

BAYESIAN FMRI DATA ANALYSIS AND BAYESIAN OPTIMAL DESIGN

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ABSTRACT

The present dissertation consists of the work done on two projects. As part of the first project, we develop methodology for Bayesian hierarchical multi-subject multiscale analysis of functional magnetic resonance imaging (fMRI) data. After modeling the brain images temporally with a standard general linear model, we transform the estimated standardized regression coefficient maps through a discrete wavelet transform. We assign to the wavelet coefficients a prior that is a mixture of a point mass at zero and a Gaussian white noise and assume equal mixture probabilities at same location and level across subjects. We develop empirical Bayes methodology to estimate the hyperparameters, carry out inference in the wavelet space and obtain smoothed regression coefficients images by inverse wavelet transform. Application to a simulated dataset has shown better performance of our multi-subject analysis compared to single subject analysis in terms of mean squared error and ROC curve based analysis. Finally, we apply our methodology to an event-related fMRI dataset from Postle (2005).

As part of the second project, we develop a novel computational framework for Bayesian optimal sequential design for random function estimation based on evolutionary Markov chain Monte Carlo. Our framework is able to consider general observation models, such as exponential family distributions and scale mixtures of normals, and allows optimality criteria with general utility functions that may include competing objectives, such as minimization of costs, minimization of the distance between true and estimated functions, and minimization of the prediction error. We illustrate our novel methodology with an application to experimental design for a nonparametric regression problem with the cubic spline prior distribution.