Analysis of the whole-head magnetoencephalogram data using multivariable autoregressive modeling

E. Bagarinao[1], K. Yoshino[1], T. Nomura[1], S. Sato[1], and M. Tonoike[2]
[1]Graduate School of Engineering Science, Osaka University, Osaka, Japan
[2] MEG Visualization Laboratory & Ultrasonic Hearing Laboratory
National Institute of Advanced Industrial Science and Technology (AIST), Japan

1 Introduction

In this paper we consider the analysis of the whole-head magnetoencephalogram (MEG) data of subjects performing periodic right-index-finger tapping experiment. Parametric analyses using multivariable autoregressive (MVAR) models were employed. We introduce an algorithm that uses auxiliary orthogonal polynomial functions to compute the coefficient matrices of the MVAR models. Numerical results showed that the algorithm is effective in estimating the values of the coefficient matrices even for short time series. Using the proposed algorithm, short-window spectral analysis of the preprocessed whole-head MEG data was performed. A measure of synchronization based on the covariance of the prediction error of the MVAR model was also computed. The results showed the effectiveness of the technique in extracting relevant information or data structure from the whole-head MEG data.

2 The Model

The multivariable autoregressive (MVAR) model is given by

$$X_n = A_1 X_{n-1} + \cdots + A_M X_{n-M} + \varepsilon_n \qquad (1)$$

where $X_n = [x_n^1, x_n^2, \ldots, x_n^d]^T$ is a d-dimensional random vector process, A_m's are $d \times d$ coefficient matrices, ε_n is zero mean, uncorrelated noise vector with covariance matrix $\mathbf{\Sigma}$, T denotes matrix transposition, and M is the order of the MVAR process.

In order to solve for the coefficient matrix A_m, we introduce the following iterative scheme:

$$\gamma_{mr} = E[X_{n-m} X_{n-r}^T], \qquad (2)$$

$$\beta_m = E[X_n X_{n-m}^T] \qquad (3)$$

$$\alpha_{mr} = \left[\sum_{j=1}^{r-1} \alpha_{mj} \alpha_{rj}^T - \gamma_{mr} \right] N_r^{-T}, \qquad (4)$$

$$B_m = \left[\beta_m + \sum_{r=1}^{m-1} B_r \alpha_{mr}^T \right] N_m^{-T}, \qquad (5)$$

$$\qquad (6)$$

where N_m is estimated by a Cholesky decomposition of the matrix $N_m N_m^T$ given by:

$$N_m N_m^T = \gamma_{mm} - \sum_{r=1}^{m-1} \alpha_{mr} \alpha_{mr}^T. \qquad (7)$$

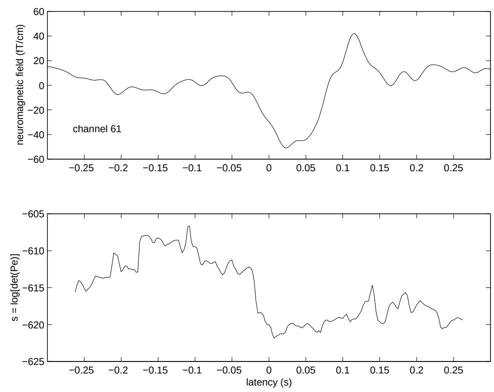

Figure 1: The value of measure s in different time windows (lower figure). For comparison, the averaged neuromagnetic field of channel 61 is shown in the above figure.

The original coefficient matrix A_m is given by:

$$A_m = \left[B_m + \sum_{r=m+1}^{M} A_r \alpha_{rm} \right] N_m^{-1}. \qquad (8)$$

for $m = M, \ldots, 1$.

3 MEG data analysis

Following [1], we computed a measure of synchronization, based on the the covariance of the prediction error, given by $s = \log[\det(P_\varepsilon)]$. The residual covariance matrix P_ε reflects the goodness of fit of the linear model to the data. Figure 1 (lower figure) shows the values of s in different time windows. For comparison, the averaged neuromagnetic field of channel 61 is also shown in the above figure. It can be observed that the decreases when the latency is zero, that is, the right-index finger contacts the ground. This should be compared with the behavior of the neuromagnetic field which also exhibits a dip in close to the ground contact.

References

[1] Franaszczuk, Piotr and Gregory K. Bergey, An autoregressive method for the measurement of synchronization of interictal and ictal EEG signals. Biol. Cybern. 81, 3–9 (1999).