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Genetic algorithms tuned expert model for detection of epileptic seizures from EEG signatures

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ABSTRACT

The uncontrolled firing of neurons in brain leads to epileptic seizures in the patients. A novel scheme to detect epileptic seizures from back ground electroencephalogram (EEG) is proposed in this paper. This scheme is based on discrete wavelet packet transform with energy, entropy, kurtosis, skewness, mean, median and standard deviation as the properties for creating features of signals for classification. Optimal features are selected using genetic algorithm (GA) with support vector machine as a classifier for creating objective function values for the GA. Clinical EEG data from epileptic and normal subjects are used in the experiment. The knowledge of neurologist (medical expert) is utilized to train the system. To evaluate the efficacy of the proposed scheme, a 10 fold cross-validation is implemented, and the detection rate is found 100% accurate with 100% of sensitivity and specificity for the data under consideration. The proposed GA-SVM scheme is a novel technique using a hybrid approach with wavelet packet decomposition, support vector machine and GA. It is novel in terms of selection of features sub set, use of SVM classifier as objective function for GA and improved classification rate. The proposed model can be used in the developing and the third world countries where the medical facilities are in acute shortage and qualified neurologists are not available. This system can be helpful in assisting the neurologists in terms of automated observation and saving valuable human expert time.

1. Introduction

Electroencephalogram (EEG) was first measured in humans by German psychiatrist Hans Berger [6] in 1929. It gives an insight into the neural activity in brain and is a non-invasive method to study cognitive processes and the physiology of the brain. It gives very useful information related to brain dynamics and different physiological and psychological aspects of the brain. Epilepsy is a chronic disorder characterized by recurrent seizures, which may vary from a brief lapse of attention or muscle jerks, to severe and prolonged convulsions in the body [47]. The seizures are caused by sudden, usually brief, excessive electrical discharges in a group of brain cells (neurons) (Cited in WHO: http://www.who.int/topics/epilepsy/en/). More than 1% (50 million people) of the world's population is affected by epilepsy [44]. Eighty percent of the epileptic seizure activity can be controlled or treated effectively, if properly detected and diagnosed (cited in WHO: http://www.who.int/topics/epilepsy/en/) [47]. The acute shortage of medical facilities in the developing and third world countries is the major cause of deaths. Even if the basic facilities of medical help may be present in some parts of these countries, yet trained neurologists are present only in super specialty hospitals in big cities. A neurologist inspects the EEG recordings over time to assess and diagnose various ailments related to brain and thereby decides the course of treatment and evaluates the pre-surgical conditions of patient if surgery is required. In rural and remote areas, some form of automated system of diagnosis of severe illness like epilepsy is required which can be operated by skilled or semi-skilled medical persons. Other benefits of designing an automated expert system are to help the neurologist to effectively assess the condition, to reduce the requirement for storage of data and to save time of manual inspection.

Many approaches towards automatic detection of this disease are reported in literature [1,3,16,18–20,23,31,32,35,37,52]. In this paper, a novel scheme is proposed, which uses the knowledge of a trained neurologist about the epileptic and non-epileptic subjects for training of the system, and once trained, it can detect epileptic seizures. The performance of an epileptic seizure detection system depends on features extraction and features selection. In this paper, the use of discrete wavelet packet decomposition with energy, entropy, kurtosis, skewness, mean, median and standard deviation, as properties for creating the feature set is proposed. A genetic

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algorithm with adaptive probability of mutation is used as the optimization algorithm for selecting optimal feature set to present to the classifier so as to maximize the classification accuracy. Support vector machine is used as a classifier for each set of values stored in each chromosome and the classification rate is chosen as the objective function value for the GA. The data of epileptic and non-epileptic subjects are taken from Andrzejak website as given in [40]. The proposed GA-SVM technique outperforms the results of recent approaches reported in [20,37,52]. In the present approach, optimal selection of feature sub set is employed, so it outperforms the approaches of [4] in terms of feature set and also in terms of correct classification rate. The proposed approach outperforms the reported techniques in that it gives 100% correct classification rate whereas the earlier approaches reported the same between 73% [37] and 99.33% [47]. The paper is organized in six sections starting with introductory section followed by literature survey and state of the art in Section 2. Data and methods are given in Section 3 followed by optimization of features selection in Section 4. Section 5 deals with experimental results and Section 6 presents conclusions and future directions.

