UNSW Course Outline

MATH3871 Bayesian Inference and Computation - 2024

Published on the 30 Sep 2024

General Course Information

Course Code : MATH3871
Year : 2024
Term : Term 3
Teaching Period : T3
Is a multi-term course? : No
Faculty : Faculty of Science
Academic Unit : School of Mathematics & Statistics
Delivery Mode : In Person
Delivery Format : Standard
Delivery Location : Kensington
Campus : Sydney
Study Level : Undergraduate
Units of Credit : 6

Useful Links

Handbook Class Timetable

Course Details & Outcomes

Course Description

After describing the fundamentals of Bayesian inference, this course will examine the specification of prior and posterior distributions, Bayesian decision theoretic concepts, the ideas behind Bayesian hypothesis tests, model choice and model averaging, and evaluate

the capabilities of several common model types, such as hierarchical and mixture models. An important part of Bayesian inference is the requirement to numerically evaluate complex integrals on a routine basis. Accordingly this course will also introduce the ideas behind Monte Carlo integration, importance sampling, rejection sampling, Markov chain Monte Carlo samplers such as the Gibbs sampler and the Metropolis-Hastings algorithm, and use of the Stan posterior simulation software.

The intended audience of this course is wide-ranging, from statistics and data science students to economics, actuarial, computer science and natural science (e.g. biology, geology, physics) students. Prior knowledge of basic probability is necessary, and knowledge of stochastic processes will be advantageous but is not required. The purpose of this course is to introduce students to Bayesian statistical concepts not seen in core courses which are primarily focused on frequentist statistics.

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 the combined tutorial/lab sessions run after the weekly lectures (weeks 2 to 10). Students should bring their laptops to the tutorials so that they can complete the coding exercises.

Course Aims

This course aims to:

- Provide a strong background in the concepts and philosophy of Bayesian inference;
- Instill an appreciation of the benefits of the Bayesian framework;
- Provide extensive practical opportunities to implement Bayesian data analyses;
- Present an overview of research activity in this field.

Relationship to Other Courses

MATH2801 or MATH2901 is a pre-requisite for students wishing to enrol in MATH3871. 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. (although this course will focus only on programming in R and Stan)

Course Learning Outcomes

Course Learning Outcomes
CLO1 : Explain and apply the background concepts underlying Bayesian inference.
CLO2 : Prove theoretic results underlying some common Bayesian models and simulation techniques.
CLO3 : Explain the importance of computational techniques that are critical for Bayesian inference.
CLO4 : Perform computational Bayesian analysis (e.g. using R) on realistic data using either common model types or using newly-constructed/bespoke models for new problems.

Course Learning Outcomes	Assessment Item
CLO1 : Explain and apply the background concepts underlying Bayesian inference.	• Final Exam • Mid Term Test
CLO2 : Prove theoretic results underlying some common Bayesian models and simulation techniques.	• Assignment • Final Exam • Mid Term Test
CLO3 : Explain the importance of computational techniques that are critical for Bayesian inference.	• Assignment • Final Exam • Mid Term Test
CLO4 : Perform computational Bayesian analysis (e.g. using R) on realistic data using either common model types or using newly-constructed/bespoke models for new problems.	• Assignment • Final Exam • Mid Term Test

Learning and Teaching Technologies

Moodle - Learning Management System | Echo 360

Learning and Teaching in this course

Lectures will be held face to face and will be livestreamed and recorded.

Assessments

Assessment Structure

Assessment Item	Weight	Relevant Dates
Assignment Assessment Format: Individual	20%	Start Date: 27/10/2024 05:00 PM Due Date: 15/11/2024 11:59 PM
Final Exam Assessment Format: Individual	60%	Start Date: During the exam period Due Date: During the exam period
Mid Term Test Assessment Format: Individual	20%	Start Date: Not Applicable Due Date: 24/10/2024 11:00 AM

Assessment Details

Assignment

Assessment Overview

This written assignment covers material from Weeks 1-7 of the course and will be due in Week 9 or 10. You will be examined on a combination of theoretical and computer simulation-based tasks (in R).

Feedback will provided one week after the submission of the assignment.

