Automatic Spike and Wave identification in the EEG of epileptic patients for the prediction of epileptic seizures

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Abstract

To analyse epileptic seizures, EEG signals are fundamental for neurologists to diagnose pathological events and evaluate medical treatments. Doing so is not very time-efficient, so an automatic method is required for faster analysis. The basis for this method is the pathological event of the spike and wave, which is indicative for epilepsy. The objective of this study is the ideation of a spike and wave detector based on a set of prototypes spike and waves and match filters to support the diagnosis of epilepsy and predict the incoming attack with the detection of spike and waves in EEG signals. The first section provides a brief anatomical, physiological and biological introduction to the central nervous system, essential to understand the fundaments of the epileptic seizures. A brief description of seizures and their classifications is also provided, along with their pathological waveforms shown in EEG recordings. The second section is dedicated to the state of the art, exploring the many algorithms dedicated to the identification of spike and waves in EEG recordings. The third section describes the dataset used in this study and each individual step of the algorithm developed for this research. The results achieved are explained in the fourth section.

1 Introduction

In biology, the central nervous system (CNS) represents the most complex part of vertebrates, including humans. The CNS is mainly composed of two structures, the brain and the spinal cord. The former one is the most intricate organ in the CNS, located in the cranial cavity of the skull and protected by layers of membranes (meninges) and cerebrospinal fluid. The brain is composed of billions of neurons, which communicate with each other through synapses, specialized junctions where neurotransmitters deliver signals from one neuron to another through action potentials. In short, neurons are linked between each other through electrical activity. Epilepsies are neurological disorder characterized by recurrent, unprovoked seizures which result from abnormal electrical activity in the brain, leading to temporary disruption in normal brain activity. Epilepsies can affect individuals of any age and its severities and manifestations vary widely, that's why electroencephalography (EEG) is important for analysing them. One of the main abnormal electrical patterns associated with epilepsies is the spike and wave (SW) pattern, the main focus of this study.

2 State of the art

Since the 1970s, scientists have been trying to develop an algorithm capable of detecting epileptiform spike and waves. Even with better and faster tools, a method for fast and accurate detection has yet to emerge. Various methods have been proposed: template matching, capable of analysing EEG signal frames and labeling them as possible putative spikes or not;

mimetic analysis, based on associate rule mining technique to emulate neurologists' thinking patterns; power spectral analysis; wavelet analysis; artificial networks, which greatly characterize the great majority of the proposed spike and wave algorithms; fuzzy clustering; chaos theory, based on power spectral density and Lyapunov index; nonlinear dynamic system theory, useful for understanding EEG epileptic signals; match filtering, which inspired this study.

3 Material and methods

The dataset used for this study is from CHB-MIT database, collected at the Children's Hospital Boston and it consists of EEG recordings from pediatric subjects with intractable seizures. All the analyzed signals are preprocessed before implementing the algorithm, resulting in cleaner signals: background noise is fitered with a band pass filter, with cutoff frequencies between 1 and 40 Hz; EOG and EMG artifacts are removed using SOBI algorithm and canonical correlation analysis (CCA) respectively; based on the preprocessed signal's envelope, signals that were deemed too noisy were scrapped.

3.1 Construction of waveforms for the identification of SWs

A set of 17 prototypes was handed, which are mathematical models of spike and waves detected by a neurologist (a sinc function to represent the spike and a gaussian function to represent the wave). To widen the range of the SWs that could be identified, all the intermediate waveforms of these prototypes are computed. Principal component analysis (PCA) and convex hulls were essentials for this step, as PCA reduces the amount of dataset by finding the most important patterns, while convex hull calculates all the possible convex combinations of the inputs.

3.2 Match filtering

This new set of prototypes is then compared to the preprocessed EEG signals with match filtering. What match filtering does is to correlate the prototypes with the time-reversed know signals, while using normalized cross-correlation. By setting an adaptive threshold, spike and waves can be detected based on their normalized-cross correlation values.

3.3 Removal of false detection

Detected spike and waves that are estimate lower than an amplitude threshold are labeled as noise and discarded.

4 Results

From the detected spike and waves, the number of spike and waves, their frequency discharge and their amplitude are first computed. The obtained values show that amplitude can be used to make predictive statements, while the former two show a more stochastic trend, this is further confirmed by the results of the Wilcoxon signed-rank test.
The standard deviation and gradient of the frequency discharge are computed, these features are then used to train MATLAB's classifiers, achieving a test accuracy of seizure prediction of 70.5% with the weighted K Nearest Neighbours classifier.

5 Conclusions

In this study a fast and accurate method is introduced, capable of being used on real-time recordings. While it has short-comings, like being prototype dependent and high levels of noise can affect its detection, results show that SWs have a factor which can be used to determine the incoming seizure.