2. Literature survey and state of the art

Richard Canton, an English physician, discovered electrical currents in the brain in 1875. Electroencephalogram (EEG) was first recorded [6] in 1929, and paved the way for studying electrical signals related to the cognitive and brain activities. EEG is a non-invasive method giving a lot of information related to the different physiological states and complex dynamical behaviour of the brain. EEG recorded over a long time span is very important for monitoring incidental disorders like epileptic seizures which are not permanently present in the recordings. EEG data for long periods of time is visually inspected by trained neurologists for detecting epileptic seizures and pre-surgical evaluation of epilepsy patients, and used for clinical diagnosis and possible treatment plans. This is a time consuming and very costly process. Efforts for predicting the epileptic seizures were first time reported in 1975 [43]; however, further attention was paid by researchers and clinical neurologists during 1990s. A recent approach (2012) presented in [52] employs a tunable support vector machine classifier for epileptic seizure detection, and gives correct classification rate of 98.72%. Tapan et al. [47] recently proposed a scheme based on discrete wavelet transform (DWT) and energy estimation at each node of the decomposition tree followed by application of probabilistic neural network (PNN) for classification, giving classification rate of 99.33%. Recently Zandi et al. reported predicting of epileptic seizures in scalp EEG based on a Variational Bayesian Gaussian mixture model of zero-crossing intervals [1]. An 8-channel scalable EEG acquisition SoC (System-on-Chip) with patient-specific seizure classification and recording processor is presented in [23]. An EEG classification system based on Wavelet-CSP for hand movements is presented in [36]. Neonatal seizure detection is addressed in [32]. The canonical correlation is used in [16], while in [35], detection of epileptic spikes by magnetoencephalography and electroencephalography (EEG) is explored. A data driven approach for identification of pre-seizure states in epilepsy is presented in [19]. Recurrent neural network based prediction of epileptic seizures in intra- and extra-cranial EEG is reported in [3].

A comparative study based on the field of seizure prediction using statistical validation of event predictors is given in [18]. A comparative analysis of feature selection from EEG, using mutual information and support vector machine is presented in [7]. Prediction of epileptic seizures using accumulated energy in a multi-resolution framework is presented in [45]. Some approaches for seizure detection like Phase space topography and the Lyapunov exponent of electrocorticograms [30], computer analysis of EEG signals with parametric models [2], artificial neural networks [38], non-linear time series analysis [24,26,33], recurrence quantification analysis [51], synchronization in intracranial electroencephalogram recordings [15] have been reported in literature. Nonlinear dynamics and chaos are used in [24,26,30,51], phase coherence in [32], and time domain analysis in [4,5], for seizure detection based on EEG. Various soft computing approaches for scalp EEG processing are explained in [25]. EEG signals are used for classification of BMD and ADHD patients [27]. Seizures anticipation in human neocortical partial epilepsy is addressed in [49]. EEG signals classification using the K-means clustering and a multilayer perceptron neural network model is presented in [48]. The methods reported in [37] by Ocak use genetic algorithms and wavelet transforms but only entropy at different levels of decomposition is taken for preparation of feature sets and a correct classification rate of 73% was achieved. The same authors attempted discrete wavelet transform and approximate entropy leading to an increased classification rate of 96% [20]. In [13], the use of mixture of experts (ME) network structure to guide model selection for classification of electroencephalogram (EEG) signals is illustrated and gives classification rate of 93.17%. In this paper, a novel scheme is proposed based on discrete wavelet packet decomposition of the signals from epileptic and non-epileptic subjects (100 segments each) and then computing the energy and other statistical and non-statistical properties at each node of decomposition tree to create the feature set for classification. The feature set thus created is vast enough, so an optimal selection of the feature sub-set is done by using a GA. This technique outperforms the results of recent approaches reported in [20,37,52]. As there is no feature sub-set selected in the approaches reported in [47], but in the present approach optimal selection of feature sub set is employed, so it outperforms the approaches of [47] in terms of feature set and also in terms of correct classification rate. The proposed approach outperforms the reported techniques in that it gives 100% correct classification rate where as the earlier approaches reported the same between 73% [37] and 99.33% [47].

3. Data and methods

3.1. Data selection

The EEG data used for this work is taken from University of Bonn, Germany, as given in [40] by Andrzejak et al. This data [40],

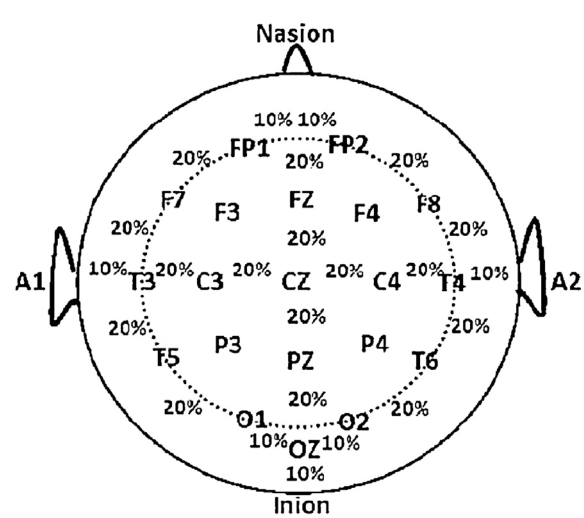

Fig. 1. 10/20 International system of electrode placement.