Advances in Automobile Engineering

Yang et al., Adv Automob Eng 2012, 1:2
DOI: 10.4172/2167-7670.1000e108

Editorial Open Access

Modeling and Analysis of Time-varying Mechanism With Applications to Neuroimaging Data

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Brain-related diseases such as epilepsy and mental disorders, normally cause suffering and place a huge toll on the health care systems of the world. To find better medical diagnosis and treatments, neuroinformaticians are developing the infrastructure and tools needed to integrate many levels of data and link symptoms to the underlying disease causes. Neuroinformatics, which applies computational tools and approaches that are essential for understanding the brain, integrates information across all levels and scales of neuroscience to help interpret the brain and treat disease. It en-compasses the computational tools and signal processing techniques for data acquisition, tuning the computational mathematical model, feature extraction and classifier training analysis, visualization, modeling and simulation. Signal processing techniques are commonly used for feature extraction in medical diagnosis, cognitive neuroscience and many other application fields. The main purpose of signal processing is to reveal underlying information on specific problems in these applications. In real-world applications and signal processing, a signal is normally assumed to be stationary. However, in many practical applications such as neuroimaging data including EEG, fMRI, this assumption is not always accurate, because relevant statistical characteristics change over the time course, depending on the mental states that are active at any given time instant. Signals with time-varying frequency components are highly non-stationary. Modeling of non-stationary signals is very difficult and reliable parametric models normally do not exist. In practice most of the signals encountered cannot satisfy the stationary assumption conditions, which explains the growing interest in non-stationary signal processing and applications. Time-varying analysis of non-stationary signals is of great interest and is very significant since the time history is a very powerful method in signal characterization.

The key idea of system identification and modeling behind the data-based modeling approach is that the process under study is treated to be a black-box where the underlying dynamics and mechanisms are unknown. The purpose and the ultimate goal of the parametric model for neuroimaging signals with both time-varying linear and nonlinear models combing machining learning techniques decode the brain functional activities in healthy subjects and patients. The integrating research findings from different experimental data are critical to understand the complex details of brain function, further to guide medical diagnosis and therapy for the clinician.

The general objective of this topic is focusing on the desire to take advantage of linear and nonlinear system identification techniques and some machine learning algorithms to obtain the time-varying linear and nonlinear models and Bayesian inference models of the neuroimaging signals that can further capture the dynamics of the signals, and extract the time-varying feature analysis, where data-based modeling and system identification techniques, aimed at building mathematical model based on limited experimental data, provide a powerful tool for neurological data modeling and analysis. Considering the adaptive parametric model method as a feature in the time-varying signals, the approaches for feature extraction are diverse and range from simple, such as the adaptive Kalman filter and recursive least square algorithms, to more complex, such as polynomial wavelet expansion approach. These methods are applied since they can provide and capture more accurate transient results than the traditional time-invariant method.

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Received April 25, 2012; **Accepted** April 25, 2011; **Published** April 26, 2012

Citation: Yang Li, Avesani P, Olivetti E (2012) Modeling and Analysis of Time-varying Mechanism With Applications to Neuroimaging Data. Adv Automob Eng 1:e108. doi:10.4172/2167-7670.1000e108