Evidence-Based Combination of Weighted Classifiers Approach for Epileptic Seizure Detection using EEG Signals

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ABSTRACT

Different brain states and conditions can be captured by electroencephalogram (EEG) signals. EEG-based epileptic seizure detection techniques often reduce these signals into sets of discriminant features. In this work, an evidence theory-based approach for epileptic detection, using several classifiers, is proposed. Within the framework of the evidence theory, each of these classifiers is considered a source of information and given a certain weight based on both its overall classification accuracy as well as its precision rate for the respective brain state. These sources are fused using the Dempster’s rule of combination. Experimental work is done where five time domain features are obtained from EEG signals and used by a set classifiers, namely, Bayesian, K-nearest neighbor, neural network, linear discriminant analysis, and support vector machine classifiers. Higher classification accuracy of 89.5% is achieved, compared to 75.07% and 87.71% accuracy obtained from the worst and best used classifiers.

Keywords: Classifiers Combination, Decision Fusion, EEG Signal Classification, Epileptic Seizure Detection, Evidence Theory, Soft Computing.

INTRODUCTION

Brain injury disturbs the nervous system and is considered the main cause of a well-known neurological condition called epilepsy. It has been reported that medication is of no help to 30% of those affected by the epileptic disease (about 1% of the world population) (Adeli et al., 2003). Depending on the patient condition, epilepsy, also known as a seizure disorder, can be determined after the occurrence of one
seizure. Electroencephalogram (EEG) signals can provide significant information regarding the electrical activities generated by the cerebral cortex nerve cells. As such, the EEG signals are considered as one of the most important physiological signals used for the purpose of epilepsy detection (Sadati et al., 2006). However, the visual inspection of EEG recordings for epileptic-related features is difficult and time consuming. Moreover, different bio-signals may exhibit disagreements regarding the same condition. Consequently, machine intelligence techniques are proposed to enhance the epileptic seizure detection process. To obtain useful features, most of the techniques reported in the literature first transform the EEG signals into the frequency domain, which contains some characteristics of waveforms that fall primarily within four frequency bands (Sadati et al., 2006). In Pregenzer and Pfurtscheller (1999), a one-second time window was used for classification. The data in the window was first transformed into the frequency domain by fast Fourier transformation (FFT), where the frequency components from 9 to 28 Hz (20) were studied. The features were then used by a modified version of Khonen’s learning vector quantization classifier to discriminate between a limited number of different brain states. Poliker et al. have proposed the use of an ensemble based data fusion approach for early diagnosis of Alzheimer’s disease (Poliker et al. 2006). The event related potentials recorded from the Pz, Cz, and Fz electrodes of the EEG were decomposed into different frequency bands using multi-resolution wavelet analysis (discrete wavelet transform DWT). The data fusion approach includes generating multiple classifiers trained with selected subsets of the training data from each source, which are then combined through a modified weighted majority voting procedure. The best classification accuracy reported was 79.2%. For the fuzzy neural network classifier presented in Sadati et al. (2006), the signals decomposed into five levels using Daubechies 4 (DB4) wavelet filter. The energy of details d1, d2, d3, d4, d5 and approximation a5 (in total 6 features) were used as the input features. The classification accuracy achieved, using artificial neural networks, is 85.9%.

EEG time-domain feature-based approaches have also been reported in the literature. In a Brain Computer Interface (BCI) application (Vidaurre et al., 2009), a feature called Time Domain Parameter (TDP) is introduced to a Linear Discriminant Analysis (LDA) classifier. The TDP is a generalized form of the Hjorth parameters and can be computed efficiently. In Valderrama et al. (2012), time and frequency domain features are used for seizure classification. Time domain features such as the first, second, third, and fourth statistical moment of EEG amplitudes, (i.e., mean, variance, skewness, and kurtosis, respectively), along with long term energy and other frequency domain features were calculated and fed to a support vector machine classifier.

In this paper, a novel evidence theory-based approach is introduced for classifying EEG signals into two categories, normal and epileptic. The evidence theory provides a general framework within which pieces of evidence provided by different information sources are combined (Shafer, 1976). To handle conflict that may arise among the information sources, the evidence theory also introduces a discounting scheme. The theory has been applied in different problem domains (Benmokhtar & Heut, 2006; Cayuela et al., 2006; Du & Chen, 2008). In this work, a set of time-domain features (including summation, mean, standard deviation, zero crossing, and energy) are extracted from an EEG benchmark dataset. Using these features, five classifiers; namely, the Naïve Bayesian (NB), k-nearest neighbor (KNN), multiple perceptron (MLP) artificial neural networks, linear discriminant analysis (LDA), and support vector machine (SVM) are trained for the purpose of epileptic detection. First, a subset of features are selected for each classifier in order to obtain high overall classification accuracy for each individual classifier. Classification accuracy of 89.5% is achieved by the proposed approach, introducing an improvement of 3.6% over the best known result; reported in Sadati et
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