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Hierarchical analysis in the human brain connectivity networks

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Abstract:
The human brain is characterized by a dense network of local and long distance bundles of fascicles. As a working hypothesis, this complex network of brain connectivity has been hypothesized to be in the core of brain's paramount computational capabilities. Given the phenomenological similarities between brain networks and the network of interconnected elements studied in complex network theories, graph theoretical elucidation of brain networks have gained increasing prominence in recent years. However, unlike regular complex networks, the complex brain network consists of numerous topological hierarchies. In the present study we utilized emerging tools from social hierarchy analyses in order to investigate how information may spread within this template of hierarchical network structure. Method: Resting state functional data were acquired using a 3 Tesla MRI scanner (Philips, Eindhoven) with the following parameters: TR = 2 sec, voxel size = 2.75×2.75×3.5 mm^3, matrix size = 80×80×31×165, and the region and/or voxel-based directed connectivity networks were derived via vector autoregression analysis (e.g. Granger causality). The analysis of the hierarchical brain network was performed by using the work of Gupte et al. [1], PageRank-based algorithms. The algorithm in [1] assigns an integral-valued rank, which is a level in a hierarchy, to each node such that the number of links from a node with large rank to a node with small rank is minimized. This can be formulated as a submodular function minimization problem such that a combinatorial algorithm can be used to search for the optimal discrete solution in polynomial time. In our implementation, these computations were optionally performed using C/C++ parallel processing for processing massive data sets; let n and m denote the number of nodes and edges in a network, then the expected algorithmic complexities are $O(n^2)$ and $O(m^2n)$ for the connectivity analysis and the hierarchical analysis, respectively. The preliminary results of our study suggest that social hierarchy algorithms are capable of capturing meaningful hierarchical structures from resting state fMRI data. It will be intriguingly to see how such social graph algorithms can be expanded to label the flow of information across the brain's complex hierarchical networks.
[1] M. Gupte, P. Shankar, J. Li, S. Muthukrishnan, and L. Iftode. Finding hierarchy in directed online social networks. In WWW'11, 2011

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