Graph theoretical analysis of functional connectivity in the brain

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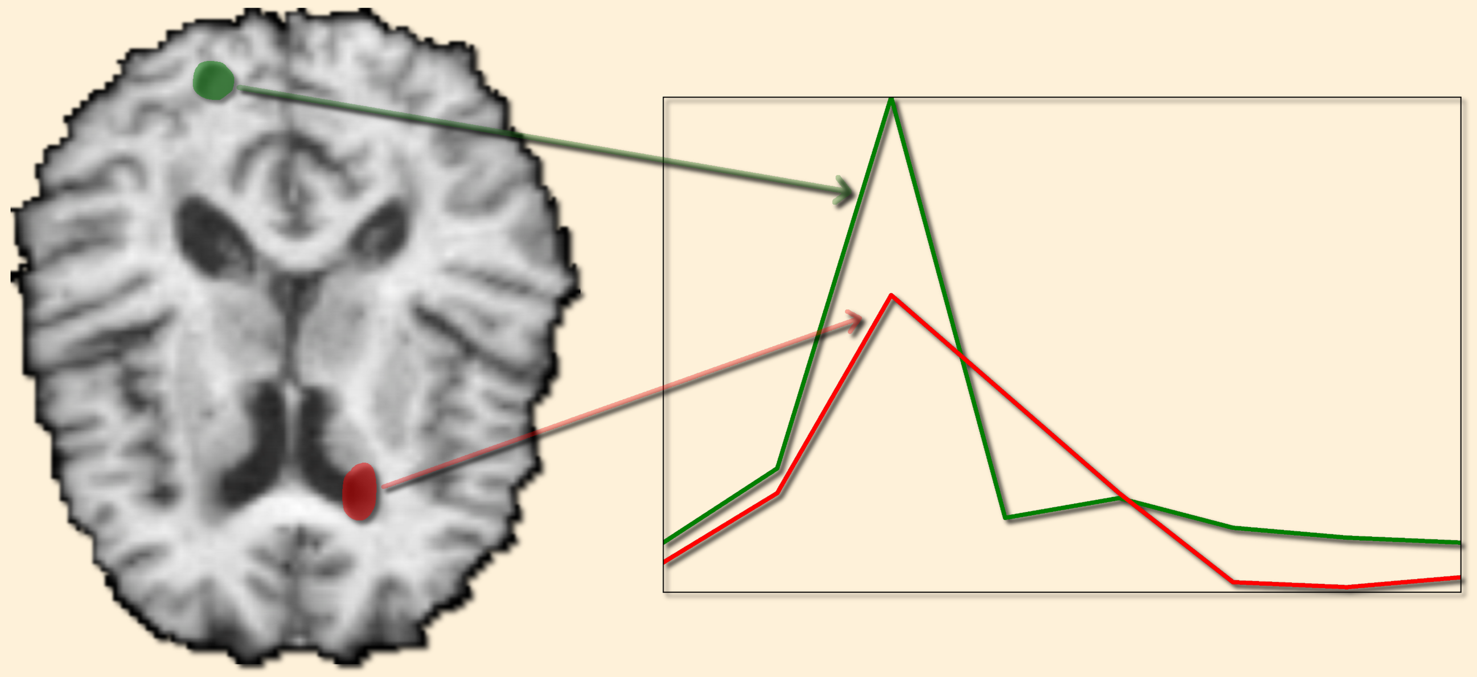
Introduction

Graph theory is becoming a popular approach for the analysis of functional connectivity in the brain. In this poster, we present our approach to the analysis of functional connectivity in fMRI data. Our techniques allow statistical analysis of global graph measures, inter and intra regional connectivity, and voxel level comparison of node measures across subject groups.

