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Dynamical Feature Extraction from Brain Activity Time Series

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INTRODUCTION

Neurologists typically study the brain activity through acquired biomarker signals such as Electroencephalograms (EEGs) which have been widely used to capture the interactions between neurons or groups of neurons. Detecting and identifying the abnormal patterns through visual inspection of EEG signals are extremely challenging and require constant attention for well trained and experienced specialists. To resolve this problem, data mining techniques have been successfully applied to the analysis for EEG recordings and other biomarker data sets. For example, Chaovalitwongse et al., (2006; 2007), Prokopyev et al., (2007) and Pardalos et al., (2007) reported the EEG patterns can be classified through dynamical features extracted from the underlying EEG dynamical characteristics. Moreover, in the area of cancer research, Busygin et al., (2006) showed promising results via Bi-clustering data classification technique using selected features from DNA microarrays. Ceci et al., (2007); Krishnamoorthy et al., (2007) also reported that data mining techniques enable protein structure characterization and protein structure prediction. From data mining aspects, feature extraction and selection for time series data sets not only play an important role in data preprocessing but also provide opportunities to uncover the underlying mechanisms of data under study. It also keeps the essential data structure and makes a better representation of acquired data sets that need to be classified.

In this work, the properties and descriptions of the most common neurological biomarker namely EEG data sets will be given as well as the motivations and challenges for abnormal EEG classification. The dynamical features for EEG classification will be reviewed and described in the second part of this work. The described dynamical features can also be applied to other types of classification applications for discovering the useful knowledge from obtained data sets. Finally, the potential applications for EEG classification will be discussed and comments for further research directions will be given in the future trends and conclusion sections.

BACKGROUND

Epilepsy is a common neurological disorder, affecting about 50 million people worldwide (WHO, 2005). Anti antiepileptic drugs (AEDs) are the mainstay of contemporary treatment for epilepsy, it can reduce frequency of seizure and prevent seizure recurrence in most cases. For subjects with uncontrolled seizures, ablative surgery is considered after two or more AEDs have failed to result for seizure freedom. The EEG (see Fig. 1 for an example) is a key tool in diagnosing seizure disorders and contributing tremendously to surgical decisions in patients with intractable epilepsy. The EEG recordings provide information about underlying interactions among neurons around the recording electrodes as a function of time. By carefully investigating EEG patterns, the spatio-temporal neuronal electrical activities can be decoded and abnormal patterns can be captured for diagnostic purposes (Berger, 1929). Through nonlinear dynamical features, data mining techniques have

Figure 1. An example of 10 second, 32-channel intracranial EEG display

made progresses in shedding light on hidden patterns in EEG recordings for such neurological disorders (Chaovalitwongse et al., 2006; 2007).

Nonlinear nature of EEG recordings has been shown by multiple researchers (Casdagli et al., 1997; Liu et al., 2007), features generated from nonlinear dynamics have also been shown to have high applicability for EEG analysis with promising results both on classifying and predicting epileptic seizures in EEG recordings (Iasemidis et al., 1990, 2003(a),2003(b), 2004; Le Van Quyen et al., 1998, 2005; Sackellares et al., 2006; Chaovalitwongse et al., 2006, 2007; Pardalos et al., 2006, 2007). The abnormal activities detected by nonlinear dynamical methods which are not able to achieve by traditional linear measurements. Classifying through these nonlinear characteristics in the feature space, the abnormal EEG pattern can be exploited and distinguished from the normal activity in the brain.

MAIN FOCUS

The spatio-temporal nonlinear dynamics has been steadily involved in EEG analysis from its conception in the 1970s, to proof-of-principle experiments in the late 1980s and 1990s, to its current place as an area of vigorous, clinical and laboratory investigation. A specific standard for future epilepsy research was to validate the presences of abnormal brain activities and eventually link them with treatment strategies that interrupt the abnormal activities (Seref et al., 2007). Results from many studies in data mining fluctuate broadly from their theoretical approaches to the problem, the amount of data analyzed and validation of the results. Relative weaknesses in this field include the lack of extensive testing on baseline data, the lack of technically rigorous validation and quantification of algorithm performance in many published studies, and the lack of methods for extracting the useful information from multi-channel and multi-feature data sets for the data per-processing. Classifications through constructed feature space, the domain of the system and solution to

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