DIGITAL SIGNAL PROCESSING ALGORITHMS FOR BIOMEDICAL APPLICATIONS IN ARTIFICIAL INTELLIGENCE

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Abstract: Research carried out in the field of digital processing algorithms of artificial intelligence and biomedical signals sets the stage for a radical transformation of modern medicine and the health system. Biomedicine signaling is a complex set of data that reflects the various physiological processes of the human body. By properly analyzing these signals and working them efficiently, early disease detection, diagnostic quality enhancement, and individual treatment strategies can be developed. Artificial intelligence technologies are creating new opportunities in the analysis of these complex signals.

Keywords: artificial intelligence, biomedicine signals, modern medicine, data, biomedicine, signals, methods, physiological processes, diseases, diagnostics.

Introduction

The role of technological progress in the field of modern medicine is growing. In particular, the use of artificial intelligence and digital signal processing algorithms in healthcare is opening the door to new opportunities. The biomedical field relies mainly on the study of the various physiological signals obtained from the human body. These signals include an electrocardiogram representing electrical impulses of cardiac activity, an electro-encephalogram measuring brain activity, and many biological parameters such as respiration or blood pressure. These signals serve as an important indicator in determining the state of human health. However, given their naturalness and, in most cases, noise, their analysis is a very complex process. Digital signal processing algorithms allow it to qualitatively improve these complex signals, clear them of noise, and identify points of medical importance. For example, small changes within signals often have diagnostic value in detecting abnormalities in the heart rhythm. By cleaning noisy signals and extracting key components, such approaches help patients receive more accurate and reliable diagnoses.

Materials and methods

One of the main achievements of artificial intelligence is the ability to detect hidden patterns in large and complex data sets. Biomedical signals also fall into just such complex information. From small changes within them, it is often possible to draw conclusions about new stages of a health condition, the onset of signs of illness or even dangerous conditions. AI algorithms have self-learning mechanisms that can train on learned patterns and identify new cases with high accuracy. Artificial intelligence techniques such as machine learning, deep learning, among others, are widely used in biomedical data processing. When processing digital signals, there is initially a stage of obtaining a signal and preparing it in advance. Here, various filters are used to get rid of various errors and noise in the signal. For example, to eliminate mid-frequency interference, special filters are used, through which the signal becomes cleaner. Signal segmentation and feature extraction are crucial for subsequent analysis steps. For epidemiological, clinical or diagnostic purposes, these characteristics are of great importance. Artificial intelligence algorithms, on the other hand, allow for deeper analysis in the above step. For example, with the help of neural networks, complex patterns within the signal are determined. Based on these patterns, predictive data can be obtained on the patient's dysfunctions or cases of the disease. Algorithms also adjust themselves from time to time, being able to work online with new data. This is a huge advantage and is especially helpful in identifying new or rare diseases.

Non-invasive vital signs monitoring is another major area of interest in applying AI algorithms to biomedical signals and images. In this context, the work by Cheng et al. (2023) proposed an AI-based approach to estimate blood oxygen saturation (SpO2) from facial videos [7]. Their approach encodes red–green–blue (RGB) facial videos into 2D spatial–temporal maps (STMaps) and estimates SpO2 levels from these maps using convolutional neural networks (CNNs), specifically ResNet-50, DenseNet-121, and EfficientNet-B3. The three CNN-based DL networks showed good performance, surpassing state-of-the-art methods and the international standard of 4% error for approved pulse oximeters. Sensitivity analyses also showed the influence of different color spaces, acquisition devices, and SpO2 ranges, while feature map visualization provided an identification of forehead, nose, and cheek facial features, which are relevant for SpO2 estimation [7]. This approach offers an accurate, rapid, and contactless alternative for SpO2 measurement that would be particularly beneficial in long-term monitoring scenarios requiring minimal physical contact, such as during infectious disease outbreaks or for patients with sensitive skin.