Functional connectivity

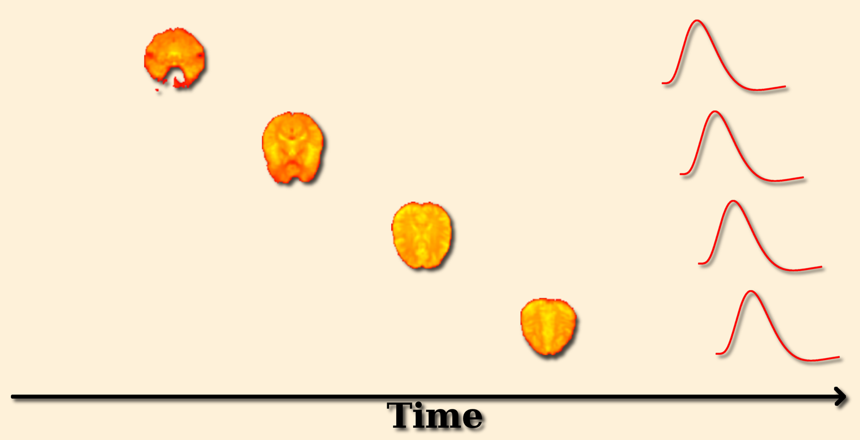
fMRI allows us to measure the ratio of oxygenated to deoxygenated blood throughout the brain. From this ratio, we may infer neural cell metabolism and thus overall neural activity. If two areas of the brain exhibit similar neural behaviour over a period of time, they are said to be *functionally connected*:



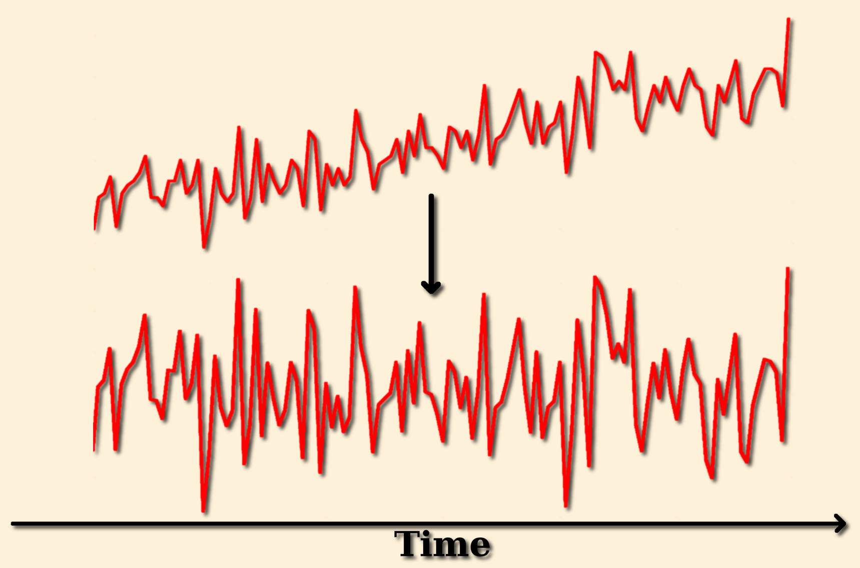
fMRI preprocessing

fMRI data are inherently noisy, and a number of preprocessing steps are required before further analysis can take place:

