Toward a Causome of the Brain

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The NIH brain initiative aims, among other things, to uncover the causal connections between brain regions that produce both normal and anomalous cognitive and behavioral functioning. Connectivity studies of the human brain using fMRI and other imaging data have almost always taken one of two forms: correlations of signals at the smallest spatial resolution possible ("voxels") or correlations or partial correlations of average values of spatially clustered voxel signals ("Regions of Interest"). Studies of the first kind claim to estimate the "connectome" of the brain. But it is well known that quite aside from leaving directions of influence unspecified, correlation and partial correlation studies may misidentify causal processes. Correlations produce false transitive connections, and partial correlations produce false connections between two voxels that are causes of a third. While statistical methods, such as the PC and GES (Greedy Equivalence Search) algorithms, can find causal connections and have existed for 25 years, they have been insufficiently fast and accurate for whole brain or whole cortex voxel analyses.

Using a recent dramatic speed-up of the GES algorithm that is called FGS, we have produced an estimate of (undirected) causal connections for the entire cortex for each of 60 resting state scans of the same individual (R. Poldrack). Our current work is focused on identifying both direct and feedback (cyclic) relations using the undirected graphical result. Methods for that purpose exist for small models, but need to be speeded up and improved in accuracy.