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A novel genetic programming approach for epileptic seizure detection

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ABSTRACT

The human brain is a delicate mix of neurons (brain cells), electrical impulses and chemicals, known as neurotransmitters. Any damage has the potential to disrupt the workings of the brain and cause seizures. These epileptic seizures are the manifestations of epilepsy. The electroencephalograph (EEG) signals register average neuronal activity from the cerebral cortex and label changes in activity over large areas. A detailed analysis of these electroencephalograph (EEG) signals provides valuable insights into the mechanisms instigating epileptic disorders. Moreover, the detection of interictal spikes and epileptic seizures in an EEG signal plays an important role in the diagnosis of epilepsy. Automatic seizure detection methods are required, as these epileptic seizures are volatile and unpredictable. This paper deals with an automated detection of epileptic seizures in EEG signals using empirical mode decomposition (EMD) for feature extraction and proposes a novel genetic programming (GP) approach for classifying the EEG signals. Improvements in the standard GP approach are made using a Constructive Genetic Programming (CGP) in which constructive crossover and constructive subtree mutation operators are introduced. A hill climbing search is integrated in crossover and mutation operators to remove the destructive nature of these operators. A new concept of selecting the Globally Prime offspring is also presented to select the best fitness offspring generated during crossover. To decrease the time complexity of GP, a new dynamic fitness value computation (DFVC) is employed to increase the computational speed. We conducted five different sets of experiments to evaluate the performance of the proposed model in the classification of different mixtures of normal, interictal and ictal signals, and the accuracies achieved are outstandingly high. The experimental results are compared with the existing methods on same datasets, and these results affirm the potential use of our method for accurately detecting epileptic seizures in an EEG signal.

1. Introduction

The human brain is the most complex organ in the human body, and perhaps the most incredible. It initiates the body movement and regulates the behavioral traits. Electroencephalography (EEG) [1] is the chronicling of electrical activity which holds the information about human brain functionality and the disorders of the nervous system. The electroencephalograph (EEG) deserves mention as one of the first ways

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of non-invasive observing human brain activity. An EEG is a recording of electrical signals from the brain made by hooking up electrodes to the subject's scalp. EEG accurately measures the deviations of electric signals within short period of time through multiple electrodes placed on the human scalp; the changes in these electric signals are measured in terms of voltage fluctuations of brain. The information about the human brain and neurological disorders is brought into being through the output at the electrodes. EEG allows researchers to follow electrical impulses across the surface of the brain and observe changes. An EEG can show the state of a person such as numb, awake, asleep because the characteristic patterns of these impulses vary for the aforementioned states. One important function of EEG is to signify the duration taken by the brain to process various stimuli.

Epilepsy [2] is a brain disorder in which clusters of nerve cells, or neurons, in the brain sometimes signal abnormally. It is a neurological disorder with prevalence of about 1–2% of the world's population [3]. In epilepsy, the normal pattern of neuronal activity becomes disrupted, instigating strange sensations, emotions, and behavior, or sometimes convulsions, muscle spasms, and loss of consciousness. It is characterized by unexpected recurrent and ephemeral disturbances of perception or behavior resulting from excessive synchronization of cortical neuronal networks; it is a neurological condition in which an individual experiences prolonged abnormal bursts of electrical discharges in the brain. The hallmark of epilepsy is intermittent seizures termed *epileptic seizures*. Epileptic seizures are classified by their clinical manifestation into partial or focal, generalized, unilateral and unclassified seizures [4]. Focal epileptic seizures involve only part of cerebral hemisphere and produce symptoms in corresponding parts of the body or in some related mental functions. Generalized epileptic seizures involve the entire brain and produce bilateral motor symptoms usually with loss of consciousness. Both types of epileptic seizures can occur at all ages.

A detailed analysis of the EEG records could provide a valuable insight in predicting seizures. Until now, the exact cause of epilepsy in individuals is unknown and the mechanisms that involved behind the seizures are little understood. Thus, efforts towards its diagnosis and treatment are of significant importance. Developing automatic seizure detection methods [5] is of great significance and can serve as first-rate clinical tools for the scrutiny of EEG data in a more unprejudiced and computationally coherent manner, since visual inspection for discriminating EEG signals is time consuming, imprecise and high costly, especially in the case of long-term recordings (Fig. 1).

In this study, a novel Constructive Genetic Programming (CGP) approach for epileptic seizure detection is proposed. In this, we put forth a new constructive crossover, constructive subtree mutation operators and a dynamic fitness value computation (DFVC) approach and subsequently specify its role in the classification of EEG signals. We initially decompose an EEG signal into set of IMFs by means of Empirical Mode Decomposition (EMD) and extract two bandwidth parameters, namely amplitude parameter (B_{am}) and frequency parameter (B_{fm}) for the classification purpose. The bandwidth parameters, calculated from the respective IMF's of each EEG signal are used as input feature set for the GP classifier to classify the EEG signals. To measure the performance of the proposed algorithm we used an EEG dataset, which is available online [6]. It is observed that the proposed GP approach yielded a very high accuracy for 50–50 training–testing partition, 30–20–50 training–validation–testing partition and for 10-fold cross validation scheme. Measures such as sensitivity, specificity and Mann–Whitney two tailed test are used to validate the performance. To show the dominance of our approach, we compared our method with a Standard Genetic Programming (ST-GP) [7] model, Constructive Crossover and Mutation operators (CCM) [8], Semantic Search Based Genetic Programming (SEM-GP) [9] and also with recently proposed algorithms applied on the EEG database. The results show that our approach works well with the EEG database and can be a good alternative to the well-known machine learning methods. The obtained high accuracies specify the outstanding classification performance of the proposed Genetic Programming approach in comparison with other approaches.

The remainder of this paper is organized as follows: Section 2 describes the related work. Section 3 overviews the essential background of the approach. It describes the Empirical Mode Decomposition and the proposed Constructive Genetic Programming approach. Section 4 presents and analyses the experimental results and finally Section 5 draws conclusion and future work directions.

2. Related work

2.1. Work related to EEG signal

A wide range of methods [10] have been proposed to forecast epileptic seizures by classifying seizure and non-seizure EEG signal which employed univariate techniques, eigen spectra of space delay correlation and covariance matrices [11], Hilbert–Huang transform [12], and autoregressive modeling and least-squares parameter estimator [13].

Kannathal et al. [14] used entropy measures for the feature extraction and developed an Adaptive Neuro-Fuzzy inference system for the classification of EEG signals into normal and ictal. The aim of their work is to compared the different entropy estimators when applied to EEG data from normal and epileptic subjects. Subsequently, Polat et al. [15] employed hybrid system based on decision tree classifier and Fast Fourier Transform (FFT) to improve the accuracy. Chandaka et al. [16] came up with a cross correlation and support vector machine. They demonstrated the idea of using cross-correlation for feature extraction in EEG signal recognition. Wang et al. [17] modified the feature extraction with the use of Wavelet Transform along with Shannon Entropy. Smart et al. [18] demonstrated that implicitly selecting features with a genetic programming (GP) algorithm more effectively determined the proper features to discern biomarker and non-biomarker interictal iEEG and fMRI activity than conventional feature selection approaches. Nicolaou et al. [19] integrated the concept of permutation entropy with the support vector machine to achieve very high classification accuracy. Particle swarm optimization proposed by Ba-Karait et al. [20] was the newest of all the methods which, while using a 10-fold cross validation technique achieved a high classification accuracy