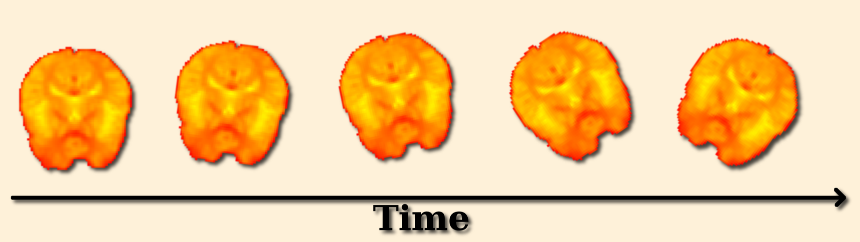
Slice timing correction



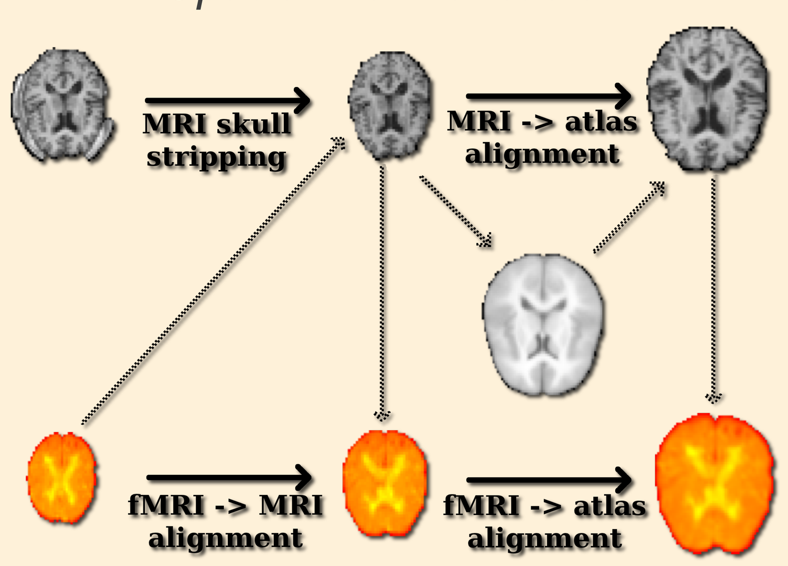
High pass filtering



Motion correction

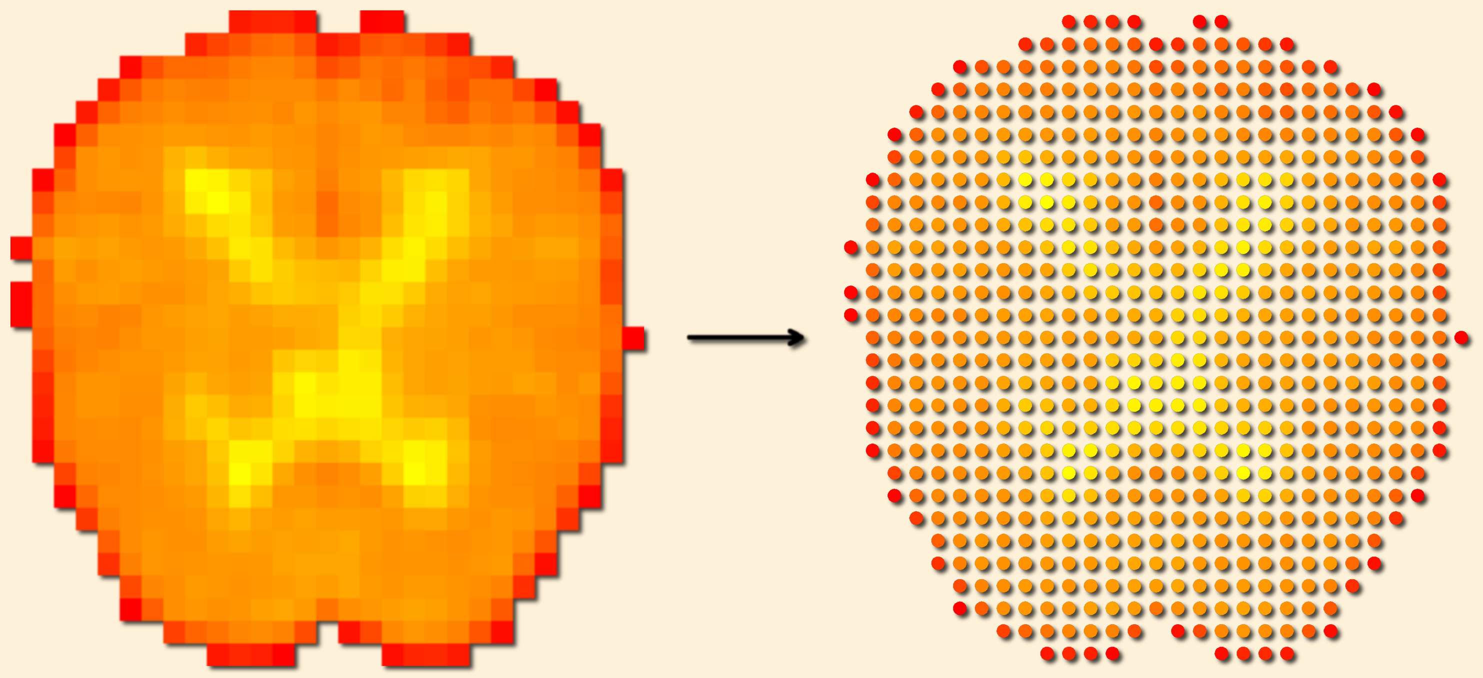


Spatial normalisation



Graph creation

