Chapter 2
Methodology for Epilepsy and Epileptic Seizure Recognition using Chaos Analysis of Brain Signals

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ABSTRACT

A novel combination of chaotic features and Adaptive Neuro-Fuzzy Inference System (ANFIS) is proposed for epileptic seizure recognition. The non-linear dynamics of the original EEGs are quantified in the form of the Hurst exponent (H), Correlation dimension (D2), Petrosian Fractal Dimension (PFD), and the Largest lyapunov exponent (λ). The process of EEG analysis consists of two phases, namely the qualitative and quantitative analysis. The classification ability of the H, D2, PFD, and λ measures is tested using ANFIS classifier. This method is evaluated with using a benchmark EEG dataset, and qualitative and quantitative results are presented. The inter-ictal EEG-based diagnostic approach achieves 98.6% accuracy with using 4-fold cross validation. Diagnosis based on ictal data is also tested in ANFIS classifier, reaching 98.1% accuracy. Therefore, the method can be successfully applied to both inter-ictal and ictal data.

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INTRODUCTION

Epilepsy is a brain disorder that is characterized by sudden and recurrent seizures. According to available reports, “approximately 1% of the world’s population suffers from epilepsy” (University of Melbourne) while about 85% of them live in the developing countries (Atlas, 2005). It can cause abnormal electrical activity in the brain and may alter consciousness, perception, sensation, behavior and body movement. Patients experience varied symptoms during seizures depending on the location and extent of the affected brain tissue. Most seizures are very brief and is rarely life threatening. Depending on the extent of the involvement of brain areas during the epilepsy, it can be divided into two main types that according to the International League Against Epilepsy (ILAE), in 1981 (ILAE, 1909) includes: 1- Generalized seizures that involve almost the entire brain, 2- Partial (or focal) seizures that originate from a circumscribed area of the brain and remain restricted to that area (Guo, 2010). Generalized seizures can be divided into several main types, such as Absence, Atypical Absence, Myoclonic, Clonic, Tonic, Tonic-clonic, and Atonic seizures. Also, Partial seizures can be divided into three main types such as Simple partial, Complex partial, and Secondarily generalized seizures.

Due to a large number of patients in Intensive Care Units (ICU) and the need for continuous observation of such conditions, several methods for epileptic seizure recognition have been developed in the past. Several quantitative system approaches incorporating statistical techniques, dynamical systems and optimization for brain disorders (Chaovatalitwongse, 2005). In assessment of epilepsy, brain activity plays a central role. Electroencephalography (EEG) is a technique, which contains much information about the patient’s psycho-physiological state (Kumar, 2011). Therefore, EEG has become the premier diagnostic method for epilepsy recognition. EEG can be recorded in two essential ways: The first and most common is non-invasive recording known as scalp recording. The second is invasive recording that often is known as inter-cranial EEG. Frequency bands of EEG signals are interesting to be interpreted such as delta (1-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz) and gamma (> 30 Hz).

In principle, there are two different scenarios of how a seizure could evolve. It could be caused by a sudden and abrupt transition, in which case it would not be preceded by detectable dynamical changes in the EEG. Such a scenario would be conceivable for the initiation of seizures in primary generalized epilepsy. Alternatively, this transition could be a gradual change in dynamics, which could in theory, be detectable. This type of transition could be more likely in focal epilepsies. About dynamical states of epileptic EEG signals, there are some main classic states of inter-ictal, pre-ictal, ictal, and post-ictal; but clinical and laboratory experiments leave little doubt that a pre-seizure period exists in temporal lobe and perhaps other forms of epilepsy. Its existence, however, raises fundamental questions about what constitutes a seizure, what brain regions are involved in seizure generation, and whether discrete inter-ictal, pre-ictal, ictal, and post-ictal physiologies exist, or blend together in a continuous process (Litt, 2002).

Feature extraction process plays a very important role on the classification performance. In this book chapter, Non-linear measures like Correlation dimension, Fractal dimension, Hurst exponent and Lyapunov exponent, quantify the degree of complexity in a time series. Features are selected so that they capture the differences between the epileptic and normal EEG. Fuzzy set theory plays an important role in dealing with uncertainty when making decisions in medical applications. Fuzzy sets have attracted the growing attention and interest in modern information technology, production technique, decision making, pattern recognition, diagnostics, and data analysis. Neuro-fuzzy systems are fuzzy systems which