Bayesian Statistics

Math5900 - Spring 2006

Instructor:	Yali Liu
Office:	Gilbreath Hall 308 - H
Office Hours:	TTH 10:00 - 11:00 am or by appointment
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Class Time and Place: MW 3:10 pm - 4:30 pm; Gilbreath Hall 205

Credits: 3

Prerequisites: Permission of the advisor or instructor

Textbooks:

1. *Bayesian Data Analysis*(2nd edition) by Andrew Gelman, John B. Carlin, Hal S. Stern and Donald B. Rubin. Required.
   Some data sets and other information used in the book can be found from
   http://www.stat.columbia.edu/ gelman/book/
2. *Computational Statistics* by Geof H. Givens and Jennifer A. Hoeting. Recommended. This book includes more of the topics crucial for statistical computing. Data sets and other information in the book can be found from
   http://www.stat.colostate.edu/computationalstatistics/
3. *Markov Chain Monte Carlo in Practice*by W.R. Gilks. Recommended. The book introduces MCMC methods and their applications while also providing some theoretical background. It is a great collection of articles on applications. Emphasis is placed on practice rather than theory, although fundamental theoretical concepts are discussed.

Course Objectives: To present the basic concepts and tools in Bayesian analysis and computational statistics. To introduce how to do the Bayesian inference and simulations in R.

Course Work:

- Homework problems will be handed out on most Wednesdays and due one week late on Wednesday. There will be 5-6 assignments. No late homework will be accepted but exceptions may be arranged if discussed in advance. You may discuss the homework problems with other students, but you should write up your solution independently. When turning in your homework, each problem must be presented

in order. This includes all relevant graphs and tables, which must be easily readable and appropriately labeled. You are limited to a maximum of 5 pages per problem. Any graph or figure that is turned in without comments or spans across more than one page will be ignored. Please edit R output using a word processor or editor. The homework accounts for 20% of your final grade.

- One mid-term exam (in-class) will be scheduled and the tentative date will be announced 2 weeks in advance. Exam is open book and open notes. There will be no makeup of exam. Request for any exceptional arrangement must be made one week before the exam. The exam accounts for 30% of your final grade.
- A take-home exam will be given at the end of the semester. It accounts for 30% of your final grade.
- A term project should be completed on a real problem using Bayesian methods. A project team should have at most 3 students. The project accounts for 20% of your final grade respectively.

  Some examples of the project are:

  - Carry out a complete Bayesian analysis of a real dataset. This might involve:
    * description of the research question and dataset
    * specifying an appropriate Bayesian model
    * determining appropriate values for prior parameters
    * fitting the model using R
    * checking convergence
    * analyzing the output
    * reporting and interpreting the results
  - Compare dfferent methods of fitting the same model to the same dataset
    * normal approximations
    * MCMC
    * other simulation methods
    * analytical computation (if feasible)
  - Carry out a Bayesian analysis of a dataset for which a classical analysis has been reported in a journal. Compare and contrast the results obtained by the two approaches.
  - Fit a Bayesian model to a dataset using several dfferent choices of prior (hyperpa rameters and/or functional form). Discuss the meaning of the dfferent results, and the robustness of the model to prior specfications.
  - Fit several different plausible Bayesian models to the same dataset. Carry out a check of model adequacy and model fit. Discuss the results.
  - There are endless other possibilities. Find something that interests you, or see me for ideas.

Projects will be carried out in two phases.

- Project proposal (due 3/15/06)
  This is a detailed description of what you plan to do, including question(s) to be addressed, dataset to be used (if any), methods to be applied. Also specify the method of presentation that you intend for the final project.
- Project report and presentation (due 4/26/06)
  Project should be written up as a paper. All computer output must be inserted in the text. An 30-minute oral presentation with overheads, slides, or computer images will be given in class during the final week of classes.

Grading Scale:

A	90 - 100	C	70- 79
B+	85 - 89	D	60- 69
B	80 - 84	F	≤ 60 or for academic misconduct

Attendance: You are expected to attend the lectures. You are responsible for any announcements and the material covered during the lecture.

Course Topics:

- Elements of Bayesian Inference:
  - Bayes theorem, prior, likelihood, posterior, exchangebility, Likelihood Principle, invariance, sufficiency, ancillarity, Bayes factors and Bayes hypothesis testing
  - Bayes Rule, Credible sets, HPD.
  - Prior selection: subjective, conjugate, non-informative, Jeffreys, reference, Prior and Posterior robustness
  - Predictive distribution, Asymptotic properties of posterior, Empirical Bayesian versus Bayes, Laplace approximation.
- Bayesian Decision Theory:
  - Frequentist Risk, Bayes Risk, Bayesian Expected Loss
  - Admissibility, Minimaxity, Bayes and Extended Bayes
- Bayesian Modelling:
  One-parameterModels, Multi-parameterModels, Nuisance parameters, Hierarchical models, model checking, model comparison.
- Computation:
  - Simulation methods: Random Number Generation, Generating Random Variables, Newton-Raphson Algorithm
  - Markov Chain Monte Carlo Techniques: Metropolis-Hastings, Gibbs Sampler, Simulated Annealing, Importance sampling.