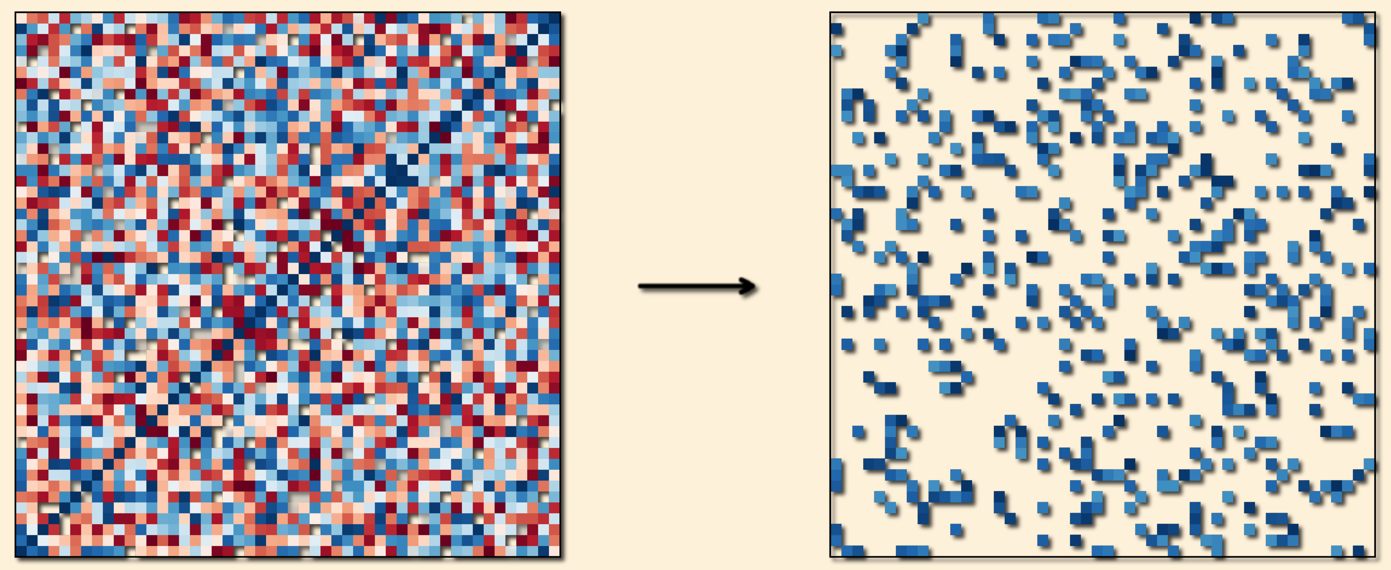
Every voxel in the fMRI volume is included as a node in a graph:



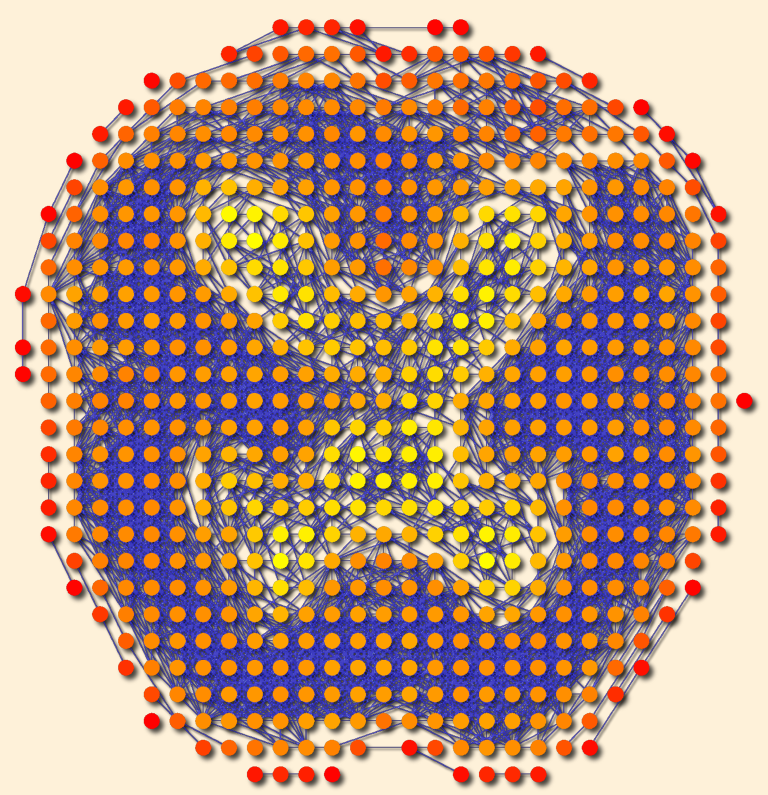
Pearson's Correlation Coefficient is calculated upon the time series for every pair of voxels:

