Adaptive Thresholding for Graph-Theoretical Analysis in Network Neuroscience

P. Gupta, J. Cerna, M. He, M. Hernandez
University of Illinois Urbana Champaign
prakhar7@illinois.edu

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, and diagnosis of psychiatric illnesses. BNs are studied using graph-theoretical metrics in a network where the connection strength is a statistical correlation metric representing phase/amplitude synchronization features between brain regions.

Evidence shows that filtering spurious connections is based on arbitrary choices, which can yield incongruous network parameters. Thresholding, the method responsible, currently lacks standardization and a systematic method to discern meaningful connections. Arbitrarily chosen thresholds, both absolute and proportional, vary greatly between studies, often leading to distorted results. We propose a novel and robust approach based on an adaptive threshold with a higher likelihood of yielding reliable results.

This approach generates a threshold based on (1) the stabilization of the average connectivity in a given set of networks and (2) the proportional impact of each edge weight relative to the weighted node degree. By iterating over a range of threshold (alpha) values and observing their effect on the average connectivity of the graph, the algorithm seeks to determine a threshold where the network structure becomes stable. Stability is inferred from the minimal change in average connectivity when alpha is adjusted. The value at which the average change of connectivity across all graphs is minimized is used as the threshold globally.

Each edge weight is evaluated relative to the weighted node degree, thereby assessing the significance of each edge in the context of the overall network. Edges that pass the thresholding test are retained, presumed to contribute meaningfully to the node's overall connectivity and, by extension, to the network's structure. The assumption is that edges contributing to stable average connectivity are likely to be relevant and meaningful in understanding network structure. Preliminary testing was performed on BNs constructed from amplitude coupling metrics from the EEG source space. Future work would involve testing inter-metric and inter-modal performance.

This contextual threshold evaluation could facilitate researcher's and clinician's ability to study general trends in their data while retaining distinctive characteristics of individual networks. Such data-driven approaches can lead to greater standardization in the construction and analyses of BNs, promoting stable and reliable results, potentially increasing their utility in clinical and non-clinical settings.