METHODS AND MEANS OF DIGITAL PROCESSING OF BIOELECTRIC SIGNALS

[1]Dilshod Elmuradovich Eshmuradov, [2]Otabek Mirkhalilovich Ismailov, [3]Malokhat Talatovna Magrupova

[1]Associate Professor, Tashkent State Technical University named after Islam Karimov,

[2]Doctor of Technical Sciences, Department of Information technology software Joint faculty of information technologies of the Tashkent university of information technologies named after Muhammad al-Khwarizmi and the Belarusian state university of informatics and radio electronics

[3]Tashkent State Technical University named after Islam Karimov

https://doi.org/10.5281/zenodo.7630233

Abstract. *The article gives the basic concepts in the digital processing of bioelectric signals, considers modern approaches in global practice, conducts a comparative analysis of scientific experience: the main advantages and disadvantages of methods and means of digital processing of bioelectric signals are identified, and the prospects for the development of this direction are determined.*

Keywords: *digital signal processing, bioelectrical signals, signal processing methods, digital processing tools.*

INTRODUCTION

Digital processing of bioelectric signals is a rapidly developing area in science and technology. It finds its application in the diagnosis of diseases, in improving the quality of life of people with disabilities, and in the sport of great achievements. This direction is closely related to human health, so two aspects are critical: human safety at the time of reading bioelectric signals and the accuracy of data transmission. The complexity of recording bioelectric signals lies in the fact that such signals are weak, at the same time, there is a significant level of interference - noise inside the human body and artifacts - noise from measuring instruments, the frequency range of which interferes with reading bioelectric signals, sometimes overlapping them [1; 219].

MATERIALS AND METHODS

Bioelectrical signals arise from electrical phenomena on the cell membrane; studies of bioelectrical signals in comparison with other types of signals can be called the most common in medicine. [2] It is customary to consider the electrical signal of a group of cells, rather than one specific cell, as a bioelectrical signal. For a single cell, signal measurement is practically impossible; a bioelectrical signal can arise both under mechanical movements in the cells themselves and from the external influence of an electric current.[3; 57] Sources of bioelectrical activity are located in the heart, brain and spinal cord, skeletal muscles, stomach, eyes, etc. Depending on the location of the source of bioelectrical activity, the frequency and amplitude indicators will differ; for example, during an electrocardiogram, the range of measured frequencies is from 0.05 to 250 Hz, during electromyography - from 0.01 to 10,000 Hz. This suggests that digital processing methods for different parts of the human body will be different. Even if we are talking about using the same method, for example, wavelet transforms to study the bioelectric signals of the brain and stomach, and this means that for each organ, the wavelet transform will be interpreted based on the goals and objectives that need to be achieved for the study on this part of the body. Modern science has a vast number of studies in the digital processing of bioelectric signals, so it is impossible to process and comprehend the entire array of data. Therefore, the article will discuss only those methods and tools that are the most common and used in global practice today, presented in table 1, table 2, and table 3.

Table 1.

Modern methods and means of digital processing in the study of bioelectrical signals of the heart.

№	Research methods	Digital processing methods	Digital Processing Tools
1.	Electrocardiography (ECG) is used to record the electrical activity of the heart muscle.	- digital filtering (classic); - wavelet transform; - adaptive noise reduction; - empirical mode decomposition (EMD); - methods based on neural networks; - clustering; - hybrid methods.	- high and low pass filter, bandpass and notch filter; - wireless mobile application; - filter and adaptive algorithm; - EMD algorithm: direct and indirect subtraction; - deep neural network; - clustering algorithm; - artificial intelligence.
2.	Vectorcardiography (VCG) - in the implementation of the work of the heart gives a spatial idea of the tension in its cells.	- digital filtering (classic); - wavelet transform; - moving average filter; - Kalman filter; - Savitsky-Golay filter; - regression of the principal component.	- Chebyshev filter, Butterworth filter; - wavelet filter; - moving average filter; - Kalman filter; - Savitsky-Golay filter; - QRS complex.

