Applied Bayesian Inference

This is an introductory course in Bayesian inference starting from first principles. The Bayesian approach is based on a different paradigm than the classical frequentist approach to statistical inference. Over the last decade, the Bayesian approach has revolutionised many areas of applied statistics such as biometrics, econometrics, market research, statistical ecology and physics. Although the Bayesian approach dates back to the 18th century, its rise and enormous popularity today is due to the advances made in Bayesian computation through computer-intensive simulation methods. Knowledge of Bayesian procedures and software packages will become indispensable for any career in Statistics. Students will be using the software package R for Bayesian computation and will be introduced to WinBUGS. Topics covered include: the Bayesian approach, conjugate distributions, prior distributions, simulation methods, Markov chain Monte Carlo methods, using the WinBUGS software, and applications to data analysis.

Prerequisites: Basic knowledge in probability and statistics
Familiarity with the classical frequentist approach to statistical inference
and knowledge of SPLUS or R is of advantage

Textbooks: Recommended for complementary reading:

Berger, J.O., Wolpert R.L. (1988):
The Likelihood Principle, IMS Lecture Notes- Monograph Series

Carlin, B.P. and Th.A. Louis (2000):
Bayes and Empirical Bayes Methods for Data Analysis,
Chapman & Hall, London

Congdon, P. (2001):
Bayesian Statistical Modelling, Wiley, New York

Gelman, A., J.B. Carlin, H.S. Stern, D.B. Rubin (2004):
Bayesian Data Analysis, Chapman & Hall, London.

Lee, P.M. (2004): *Bayesian Statistics: An Introduction*,
Halsted Press, New York.

Albert, J. (2007):
Bayesian Computation with R, Springer, New York.

Assignment questions, solutions and other handouts will be distributed in lectures. After class extra copies can be obtained from the lecturer's office or the course webpage.

Course Outline:

1. **Introduction to R and WinBUGS**
2. **Introduction to the Bayesian approach**
   (a) History of statistical inference
   (b) Bayes' theorem: discrete case
   (c) Likelihood-based functions
   (d) Bayes' theorem: continuous case
   (e) Conjugate examples: Bernoulli, Binomial, Uniform, Normal, Poisson, and Exponential
   (f) Exchangeability
   (g) Sequential Learning
   (h) Comparing Bayesian and Frequentist Inference for a Proportion
3. **Fundamental Principles**
   (a) Likelihood Principle
   (b) Conditionality Principle
   (c) Sufficiency Principle
   (d) Stopping Rule Principle
4. **Prior Distributions**
   (a) Subjective priors
   (b) Conjugate priors
   (c) Noninformative priors
   (d) Jeffreys priors
   (e) Empirical Bayes priors
   (f) Hierarchical priors

In case the course will be offered in two parts, the preceding chapters 1-4 will be covered in the 1-week block course before the begin of the winter semester while the following chapters 5-7 will be taught in a regular (2+1) class during the semester.

5. **Posterior Computation**
   (a) Numerical integration
   (b) Asymptotic approximations
   (c) Non-iterative simulation: inverse transform and rejection method
   (d) Stochastic Simulation: rejection and SIR
   (e) Markov Chain Monte Carlo (MCMC) Methods
   (f) Metropolis-Hastings algorithm
   (g) Practical implementation issues
   (h) Markov chain theory
   (i) Gibbs sampler
   (j) Adaptive Rejection Sampling
6. **Software: WinBUGS**
   (a) Introduction
   (b) Linear Models and applications
   (c) Generalized Linear Models and applications
   (d) Dynamic Models and applications
   (e) Convergence Diagnostics using CODA
7. **Model Checking**
   (a) Bayes factors
   (b) Bayesian p-values
   (c) Bayesian deviance (DIC)