Adaptive Thresholding for Graph-Theoretical Analysis in Network Neuroscience

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Connectivity analyses of brain networks (BNs) play a key role in our understanding of activity in the brain. Functional and structural connectivity analyses provide insights into time-varying activity in different 'regions of interest'. BNs have several clinical applications - evaluation of brain disease vulnerability, neurosurgical planning, invasive electrode placement, and diagnosis of psychiatric illnesses. BNs are commonly studied using graph-theoretical metrics in a network where the connection strength is a statistical correlation metric or phase/amplitude synchronization feature between parts of the brain.

The applications of BNs have been limited to research. The lack of standardization in graph analysis of networks is hindering greater adoption of BNs. One of the most important steps in BN analysis is thresholding. The weakest connections from the network are removed, eliminating insignificant/noisy connections. Most connectivity studies and toolboxes utilize this step, but there is no consensus in the scientific community about the exact method used. Threshold values are arbitrary and vary greatly between studies. This has a big impact on final graph metrics like small-worldliness, clustering, and efficiency - leading to significant distortion of results.

This paper proposes a novel approach to obtaining a threshold value by iterating over a range of threshold values. The different thresholds are applied to a graph, where an edge is removed if its relative weight is less than alpha. After all edges have been filtered, the average connectivity of the graph is calculated. This effectively builds a threshold-connectivity cost function. By evaluating the rate of change of average connectivity for each graph in the dataset, we can select a point of most stability. Here, the average rate of change of connectivity is minimized for all BNs in the dataset. This contextual threshold evaluation, facilitates researchers and clinicians to study general trends in the data, while also retaining distinct characteristics for individual networks. After testing this method on BNs constructed using amplitude coupling metrics on the EEG Source Space, it was found that the ideal range for iterating threshold values is between 0.001 to 0.1, as anything greater resulted in excessive edge removal.

The adaptive thresholding algorithm's cross-metric and inter-modal performance is yet to be established, but it has great potential for addressing the arbitrary thresholding problem. Such data-driven approaches can lead to greater standardization in the construction and analyses of BNs, promoting greater use in clinical settings.