Section III. Sabbatical Leave Plan

A description of the research/creative project being pursued while on sabbatical. Include
1) the connection and importance of this project to your ongoing research or creative work;
2) the impact this project will have on your teaching — specifically if the project will affect particular courses (new material, new methodology, or new course);
3) the intended outcome of your proposal including presentation or publication.

Summary: Visit UC Irvine and MRN to
- learn more about Bayesian graphical models,
- learn more about Hamiltonian Monte Carlo (HMC),
- learn about their statistical and computational implementations, and
- apply both to extend current models in the application to fMRI brain imaging data.
- Continue UNM 100-level statistics and mathematics education initiatives to understand factors influencing student success and find strategies to increase success.

Connection to ongoing research

Bayesian graphical models

Since my postdoc in 2009, I have been developing models applied to fMRI brain data. Spatial independent component analysis (ICA) applied to functional magnetic resonance imaging (fMRI) data is a decomposition strategy applied with great success to identify functionally connected networks by estimating spatially independent patterns from their linearly mixed fMRI signals [1]. The time courses for estimated components can be correlated to estimate functional connectivity, the temporal association between spatial brain regions [2]. Dynamic functional connectivity (dFC) models the spontaneous fluctuations of association between brain regions. dFC was first studied in 2008 [3, 4] and has since exploded with applications of our 2012 data-driven method [5], and I've contributed to a range of those dFC projects [6–9]. However, there are limitations to our sliding-window method of estimating precision matrices followed by clustering of the connectivity patterns.

I believe our current Bayesian graphical model with embeded hidden Markov model strategy is very promising for both generalization and specialization [10]. However, the current Markov chain Monte Carlo (MCMC) algorithm is complicated and computationally demanding. Also, our model currently only estimates brain states for a single subject. Method development is required to extend to a multiple subject analysis, increase the number of components estimated (dimension) strategies to incorporate covariates information to compare dFC between groups of subjects by demographics or diagnostic status, as well as more informative prior elicitation on the networks (e.g., using structural information). Realistic multi-subject fMRI simulations can be used to assess model developments [11, 12]. For such extensions, however, several aspects of the modeling and computations need careful thought.

I'm at the edge of my comfort zone, both with the statistical methods for the proposed model extensions and with the computation involved. In short, this primary part of my sabbatical plan is to learn about the existing Bayesian graphical modeling and related methods, and the state-of-the-art computation methods required to fit these models. The experts and collaborators at UCI (and nearby UCLA) and MRN will provide the methological support I need to learn these fundamentals.

Hamiltonian Monte Carlo

Bayesian statistical methods are required to estimate complex models, such as the one described in the previous section, and sampling-based methods are often required to calculate otherwise intractable integrals. Hamiltonian Monte Carlo (HMC) is a modern MCMC method [13] that has substantial advantages over now traditional MCMC methods. Stan (`mc-stan.org`) is statistical software designed for HMC [14, 15].

I believe that applying HMC to the Bayesian graphical modeling above has the potential to simplify and speed computation, making higher dimensional problems of greater complexity possible. I intend to spend roughly a couple months learning Stan and HMC, and how to apply it to both standard problems and our current Bayesian graphical model and extensions.

Impact on teaching

Stan and Hamiltonian Monte Carlo (HMC)

Learning Stan and HMC will allow me to bring these modern statistical methods into the classroom with an "Applied Bayesian Data Analysis" course (a course that I was previously scheduled to teach Fall 2016 with 20+ registered students, before I had to cancel it due to winning a teaching fellowship and needing that time for course redesign.) I intend to spend roughly one month developing this course.

100-level UNM Math and Stat instruction

I am a 2016–17 Teaching Fellow at UNM working to improve both Statistics and Mathematics education for our largest courses (Stat 145 with 1200 students/semester and Math 101-102-103 with 1000 students/semester). In an email from A&S Dean Mark Peceny on 10 Aug 2016 discussing improvements in Math & Stat teaching: "The next step in the comprehensive reform of 100 level courses in the department will involve a comprehensive overhaul of the way Statistics 145 is taught, led by newly promoted Associate Professor Erik Erhardt."

After my Stat 145 redesign running in Spring 2017, I will have the summer to reflect and present my findings at the US Conference on Teaching Statistics (USCOTS) 2017.

I am also PI on a project to determining factors influencing student success in Intermediate Algebra (Math 101-102-103). The UNM historical pass rates for traditional lecture-based Intermediate Algebra (Math 101, 102, 103) have been around 45%, and since implementation of a computer-based learning system (ALEKS) in Spring 2012 they have increased to around 60%, but this still represents a low pass rate. My goal through a few semesters of study are to develop a statistical model that can identify students at most risk of failing so that early interventions can increase overall student success.

Intended outcomes and locations

UCI. I have been collaborating with with Michele Guindani over e-mail, but we really need to work in closer proximity. I plan to spend some time at UC Irvine. The timing of my visit is not set, but is expected to be roughly one week a month over the two semester sabbatical. I anticipate both statistical papers and presentations from our joint work.

MRN. While I have long-standing collaborations at the Mind Research Network here in Albuquerque, sabbatical will allow me to learn critical software programs necessary for data processing, as well as to engage more closely with pressing analytical needs. I anticipate neuroscience papers from my joint work with Vince Calhoun and colleagues.

See Section V, where more specific outcomes are detailed.

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