FACULTY OF SCIENCE

SCHOOL OF MATHEMATICS AND STATISTICS

MATH3871/MATH5960

Bayesian Inference and Computation

Session 2, 2018

Cricos Provider Code: 00098G

Units of Credit:	6
Exclusions:	MATH3871, MATH5960.
Course Instructor	Dr. Zdravko Botev
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Pre-requisites

The formal prerequisites for this course are MATH2901 (Higher Theory of Statistics) and MATH2931 (Higher Linear Models). If you have not done these courses, make sure that you:

- know sufficient statistical theory to be comfortable working with likelihood functions;
- are able to algebraically integrate and differentiate;
- have competency in at least one programming language such as R, Matlab, Julia, Python.

The lecturer can provide course notes for the MATH2931/2901 if you wish to fill in gaps in your knowledge.

Lectures:

This course is jointly taught at two levels. MATH3871 is for 3rd year undergraduates, whereas MATH5960 is for Honours/Masters students. Lectures will be conducted simultaneously for both streams, but tutorial classes and computer labs will be conducted separately for the two groups. The lectures run from weeks 1 to 12, and tutorials and labs run after the weekly lectures (so weeks 1–12 for MATH5960 and weeks 2–13 for Math3871).

MATH3871

Monday	18:00-20:00pm	Lectures	Old Main Building 149	Weeks 1:12
Tuesday	13:00-14:00pm	Tutorial	Old Main Building G31	Weeks 2:13
Tuesday	14:00-15:00pm	Lab	Red Centre Central Wing G12B	Weeks 2:13

MATH5960

Monday	18:00-20:00pm	Lectures	Old Main Building 149	Weeks 1:12
Monday	20:00-21:00pm	Tutorial/Lab	Red Centre Central Wing G12A	Weeks 2:13

Planned lecture topic schedule:

Week 1	Introduction to Bayesian inference and Monte Carlo
Week 2	Priors and inversion sampling
Week 3	Multivariate (linear) models
Week 4	Monte Carlo integration and rejection sampling
Week 5	Loss functions, asymptotics and importance sampling
Week 6	Markov chain Monte Carlo, Gibbs sampling, assessing convergence
Week 7	Regenerative processes and simulation
Week 8	Regenerative chain Monte Carlo
Week 9	Bayesian hypothesis/model testing
Week 10	Bayes factors with improper priors
Week 11	TBA (e.g., Hierarchical models)
Week 12	Revision

Course Overview

Bayesian statistics could be described as the systematic application of Bayes formula from first year probability theory. It is a completely probabilistic approach to inference where we set up a full probability model for the data and unknowns in a problem and then condition on the data, making inference about unknowns from the conditional distribution of the unknowns given data (the so-called posterior distribution). Specification of a full probability model in a decision making problem involves determination of the likelihood function from classical inference but also specification of a prior distribution which expresses probabilistically what we know about the unknowns before observing data.

After describing the fundamentals of Bayesian inference this course will examine specification of prior distributions, links between Bayesian and classical frequentist inference, Bayesian model comparison and Bayesian computational methods. Markov chain Monte Carlo (MCMC) methods for computation will be described and implemented. We will illustrate the advantages of the Bayesian approach by describing Bayesian inferential methods for a variety of models.

Course Aims

This course aims to:

1. provide a background in the concepts and philosophy of Bayesian inference;

2. instil an appreciation of the flexibility of many standard modelling frameworks;

3. provide opportunities to implement these models in practice.

Student Learning Outcomes

In attending this course students will:

1. extend their statistical knowledge beyond the "classical" statistical methodology, and understand when the Bayesian approach can be beneficial;

2. understand how the various standard models work, and be able to construct new models for the problem at hand.

Teaching Strategies

Students will be provided electronic copies of lecture notes used during lecture times, but are ancouraged to read selected reference books papers in order to gain a solid grasp of the topics taught (see *Recommended Reading Material*).

Students will be given tutorial and computer lab problems for practice and to develop understanding of the course material.

Assessment

Assessment	Weight	Date
Final Exam	60%	See examinations timetable.
Assignment 1	20%	Due in Lecture in week 6 (approximate – see class)
Assignment 2	15%	Due in Lecture in week 10 (approximate – see class)
Class Participation	5%	Throughout semester

Course assessment will consist of 60% final examination (2 hours). Two written assignments will be set on computational, modelling and theoretical aspects of the course. The class participation component will require a student to answer at least one question during the course of all lectures.

Recommended Reading Material

Some content for this course is drawn from a number of text books in order that you might use these for more detailed reading than is provided in the Lecture Notes. These sources are as follows:

- Statistical Modeling and Computation, D.P. Kroese and J.C.C. Chan, Springer, 2014.
- Bayes and Empirical Bayes Methods for Data Analysis (second edition), B.P.Carlin and T.A.Louis, Chapman and Hall
- Bayesian Inference, 2nd Edition, Vol 2B of "Kendall's Advanced Theory of Statistics," A. O'Hagan and J. J. Forster (2004), Arnold, London.

Computational Software

Computations can be performed using Matlab/Julia/Python/R. For the freeware *R*, you can use *BuGS* software packages. Students may download these packages from the internet at:

- *R:* `http://www.r-project.org/` (plus the `BRuGS` package)
- *WinBugs:* `http://www.mrc-bsu.cam.ac.uk/bugs/welcome.shtml`
- *OpenBugs:* `http://www.math.helsinki.fi/openbugs/`

Note: *OpenBugs* is an open-source version of *WinBugs* and is installed in the Maths Computer Labs.