0{,}01; 0{,}1\}$ is declared).

The threshold level q is calculated for estimates of the averaged products of covariates within the time zone without the manifestation of an epileptic seizure according to the expression:

$$q=\sqrt{D\left(\widehat{Y}_m(t)\right)}F^{-1}\left(1-p_f\right)+m\left(\widehat{Y}_k(t)\right), \tag{8}$$

where $t\in\left[0,T_{\text{absence}}\right)$ – a period of time without the appearance of an epileptic seizure;

$m\left(\widehat{Y}_k(t)\right)$ і $D\left(\widehat{Y}_k(t)\right)$ – mathematical expectation and variance of estimates of the averaged products of covariates for the period of time without the manifestation of an epileptic seizure;

F – the integral of the normal distribution, $F(x) = erf(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{t^2}{2}} dt$.

Using expression (8), the value of the threshold was calculated with a minimum error of the accepted decision of 0,001, which is equal to $2{,}0321 \cdot 10^{-48}$ mV^2.

Taking into account the threshold value at the level of $2{,}0321 \cdot 10^{-48}$ mV^2, the time intervals of the manifestation of epileptic seizures were determined, which are presented in Table 1.

Table 1

Results of detection of moments of epileptic seizures

№	Manifestations of an epileptic seizure	The probability of a decision error
1	The first manifestation of an epileptic seizure: the time point of the peak manifestation of an epileptic seizure – **3.49 hour**	0,001
2	The second manifestation of an epileptic seizure: the time point of the peak manifestation of an epileptic seizure – **19.04 hour**	

So, the developed software makes it possible to automatically determine the moments of epileptic seizures in a person with an error probability of 0.001.

Conclusions. The structure of the model of the mathematical daily EEG signal in the form of a random sequence of white Gaussian noise zones and additive mixtures of different-frequency harmonic components is substantiated, which enables the study of structural variations in a time interval for the purpose of detecting epileptic seizures in humans. The method and algorithm of time-shift window processing of the daily EEG signal was developed on the basis of a well-founded mathematical model and the mutual covariance method with multiple kernels in the form of different-frequency harmonic functions. In the MATLAB environment, a software tool with a graphical user interface was developed for computer EEG systems in order to process the daily EEG signal. New informative signs of daily EEG signal processing were calculated in the form of averaged values of the power of covariances, which make it possible to quantitatively determine the time points of manifestation and duration of epileptic seizures in humans.

References

1. Cerf R, el Hassan el Ouasdad. Spectral analysis of stereo-electroencephalograms: preictal slowing in partial epilepsies. Biological Cybernetics. Volume 83. P. 399–405. 2000. https://doi.org/10.1007/s004220000178
2. Liang S. F., Wang H. C., Chang W. L. (2010). Combination of EEG complexity and spectral analysis for epilepsy diagnosis and seizure detection. EURASIP Journal on Advances in Signal Processing, 853434. https://doi.org/10.1155/2010/853434
3. Tsipouras M. G. (2019). Spectral information of EEG signals with respect to epilepsy classification. EURASIP Journal on Advances in Signal Processing. 10. Current Neurology and Neuroscience Reports 12 (4):419-28. https://doi.org/10.1186/s13634-019-0606-8
4. Jeffrey D Kennedy, Elizabeth E Gerard. Continuous EEG Monitoring in the Intensive Care Unit. June 2012. Current Neurology and Neuroscience Reports 12 (4):419-28. Doi: 10.1007/s11910-012-0289-0.
5. Friedman D., Claassen J., Hirsch L. J. Continuous electroencephalogram monitoring in the intensive care unit. Anesthesia & Analgesia: August 2009. Volume 109. Issue 2. P. 506–523. https://doi.org/10.1213/ane.0b013e3181a9d8b5
6. Young G. B., Jordan K. G., Doig G. S. An assessment of nonconvulsive seizures in the intensive care unit using continuous EEG monitoring: an investigation of variables associated with mortality. Neurology. 1996;47(1):83–9. https://doi.org/10.1212/WNL.47.1.83

