4th Annual Research Symposium
HFMG Academic Affairs
(To be held on April 13, 2007 at Henry Ford Hospital, E&R Building)
Abstract Deadline: March 23, 2007

Integrated Model for Simultaneous Analysis of EEG or MEG with fMRI

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Introduction: For the diagnosis and treatment evaluation of some neurological disorders such as epileptic patients, multi-modality analysis of electroencephalography (EEG) or magnetoencephalography (MEG) with functional Magnetic Resonance Imaging (fMRI) is expected to be beneficial. An integrated model of the brain is crucial for this multi-modality analysis.

Methods: In this paper, a bottom-up model is proposed for integrating EEG or MEG with fMRI. The external stimulus is the input of the model and simultaneous EEG and Blood Oxygen Level Dependent (BOLD) signals are the outputs of the model. An extended neural mass model is developed based on the physiological principles of cortical minicolumns and their connections. In our method, we extend the classical neural mass model according to the physiological principles of the cortical minicolumns and their connections. The populations of different cells interact with themselves in a minicolumn and also receive inputs from the axons of the pyramidal cells in the neighboring minicolumns. This model allows extraction of neural activity from the fMRI, EEG, and MEG signals.

Results: We have conducted simulation studies to evaluate the proposed model. These studies have shown that the proposed extended neural mass model is capable of generating various types of event related potentials (ERP) and generating various types of event related fields (ERF). Following our extension of the neural mass model, the neural mass model that has so far been used for the M/EEG modeling only, is now used for the first time for the fMRI modeling. Our approach has developed a non-linear relationship between the stimuli and the neural activity.

Conclusions: The work has employed neural mass model to develop an integrated model for MEG, EEG, and fMRI model. Different applications are foreseen for this integrated model. For example, certain neurological diseases may change properties of some minicolumns in a brain region. These properties are characterized in our model by certain parameters, which can be estimated using M/EEG and fMRI data. Thus, our model and its parameterization can be used to diagnose or characterize related neurological diseases. In addition, the proposed bottom-up model is instrumental in evaluating the upcoming top-down combined methods for simultaneous analysis of M/EEG and fMRI.