Advanced Bayesian Modeling

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Course Information

Meeting Times: 1:00-3:00pm Daily
Meeting Location: TBA
Teaching Assistant: Daniel Gustafson
TA Office Hours & Location: 9-11:30am; 220 Helen Newberry
TA E-mail: dgustaf@live.unc.edu
Class Website: Dropbox Link & Listserv (contact TA if you have difficulty accessing course materials)

Course Outline:

This course covers the theoretical and applied foundations of Bayesian statistical analysis at a level that goes beyond the introductory course at ICPSR. Knowledge of basic Bayesian statistics (such as that obtained from the Introduction to Applied Bayesian Modeling for the Social Sciences workshop) is assumed. First, we will discuss model checking, model assessment, and model comparison, with an emphasis on computational approaches. Second, the course will cover Bayesian stochastic simulation (Markov chain Monte Carlo) in depth with an orientation towards deriving important properties of the Gibbs sampler and the Metropolis Hastings algorithms. Extensions and hybrids will be discussed. The third and fourth modules will focus on applications of Bayesian statistics in social science data analysis. The topics include Bayesian Hierarchical models for cross-sections and panel data, factor analysis models, and Instrumental Variable Models. Throughout the workshop, estimation with modern programming software (R, JAGS, and a little Stan) will be emphasized.

Readings:

Recommended textbook:

- Gill, J. (2014). *Bayesian Methods: A Social and Behavioral Sciences Approach*, 3rd edition. Chapman & Hall/CRC.

All other readings will be available on the course website.

Week I: Introduction & MCMC (Menninga)

Monday: Introductions

- Introductions
- Recommended: start tomorrow's reading.

Tuesday: Why Bayes? & Quick Overview of Bayesian Logic

- Why Bayes?
- What is Bayes?
- Essential Reading:
  - Gill (2014) Chapters 1-5
- Recommended Reading:
  - Buckley, J. (2004) "Simple Bayesian Inference for Qualitative Political Research" *Political Analysis*
  - Gelman, A. (2008). "Objections to Bayesian Statistics" *Bayesian Analysis*
  - Greenland et al. (2016). "Statistical tests, P values, confidence intervals, and power: a guide to misinterpretations" *European Journal of Epidemiology*
  - Gross, J. (2015). "Testing What Matters (If You Must Test at All): A Context-Driven Approach to Substantive and Statistical Significance" *American Journal of Political Science*
  - Lindley. (2000). "The Philosophy of Statistics" *The Statistician*
  - Nuzzo, R. (2014). "Scientific Method: Statistical Errors" *Nature*
  - Seaman, J. et al. (2012). "Hidden Dangers of Specifying Noninformative Priors" *American Statistician*
  - Wasserstein, R. & Lazar, N. (2016). "The ASA's Statement on p-Values: Context, Process, and Purpose" *The American Statistician*

Wednesday: Posterior Prediction & Assessing Model Quality

- Posterior Predictive Distributions
- Global & Local Sensitivity Analysis
- Global & Local Robustness
- Comparing Data to the Posterior Predictive Distribution
- Model Selection
- Model Expansion
- Essential Reading:

  - Gill (2014) Chapter 6
- Recommended Reading:
  - Berger et al. (2000). "Bayesian Robustness" in *Robust Bayesian Analysis*
  - Draper. (1995). "Assessment and Propogation of Model Uncertainty" *Journal of the Royal Statistical Society B*
  - Gelman, A. & D.B. Rubin (1995). "Avoiding Model Selection in Bayesian Social Research". *Sociological Methodology*
  - Gelman, A. & C.R. Shalizi (2013). "Philosophy and the practice of Bayesian statistics" *British Journal of Mathematical and Statistical Psychology*
  - Greco, Racugno, & Ventura. (2008). "Robust likelihood functions in Bayesian inference" *Journal of Statistical Planning and Inference*
  - Lavine. (1991). "Sensitivity in Bayesian Statistics: The Prior and the Likelihood" *Journal of the American Statistical Association*
  - Lopes & Tobias. (2011). "Confronting Prior Convictions: On Issues of Prior Sensitivity and Likelihood Robustness in Bayesian Analysis" *Annu. Rev. Econ.*
  - Moreno. (2000). "Global Bayesian Robustness for Some Classes of Prior Distributions" in *Robust Bayesian Analysis*
  - Shyamalkumar. (2000). "Likelihood Robustness" in *Robust Bayesian Analysis*
  - Sivaganesan. (2000). "Global and Local Robustness Approaches: Uses and Limitations" in *Robust Bayesian Analysis*