$$r(x,y) = \frac{\sum(x_i - \overline{x})\,(y_i - \overline{y})}{\sqrt{\sum(x_i - \overline{x})^2\,\sum(y_i - \overline{y})^2}}$$

The absolute values of the resulting correlation matrix are thresholded to remove any weak relationships:

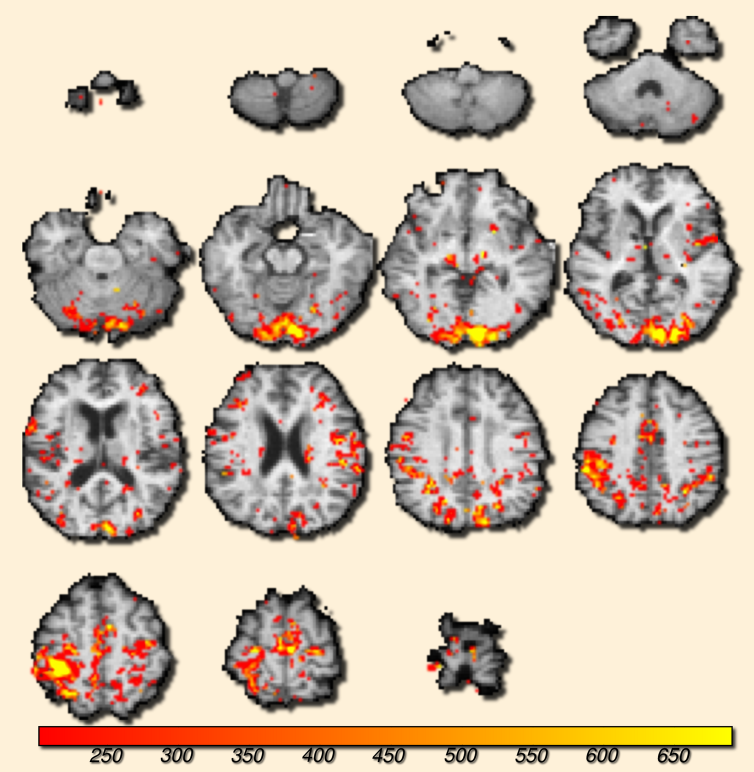


Edges are added to the graph, representing strong temporal correlation between pairs of voxels:



