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An epileptic seizure detection system based on cepstral analysis and generalized regression neural network

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ABSTRACT

This study introduces a new and effective epileptic seizure detection system based on cepstral analysis utilizing generalized regression neural network for classifying electroencephalogram (EEG) recordings. The EEG recordings are obtained from an open database which has been widely studied with many different combinations of feature extraction and classification techniques. Cepstral analysis technique is mainly used for speech recognition, seismological problems, mechanical part tests, etc. Utility of cepstral analysis based features in EEG signal classification is explored in the paper. In the proposed study, mel frequency cepstral coefficients (MFCCs) are computed in the feature extraction stage and used in neural network based classification stage. MFCCs are calculated based on a frequency analysis depending on filter bank of approximately critical bandwidths. The experimental results have shown that the proposed method is superior to most of the previous studies using the same dataset in classification accuracy, sensitivity and specificity. This achieved success is the result of applying cepstral analysis technique to extract features. The system is promising to be used in real time seizure detection systems as the neural network adopted in the proposed method is inherently of non-iterative nature.

1. Introduction

The International League Against Epilepsy (ILAE) and the International Bureau for Epilepsy (IBE) agreed on the definitions of both epileptic seizure and epilepsy which state epileptic seizure as ''*a transient occurrence of signs and/or symptoms due to abnormal excessive or synchronous neuronal activity of brain*'' and also epilepsy is defined as ''*a disorder of the brain characterized by an enduring predisposition to generate epileptic seizures and by neuro-biologic, cognitive, psychological, and social consequences of condition*'' [1]. Nearly, one percent of the world population suffers from epilepsy disease [2].

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Epilepsy patients suffer from physical, psychological and social consequences [2] of this disease. Such patients are in need of somebody in their daily lives. Because of the irregular and unpredictable nature of the disease, it is almost impossible to take measures against it. For the complexity of the behavior of the patients, it is not easy to make decisions about the disease. Thus, the aim of the work is to assist the medical professionals in diagnosis.

Misdiagnosis and mistreatment are harmful to the health of patients due to side-effects of drugs taken in the treatment course of the disease [1]. Thus, efforts concerning the correct diagnosis and treatment of the disease become of more importance.

Timely diagnosis of epileptic seizures occurrence is one of the main challenges. Since it has an irregular and unpredictable nature, detection of epileptic seizures is essentially performed by medical specialists manually reading the electroencephalogram (EEG) recordings, which is a time-consuming process and mainly depends on the experience of the specialists. Therefore, automatic seizure detection from EEG recordings is a necessity for the comfort of patients and medical professionals.

In the diagnosis of epilepsy disease, EEG signals taken from the scalp, called as scalp EEGs, should be analyzed in detail. An EEG signal carries lots of information about the electrical activities of human's brain. Although these electrical signals typically are of low frequency and non-stationary, their processing requires heavy computational task. Visual inspection of EEG recordings is usually performed by medical specialists. Thus, real time processing is hard to realize.

Thus, it is of great significance to develop automatic seizure detection systems for epilepsy disease in order to preclude the possibility of any missing information and clues about patients so that chance of timely diagnosis could be maximized and consequent possible treatment plan could start earlier. The most important part of seizure detection systems is the phase of feature extraction from EEG signals. Therefore, the main challenge is on designing and adopting the proper feature extraction approach, which would well characterize low-frequency non-stationary signals and extract the most useful information from them.

The rest of the paper is organized as follows. Section 2 covers related works presented in literature. Section 3 introduces the proposed seizure detection model and the dataset used. The model validation and experiments are demonstrated in Section 4. Finally, conclusion and future work being under study are summarized in Section 5.

2. Literature review

Researches on automatic epileptic seizure detection systems date back to 1970s. Various studies have been done until now. Costa et al. [3] tried to classify patients into four possible epileptic behaviors named inter-ictal, pre-ictal, ictal and post-ictal. In order to achieve successful results, they have utilized EEG signals and extracted only 14 features from different concepts. Of these features, four were extracted with signal energy, eight extracted using wavelet transform and last two attained from using nonlinear system dynamics. After normalizing, these features were fed to 6 different types of artificial neural network (ANN) with 3 different success metrics named sensitivity, specificity and accuracy. Two different patient data sets were used for training and tests. Authors concluded that 99% of success achieved. However, their classifier developed for one patient has failed in the test of other patients, presenting patient-specific classifier.

In the work of Tzallas et al. [4], it has been aimed to detect existence of the seizure. In order to attain better results, first of all, time frequency (TF) analysis of the EEGs was done to get the spectrums. Features of these spectrums were extracted using fractional energy on TF windows. Smoothed pseudo-Wigner–Ville distribution (SPWVD) was exploited to draw out features from spectrums. Obtained features were further fed to principal component analysis (PCA) to reduce the dimensions of the features. Afterwards, feed-forward ANN was utilized to classify the signals. Performance metrics such as sensitivity, specificity and selectivity were used and results ranging from 97% to 100% were attained. Besides, some artifacts in the EEGs have been removed manually after visual inspection. Authors asserted that their methodology has promising potential and needs further evaluation.

In the study presented by Murugavel and Ramakrishnan [5], the same dataset was employed to classify epileptic seizure making use of wavelet transform, approximate entropy (ApEn) and probabilistic neural network (PNN). After exposing EEG signals to wavelet transform, their features were extracted using ApEn, and the best thirty features were selected for further to be processed in ANNs. This new selection process involves choosing the features having the minimal variance within the class and maximum absolute difference between classes. System evaluation metric was only based on the accuracy as high as 100%.

Two neural networks were compared for their classification performance for epileptic seizure detection, namely time delay neural network (TDNN) and PNN by Goshvarpour et al. [6]. Lyapunov exponents and entropy were used for feature extraction. In that study, it has been shown that PNN has superior performance in classification, despite the fact that the sigma value has been derived by trial and error.

In the work of Patil and Khadse [7], the same EEG dataset was utilized to classify epileptic seizure using two neural networks which are Elman and PNN. The EEG signals were first presented to the ApEn for feature extraction, and then these features were fed to the networks as input for classification. Sensitivity, specificity and overall accuracy were used as performance metrics and they obtained high accuracy even for real time applications.

Bao et al. [8] used the same dataset to establish an automated epilepsy diagnosis system. Features of EEG signals were extracted using four concepts namely power spectral features, fractal dimensions, Hjort parameters and lastly mean and standard deviation. 38 features were obtained from these methods. All these features were normalized before they were fed to PNN. The classifier was validated using leave-one-out cross-validation (LOO-CV). As conclusion, an automated EEG diagnostic system for epilepsy with an accuracy of 99.5% has been achieved.

Guo et al. [2] explored a new scheme of automated seizure detection for epilepsy disease. The scheme utilized wavelet