Functional brain signal processing : EEG and fMRI

Electroencephalogram (EEG): Cortical sources of the scalp EEG signals; Linear propagation model (forward problem); Acquisition of EEG; Artifacts of EEG; Preprocessing – filtering, principal component analysis, independent component analysis; Different frequency bands of interest in EEG; Event related potential (ERP); Sleep EEG; Spectral decomposition and feature identification by time frequency analysis – Fourier, wavelet, Hilbert transformation and spectral estimation; Various coherence and synchronization measures. Pattern classification by linear discriminants, support vector machine (SVM) and artificial neural networks (ANN). MATLAB coding assignments; Familiarization with EEGLAB (a MATLAB based open source software for EEG signal processing).

Functional Magnetic Resonance Imaging (fMRI): Hemodynamic activity in our brain and the basic physics of fMRI; T1, T2 and $T2^*$ weighted images; 3D reconstruction of the MR images – K space and Talairach coordinate system, and functional sequencing over time; Fast fMRI acquisition – Echo-Planar Imaging (EPI); Preprocessing – Artifacts removal; Spatial normalization; Spatial smoothing; Statistical analysis – General linear model (GLM) for single subject analysis; GLM for group analysis; Inferencing blood oxygen level dependent (BOLD) patterns of activations; Multi-voxel pattern analysis (MVPA). Familiarization with SPM (MATLAB based open source software for fMRI processing) and FSL (Unix based open source software for fMRI processing).

Simultaneous EEG-fMRI acquisition – an overview.

References

1. A brief survey of quantitative EEG analysis, Kaushik Majumdar (under preparation under a contract with the Taylor & Francis); relevant portions will be distributed during the course.
2. Electroencephalogram processing using neural networks, C. Robert, J.-F. Gaudy and A. M. Limoge, *Clinical Neruophysiology*, vol. 113, pp. 694–701, 2002.
3. BCI competition 2003 – data set IIb: support vector machines for the P300 speller paradigm, *IEEE Transactions on Biomedical Engineering*, vol. 51(6), pp. 1073–1076, 2004.
4. Modern spectral estimation: theory and application, S. M. Kay, *Pearson*, 1988.
5. Handbook of functional MRI data analysis, R. A. Poldrack, J. A. Mumford and T. E. Nichols, Cambridge University Press, New York, 2009.
6. Beyond mind-reading: multi-voxel pattern analysis of fMRI data, K. A. Norman, S. M. Polyn, G. J. Detre and J. V. Haxby, *Trends in Cognitive Science*, vol. 10(9), pp. 424–430, 2006.

Prerequisites: Signal or image processing, good programming concept in any one of C, C++, Python and Unix shell script. Knowledge of MATLAB will be a plus but not essential. Familiarity with elementary linear algebra, and basic statistics and probability

will be very helpful. However attempts will be made to make the course as self-contained as possible.

Co-requisites: Participants in the course are encouraged to take Image Processing or Signal Processing or Pattern Recognition or Data Mining optional course prescribed in the M.Tech. (CS) curriculum.

50% weightage will be on written examination and the remaining 50% will be on laboratory assignments. The course will be covered in 3 hour lecture for every week for 16 weeks. Hours spent on computer assignments on real data sets will be extra.