SCHOOL OF MATHEMATICS AND STATISTICS

MATH3871/MATH5960
Bayesian Inference and Computation

Term 3, 2022

Units of Credit:	6
Exclusions:	MATH3871, MATH5960.
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Pre-requisites

There are no formal pre-requisites for this course. However, students taking the course should:

- know sufficient statistical theory to be comfortable working with likelihood functions;

- be able to algebraically integrate and differentiate;

- have competency in a programming language such as R, Matlab, Python etc.

Only advice on coding in R will be provided by the Instructor, with other languages the responsibility of the student.

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 10, and tutorials and labs run after the weekly lectures (so weeks 2 to 10). Students should bring their laptops to the tutorials so that they can complete the coding exercises. Please ensure you have installed `R` (`RStudio` is highly recommended).

There will be a (virtual) guest lecture from a Quantitative Researcher from Citadel on Wednesday 19th October (Week 6).

MATH3871

Wednesday	2:00-4:00pm	Lectures	online	Weeks 1–5,7–10
Thursday	9:00-11:00am	Tutorial/Lab	RC-1041	Weeks 2–5,7–10
Thursday	11:00am-1:00pm	Tutorial/Lab	RC-1041	Weeks 2–5,7–10
Thursday	2:00-4:00pm	Tutorial/Lab	RC-1041	Weeks 2–5,7–10
Thursday	4:00am-6:00pm	Tutorial/Lab	RC-1041	Weeks 2–5,7–10

MATH5960

Wednesday	2:00-4:00pm	Lectures	online	Weeks 1–5,7–10
Thursday	3:00-5:00pm	Tutorial/Lab	OMB-149	Weeks 2–5,7–10
Monday	2:00pm-4:00pm	Tutorial/Lab	online	Weeks 2–5,7–10

Planned lecture topic schedule:

Week 1	Introduction to Bayesian inference and Monte Carlo
Week 2	Priors and inversion sampling
Week 3	Multivariate models, Monte Carlo integration and rejection sampling
Week 4	Loss functions, asymptotics and importance sampling
Week 5	Markov chain Monte Carlo, Gibbs sampling, assessing convergence
Week 6	$\longrightarrow$ *Flex Week - Guest Lecture from Quant Researcher* $\longleftarrow$
Week 7	Metropolis-Hastings, conditional independence graphs, Stan
Week 8	Bayesian hypothesis/model testing & Bayes Factors
Week 9	Hierarchical models
Week 10	Mixture models

NB: No tutorials will be held on Thursday 22nd September (Week 2) due to Public Holiday. If you are enrolled in that tute, please attend the (online) tutorial on Monday or view the recording.

Course Overview

Bayesian statistics could be described as the systematic application of probability to decision making in the face of uncertainty. 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 including linear models and various kinds of hierarchically structured 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 (essential for employment prospects);

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;

3. gain first-hand experience in performing real-world Bayesian data analyses;

Teaching Strategies

Students will be provided electronic copies of lecture notes and used during lecture times and lectures will be recorded. However, students are encouraged 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 problems that are a mixture of theory and coding for practice and to develop understanding of the course material. It is advised that students work through these problems at their own pace, before the tutorial session. This will provide an opportunity for students to ask questions during the tutorial, where discussion will be encouraged. Partial solutions to tutorials will be provided for guidance, usually one week after the relevant tutorial.

Assessment

Assessment	Weight	Due Date
(Online) Final Exam	60%	See examinations timetable.
Assignment 1 (Individual)	15%	Week 4
(Online) Mid-session Test	10%	Week 7
Assignment 2 (Group)	15%	Week 9

Course assessment will consist of 60% final examination. Two written assignments (15% each) will be set on computational, modelling and theoretical aspects of the course. The first assignment should be completed individually, whereas the second assignment can be completed in groups (although you may also complete it individually, if you wish). A statement of contribution of all group members should be provided. Assignments will be graded and returned with comments where appropriate in order to provide feedback and encourage student reflection. 5% of marks for written assignments will be given for presentation. Assignments will be released 2 weeks before the due date. There will be a mid-session test (10%) covering all topics from the first 5 weeks of the course. This will be time-limited.

Late Submission of Assessment Tasks

A late penalty of 5% of the maximum mark for the task will be applied per day or part day any assessment task is submitted more than 1 hour

late. (Where "late" in this context means after any extensions granted for Special Consideration or Equitable Learning Provisions.) For example, an assessment task that was awarded 75% would be given 65% if it was 1-2 days late. Any assessment task submitted 7 or more days late will be given zero. Note that the penalty does not apply to

- Assessment tasks worth less than 5% of the total course mark, e.g. weekly quizzes, weekly class participation, or weekly homework tasks.

- Examinations and examination-style class tests

- Pass/Fail Assessments

Applications for Special Consideration for Missed Assessment

Please adhere to the Special Consideration Policy and Procedures provided on the web page below when applying for special consideration. `https://student.unsw.edu.au/special-consideration`

Please note that the application is not considered by the Course Authority, it is considered by a centralised team of staff at the Nucleus Student Hub. The School will contact you (via student email account) after special consideration has been granted to reschedule your missed assessment, for a lab test or paper-based test only.

