

functional connectivity and graph analysis of fMRI with graphical gaussian models

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Graph-theoretical analysis of neural recording data has recently become popular. Graphs consist of both a set of nodes and set of pairwise connections between those nodes, called edges. Many studies analyze graphs of neural connectivity for small-world and scale-free characteristics. These characteristics are of particular interest in neuroscience because they can provide insight into the synchronization between brain areas and the process which generated the connections in the network.

In graph-theoretical analysis of functional MRI data, most graphs have been inferred by thresholding a matrix of correlation coefficients. This commonly used method of graph learning can inflate or neglect important independence relationships in the data. Another issue is the use of correlation vs partial correlation, as the latter is better able to distinguish between direct and mediated connections. Both of these issues can affect interpretation of the resulting graph.

These issues can be resolved by explicitly mapping between graphs and probability distributions. We fit the data with two undirected graphical models, corresponding to a Gaussian distribution with the constraint that it preserves a set of independence relationships, which map to edges in our graph. Preserving conditional independence, corresponding to significant partial correlations between nodes, yields a model known as a graphical Gaussian model. Preserving marginal independence, corresponding to correlation coefficients, yields a model known as a concentration graph.

Armed with this mapping between graphs and probability distributions, we can then ask how much evidence exists for the probability distribution implied by a particular graph given the data we have at hand. We conduct both simulation studies and analysis of resting-state fMRI data to illustrate the issue with thresholding and pairwise correlation, and suggest improved means of learning and selecting a graphical model, drawing upon recent research in machine learning and statistics.