RESULTS

The digital filtering method has several advantages compared to other methods: it is pretty efficient, it has low technical requirements, it can work in real-time, and its cost is affordable. However, it is characterized by low productivity and can only be used if interference and bioelectrical signals are in different frequency ranges. Otherwise, signal reading will be impossible. Methods based on neural networks also have many advantages: good efficiency, they can work in real-time, and they have high-quality signal transmission without interference, but these methods still need to be available for use by a broad audience. The optimal ECG method can be called the adaptive noise reduction method, which has good efficiency, works in real-time, has good signal processing quality, and is available for implementation. However, it has high technical characteristics and requires certain time costs for the study associated with setting up the equipment. For VCG, the most appropriate method to date is the Savitsky-Golay filter method. [2]

Table 2.

Modern methods and means of digital processing in the study of bioelectrical signals of the brain.

№	Research methods	Digital processing methods	Digital Processing Tools
1.	Electroencephalography (EEG) is used to record the electrical activity of the	- filtering methods; - wavelet transform; - analysis of independent	- non-integer order filters (fractional); - wavelet transform:

	brain.	components (ANC); - empirical mode decomposition (EMD); - time-frequency reduction of the image dimension; - neural networks; - adaptive neural-fuzzy inference system (ANSF); - hybrid methods.	continuous, discrete, stationary, step-synchronous; - ANC algorithm; - EMD algorithm; - time-frequency reduction of the image dimension; - radial basis function and neural network of functional connection; - adaptive filtering using ANSLW; - wavelet transform and analysis of independent components.
2.	Evoked potentials (EPs) - a study of the brain's response to external stimuli (auditory, visual, somatosensory).	- wavelet transform; - Principal component analysis (PCA); - analysis of independent components (ANC); - hybrid methods;	- wavelet filter; - AGK algorithm; - ANC algorithm; - wavelet transform, ANC;
3.	Electrocorticography (ECoG) is a method used to examine patients with epilepsy, Parkinson's disease, characterized in that the electrodes are applied directly to the cerebral cortex.	- empirical wavelet transform (EWT); - empirical mode decomposition (EMD); - dynamic mode decomposition (DMD); -frequency-time reduction of image dimension.	- Fourier transform, method of scale-spatial detection, EEW; - Hilbert-Huang transformation, EMD; - DMD; -frequency-time reduction of image dimension.

DISCUSSION

The wavelet transform method and analysis of independent components can be considered as the optimal methods of digital processing for EEG and EP; for ECoG - the method of empirical mode decomposition, because all these methods have good noise suppression, good efficiency, work in real-time, good signal processing quality, the disadvantage of these methods is high technical requirements and, as a result, the cost of research. [4]

Table 3.

Modern methods and means of digital processing in the study of bioelectrical signals of skeletal muscles, neurons in the central nervous system, stomach, and eyes.

№	Research methods	Digital processing methods	Digital Processing Tools
1.	Electromyography (EMG) is used to record the electrical activity of skeletal muscles.	- digital filtering (classic); - adaptive noise reduction; - wavelet transform; - analysis of independent components (ANC); - empirical mode decomposition (EMD); - hybrid methods.	- bandpass filter; - adaptive filter, algorithm based on the least squares method; - wavelet filter; - multiple calculation of the ANC algorithm; - EMD algorithm, median filter;

			- wavelet transform, ANC.
2.	Electroneurography (ENG) is used to record the electrical activity of neurons in the central nervous system.	- digital filtering (classic); - adaptive noise reduction; - wavelet transform; - analysis of independent components (ANC); - empirical mode decomposition (EMD).	- digital filter; - adaptive filter; - wavelet filter, Weiner filter; - ANC algorithm; - algorithm (EMD).
3.	Electrogastrography (EEG) - used to record the electrical activity of the stomach.	- digital filtering (classic); adaptive noise reduction; - wavelet transform; - analysis of independent components (ANC); - empirical mode decomposition (EMD): - hybrid methods.	- digital filter; - adaptive filter; - wavelet filter; - ANC algorithm; - EMD algorithm, portable recorder; - EMD algorithm, adaptive filter; - bandpass filter, ANC algorithm, adaptive filter.
4.	Electrooculography (EOG) - used to record the electrical activity of the eye muscles.	- support vector machine; - Savitsky-Golay smoothing filter; - a method based on distributed arithmetic.	- algorithm based on the support vector machine; - Savitsky-Golay smoothing filter; - Algorithm based on distributed arithmetic.
5.	Electroretinography (ERG) - used to record the electrical activity of the retina.	- digital filtering (classic); - adaptive noise reduction; - wavelet transform; - empirical mode decomposition.	- digital filter; - adaptive filter; - discrete wavelet filter; - EMD algorithm, multifocal electroretinography.