For applications for special consideration for assignment extensions, please note that the new submission date and/or outcome will be communicated through the special consideration web site only, no communication will be received from the School.

For Dates on Final Term Exams and Supplementary Exams please check the "Key Dates for Exams" ahead of time to avoid booking holidays or work obligations. `https://student.unsw.edu.au/exam-dates`

If you believe your application for Special Consideration has not been processed, you should email `specialconsideration@unsw.edu.au` immediately for advice.

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:

- Bayesian Data Analysis (second edition), A Gelman, J Carlin, H Stern and D Rubin, Chapman and Hall

  http://www.stat.columbia.edu/∼gelman/book/

- Bayes and Empirical Bayes Methods for Data Analysis (second edition), B.P.Carlin and T.A.Louis, Chapman and Hall

- Markov Chain Monte Carlo - Stochastic simulation for Bayesian inference, D. Gammerman, 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

Computation will be performed using the freeware *R* and *Stan* software packages It is expected that these will be used for computer labs and written assignments. Students may download these packages from the internet at:

- *R:* http://www.r-project.org/

- *Stan:* https://mc-stan.org/

A comprehensive guide to using R can be found at: https://cran.r-project.org/doc/manuals/r-release/R-intro.pdf

Other Information

Course information, including plagiarism statements and other resources, can be found on *Moodle* available to registered students at:
http://moodle.telt.unsw.edu.au/

Course Evaluation and Development

The School of Mathematics and Statistics evaluates each course each time it is run. We carefully consider the student responses and their implications for course development. It is common practice to discuss informally with students how the course and their mastery of it are progressing. Feedback to the course instructor on any course aspect at any time is strongly encouraged.

School and UNSW policies

The School of Mathematics and Statistics has adopted a number of policies relating to enrolment, attendance, assessment, plagiarism, cheating, special consideration etc. These are in addition to the Policies of The University of New South Wales. Individual courses may also adopt other policies in addition to or replacing some of the School ones. These will be clearly notified in the Course Initial Handout and on the Course Home Pages on the Maths Stats web site.

Students in courses run by the School of Mathematics and Statistics should be aware of the School and Course policies by reading the appropriate pages on the Maths Stats web site starting at: `https://www.maths.unsw.edu.au/currentstudents/assessment-policies`

The School of Mathematics and Statistics will assume that all its students have read and understood the School policies on the above pages and any individual course policies on the Course Handout and Course Home Page. Lack of knowledge about a policy will not be an excuse for failing to follow the procedure in it.

Academic Integrity and Plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW staff and students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.

The UNSW Student Code provides a framework for the standard of conduct expected of UNSW students with respect to their academic integrity and behaviour. It outlines the primary obligations of students and directs staff and students to the Code and related procedures.

In addition, it is important that students understand that it is not permissible to buy essay/writing services from third parties as the use of such services constitutes plagiarism because it involves using the words or ideas of others and passing them off as your own. Nor is it permissible to sell copies of lecture or tutorial notes as students do not own the rights to this intellectual property. If a student breaches the Student Code with respect to academic integrity, the University may take disciplinary action under the Student Misconduct Procedure.

The UNSW Student Code and the Student Misconduct Procedure can be found at: `https://student.unsw.edu.au/plagiarism` An online Module "Working with Academic Integrity" (`https://student.unsw.edu.au/aim`) is a six-lesson interactive self-paced Moodle module exploring and explaining all of these terms and placing them into your learning context. It will be the best one-hour investment you've ever made.

Plagiarism is presenting another person's work or ideas as your own. Plagiarism is a serious breach of ethics at UNSW and is not taken lightly. So how do you avoid it? A one-minute video for an overview of how you can avoid plagiarism can be found `https://student.unsw.edu.au/plagiarism`.

Administrative Contacts

Please visit the School of Mathematics and Statistics website for a range of information on School Policies, Forms and Help for Students.

For information on Courses, please go to "Student Life & resources page" and either Undergraduate Courses and/or Postgraduate Courses for information on all course offerings.

The "Student Notice Board" can be located by going to the "Student Life & resources" page; Notices are posted regularly for your information here. Please familiarise yourself with the information found in these locations. The

School web page is: `https://www.maths.unsw.edu.au`

If you cannot find the answer to your queries on the web you are welcome to contact the Student Services Office directly.

By email:
Undergraduate: `ug.mathsstats@unsw.edu.au`
Postgraduate: `pg.mathsstats@unsw.edu.au`

By phone: 9385 7011 or 9385 7053

Should we need to contact you, we will use your official UNSW email address of in the first instance. It is your responsibility to regularly check your university email account. Please state your student number in all emails.

Note

The information contained herein is for general guidance of students and is as accurate as possible at the date of issue. You will be informed of any changes.