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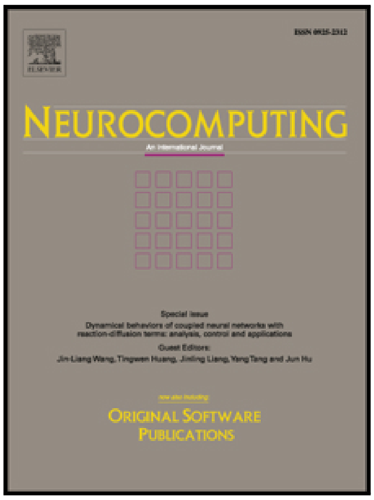

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Chaos Feature Study in Fractional Fourier Domain for Preictal Prediction of Epileptic Seizure

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***Abstract*—Epileptic seizure prediction are limited by the unstable performance of suboptimal models. Studies of new methods for reliable preictal prediction have significant impact on the control, early care and online treatment of epileptic seizure. The traditional chaos measure does not effectively identify multiple states of epileptic electroencephalogram (EEG). A novel method was adopted to capture subtle chaotic dynamics for epileptic signals in fractional Fourier transform domain. Algorithm of the largest Lyapunov exponent was modified to adapt the transformed series by using an energy measure to determine appropriate fractional order. The performance of our proposed method was evaluated with an automatic model of preictal prediction using artificial neural networks as classifier. The results showed that the new model yielded higher accuracy in identifying the preictal state compared to the original largest Lyapunov exponent. Experimental results with noisy scalp epileptic EEGs also demonstrated the potential and robustness of our approach to discriminate preictal from interictal and ictal states, and it provided a novel methodology for reliable preictal prediction of epileptic seizure.**

***Index Terms*—chaos, fractional Fourier transform, largest Lyapunov exponent, epilepsy, seizure prediction**

I. Introduction

Epilepsy, the second most common neurological disorder after stroke, affects almost 60 million people world wide and occurs in all age groups [1]. Characterized by recurrent and abrupt seizure, this serious disorder poses life-threatening danger for the patients and limits their social and vocational activities. If seizure could be predicted reliably, not only will it improve patients' quality of life by taking preventive measures, but also have a far reaching impact on control and treatment of epilepsy [2]. Although the problem of automated seizure prediction remains unsolved and challenging, it is feasible to develop methods that have much higher sensitivity and accuracy than what's been currently used, and methods for preictal prediction of epileptic seizure is the most important among all the critical factors for improving reliability [3, 4].

Identifying preictal state from scalp or intracranial electroencephalogram (EEG) had been the goal of many researches, since it was not only a crucial step in modelling research for seizure prediction of epilepsy, but also helpful to evaluate the performance of algorithm that was applied to extract feature information from it. Specifically, methodology adopted by many researches for preictal prediction can be summarized as: 1) extracting measurements from EEG signals by utilization of specified algorithms; 2) classifying ensued features into relevant epileptic states [5, 6].

There had been two main approaches used to extract univariate features for preictal prediction of seizure in the literature. One of them was linear technique, which used linear signal processing method to quantify changes of EEG. Spike rate, spectral power of different EEG frequency bands, accumulated energy, and autoregressive coefficients were among the linear measures [7-11]. Linear measures had the advantage of simple implementation and low cost of computation, whereas application of related measures was restricted by susceptibility to noise and difficulty in tackling patient-specific parameter configurations. The other approach used nonlinear theory to characterize dynamics of epileptic EEG, which included Lyapunov exponent, dimension, entropy, complexity, as well as dynamic similarity index [12-16]. These measures had merits such as characterizing the uncertainty of the EEG signal, quantifying chaotic dynamics with prominent robustness, therefore rendered higher seizure predictability [17, 18]. However, a considerable increase in computation cost was needed than linear ones. For different states during the transition of epileptic seizure, the corresponding dynamic properties of EEG signals were complex, and some even represented too weak characteristic to be discerned, and this made method study more difficult and intricate.

Recently, new techniques for preictal prediction had been intensively investigated with linear and nonlinear analysis. Valuable works in this field included: relative spectral power with support vector machine (SVM) [19], sample entropy with extreme learning machine [20], linear frequency using *k*-nearest neighbor (*k*-NN)-based undersampling combined with SVM [21], the dynamical similarity of zero-crossing intervals on a variational Bayesian gaussian mixture (VbGm) [22], wavelet energy and entropy [23], approximate entropy

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