AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Computer and Systems Engineering

Predicting Pre-ictal State of Epileptic Seizures from Electroencephalography Signals

A Thesis submitted in partial fulfilment of the requirements of the degree of
Master of Science in Electrical Engineering
(Computer and Systems Engineering)
by

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Bachelor of Science in Electrical Engineering
(Computer and Systems Engineering)
Faculty of Engineering, Ain Shams University, 2013

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Date: 21 April 2017

Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract

Epilepsy is the second most common neurological disease worldwide. Epileptic seizures can happen abruptly without warning signs which can cause risks and complications. Therefore, predicting epileptic seizure can provide an enormous aid to epileptic patients. In this research, we have worked on seizure prediction for epileptic patients through electroencephalography (EEG) signals. We have studied the different changes in EEG signals during and before seizures, and we examined different signal processing and feature extraction approaches. In addition, we have introduced a novel, enhanced and more real-time applicable method for seizure prediction that depends on zero-crossings analysis of wavelet detail coefficients, SVM classification, and an adaptive channel selection algorithm. The method achieves 94% accuracy in discriminating between preictal (one hour preceding seizure onset) and interictal (normal EEG signals with at least 4 hours separation from the next or previous seizures) classes even when using testing data of seizures that were not included in the training data. The introduced approach outperforms other examined approaches. Moreover, to compare the efficacy of the proposed adaptive channel selection approach with other channel selection methods, we have examined the use of autoencoders and deep learning concepts in channel selection and learning phase which yielded an average accuracy of 80% between preictal and interictal classes.

Finally, we have examined classifying the preictal class to further classes including early and late preictal to be able to have an accurate measure for the expected onset time. When using Support Vector Machine (SVM) classifier, the adaptive channel selection algorithm and wavelet coefficients zero crossings as features, an accuracy of 80% is achieved in discriminating

between early and late preictal classes when setting the early preictal class as the first 10 minutes of the preictal hour, and the late preictal class as the last 10 minutes of the preictal hour preceding seizure onset. When setting the early and late preictal classes as the first and last 30 minutes of the preictal hour respectively, an accuracy of 70% is achieved between the two classes. Taken together, these results indicate the efficacy of using the introduced zero-crossings wavelet analysis approach in predicting epileptic seizures onset.

Thesis Summary

Predicting the occurrence of epileptic seizures can provide an enormous aid to epileptic patients and enhance their lives' quality significantly. In this thesis, we have examined different approaches of seizure prediction applied to scalp Electroencephalography (EEG) signals. We have introduced a new method that relies on the count of zero-crossings of wavelet detail coefficients of EEG signals as the major feature. This is followed by a binary classifier that discriminates between preictal and interictal states.

We have introduced new enhancements to seizure prediction methods making them more practical for real-time applications through reducing the computational complexity as we use an adaptive algorithm for channel selection to identify the optimum number of needed electrodes. Another enhancement is using shorter amount of training data to enhance the setup process of real time applications. In addition, the method was demonstrated to be robust against variations between seizures for the same patient. Applied to data from 8 patients, the proposed method achieved high accuracy and sensitivity with an average accuracy of 94% and an average sensitivity of 96%. These results were obtained using only 10 minutes of training data as opposed to using hours of recordings typically used in traditional approaches.

We studied the effects of changing wavelet functions, wavelet levels, different dimensionality reduction approaches, and using different classifiers, on the accuracy. Moreover, we have examined the efficiency of using autoencoders as a channel reduction approach; using different autoencoders number of levels, encoder and decoder activation functions, and different number of hidden nodes were also examined. Our findings are that using Haar

wavelet, along with using the iterative feature selection and SVM classifier achieves the highest performance.

In addition, we studied the difference between the first and last 10 minutes of the preictal hour (early and late preictal) to be able to have an estimate of the exact onset time rather than just predicting the occurrence possibility without a time measure.

The contents of this thesis can be described as follows:

Chapter 1 gives an introduction to the research in this thesis.

Chapter 2 contains biological and theoretical background of topics involved in the thesis' work.

Chapter 3 discusses the implementation and results of using different seizure prediction methods and features of wavelet coefficients that were previously introduced in the literature, and demonstrates our results of these methods on our used data.

Chapter 4 introduces a new approach in seizure prediction using zero-crossings of wavelet detail coefficients. It also discusses the use of autoencoders in feature reduction.

Chapter 5 studies the classification of preictal data to early and late preictal to have more accurate measure of the onset time.

Finally, chapter 6 gives a conclusion for the thesis' work, and potential directions and enhancements for future work.

Key words: Epilepsy; seizure prediction; wavelets; classification; Preictal classification; Autoencoders.