Thursday: Model Comparison & Bayesian Hypothesis Testing

- Posterior Probability Comparison
- Cross-Validation
- Bayes Factors
- AIC, BIC, DIC
- Software Issues
- Replication Bayes Factors
- Essential Reading:
  - Gill (2014) Chapter 7
- Recommended Reading:
  - Carlin, B. P. and Chib, S. (1995). "Bayesian Model Choice via Markov Chain Monte Carlo Methods." *Journal of the Royal Statistical Society, Series B* 57, 473-484.
  - Etz, A. and Vandekerchkhove, J. (2016). "A Bayesian Perspective on the Reproducibility Project: Psychology" *Plos One*
  - Geisser & Eddy. (1979). "A Predictive Approach to Model Selection" *Journal of American Statistical Association*

  - Gelman et al. (2014) "Understanding predictive information criteria for Bayesian models" *Statistical Computing*
  - Myung and Pitt. (1997). "Applying Occam's Razor in Cognitive Modeling: A Bayesian Approach" *Psychonomic Bulletin & Review*
  - Spiegelhalter et al. (2002). "Bayesian measures of model complexity and fit" *J. R. Statist. Soc. B*
  - Vanpaemel. (2010). "Prior Sensitivity in Theory Testing: An Apologia for the Bayes Factor" *Journal of Mathematical Psychology*
  - Vehtari & Lampinen. (2002). "Bayesian Model Assessment and Comparison Using Cross-Validation Predictive Densities" *Neural Computation*
  - Verhagen and Wagenmakers. (2014). "Bayesian Tests to Quantify the Result of a Replication Attempt" *Journal of Experimental Psychology: General*
  - Wagenmakers et al. (2010). "Bayesian Hypothesis Testing for Psychologists: A Tutorial on the Savage-Dickey Ratio" *Cognitive Psychology*

Friday: Introduction to Simulation Based Inference

- Classical Numerical Integration
- Rejection Sampling
- Importance Sampling
- Mode finding and the EM Algorithm
- What are Markov Chains?
- Properties of Markov Chains
- The Ergodic Theorem
- Essential Reading:
  - Gill (2014) Chapter 9
- Recommended Reading:
  - Carsey, T.M. and J.J. Harden: *Monte Carlo Simulation and Resampling Methods for Social Science*. Thousand Oaks, CA: Sage.
  - Go, C. & Batzoglou, S. (2008). "What is the expectation maximization algorith?" *Nature Biotechnology*
  - Jackman, S. (2000). "Estimation and Inference via Bayesian Simulation: An Introduction to Markov Chain Monte Carlo." *American Journal of Political Science* 44, 375-404.
  - Metropolis, N. and Ulam, S. (1949). "The Monte Carlo Method." *Journal of the American Statistical Association* 44, 335-3.
  - Peskun, P. H. (1973). "Optimum Monte Carlo Sampling Using Markov Chains." *Biometrika* 60, 607-612.
  - Tierney, L. (1994). "Markov Chains for Exploring Posterior Distributions." *Annals of Statistics* 22, 1701-1728.