7. Lawrence J. Hirsch. Continuous EEG Monitoring in the Intensive Care Unit. October 2004. American journal of electroneurodiagnostic technology. 44(3):137–58. https://doi.org/10.1080/1086508X.2004.11079478
8. Selim R. Benbadis, MD, Diego Rielo, MD (co). EEG Artifacts. eMedicine Neurology, 2019. URL: https://emedicine.medscape.com/article/1140247-overview.
9. Roy Sucholeiki, MB, BCh, MD. Normal EEG Variants. eMedicine Neurology, 2019. URL: https://emedicine.medscape.com/article/1139291-overview.
10. Alarcon G., Binnie C. D., C.Elwes R. D., Polkey C. E. Power spectrum and intracranial EEG patterns at seizure onset in partial epilepsy. Electroencephalography and Clinical Neurophysiology. Volume 94. Issue 5. May 1995. P. 326–337. https://doi.org/10.1016/0013-4694(94)00286-T
11. Ocak H. Optimal classification of epileptic seizures in EEG using wavelet analysis and genetic algorithm. Signal Process. 88 (7). P. 1858–1867. 2008. Doi: https://doi.org/10.1016/j.sigpro.2008.01.026.
12. Bhattacharyya A., Pachori R. B., Upadhyay A., Acharya U. R. Tunable-Q wavelet transform based multiscale entropy measure for automated classification of epileptic EEG signals. Appl. Sci. 7. 385. 2017. https://doi.org/10.3390/app7040385
13. Boyko R., Khvostivskyi M., Fuch O. Mathematical Model of the 24-hour EEG Signal of People with Manifestations of Epilepsy for Computer EEG Systems. Proceedings of the XXVII International Scientific and Practical Conference. Edmonton, Canada. 2023. P. 179–184. ISBN 979-8-89074-573-6. Doi: 10.46299/ISG.2023.1.27.
14. Khvostivskyy M., Khvostivska L., Boyko R. Software, mathematical and algorithmic tools for the computer electroencephalography system of humans epilepsy manifestations detecting. Visnyk NTUU KPI Seriia – Radiotekhnika Radioaparatobuduvannia. 84 (Mar. 2021). P. 66–77. Doi: https://doi.org/10.20535/RADAP.2021.84.66-77.
15. Hvostivska L. V., Osukhivska H. M., Hvostivskyy M. O., Shadrina H. M., Dediv I. Yu. Development of methods and algorithms for a stochastic biomedical signal period calculation in medical computer diagnostic systems. Visnyk NTUU KPI Seriia – Radiotekhnika Radioaparatobuduvannia. (79). P. 78–84. https://doi.org/10.20535/RADAP.2019.79.78-84

Список використаних джерел

1. Cerf R, el Hassan el Ouasdad. Spectral analysis of stereo-electroencephalograms: preictal slowing in partial epilepsies. Biological Cybernetics. Volume 83. P. 399–405. 2000. https://doi.org/10.1007/s004220000178
2. Liang S. F., Wang H. C., Chang W. L. (2010). Combination of EEG complexity and spectral analysis for epilepsy diagnosis and seizure detection. EURASIP Journal on Advances in Signal Processing, 853434. https://doi.org/10.1155/2010/853434
3. Tsipouras M. G. (2019). Spectral information of EEG signals with respect to epilepsy classification. EURASIP Journal on Advances in Signal Processing. 10. Current Neurology and Neuroscience Reports 12 (4):419-28. https://doi.org/10.1186/s13634-019-0606-8
4. Jeffrey D Kennedy, Elizabeth E Gerard. Continuous EEG Monitoring in the Intensive Care Unit. June 2012. Current Neurology and Neuroscience Reports 12 (4):419-28. Doi: 10.1007/s11910-012-0289-0.
5. Friedman D., Claassen J., Hirsch L. J. Continuous electroencephalogram monitoring in the intensive care unit. Anesthesia & Analgesia: August 2009. Volume 109. Issue 2. P. 506–523. https://doi.org/10.1213/ane.0b013e3181a9d8b5
6. Young G. B., Jordan K. G., Doig G. S. An assessment of nonconvulsive seizures in the intensive care unit using continuous EEG monitoring: an investigation of variables associated with mortality. Neurology. 1996;47(1):83–9. https://doi.org/10.1212/WNL.47.1.83
7. Lawrence J. Hirsch. Continuous EEG Monitoring in the Intensive Care Unit. October 2004. American journal of electroneurodiagnostic technology. 44(3):137–58. https://doi.org/10.1080/1086508X.2004.11079478
8. Selim R. Benbadis, MD, Diego Rielo, MD (co). EEG Artifacts. eMedicine Neurology, 2019. URL: https://emedicine.medscape.com/article/1140247-overview.
9. Roy Sucholeiki, MB, BCh, MD. Normal EEG Variants. eMedicine Neurology, 2019. URL: https://emedicine.medscape.com/article/1139291-overview.
10. Alarcon G., Binnie C. D., C.Elwes R. D., Polkey C. E. Power spectrum and intracranial EEG patterns at seizure onset in partial epilepsy. Electroencephalography and Clinical Neurophysiology. Volume 94. Issue 5. May 1995. P. 326–337. https://doi.org/10.1016/0013-4694(94)00286-T
11. Ocak H. Optimal classification of epileptic seizures in EEG using wavelet analysis and genetic algorithm. Signal Process. 88 (7). P. 1858–1867. 2008. Doi: https://doi.org/10.1016/j.sigpro.2008.01.026.
12. Bhattacharyya A., Pachori R. B., Upadhyay A., Acharya U. R. Tunable-Q wavelet transform based multiscale entropy measure for automated classification of epileptic EEG signals. Appl. Sci. 7. 385. 2017. https://doi.org/10.3390/app7040385
13. Boyko R., Khvostivskyi M., Fuch O. Mathematical Model of the 24-hour EEG Signal of People with Manifestations of Epilepsy for Computer EEG Systems. Proceedings of the XXVII International Scientific

