Recent Surge of Time Series Methods in Neuroscience

- Causal modeling & Time-Varying Innovation Variances -

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1. Introduction

Recent development of measurement technology in brain science has been producing massive time series data. A typical example is MEG/EEG data which are the measurement of the temporal change of electrical and magnetic activity in the brain. The electro-magnetic change is measured at 20 to 100 locations on the surface of the brain at every ten millisecond. Another example is the functional MRI (fMRI) data which is a measurement of the haemodynamics inside the brain, where about 140,000 dimensional time series are generated each 2 or 3 second. To take advantage of these massive data in the neuroscience study, efficient statistical method is expected in the neuroscience community.

Although the expectation to the time series analysts has been strong, it must be admitted that the time series techniques have not been fully exploited in the analysis of neuroscience data. Most commonly used techniques in these studies are not time series oriented. For example ICA(Independent Component Analysis) has been very popular for removing artifact from multi channel time series data, but obviously the dynamic structure of the signal in the data is ignored in the ICA treatment. Another example is the SPM(Statistical Parametric Mapping) methods for the fMRI data analysis, where the main techniques employed are non-dynamic general linear models and spatial statistics methods. Here the stochasticity of dynamics is ignored in the haemodynamics and only measurement noise is allowed to have continuous spectrum to be stochastic.

The authors' interest in the present talk is to show that the same data can be treated from time series view point, and can be modeled efficiently, so that the neural and physiological information can be extracted more efficiently (see references, (1) - (10)). Here the two main typical time series concepts play important role: one is the causal modelling, where the model is dynamic so that the temporal correlation with direction from the past to the future plays essential role. Another important concept is the heteroschedasticity. The time-varying scale of noise variance is typically seen in neural activity. The time series techniques developed in financial data analysis can be efficiently generalized to solve similar heteroschedastic problems in neuroscience data analysis by generalizing the techniques into a state space model framework.

In the present talk, we show how these two main ideas can be utilized in the analysis of consciousness of an anaesthetized patient in the surgery using his (or her) EEG recording. Possibility of the application of the same GARCH type generalization to other problems such as Dynamic Inverse Problem for EEG/MEG, signal decomposition of multi-channel time series are also briefly discussed.

Ackowledgement ; The present work has been done under the financial support from JSPS by the grant Kiban B No.173000922301.

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