The most appropriate digital processing method for EMG, ENG, and ERG is adaptive noise reduction. This method has high signal processing quality, good performance, and real-time operation but requires high technical requirements and is expensive. For EGG, these are wavelet transform and adaptive noise reduction methods. The methods have good signal processing quality, good performance, and work in real-time, but they also require high technical requirements and are expensive. For EOG, the Savitsky-Golay smoothing filter will be the optimal method. The method has high signal processing quality, and high performance works in real-time; high technical requirements are also required, as a result of which it is expensive [5,6].

CONCLUSION

Thanks to the digital processing methods of bioelectric signals, it is already possible to obtain good quality data when conducting a study of the human body and accurately diagnose diseases, and detect diseases in the early stages for the cardiovascular system, brain, stomach, etc. The problem with such diagnostics lies in the difficulties of implementing the methods in practice, which means that diagnostics still need to be made available for mass research because methods that give accurate results seem expensive and require complex manipulations during their implementation.

The scientific community, in turn, has high hopes for developing methods for the digital processing of bioelectric signals. At present, attempts have been made with their help to control prostheses utilizing brain signals in people with disabilities and type text on a computer using human eye movements; The researchers plan to implement the transfer of information from the human brain to a computer using big data. Thus, discoveries in the field of digital processing can globally affect the way people live.

REFERENCES

1. Filist S. A. Production of biotechnical and medical devices and systems / S. A. Filist, O. V. Shatalova - Moscow: Yurayt, 2023. - 309 p.
2. Martinek R. Advanced Bioelectrical Signal Processing Methods: Past, Present and Future Approach—Part I: Cardiac Signals / R. Martinek, M. Ladrova, M. Sidikova, R. Jaros, K. Behbehani, R. Kahankova, A. Kawala-Sterniuk // Multidisciplinary Digital Publishing Institute [website], 2021. – URL: https://www.mdpi.com/1424-8220/21/15/5186 (date of the application: 13.12.2022).
3. Bakalov V. P. Medical electronics. Fundamentals of biotelemetry / V.P. Bakalov - Moscow: Yurayt, 2019. - 326 p.
4. Martinek R. Advanced Bioelectrical Signal Processing Methods: Past, Present and Future Approach—Part II: Brain Signals: Cardiac Signals / R. Martinek, M. Ladrova, M. Sidikova, R. Jaros, K. Behbehani, R. Kahankova, A. Kawala-Sterniuk // Multidisciplinary Digital Publishing Institute [website], 2021. – URL: https://www.mdpi.com/1424-8220/21/19/6343#B120-sensors-21-06343 (date of the application: 14.12.2022).
5. Martinek R. Advanced Bioelectrical Signal Processing Methods: Past, Present, and Future Approaches—Part III: Other Biosignals .Kawala-Sterniuk // Multidisciplinary Digital Publishing Institute [February], 2021. – URL: https://www.mdpi.com/1424-8220/21/18/6064
6. Attokurov U., Omorova S., Eshmuradov D. Analysis of the most dangerous interference affecting the operation of a relay radio station //Science and Innovation. – 2022. – T. 1. – №. 6. – C. 484-488.
7. Эшмурадов Д.Э., Магрупова М.Т., Неъматова Д.Х. ОПТИМАЛЬНЫЕ МЕТОДЫ ЦИФРОВОЙ ОБРАБОТКИ БИОЭЛЕКТРИЧЕСКИХ СИГНАЛОВ. [Электронный ресурс]// Теория и практика современной науки.-2022.- №1(91) (дата публикации: 16.01.2023).- URL: https://www.modern-j.ru/teknomer (дата обращения: 31.01.2023)