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APPLICATION OF MACHINE LEARNING IN THE ANALYSIS OF BIOELECTRICAL SIGNALS (EEG, ENG, EMG)

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Abstract
This article discusses the application of Machine Learning algorithms in the analysis of electroencephalography (EEG), electroneurography (ENG), and electromyography (EMG) signals. Based on EEG signals, Machine Learning algorithms are used for early detection of epileptic seizures, assessment of brain activity after stroke, and identification of changes in brain rhythms in Parkinson's and Alzheimer's diseases. This enables early diagnosis and timely initiation of treatment. In EMG analysis, Machine Learning is widely applied to detect muscle diseases (myopathies), peripheral nerve injuries, and neuromuscular junction disorders. Machine Learning–based analysis of ENG signals is used to assess peripheral nerve conduction, and for early detection and prevention of diabetic neuropathy, traumatic nerve injuries, and demyelinating diseases.
Keywords
EEG analysis, ENG signals, EMG monitoring, bioelectrical signals, machine learning, deep learning, signal classification, neurophysiological diagnostics, automated analysis, neurological diseases.

Introduction

EEG, ENG, and EMG signals are among the most important diagnostic sources for assessing changes in the nervous system and muscle activity. Due to their complex and noisy nature, traditional analysis methods often fail to provide sufficient accuracy. In recent years, the application of Machine Learning algorithms has enabled more accurate, automated, and rapid analysis of bioelectrical signals. This article highlights the effectiveness and practical applications of modern ML approaches in processing EEG, ENG, and EMG signals. The rapid development of Machine Learning technologies has given new momentum to bioelectrical signal analysis by enabling the detection of hidden patterns, automatic classification of pathological conditions, and extraction of subtle features important for early diagnosis. In particular, Deep Learning models demonstrate high efficiency in predicting diseases related to EEG rhythms, nerve conduction, and muscle activity.

Main Part

Electroencephalography (EEG) is a method for examining brain activity by recording its bioelectrical signals using an electroencephalograph. The clinical significance of recording brain bioelectrical activity was first identified by the German psychiatrist Hans Berger in 1929. EEG is used for both research and diagnostic purposes. The brain, like other organs and tissues, generates very small electrical potentials during its activity, which can be recorded using an

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electroencephalograph. Plate-shaped electrodes are placed on the patient's scalp and connected to the device, which records the brain's biopotentials.

The electrode placement scheme may vary; one of the most convenient is the Jung method, which uses 12 electrodes. EEG waveforms with different frequencies, phases, and amplitudes reflect the functional state of neurons and synapses in the cerebral cortex. Electroencephalography can record both physiological and pathological conditions of the brain.

Modern EEG devices are multi-channel systems equipped with independent amplification and filtering units, signal selection units, and recording mechanisms. Current EEG systems typically use 8–24, sometimes up to 32 channels, with 8 or 16 channels commonly applied in clinical diagnostics. The examination room should be protected from light and noise, and the procedure must be explained to the patient as completely harmless and painless.

Because brain biopotentials are very small, powerful electronic amplifiers are required for recording. EEG can be recorded using monopolar or bipolar methods in various combinations. Functional activation techniques may be applied during EEG recording to stimulate the brain and reveal hidden wave patterns, aiding in disease detection.

EMG (electromyography) measures the electrical activity of muscles, ENG (electroneurography) measures nerve impulse conduction, EEG (electroencephalography) records brain electrical activity, and ECG (electrocardiography) measures the electrical activity of the heart.

Electromyography (EMG) is a diagnostic method used to assess the health of muscles and the nerve cells that control them. It helps identify muscle dysfunction, nerve dysfunction, and problems in neuromuscular transmission. Electrical signals generated by motor neurons are converted into graphs, sounds, or digital values using electrodes for specialist interpretation.

Electroneurography (ENG) is a neurological diagnostic method used to evaluate peripheral nerve function by applying safe electrical impulses and measuring conduction speed. It helps detect nerve damage, its location, and severity in conditions such as diabetes, carpal tunnel syndrome, trauma, and multiple sclerosis. ENG is often performed together with EMG.

Conclusion

EEG, ENG, and EMG signals are essential diagnostic tools for evaluating nervous system and muscle function. Machine Learning algorithms enable automated signal analysis, noise reduction, detection of pathological conditions, and improved diagnostic accuracy. Using classical ML models (SVM, Random Forest) and Deep Learning models (CNN, LSTM), epilepsy, nerve, and muscle diseases can be detected with high accuracy. Overall, Machine Learning accelerates, automates, and enhances the effectiveness of bioelectrical signal analysis in clinical practice.

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