Bayesian Statistics and Multilevel Models

Instructor Information:
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1. COURSE DESCRIPTION

This course is designed to achieve three broad objectives. First, it introduces you to the basic ideas of the Bayesian approach to statistical inference. This course discusses general properties of posterior distributions, prior specifications, Markov chain Monte Carlo (MCMC) methods, and Bayesian inference tools including point and interval estimation, prediction, and model comparison. Second, this course aims to equip you with computational skills necessary to implement Bayesian methods for data analysis. Statistical software R (http://www.r-project.org) will be intensively used for in-class exercises and homework assignments. Finally, this course introduces you to the Bayesian approach to multilevel/hierarchical data structures, which are frequently encountered in the social and behavioral sciences. In doing so, you are encouraged to use the tools you learn throughout the course to conduct data analysis for your own research.

2. EVALUATION

- **Homework Assignments (70%)**: Eight homework assignments will be distributed throughout the course. They should be submitted at the beginning of class on the specified date. The assignments are intended to expand upon the lecture material and to help you develop the actual skills that will be useful for your work. These are individual assignments that you should prepare yourself, though you may ask your colleagues for help.

- **Final Project (30%)**: You should submit an analysis of real research using Bayesian methods in your field along with 5 to 10 pages on the last day when you should also present your analysis. This final project may be either applying Bayesian methods to data analysis or developing a new methodological tool. For the former type of research, you should include a description of your data, your model, model diagnostics, and your substantive findings. For the latter type of research, you should
demonstrate why the method introduced in your project is different from existing methods and how it contributes to statistical inference. Consider this assignment to be the start of a research manuscript to be eventually submitted to an academic journal.

3. COURSE MATERIALS

- Academic articles available online.

4. COURSE OUTLINE

- Week 1: Introduction – Comparison of Frequentist and Bayesian Statistics
  - Gill. Chapter 1
  - Greenberg. Chapter 2
- Week 2: Posterior Distributions and Inference
  - Gill. Chapter 2
  - Greenberg. Chapter 3
- Week 3: Prior Distributions
  - Gill. Chapter 5
  - Greenberg. Chapter 4
- Week 4: Markov chain Monte Carlo (MCMC) Methods I – Classical Simulation, Basics of MCMC, and Convergence
  - Gill. Chapters 9.1, 9.2, 11.4, 11.5, 12.1, 12.2
  - Greenberg. Chapters 5 and 6
  - Assignment 1 Due
• Week 5: MCMC Methods II – Gibbs Algorithm
  – Gill. Chapter 9.3
  – Greenberg. Chapter 7.1
  – Writing a Gibbs sampler for a Normal-Normal model in R

• Week 6: MCMC Methods III – Metropolis-Hastings Algorithm
  – Gill. Chapter 9.4
  – Greenberg. Chapter 7.2
  – Writing a Metropolis-Hastings algorithm for a Normal-Normal model in R

• Week 7: Linear Regression
  – Gill. Chapter 4.1
  – Greenberg. Chapter 8.1
  – Normal errors and robust regression via t-errors
  – Assignment 2 Due

• Week 8: Limited Dependent Variables – Tobit Model, Binary Probit/Logit Model, Ordinal Probit Model
  – Greenberg. Chapter 8.2

• Week 9: Model Comparison I – Bayesian Hypothesis Testing and The Bayes Factor
  – Gill. Chapter 7
  – Assignment 3 Due

• Week 10: Model Comparison II – Marginal Likelihood
  – Writing marginal likelihood from the Gibbs output in R
• Week 11: Bayesian Hierarchical/Multilevel Models I – Basics
  – Gelman and Hill. Chapters 11 and 12
  – Gill. Chapter 10.1, 10.2
  – Assignment 4 Due

• Week 12: Bayesian Hierarchical/Multilevel Models II – Running JAGS in R
  – Gelman and Hill. Chapters 16 and 18
  – Assignment 5 Due

• Week 13: Bayesian Hierarchical/Multilevel Models III – Running JAGS for Linear Models
  – Gelman and Hill. Chapters 16 and 17
  – Assignment 6 Due

• Week 14: Bayesian Hierarchical/Multilevel Models IV – Running JAGS for Generalized Linear Models
  – Gelman and Hill. Chapters 16 and 17
  – Assignment 7 Due

• Week 15: Final Project Presentations
  – Final paper Due
  – Assignment 8 Due