Similarly, Hwang et al. (2023) and Zhao et al. (2023) investigated the application of AI to the non-invasive monitorization of respiratory rate (RR) using biomedical signals [8,10]. Hwang et al. (2023) developed seven DL models, including a newly proposed dilated residual neural network, to estimate RR from photoplethysmography (PPG) data [8]. Their DL models showed promising results, although the authors acknowledged challenges such as motion artifacts and limited data diversity. Conversely, Zhao et al. (2023) proposed a transformer-based model, called TransRR, to predict RR from PPG and ECG data [10]. TransRR outperformed conventional CNN-based and long short-term memory (LSTM)-based models, although the authors acknowledged that more data are required to train a highly generalizable and clinically reliable RR estimation model. Overall, Hwang et al. (2023) and Zhao et al. (2023) highlight the potential of AI-based approaches in enhancing non-invasive RR monitoring across diverse clinical settings, including ICUs, emergency departments, and intensive care patients [8,10].

Results and discussion

The creation of medical classification and forecasting systems using biomedical signals is also one of the current areas of the field of artificial intelligence and digital signal processing. Doctors can use these systems as additional diagnostic tools to make a more accurate diagnosis. This process reduces human error, makes medical practice more efficient and fast. The use of algorithms in medicine allows for an individual approach to patients, that is, the establishment of a diagnostic and therapeutic regimen taking into account the physiological characteristics of each person.

HL, artificial intelligence and digital signal processing technologies are in the process of continuous development. As a result of the expansion of their capabilities in the future, the development of new diagnostic methods, the scale of human health and medical care will radically change. For example, with the help of real-time monitoring systems, constant control of the patient's condition, their detection in the early stages of various diseases and the possibility of starting timely treatment will expand. The role of these technologies will also be greater in the areas of long-distance medical supervision and remote diagnostics. Each biomedical signal processing algorithm has its own characteristics. They are developed in accordance with the type, quality of Signals, Medical function. For example, since EEG signals consist of many parasites and noise, special filters and signal separation methods are applied to them. At the same time, the ECG signals used in the study of cardiac activity are distinguished by other aspects. Therefore, algorithms must also be relevant and tailored to the purpose.

Currently, the importance of artificial intelligence in Biomedical Services is not limited only to signal processing. It is used not only to analyze data, but also to draw clinical conclusions, formulate treatment plans and even recommend various therapy methods. This is considered one of the most important directions that determine the future of Medicine. For the successful implementation of these processes, it is necessary to have quality information. Therefore, biomedical data collection methods, sensors, monitoring devices are also constantly being improved. The high sensitivity of the sensors, the possibility of deep and accurate capture of signals erti provides a good foundation for digital signal processing. As a result, the digital signal processing algorithms used in artificial intelligence are complex, multistage, and continuously evolving systems. With their help, it is possible to quickly and accurately diagnose diseases in the biomedical field, constantly monitor patients, and create an individual approach. Technological innovations in this area will radically improve the quality of human life and lead to the modernization of the global healthcare system.

Now, each new technological breakthrough should serve to improve the quality of life of a person in the field of Medicine, be used in the creation of new diagnostic and therapeutic methods by analyzing complex and ambiguous biomedical signals. Digital signals being processed using artificial intelligence are becoming a tool to help patients with greater accuracy. This is one of the achievements of not only representatives of science prepared for this, but also of all mankind. Creative and practical approaches in the field of biomedical signal processing algorithms will certainly find their place in the radical transformation of the health system in the future and will serve to save the lives of many people.

Conclusion:

In conclusion, the combination of digital signal processing algorithms and artificial intelligence is opening up new horizons in the development of biomedical applications. Scientific research carried out in this direction, the creation of new algorithms, their introduction into practice will bring the medical field to a higher level. At the same time, it offers great opportunities for maintaining human health and preventing diseases. Work in this direction will serve to create more efficient and robust systems in the future. Therefore, further improvement of artificial intelligence and digital signal processing algorithms and their expansion of applications in the biomedical field remain an important and urgent task.

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