  - Von Hilgers, P. & Langville, A. (N. date). "The Five Greatest Applications of Markov Chains"

Week II: MCMC & Special Topics (Menninga)

Monday: MCMC Algorithms & Convergence Diagnostics

- The Gibbs Sampler
- The Metropolis-Hastings Algorithm
- The Hit-and-Run Algorithm
- RJ MCMC
- Hamiltonian MCMC
- Visual & Empirical Convergence Diagnostics
- Essential Reading:
  - Gill (2014) Chapter 10 & 14
- Recommended Reading:
  - Casella, G. and George, E. I. (1992). "Explaining the Gibbs Sampler." *The American Statistician* 46, 167-174.
  - Cowles, M. K., Roberts, G. O., and Rosenthal, J. S. (1999). "Possible Biases Induced by MCMC Convergence Diagnostics." *Journal of Statistical Computation and Simulation* 64, 87-104.
  - Gallistel. (2009). "The Importance of Proving the Null" *Psychological Review*
  - Gelfand, A. E. and Smith, A. F. M. (1990). "Sampling-Based Approaches to Calculating Marginal Densities." *Journal of the American Statistical Association* 85: 389-409.
  - Gelman, A., Rubin, D. B. (1992). "Inference from Iterative Simulation Using Multiple Sequences." *Statistical Science* 7, 457- 511.
  - Geman, S. and Geman, D. (1984). "Stochastic Relaxation, Gibbs Distributions and the Bayesian Restoration of Images." *IEEE Transactions on Pattern Analysis and Machine Intelligence* 6,721- 741.
  - Geyer, C. J. (1992). "Practical Markov Chain Monte Carlo." *Statistical Science* 7, 473-511.
  - Hastings, W. K. (1970). "Monte Carlo Sampling Methods Using Markov Chains and Their Applications." *Biometrika* 57, 97-109.
  - McKeague & Wefelmeyer. (2000)."Markov chain Monte Carlo and Rao-Blackwellization" *Journal of Statistical Planning and Inference*
  - Zellner, A. and Min, C-K. (1995). "Gibbs Sampler Convergence Criteria." *Journal of the American Statistical Association* 90, 921-927.

Tuesday: Bayesian Change Point Analysis

- Essential Reading:
  - Gill (2014) Brief Example p. 346
- Recommended Reading:
  - Barry & Hartigan. (1993). "A Bayesian Analysis for Change Point Problems" *Journal of the American Statistical Association*
  - Carlin, Gelfand, & Smith. (1992). "Hierarchical Bayesian Analysis of Changepoint Problems" *Applied Statistics*
  - Chib. (1998). "Estimation and comparison of multiple change-point models" *Journal of Econometrics*
  - Park. (2010). "Structural Change in U.S. Presidents' Use of Force" *American Journal of Political Science*
  - Park. (2011). "Changepoint Analysis of Binary and Ordinal Probit Models: An Application to Bank Rate Policy Under the Interwar Gold Standard" *Political Analysis*
  - Western & Kleykamp. (2004). "A Bayesian Change Point Model for Historical Time Series Analysis" *Political Analysis*

Wednesday: Dan Gustafson Special Topic TBD

- Recommended Reading:
  - Keep an eye on the listserv and Dropbox folder.

Thursday: Topic Modeling & Bayes

- Recommended Reading:
  - Andrews & Vigliocco. (2010). "The Hidden Markov Topic Model: A Probabilistic Model of Semantic Representation" *Topics in Cognitive Science*
  - Blei. (2012). "Probabilistic Topic Models" *Communications of the ACM*
  - Grimmer. (2010). "A Bayesian Hierarchical Topic Model for Political Texts: Measuring Expressed Agendas in Senate Press Releases" *Political Analysis*
  - Grimmer & Stewart. (2013). "Text as Data: The Promise and Pitfalls of Automatic Content Analysis Methods for Political Texts" *Political Analysis*
  - Schofield et al. (2017). "Pulling Out the Stops: Rethinking Stopword Removal for Topic Models" *Proceedings of the 15th Conference of the European Chapter of the Association for Computational Linguistics*
  - Schofield & Mimno. (2016). "Comparing Apples to Apple: The Effects of Stemmers on Topic Models" *Transactions of the Association for Computational Linguistics*

