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BAYESIAN INFERENCE OF SPATIALLY VARYING CORRELATIONS VIA THE THRESHOLDED CORRELATION GAUSSIAN PROCESS

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Abstract: A central question in multimodal neuroimaging analysis is to understand the association between two imaging modalities and to identify brain regions where such an association is statistically significant. In this article, we propose a Bayesian nonparametric spatially varying correlation model to make inference of such regions. We build our model based on the thresholded correlation Gaussian process (TCGP). It ensures piecewise smoothness, sparsity, and jump discontinuity of spatially varying correlations, and is well applicable even when the number of subjects is limited or the signal-to-noise ratio is low. We study the identifiability of our model, establish the large support property, and derive the posterior consistency and selection consistency. We also develop a highly efficient Gibbs sampler and its variant to compute the posterior distribution. We illustrate the method with both simulations and an analysis of functional magnetic resonance imaging data from the Human Connectome Project.

Key words and phrases: Bayesian modeling, Gaussian process, multimodal correlation analysis, neuroimaging analysis.

1. Introduction

Multimodal neuroimaging is now prevailing in neuroscience research, where different types of brain images are collected for a common set of subjects. Common imaging modalities include anatomic magnetic resonance imaging (MRI), resting-state or task-based functional MRI (fMRI), diffusion tensor imaging (DTI), and positron emission tomography (PET), among many others. Multimodal neuroimaging analysis aggregates such diverse but often complementary information, consolidates knowledge across different modalities, and produces improved understanding of neurological disorders. See Uludağ and Roebroeck (2014) and Zhu, Li and Zhao (2023) for some excellent reviews on multimodal neuroimaging analysis.

A central question in multimodal neuroimaging analysis is to understand the association between two imaging modalities and to identify brain regions where such an association is statistically significant. This question is of great scientific interest. For instance, Zhu et al. (2014) surveyed and showed joint analysis

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