Neuroimaging and Brain Network Analysis

Priyank Lohariwal
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Abstract

Various parts of the brain are responsible for specialized functions related to processing of sensory inputs, cognitive functions and motor response. The functional integration is achieved by the co-ordination of the anatomically segregated regions. The activation of neurons and their correlations reflect the segregation and integration of brain functions. Such activation are usually studied with BOLD signals captured using functional Magnetic Resonance Imaging (fMRI). These signals capture the time varying demand of oxygen in a brain region, which reflects the localized neuronal processing.

This study aims to analyse the captured fMRI responses for different tasks, model the functional connectivity of different regions of the brain and the ability to classify the signals within a given set of tasks. This study uses the fMRI datasets for four types of functional tasks namely, (i) visual word and object, (ii) working memory, (iii) decision making (Simon Task) and (iv) tone counting. This study uses the diverse set of data to analyse the functional Regions of Interests (ROIs) in conjuction with the anatomical specificity. There are two approaches taken for the same which are briefly described in the following sections.

Approach-I This approach is further classified into two steps:

- Static analysis
- Dynamic analysis

In the first step, the brain's behaviour is analysed without considering its change with time. Hence, the mean activation values are used to compare the different tasks in hand. A statistics based approach was used to find the possible activated regions of the brain for each tasks and how these regions differ from task to task. In the second step, the brain's dynamic response used to accurately represent the brain networks. A sliding window Time Varying Correlation Coefficient estimation method is used to study the dynamic patterns of functional connectivity among different anatomically parcellated regions.

Approach-II The dynamic patterns displayed by the data stores the information of the task stimuli. If the dynamic patterns for the selected tasks are distinguishable, then it is safe to suggest that these patterns can be used to classify the tasks of similar nature. Hence, this approach proposes a new metric, Temporal Consistency in Activation Levels (TCAL) that can be used to model the fMRI functional data in a more precise way than the previous used metrics in the domain. All these metrics are studied to determine their classification ability. K-fold cross validation was used for splitting the data into training and testing parts. Finally, a thorough comparison of different metrics is done by tuning the parameters of the algorithm adopted.

The methods described above are able to recognise the regions of interests that adhere to the research works done previously. The static analysis in the first approach is able to distinguish different tasks based on the mean activated regions and its dynamic analysis provide top correlated pair of regions for different tasks that provide insights on the most functionally connected regions of the brain for a given stimuli. The second approach provided a fair classification accuracy for different metrics. The study also shows that TCAL outperforms the commonly used standard metrics to quantify the similarity/dissimilarity in the activation patter between the brain regions.