Chapter 2

Automated Classification of Focal and Non-Focal EEG Signals Based on Bivariate Empirical Mode Decomposition

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ABSTRACT

The chapter presents a new approach of computer aided diagnosis of focal electroencephalogram (EEG) signals by applying bivariate empirical mode decomposition (BEMD). Firstly, the focal and non-focal EEG signals are decomposed using the BEMD, which results in intrinsic mode functions (IMFs) corresponding to each signal. Secondly, bivariate bandwidths namely, amplitude bandwidth, precession bandwidth, and deformation bandwidth are computed for each obtained IMF. Interquartile range (IQR) values of bivariate bandwidths of IMFs are employed as the features for classification. In order to perform classification least squares support vector machine (LS-SVM) is used. The results of the experiment suggest that the computed bivariate bandwidths are significantly useful to discriminate focal EEG signals. The resultant classification accuracy obtained using proposed methodology, applied on the Bern-Barcelona EEG database, is 84.01%. The obtained results are encouraging and the proposed methodology can be helpful for identification of epileptogenic focus.

INTRODUCTION

Electrical activities related to different pathological conditions of brain are commonly measured using electroencephalogram (EEG) signals. EEG signals are frequently used for assessment of the different mental states of a person for example (Ahmadlou and Adeli, 2014), autistic spectrum disorder (Ahmadlou

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et al., 2010), Alzheimer disease (Adeli et al., 2008), epilepsy (Adeli et al., 2003) etc. The epilepsy is of two types generalized epilepsy and focal (partial) epilepsy (Badawy et al., 2007). In case of focal epilepsy, limited area of brain gets affected by onset of the epileptic seizures. With the time, approximately 20% patients of generalized epilepsy and 60% patients of partial epilepsy grow immunity for drugs during medication (Pati and Alexopoulos, 2010). For such patients, surgical resection of affected brain region is considered as the therapy option in order to reduce seizure occurrence frequency or get cured (Rosenow and Lüders, 2001). The identification of the epilepsy affected brain region from EEG signals can serve as vital step prior to surgery.

BACKGROUND

Many methods are developed for assessment of the characteristic changes in EEG signals related to epileptic seizure activities. These techniques can be helpful for localization of epileptogenic zone. In (Gutiérrez et al., 2001), the electrocorticography (ECoG) recordings of the 21 patients are studied and processed with wavelet packet functions to characterize the spikes in ECoG segments. The frequency-entropy templates are computed by wavelet packet decomposition and the best basis algorithm for each electrode (Ben-Jacob et al., 2007). It is suggested that epileptogenic focus can be associated with the locations of high template similarity of ictal template. In (Panet-Raymond and Gotman, 1990, Mariani et al., 1992), delta band activities based asymmetry measures are shown as significantly reliable indicator of epileptogenic focus. The EEG recordings acquired from 23 patients are analyzed and it is found that epileptiform oscillations in high-frequency range (60-100 Hz) may be clinically important to localize seizure onset zone in patients affected by neocortical epilepsy (Worrell et al., 2004). In another study (Sabesan et al., 2009), intracranial EEG signals from four epileptic patients are analyzed using surrogate analysis of the transfer entropy to localize the epileptogenic focus. Interelectrode synchrony is studied in (Schevon et al., 2007) and it is speculated that local synchrony can indicate the epileptogenic cortex. In (Warren et al., 2010), neural synchrony measures such as linear mean phase coherence and cross-correlation of local field potentials are investigated using the intracranial EEG recordings, and it is observed that brain region affected by epilepsy is functionally isolated from the remaining brain regions in patient with partial epilepsy.

Several nonlinear parameters are used to quantify the change in dynamics of the cortex like correlation dimension and measurement of complexity loss (Lehnertz and Elger, 1995, Widman et al., 2000). Functional connectivity patterns obtained by analyzing EEG signals are used to predict the seizure activity and localization of the seizure onset zone (van Mierlo et al., 2014). In (van Mierlo et al., 2013), effective connectivity patterns are computed for the first 20 seconds of ictal intracranial EEG signals from eight patients and ictal onset zone is localized considering the highest total out-degree. The focal and non-focal EEG signals refer to intracranial recordings acquired from the patients of pharmacoresistant focal epilepsy (Andrzejak et al., 2012). The focal EEG signals and non-focal EEG signals are denoted by $X_f$ and $X_{nf}$ respectively. It should be noted that $X_f$ signals refer to the recordings of electrodes where changes related to seizure onset are detected. The EEG recordings of the electrodes from other brain areas that are not associated with the seizure onset referred as $X_{nf}$ signals (Andrzejak et al., 2012). By performing classification of $X_f$ and $X_{nf}$ signals one may identify focal and non-focal regions. Therefore, it can help in determination of epileptogenic focus.