Recent Surge of Time Series Methods in Brain Science
-Causal modeling & Heteroscedasticity-

T.Ozaki
Institute of Statistical Mathematics, Tokyo, Japan

K.F.K.Wong
Graduate University of Advanced Studies, Tokyo, Japan

A.Galka
Kiel University, Dept. of Neurology, Germany

R.John
New York University Medical Center, USA

Recent advances in brain science measurement technology have given researchers access to very large scale time series data. One typical example is in the field of MEG/EEG, where the data are measurements of the temporal change of electrical and magnetic activity in the brain. Here dynamic changes in electro-magnetic field may be measured at 20 to 100 locations on the surface of the brain at ten millisecond intervals. Another example is functional MRI (fMRI) where the hemodynamics of the brain give rise to a 140,000 dimensional time series generated every 2 or 3 seconds. To take advantage of these massive data in the neuroscience study, efficient statistical methods have been needed in the neuroscience community. Regrettably, the most commonly used analysis techniques have been non-time series oriented. For example the solution of EEG/MEG inverse problems is derived at each slice of time without taking advantage of the information of temporal correlations contained in the data. Another example is the ICA (Independent Component Analysis) technique for signal decomposition of EEG, and MEG/fMRI time series. Obviously, the dynamic nature of the signal in the data is ignored in the ICA treatment, again yielding less efficient results than could be obtained by a time series approach. The authors present the same data from the time series view point, and show how time series techniques may be used to extract neural and physiological information more efficiently (see references, (1) - (13)). The two main time series concepts that play an important role are causal modeling and heteroscedasticity. In causal modeling, the model is dynamic so that the temporal correlation from the past to the future plays an essential role. Neural activity also typically displays time-varying noise variance or heteroscedasticity, which can also be dealt with by time series techniques. For example, methods developed for the analysis of financial data can be efficiently modified to solve similar heteroscedastic problems in neuroscience data analysis by generalizing the techniques into a state space framework. We show how these two main ideas may be utilized in the analysis of consciousness in an anaesthetized patient by means of his (or her) EEG recording. The possible application of the same GARCH type heteroscedastic generalization to other problems such as the Dynamic Inverse Problem in EEG/MEG, and the signal decomposition of multi-channel time series are also briefly discussed.

[Tohru Ozaki, The Institute of Statistical Mathematics, Tokyo, Japan and Department of Statistical Sciences, Graduate University of Advances Studies, Tokyo, Japan ; ozaki@ism.ac.jp]