## EEG Source-space imaging to decode motor functions

The human brain is arguably one of the most complex structures in the universe and has inspired researchers from various disciplines. Computational intelligence plays a significant role in the conceptual modeling of the human brain and has led to artificial neural networks and related clustering algorithms. Electroencephalography (EEG) is one of the most popular noninvasive brain signal recording techniques due to the advantage of portability, cost-effectiveness, and high temporal resolution, however its application in neuroimaging is limited because of the spatial resolution. The major challenge in source imaging using EEG is the precise localization of task-related cortical sources, although the recording is done using few (usually less than 100 channels). EEG source localization itself is an ill-posed problem due to the limited number of EEG channels (less than 100) as compared to the significantly larger number of cortical sources (order of few billion). Furthermore, to classify complex motor imagery tasks such as shoulder abduction, elbow flexion, wrist pronation and supination and other related ones, we need to know more about the underlying neurophysiological phenomenon that concerns the activation of these complex tasks. Therefore, it is necessary to use a priori information to solve this ill-posed problem by employing head model, a noise model, and cortical region of interest. Even then, the inverse modeling alone may not provide any discriminative information about a given task. Therefore, there is scope for developing new algorithms that can provide discriminative information in the cortical subspace while still justifying the neurophysiological phenomenon. Any such desirable algorithm to analyze source space should ideally be able to,

(1) Solve the inverse problem
(2) Handle data non-stationarity and noise
(3) Explain the collective behavior of neural population
(4) Explain the variability within the neural population
(5) Justify the neurophysiological phenomenon of a given task
(6) Provide sufficient information for the robust classification of complex tasks

Since the EEG recordings can be used to model the cortical source activity regarding source dipoles, clustering of these source dipoles particular for a given task can be done using nature-inspired computational intelligence algorithms. Motor homunculus is a familiar concept in neuroscience, which presents a neurological map of the anatomical division of the body. According to this concept, the cortical sources associated with the activation of different body parts are mapped to different regions in the motor cortex. Thus, several cortical sources would be related to each other in functionality, and their dimensions can be substantially reduced without losing much of useful information. To achieve this, we use robust dimension reduction algorithms such as Locality Preserving Projections which take neighborhood information into account. Further, we developed the supervised approach of Factor analysis for robust feature extraction. The main highlight of supervised factor analysis is identifying the task-dependent cortical sources for a given class to classify multiclass tasks. Motivation to use factor analysis lies in its inherent data modeling properties that is suitable for non-stationary cortical source timeseries data. Extending further, several machine learning techniques such as latent variable models can be explored in EEG source imaging applications. Cortical source-space EEG measures have applications in prognosticating the neuromotor diseases such as stroke by using the connectivity measures as cortical biomarkers.