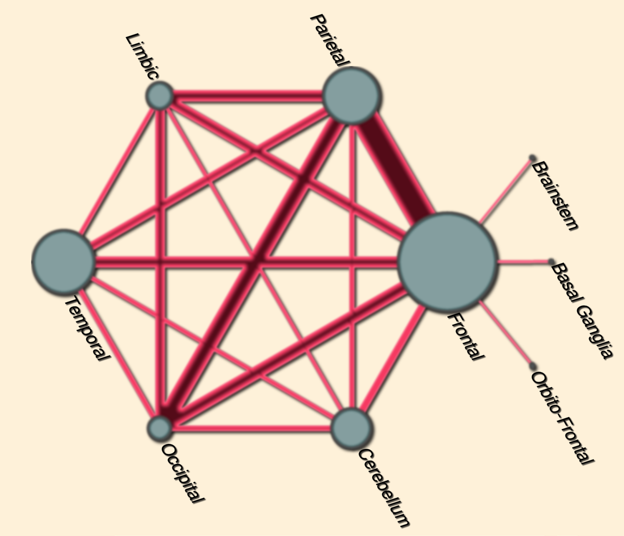
Global analysis

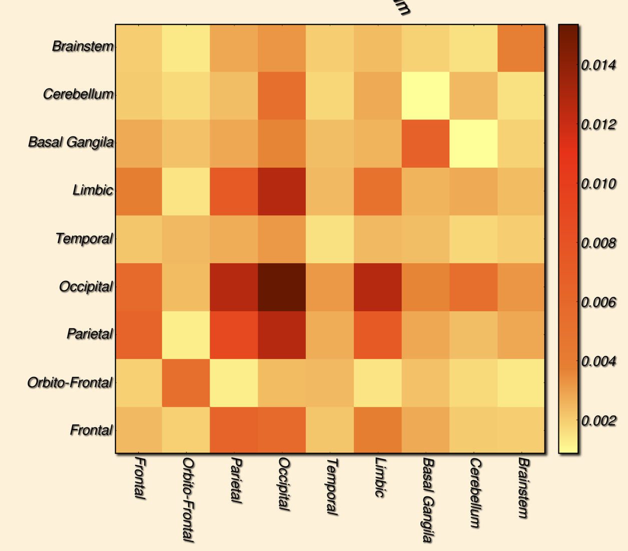
Here we show a degree map for the most strongly connected voxels, in a graph generated from the data for one subject; the data were obtained from a study conducted by Buckner et. al. 2000. We can identify strong functional connectivity in the occipital lobe, and the sensory motor cortex (in the parietal lobe) of the left hemisphere; this corresponds to the nature of the experiment: a visual-motor task involving right hand movement.



Regional analysis

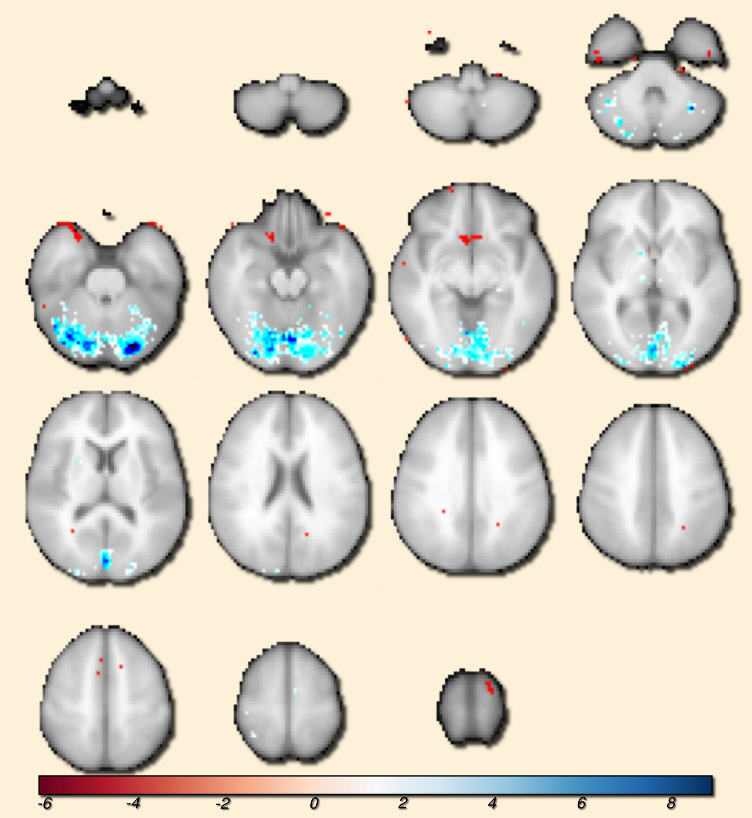
Here we have reduced the graph, merging voxels from the same region into single nodes, and weighting edges by counting the number of connections between regions in the original graph. The radius of each node is proportional to the number of voxels in that region. Similarly, the width of each edge is proportional to the number of connections between corresponding regions. The connectivity matrix shows relative inter and intra-regional densities. We can see strong connectivity between the frontal, parietal and occipital lobes, and strong connectivity within the occipital lobe.





Voxelwise statistical analysis

By aligning the fMRI images from multiple subject groups to the same anatomical space, we are able to perform voxelwise statistical analyses. Here we show t values of voxels (as calculated by a t-test) which have significantly different ($p < 0.05$) clustering coefficient, between a group of young subjects, and a group of aged subjects suffering from Alzheimer's disease (AD). The p values were corrected for multiple comparisons using the False Discovery Rate. We can see a widespread reduction in occipital lobe clustering, in the subjects suffering from AD.



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