Advanced Bayesian Models for the Social Sciences


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TA: TBD.

Date and Time: July 19 to August 13, 1-3 PM.

Office Hours: TBD.

Description and Schedule:

This course covers the theoretical and applied foundations of Bayesian statistical analysis at a level that goes beyond the introductory course at ICPSR. Therefore knowledge of basic Bayesian statistics (such as that obtained from the Introduction to Applied Bayesian Modeling for the Social Sciences workshop) is assumed. The course will consist of four modules. 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 module will focus on Bayesian item response theory (IRT) models, looking at theoretical foundations as well as practical issues such as identification and specification of hierarchies. The fourth week introduces the Bayesian approach to modeling time series data. This includes basic forms as well as recent developments such as Bayesian vector autoregression methods. Throughout the workshop, estimation with modern programming software (R, C, C++, and WinBUGS) will be emphasized.

Week I: Bayesian Model Checking, Assessment and Comparison.

Skyler Cranmer (University of North Carolina)

The first week has three components: assessing model quality, comparing models in a Bayesian context, and standard statistical computing tools that are useful for Bayesian analysis. The emphasis is on in-depth technical understanding of the mathematical statistics that justify and govern the use of these tools.

Monday: Quick Review of Bayesian Inference

1. This is not intended to be (nor will it be) a substitute for an introductory Bayes course. Rather it will be a refresher to make sure we’re all on the same page.

2. Essential Reading: Gill (2007) Chapters 1-4 or equivalent
Tuesday: The Bayesian Prior
1. Bayesian Shrinkage
2. (Many) Types of Priors

Wednesday: Assessing Model Quality
1. Global Sensitivity Analysis
2. Local Sensitivity Analysis
3. Global Robustness
4. Local Robustness
5. Comparing Data to the Posterior Predictive Distribution

Thursday: Model Comparison
1. Posterior Probability Comparison
2. Cross-Validation
3. Bayes Factors
4. AIC, BIC, DIC
5. Software Issues

Friday: Introduction to Monte Carlo Integration
1. Rejection Sampling
2. Classical Numerical Integration
3. Importance Sampling
4. Mode finding and the EM Algorithm
5. Essential Reading: Gill (2007) Chapter 8

Optional Additional Reading (for the week):


Week II: Markov Chain Monte Carlo.
Skyler Cranmer (University of North Carolina)

This week we continue our focus on computational techniques. We will expand on the idea of Monte Carlo integration introduced last week and then discuss Markov chains, Markov Chain Monte Carlo, MCMC algorithms (esp. Metropolis-Hastings and Gibbs Sampling) and conclude by discussing convergence diagnostics.

Monday: Markov Chains

1. What are Markov Chains?
2. Some Simple Examples
3. Marginal Distributions
4. Properties of Markov Chains
5. The Ergodic Theorem
6. Essential Reading

Tuesday: Gibbs Sampling

1. The Gibbs Sampler
2. Software Topic: Bayesian Analysis with MCMCpack

Wednesday: Metropolis-Hastings

1. The Metropolis-Hastings Algorithm
2. The Hit-and-Run Algorithm
3. Software Topic: Bayesian Analysis with WinBUGS

Thursday: Convergence Diagnostics

1. Trace Plots
2. Running mean plots
3. Density/HPD plots
4. The Geweke Diagnostic
5. The Gelman and Rubin Diagnostic
6. The Raftery and Lewis Diagnostic
7. The Heidelberger and Welch Diagnostic

Friday: Convergence Diagnostics (cont)

1. Finish whatever we did not cover Thursday (~ 1/3)
2. Software topic: Using the CODA and BOA packages in R
Optional Additional Reading (for the week):


WEEK III: Bayesian Methods for Ideal Point Estimation.
Jong Hee Park (University of Chicago).

This module covers theoretical foundations and Bayesian estimations of item response theory (IRT) models. We start from the history of roll call data analysis in political science and social sciences and discuss the connection between spatial voting models and item response theory models. We learn Bayesian implementation of item response theory models using Markov chain Monte Carlo methods. Then, we review important extensions of IRT models such as the issue of multidimensionality, dynamic ideal points, and hierarchical modeling. Students are expected to have basic understandings of Bayesian statistics and working knowledge of R programming.

Monday: History of Roll Call Data Analysis


Keith Poole, 2000, "Non-parametric unfolding of binary choice data" *Political Analysis* 8: 211-32.

Tuesday: Binary Choice Models and IRT Models


**Wednesday: Bayesian Estimation of IRT Models in Political Science**


**Thursday: Extensions, Applications, and Critiques**


Friday: Software Implementations
Example BUGS and R codes.

Week IV: Bayesian Time Series.
Patrick Brandt (University of Texas, Dallas).

This week's material is divided into five parts corresponding roughly to the presentations on each of the five days. We begin with a brief review of frequentist approaches to analyzing multiple time series. Topics covered include Granger causality, innovation accounting and unit root testing. The role that asymptotic theory plays in these and other aspects of the frequentist approach is stressed (e.g., in the construction of error bands for impulse responses in (S)VAR models and in knife-edge type tests for non-stationarity). We then turn, in parts two and three, to Bayesian time series analysis. We discuss time series priors and how elicitation and elucidation are used to construct these priors. Part three studies the Sims-Zha prior and analyzes in more depth such things as the way error bands are constructed for impulse responses. We illustrate the application of this prior and of likelihood shaped error bands. This includes a presentation of a recent piece on forecasting conflict and cooperation in the Levant. Problems of computation and of model evaluation are studied in part four. A topic from the frontiers of Bayesian time series analysis is presented on the last day of the week--Markov-switching. Frequentist approaches to studying Markov switching are reviewed. Then some new developments in the Bayesian approach to analyzing switching are presented. The application on this last day is an application of a Markov-switching BVAR for forecasting.

Students will be given some experience using two software packages: RATS and Brandt's MSBVAR. Details of the week follow.

Monday:  Review. The frequentist approach to analyzing multiple time series
1. Principles/basic time series concepts
2. Granger causality, impulse responses, DFEVS (and relationships to univariate analogs).
3. Topics
   a. Vector autoregressions
   b. Error correction models
   c. Structural VARs
4. Fitting frequentist models in STATA
5. Required Reading:
6. Reference Reading:
Tuesday: **Bayesian time series analysis, Part One**

1. Principles D
2. Time series priors, elicited and elucidated
3. VAR v. BVAR example
4. Fitting BVARs in RATS and MSBVAR
5. Required Reading:
6. Reference Reading:


**Wednesday: Bayesian time series analysis, Part Two**

1. Error bands for impulse response functions, The concept of Bayesian shape error bands
2. Testing theories with Bayesian SVAR models
3. Forecasting with Bayesian VAR models
4. Introduction to the package MSBVAR
5. Required readings

6. Reference papers


**Thursday:** Practical problems in using Bayesian time series models
   1. Computational challenges
   2. Formulating priors
   3. Assessing model fit
   4. More on MSBVAR
   5. Required readings:
      d. Notes on MSBVAR, R Package for B-(S)VAR models.
   6. Reference papers:

**Friday:** Frontiers of research in Bayesian time series analysis
   -- The concept of switching
   1. Frequentist approaches, Testing for structural change with frequentist methods, Hamilton's switching model
   2. Application: the political economy of exchange rates
   3. The MSBVAR model
   4. Applications
   5. Required readings:

6. Reference papers: