Toward Reliable Graph Analysis: Uncertainty Quantification for fMRI Connectivity

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Abstract

Inferring brain graphs from fMRI data relies on correlation matrices, yet standard estimators are unstable in high-dimensional, low-sample-size settings. We propose a general Bayesian framework that avoids structural assumptions and quantifies uncertainty through credible regions for these matrices. Our method constructs these credible regions to account for the dependencies between all coefficients while maintaining reasonable computational cost. This approach enables applications not feasible with point estimates: (i) diagnosing estimator instability, (ii) robust edge detection with posterior control of the Family-Wise Error Rate (FWER), and (iii) direct comparison of two fMRI scans via the posterior probability of matrix equality. This simple, assumption-light framework improves the reliability and interpretability of downstream connectivity analyses.

Keywords: Bayesian Statistics, fMRI, brain connectivity, credible region, multiple testing, FWER, uncertainty quantification

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