Friday: Dynamic Latent Space Models

- Recommended Reading:
  - Hoff & Ward. (2004). "Modeling Dependencies in International Relations Networks" *Political Analysis*
  - Hoff, Raftery, & Handcock. (2002). "Latent Space Approaches to Social Network Analysis" *Journal of the American Statistical Association*
  - Sewell & Chen. (2015). "Latent Space Models for Dynamic Networks" *Journal of the American Statistical Association*
  - Sewell & Chen. (2016). "Latent Space Approaches to Community Detection in Dynamic Networks" *Bayesian Analysis*
  - Sewell & Chen. (2016). "Latent space models for dynamic networks with weighted edges" *Social Networks*
  - Ward, Hoff, & Lofdahl. (2003). "Identifying International Networks: Latent Spaces and Imputation"
  - Ward, Ahlquist, & Rozenas. (2013). "Gravity's Rainbow: A dynamic latent space model for the world trade network" *Network Science*

Bonus Topic if we have time: Bayesian Decision Theory

- Essential Reading:
  - Gill (2014) Chapter 8
- Recommended Readings:
  - Dienes. (2011). "Bayesian Versus Orthodox Statistics: Which Side Are You On?" *Perspectives on Psychological Science*
  - Gallistel. (2009). "The Importance of Proving the Null" *Psychological Review*
  - Rouder. (2009). "Bayesian t-tests for accepting and rejecting the null hypothesis" *Psychonometric Bulletin & Review*

Week III: (Stegmueller)

Monday: The Linear Model and Extensions

1. Bayesian linear model
2. Robust regression via t-errors
3. Bayesian tobit model

4. Diagnostics, model comparison, and prediction
5. Conjugate and nonconjugate priors

Tuesday: Models for Binary & Count Outcomes

1. Bayesian estimation of Probit models via latent data augmentation
2. Bayesian estimation of Logit models
3. Bayesian estimation of Poisson and negative binomial models
4. Dealing with complete separation in binary data models
5. Diagnostics via latent Bayesian residuals
6. Model comparison
7. Prediction and effective graphical presentation

Wednesday: Discrete Choice Models I: Ordered Outcomes

1. Bayesian estimation of ordered choice models
2. Priors and sampling strategies for latent variable cutpoints
3. Diagnostics and model comparison
4. Prediction, interpretation, and effective graphical presentation

Thursday: Discrete Choice Models II: Unordered Outcomes

1. Multinomial and Conditional Logit Models: Principles and Bayesian estimation
2. Identification problems in discrete choice models
3. Multinomial Probit Models: Principles and various Bayesian estimation strategies
4. Understanding prior choices
5. Prediction, interpretation, and effective graphical presentation

Friday: Seemingly Unrelated Regression / Multivariate Outcomes

1. The Bayesian Seemingly Unrelated Regression Model: Priors and Estimation
2. Multivariate Probit Model: Identification and Estimation
3. Discuss anything left over from previous sessions; Questions

Week IV: (Stegmueller)

Monday: Hierarchical/Multilevel Models

1. The Bayesian Hierarchical Linear Model
2. Hierarchical Logit/Probit Models
3. Understanding and choosing variance component priors
4. Advantages of Bayesian vs. Frequentist hierarchical models
5. 'Mr.P': Multilevel regression and post-stratification

Tuesday: Bayesian Models for Panel and TSCS Data

1. Heterogeneity in units via random effects models: priors and estimation
2. Heterogeneity in effects via random coefficient models: priors and estimation
3. Correlated random effects
4. Serially correlated residuals
5. Change point models

Wednesday: Latent Factor Models

1. Bayesian factor analysis for multivariate normal data
2. Ideal-point / item-response theory models
3. Identification issues in IRT models
4. IRT models with covariates
5. Bayesian factor analysis for continuous-discrete data

Thursday: Bayesian Instrumental Variable Models

1. The classical instrumental variables estimator
2. Bayesian instrumental variable model: priors and estimation
3. Advantages of Bayesian IV in the presence of weak instruments
4. Robust Bayesian IV via flexible error distributions

Friday: Final topic to round off the course. Depending on participants' preferences, either

- Bayesian thinking in causal inference, or
- Bayesian nonparametrics