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Approach to Epilepsy using Machine Learning

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Introduction

Epilepsy is a category of neurological illnesses defined by a long-term proclivity for repeated seizures that can affect people of any age. Epilepsy is caused by the 'epileptogenesis' process, which causes the normal brain network to fire neurons in a self-sustaining hyper-synchronized way in the cerebral cortex. A rapid aberrant, self-sustained electrical discharge in the cerebral networks causes an epileptic seizure (ES), which normally lasts less than a few minutes. Patients with epilepsy's brain activity can be classified into four states: pre-ictal (immediately preceding seizure), ictal (during a seizure), post-ictal (immediately following a seizure), and interictal (immediately following a seizure) (in-between seizures). During an ES episode, electroencephalography (EEG) is a very efficient diagnostic tool for studying the functional anatomy of the brain. EEG signals are non-Gaussian and non-stationary signals that measure electrical activity in the brain and are used to diagnose various brain illnesses. EEG measurements are used to distinguish between normal and pathological brain function. Various studies have used machine learning (ML)-based prediction algorithms to solve this issue over the years. Deep learning (DL) is an advanced machine learning (ML) technique that uses a multi-layer hierarchical design to discover patterns more precisely from massive datasets. The potential of DL to deliver extremely accurate findings has motivated academics to apply DL techniques to a variety of real-world applications, with several researchers suggesting DL-based systems for ES prediction in the previous five to six years [1-4].

Description

Wearable devices

For seizure detection and prediction, Wearable Devices (WDs) have been created. For patients and caregivers, the unexpected nature of seizure incidence is distressing and burdensome, affecting their quality of life and leading to social isolation. Because generalised tonic-clonic seizures (GTCS), including focal-to-bilateral tonic-clonic seizures, are associated with the highest morbidity and death, automated seizure alerts calling for help are extremely crucial. Seizures can be detected by scalp electroencephalography (EEG), with sensitivity ranging from 75% to 90% and false alarm rates (FARs) ranging from 0.1 to 5 per hour, according to published studies. When only a few electrodes are employed and spatial sampling is limited, the accuracy of EEG-based seizure detection suffers, and conclusive proof for the accuracy of these devices is still missing. Machine learning (ML) is becoming more widely recognised as a strong tool for managing large amounts of epilepsy data. The field of machine learning (ML) comprises a wide range of algorithms for training mathematical models, ranging from simple linear classifiers to deep neural networks with millions of parameters that must be fitted ("learned"). From cancer diagnosis to seizure detection, machine learning has shown enormous promise in health care.

EEG signal analysis for epilepsy

Before and during a seizure, EEG data contain characteristics that can be utilised to distinguish between the distinct stages of an epileptic seizure, as well as the pre- and post-seizure periods. Changes in the spike rate of EEG data before to epilepsy have also been investigated extensively, demonstrating the logical existence of a preictal state. However, there are no specific traits that may be used to categorise EEG states [1,2]. The wave pattern could reveal important details about brain activity. By visually viewing EEG data, experienced neurologists can discover problems. However, due to the high temporal and spatial characteristics of the dynamic non-linear EEG data, this technique is time-consuming and prone to erroneous detection. As a result, computational techniques, as well as the extraction and analysis of EEG signal characteristics, can be extremely useful in diagnostics.

Prediction of epileptic seizures using machine learning

The analysis of EEG recordings was the first focus of ES prediction research since EEG data are a crucial source for monitoring brain activity before, during, and after ES. Eye movements, blinks, heart signals, and muscular noise contaminate EEG signals. To reduce the impact of these many sources of noise and distortions, several filtering and noise reduction approaches are applied. After removing artefacts, important characteristics are required for developing machine learning approaches for identifying and classifying pre-ictal and interictal stages. Automated identification of interictal epileptiform discharges, in addition to identifying seizures, is critical for the diagnostic workup of epilepsy patients. Long-term video-EEG monitoring, including home monitoring, is becoming more common. Spike detection that is reliable and automated makes it easier to analyse this massive volume of data. EEG epochs without spikes were identified using machine learning methods, removing them from visual analysis [4,5].

EEG seizure predictions using machine learning

In a prospective scenario, one clinical trial for an implantable seizure advisory device proved successful use of machine learning for seizure forecasting. In the human trial, classifiers were trained after 4 months of recording using a decision tree-type classifier with hand-coded data (line length and power in various frequency bands). The results were impressive, with seizure prediction accuracy of 100 percent in some situations; however, ML classifiers failed to give relevant projections for other people. Following that, a competition on three of the most difficult patients revealed considerable advances, indicating that algorithms must be flexible enough to deal with patient-specific pre-ictal signals. A variety of machine learning systems have been used to predict seizures using databases of scalp EEG, with various deep learning methods reporting great results. The limited period of scalp EEG recordings, on the other hand, hinders the capacity to rigorously test seizure-prediction techniques. Studies of scalp EEG for seizure prediction often use fewer than 10 seizures per person, limiting the ability to train machine learning algorithms and resulting in low generalizability on new data [2,3].

Conclusion

ES prediction is a broad topic in the context of EEG analysis, feature selection, ES detection, and prediction, as well as the evaluation of prediction or detection methods. In contrast to the conclusions of this study, the majority

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of prior survey publications focused solely on EEG analysis, with only a handful covering the evolution of prediction algorithms. Using WD for seizure detection, prediction, and characterisation has a lot of potential. This could assist to reduce seizure-related morbidity and death, as well as the anxiety caused by the unpredictability of seizure incidence.

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Conflict of Interest

The authors reported no potential conflict of interest.

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