Chapter XLI
Nonlinear Signal Processing Techniques Applied to EEG Measurements

Christos L. Papadelis
Aristotle University of Thessaloniki, Greece

Chrysoula Kourtidou-Papadeli
Greek Aerospace Medical Association and Space Research, Greece

Panagiotis D. Bamidis
Aristotle University of Thessaloniki, Greece

Nicos Maglaveras
Aristotle University of Thessaloniki, Greece

ABSTRACT

The electrical activity of the brain is sensitive to its oxygen supply, and electroencephalography (EEG) has been proposed as a suitable measurement to detect brain activity alterations induced by hypoxia. Since, linear processing techniques that have been used so far in hypoxia studies are based on false linearity assumptions about the generation of the EEG signal, there is a definite need for nonlinear approaches to be applied on EEG data derived from hypoxic conditions. The aim of the present study is to compare nonlinear techniques' effectiveness to identify significant variations in EEG due to hypoxia. EEG data from two channels were derived from ten healthy subjects participated in the present study. Oxygen and nitrogen mixture was used to simulate hypoxic conditions that correspond to an altitude of 25.000 feet. Non-linear measurements such as correlation dimension, approximate entropy, Lyapunov exponent and detrended fluctuation analysis (DFA) parameters were estimated for EEG signals. The results of the present study confirm the effectiveness of nonlinear techniques to identify significant variations in EEG, which reflect alterations in cerebral function induced by cerebral hypoxic conditions.

INTRODUCTION

It has been well over a century since it was discovered that the mammalian brain generates a small but measurable electrical signal (Gloor, 1969). The technique of measuring this electrical activity, called electroencephalography (EEG), is a sensitive but nonspecific measure of brain function, and it is widely applicable in the clinical diagnosis of brain disorders and in brain physiological processes research. Nevertheless, in most of the applications used so far, the EEG recordings result in long traces with marked interobserver variability (Williams, Luders, Brickner, Goormastic, & Klass, 1985). The need for more specific, compact, and reliable medical information derived from EEG has been partially satisfied by quantitative EEG analysis (qEEG). This technique has been confined to feature analysis, conventional power spectrum analysis, parametric description of EEG, or frequency analysis (Geocadin et al., 2000). The theory of linear stochastic processes had led to the development of a collection of tools and techniques for the analysis of EEG. Basically, these were tools for a precise description of the deterministic and stochastic aspects of given time series, and, unfortunately, were based on very simple assumptions about the system (brain) that produced the EEG signal (linearity assumption). Although linear techniques contribute a lot in EEG applicability in clinical practice, the brain's electrical activity presents aperiodic waveforms that suggest its origin in chaotic dynamics (Galka, 2000).

One of the most important mathematical discoveries of the past few decades is that random behaviour can arise in deterministic nonlinear systems with just a few degrees of freedom. The broad spectra and aperiodic oscillations that are observed in recordings of brain activity have suggested to many researchers the possibility that this activity is generated by nonlinear dynamic systems governed by chaotic attractors (Henry, Lovell, & Camacho, 2001). The contribution of models derived from deterministic chaotic systems, such as the Lorentz, Rössler, and Chua attractors, was of fundamental importance for the development of nonlinear signal-processing techniques.

Nonlinear dynamics help us to understand that irregular and seemingly unpredictable time evolutions do not necessarily have to be a result of pure randomness, but on the contrary, can be the result of completely deterministic and fairly simple (low-dimensional) dynamical systems. Moreover, the unpredictability of these systems can be explained as their dynamics are strongly dependent on the starting condition (Lorenz, 1963). The theoretical description of this dynamic behaviour is called deterministic chaos (Signorini & Cerutti, 1999).

The essential problem in deterministic chaos is to determine whether or not a given time series is a deterministic signal from a low-dimensional dynamical system. Grassberger and Procaccia (1983) provided a simple algorithm for the estimation of the correlation dimension from time series. Since then, many scientists have presented a large number of studies reporting low dimension in EEG measurements (Babloyantz & Destexhe, 1986; Babloyantz, Salazar, & Nicolis, 1985). It has also been supported that a chaotic and rather high-dimensional EEG characterizes the healthy state of the brain, whereas a reduction of dimension and a tendency toward nonchaotic, periodic dynamics is characteristic of present or imminent pathologies (Galka, 2000). However, the reports of finite dimension in EEG recordings were and are still received with scepticism by several authors working in the field of nonlinear time-series analysis. First, it is hard to believe that a highly complex system as the brain should exhibit as little complexity as, for example, the Lorentz system (Kantz &

Related Content

Determinants of Time-to-Under-Five Mortality in Ethiopia: Comparison of Parametric Shared Frailty Models

Abebe Argaw Wogi, Shibru Temesgen Wakweyaand Yohannes Yebabe Tesfay (2018). *International Journal of Biomedical and Clinical Engineering (pp. 1-24).*

www.irma-international.org/article/determinants-of-time-to-under-five-mortality-in-ethiopia/199093

Use of Clinical Simulations to Evaluate the Impact of Health Information Systems and Ubiquitous Computing Devices Upon Health Professional Work

Elizabeth M. Boryckiand Andre W. Kushniruk (2010). *Ubiquitous Health and Medical Informatics: The Ubiquity 2.0 Trend and Beyond (pp. 552-573).*

www.irma-international.org/chapter/use-clinical-simulations-evaluate-impact/42950

The Impact of Professional Certifications on Healthcare Information Technology Use

Neset Hikmetand Anol Bhattacherjee (2009). *Medical Informatics: Concepts, Methodologies, Tools, and Applications (pp. 1646-1656).*

www.irma-international.org/chapter/impact-professional-certifications-healthcare-information/26326

Statistical Based Analysis of Electrooculogram (EOG) Signals: A Pilot Study

Sandra D'Souzaand N. Sriraam (2013). *International Journal of Biomedical and Clinical Engineering (pp. 12-25).*

www.irma-international.org/article/statistical-based-analysis-of-electrooculogram-eog-signals/96825

Personal Health Records Systems Go Mobile: Defining Evaluation Components

Phillip Ollaand Joseph Tan (2009). *Mobile Health Solutions for Biomedical Applications (pp. 45-70).*

www.irma-international.org/chapter/personal-health-records-systems-mobile/26765