Empirical Wavelet Transform for Seizure Detection

Sanju Kumar
2001EE62
sanjuphogat8238@gmail.com
Electrical and Electronics Department
Indian Institute of Technology Patna

Supervised by:
Dr. Maheshkumar H. Kolekar
Electrical and Electronics Department
Indian Institute of Technology Patna

Abstract

Signal processing and machine learning methods are valuable tools in epilepsy research, potentially assisting in diagnosis, seizure detection, prediction and real-time event detection during long term monitoring. Recent approaches involve the decomposition of EEG signals into different modes in a data-dependent and adaptive way, which may provide advantages over commonly used Fourier based methods when dealing with nonlinear and non-stationary data. Examples of such methods include empirical mode decomposition (EMD), extended EMD (EEMD), complete EEMD with adaptive noise (CEEMDAN), empirical wavelet transform (EWT) and variational mode decomposition (VMD). In this work, feature sets extracted from original non-decomposed signals and from the EWT are evaluated for the classification of EEG seizure data using two freely available datasets.

1. Introduction

Epilepsy is a burdening neurological disease that has a prevalence rate of around 6 per 1000 persons and incidence rate of 61 per 1000 person-years. One of the factors contributing for its high incidence rate is the large number of causes leading to this condition, such as: genetic predisposition, dysplasia, cerebrovascular disease (CVD), trauma, tumor, infection, ischemia, among others.

Recurrent seizures are considered the hallmark of Epilepsy. These events reflect the abnormal firing of groups of neurons in the brain, in general synchronous and of high intensity. This deviation from the normal functioning patterns of neurons may invoke sensations varying from strange feelings, behaviors and sensations to seizures with muscular spasms and possible loss of conscience.

The electroencephalogram (EEG) is a high temporal resolution recording of brain electrical activity and an essential method for the diagnosis of epilepsy and other neurological disorders. EEG can reflect abnormal neuronal activity during ictal (i.e. seizures) or interictal periods, such as sharp transients occurring in-between seizures. These signals are commonly interpreted by experienced neurologists through visual inspection, taking into account features such as frequency, amplitude and regularity of waveforms, reactivity to stimuli, spatial range and temporal persistence of the signal's anomalies. However, this method may be cumbersome and time consuming, especially for long series and multi-channel data, which can lead to an increasingly high ratio of false-negative results. Furthermore, there is a series of subtle signal features and components, as well as inter-channel relationships, which are virtually impossible to detect by simple visual inspection. This task may be assisted by signal processing and classification algorithms that can deal with signal nonlinearities and subtleties, high-dimensional data and real-time processing. As such, these automated methods are valuable tools for the diagnosis, detection and prediction of epilepsy and epileptic seizures.

The empirical wavelet transform (EWT) addresses some limitations of EMD. By adapting some of the wavelet formalisms, this method designs appropriate wavelet filter banks and decomposes a signal into a predetermined number of modes. The use of EWT has been explored in different areas such as compression of electrocardiogram (ECG) signals, decomposition of seismic activity and time-frequency representation of non-stationary signals. Although the use of wavelets for seizure detection and classification has been widely explored, few works evaluate EWT for processing seizure EEG signals.

2. Method

2.1 Dataset

This work uses two public online EEG datasets: (i) one is offered by the University of Bonn and is commonly used as benchmark for seizure detection algorithms and (ii) another from epilepsy patients collected at the Neurology and Sleep Centre, Hauz Khas, New Delhi (NSC-ND).

2.2 Adaptive decomposition method

The EWT method aims to extract the oscillatory amplitude (AM) and frequency (FM) components of a signal, considering these as having compact Fourier support. Unlike traditional wavelet transforms, which use predefined filter bank structures, the EWT method defines the supports of the filters in accordance with the spectral distribution of the signal, in a fully adaptive way. Some considerations are made for analysis: (1) the signal must be real valued, due to the need for symmetry, and (2) a normalized frequency axis with 2π periodicity is considered, but analysis is restricted to $[0, \pi]$, due to Shannon's sampling criterion.

A number of modes N is defined a priori, determining how the original signal will be decomposed and how many segments the spectrum is partitioned in the range $[0, \pi]$. Among the $N + 1$ frequency boundaries to be determined, two are already predefined ($\omega 0$ and ωN), corresponding to frequencies of 0 and π, respectively.

The remaining N-1 limits are set according to the distribution of the signal's frequency spectrum: the N-1 local maxima are found, and the boundaries ωn ($n = 1, 2, \ldots$ N-1) are defined as midpoints between two consecutive maxima.

2.3 Feature selection and classification

For feature selection and classification algorithms, functions from scikit-learn package were used.

Since the number of extracted features of each signal is relatively large, and not every feature is relevant for class discrimination, there is a need for a feature selection or ranking method.

4. Conclusion

The development of feature extraction and classification methods is a key step both for understanding of the operating mechanisms of epilepsy, as for clinical analysis, including possible applications for seizure detection and prediction devices.

5. References

[1] Carvalho, Vinícius Rezende et al. "Evaluating five different adaptive decomposition methods for EEG signal seizure detection and classification." *Biomed. Signal Process. Control.* 62 (2020): 102073.