Editorial for the Special Issue *Challenges in Computational Neuroscience*

Hongtu Zhu¹

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Neuroscience is accumulating exponentially growing volumes of data and knowledge on specific aspects of the healthy and diseased brain, in different species, at different ages as the BRAIN and Human brain projects gather momentum. Brain theory, modeling, and statistics are essential to turn knowledge into better understanding of the brain, even though this is a formidable task.

The Challenges in Computational Neuroscience program was a year-long program sponsored by The Statistical and Applied Mathematical Sciences Institute (SAMSI) in 2015–2016. This program stimulated many new mathematical and statistical methods for several key problems in neuroscience. Key problems include understanding the mechanisms that bridge multiple spatial and temporal scales, linking the activity of individual components (e.g., molecular biology, genetics, and neuron networks) and their interactions to the overall complex dynamic behavior of the brain and nervous system.

This special issue is dedicated to the Challenges in Computational Neuroscience program. In this issue, we are very excited to include four interesting articles, which represent a wide range of topics within computational neuroscience. These papers address several key problems in fMRI, MRI, rest-fMRI, and data integration, and comprehensively cover the wide spectrum of statistical methods in neuroscience research.

The first paper introduces NPBayes-fMRI, a user-friendly MATLAB GUI that implements a unified, probabilistically coherent nonparametric Bayesian framework for the analysis of task-related fMRI data from multisubject experiments. The key novelty of NPBayes-fMRI is the use of spatiotemporal linear regression model that specifically accounts for the between-subjects heterogeneity in neuronal activity via a spatially informed multisubject nonparametric variable selection prior. It leads to a clustering of the subjects into subgroups characterized by similar brain responses, while simultaneously producing group-level as well as subject-level activation maps.

✉ Hongtu Zhu
htzhu@email.unc.edu

¹ University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

The second paper proposes a spatiotemporal regression model for image response and image predictors that are acquired longitudinally, with images being co-registered within the subject but not across subjects. The key novelty of this model is that the response at a voxel is dependent on the available covariates not only through the current voxel but also on the imaging information from the voxels within a neighboring spatial region as well as their temporal gradients. The author assessed the model fitting and the prediction performance using longitudinally acquired MRI images from 46 multiple sclerosis (MS) patients.

The third paper presents a novel regularization method to estimate the association between the brain structure features and a scalar outcome within the linear regression framework. The proposed regularization technique provides a principled approach to use external information from the structural brain connectivity and inform the estimation of the regression coefficients. The authors applied their regularization method to study the associations between the alcoholism phenotypes and brain cortical thickness using a diffusion imaging derived measure of structural connectivity.

The fourth paper, describes how to model and measure functional and effective (directional) connectivity in multichannel brain physiological signals. This method fits a vector autoregressive (VAR) model with potentially high lag order so that complex lead–lag temporal dynamics between the channels can be captured. This novel method not only quantifies patterns of effective connectivity across electrode locations, and captures how these patterns varied across trial epochs and trial types.