and Practical Conference. Edmonton, Canada. 2023. P. 179–184. ISBN 979-8-89074-573-6. Doi: 10.46299/ISG.2023.1.27.

14. Khvostivskyy M., Khvostivska L., Boyko R. Software, mathematical and algorithmic tools for the computer electroencephalography system of humans epilepsy manifestations detecting. Visnyk NTUU KPI Seriia – Radiotekhnika Radioaparatobuduvannia. 84 (Mar. 2021). P. 66–77. Doi: https://doi.org/10.20535/RADAP.2021.84.66-77.
15. Hvostivska L. V., Osukhivska H. M., Hvostivskyy M. O., Shadrina H. M., Dediv I. Yu. Development of methods and algorithms for a stochastic biomedical signal period calculation in medical computer diagnostic systems. Visnyk NTUU KPI Seriia – Radiotekhnika Radioaparatobuduvannia. (79). P. 78–84. https://doi.org/10.20535/RADAP.2019.79.78-84

УДК 004.021:004.422.8:616.853:517.57:519.21

МЕТОД ТА ПРОГРАМНИЙ ЗАСІБ ОБРОБКИ ДОБОВИХ ЕЕГ-СИГНАЛІВ ДЛЯ ВИЯВЛЕННЯ ЕПІЛЕПТИЧНИХ НАПАДІВ У ЛЮДИНИ

Микола Хвостівський; Роман Бойко

Тернопільський національний технічний університет імені Івана Пулюя, Тернопіль, Україна

Резюме. *Розроблено метод, алгоритм та програмний засіб обробки добового ЕЕГ-сигналів для комп'ютерних електроенцефалографічних систем для виявлення прояві епілептичних нападів у людини. Математично добовий ЕЕГ-сигнал подано як випадкова послідовність зон білих гаусових шумів та адитивних сумішей різно-частотних гармонічних компонент. Модель побудовано за припущення, що реалізація ЕЕГ-сигналу в часовій зоні без прояву епілептичних нападів є наближенню за структурою до білого гаусового шуму, а в зоні прояву є наближеною до сукупності різно-частотних гармонічних компонент. Ядром методу обробку добових ЕЕГ-сигналів є часо-зсувна віконна взаємоковаріаційна обробка з множиною ядр у вигляді різно-частотних гармонічних функцій діапазону частот* $[f_1; f_2]$ *в залежності від типу виявлення епілептичного нападу. На базі методу віконної обробки реалізовано алгоритм та програмний засіб обробки добового ЕЕГ-сигналу з графічним інтерфейсом користувача при використанні середовища MATLAB та його утиліти GUIDE. Розроблений програмний засіб може експлуатуватися як складова одиниця у складі комп'ютерних ЕЕГ-систем. Результати обробки добового ЕЕГ-сигналу при використані програмного засобу відображено у вигляді усереднених добутків результатів коваріацій (значення вимірюється в одиницях потужності) в межах кожного вікна обробки, які кількісно відображають часові моменти прояву та тривалості епілептичних нападів у людини. Прояви епілептичних нападів відображаються через приріст усереднених значень потужності коваріацій по відношенню до інтервалів спостереження без відповідних проявів цих нападів. Для забезпечення авторизації процесу визначення рівня прийняття рішення щодо виявлення епілептичних нападів (перевищенні рівня норми) за значеннями усереднених добутків результатів коваріацій застосовано пороговий алгоритм, Баєсівську концепцію відношень правдоподібності та статистичний критерій Неймана-Пірсона.*

Ключові слова: *добовий ЕЕГ-сигнал, метод обробки, програмний засіб, часо-зсувне вікно, взаємоковаріація, гармонічні функції різних частот, критерій Неймана-Пірсона, комп'ютерна ЕЕГ-система, MATLAB.*

https://doi.org/10.33108/visnyk_tntu2024.01.119 *Отримано 04.01.2024*