Course Learning Outcomes

- CLO2 : Prove theoretic results underlying some common Bayesian models and simulation techniques.
- CLO3 : Explain the importance of computational techniques that are critical for Bayesian inference.
- CLO4 : Perform computational Bayesian analysis (e.g. using R) on realistic data using either common model types or using newly-constructed/bespoke models for new problems.

Assessment Length

No more than 6 pages

Assignment submission Turnitin type

This assignment is submitted through Turnitin and students do not see Turnitin similarity reports.

Generative AI Permission Level

No Assistance

This assessment is designed for you to complete without the use of any generative AI. You are not permitted to use any generative AI tools, software or service to search for or generate

information or answers.
For more information on Generative AI and permitted use please see here.

Final Exam

Assessment Overview

The final exam will be 2 hours in duration and held during the formal examination period. It will cover all lecture and tutorial/lab material covered in the course. The exam will test your understanding of concepts covered in the course as well as your ability to apply them to solve problems. You may be expected to provide pseudocode in your responses.

Feedback is available through inquiry with the course convenor.

Course Learning Outcomes

- CLO1 : Explain and apply the background concepts underlying Bayesian inference.
- CLO2 : Prove theoretic results underlying some common Bayesian models and simulation techniques.
- CLO3 : Explain the importance of computational techniques that are critical for Bayesian inference.
- CLO4 : Perform computational Bayesian analysis (e.g. using R) on realistic data using either common model types or using newly-constructed/bespoke models for new problems.

Assessment Length

2 hours

Assignment submission Turnitin type

Not Applicable

Generative AI Permission Level

No Assistance

This assessment is designed for you to complete without the use of any generative AI. You are not permitted to use any generative AI tools, software or service to search for or generate information or answers.
For more information on Generative AI and permitted use please see here.

Mid Term Test

Assessment Overview

The mid-term test will be held during the lecture slot in Week 7. It will cover lecture material from Weeks 1-4 and tutorial/lab material from Weeks 2-5. The exam will test your understanding of

concepts covered in the course as well as your ability to apply them to solve problems. The exam may consist of a combination of hand-written and computer simulation based tasks.

Feedback will provided within two weeks following completion of the test.

Course Learning Outcomes

- CLO1 : Explain and apply the background concepts underlying Bayesian inference.
- CLO2 : Prove theoretic results underlying some common Bayesian models and simulation techniques.
- CLO3 : Explain the importance of computational techniques that are critical for Bayesian inference.
- CLO4 : Perform computational Bayesian analysis (e.g. using R) on realistic data using either common model types or using newly-constructed/bespoke models for new problems.

Assessment Length

1.5 hours

Assignment submission Turnitin type

Not Applicable

Generative AI Permission Level

No Assistance

This assessment is designed for you to complete without the use of any generative AI. You are not permitted to use any generative AI tools, software or service to search for or generate information or answers.
For more information on Generative AI and permitted use please see here.

General Assessment Information

Standard rules apply for late submissions of Assessment 1. UNSW has a standard late submission penalty of:

- 5% per day,
- for all assessments where a penalty applies,
- capped at five days (120 hours) from the assessment deadline, after which a student cannot submit an assessment, and
- no permitted variation.

Grading Basis

Standard

Requirements to pass course

At least 50% in final exam.

Course Schedule

Teaching Week/Module	Activity Type	Content
Week 0 : 2 September - 8 September	Lecture	O-week (no lectures)
Week 1 : 9 September - 15 September	Lecture	Introduction to Bayesian inference and Monte Carlo
Week 2 : 16 September - 22 September	Lecture	Introduction to Bayesian inference and Monte Carlo
	Lecture	Priors and inversion sampling
Week 3 : 23 September - 29 September	Lecture	Multivariate models, Monte Carlo integration and rejection sampling
Week 4 : 30 September - 6 October	Lecture	Loss functions, asymptotics and importance sampling
Week 5 : 7 October - 13 October	Lecture	Markov chain Monte Carlo, Gibbs sampling, assessing convergence
Week 6 : 14 October - 20 October	Lecture	Flexibility Week (no lectures)
Week 7 : 21 October - 27 October	Lecture	Metropolis-Hastings, conditional independence graphs, Stan.
Week 8 : 28 October - 3 November	Lecture	Bayesian hypothesis/model testing & Bayes factors
Week 9 : 4 November - 10 November	Lecture	Hierarchical models
Week 10 : 11 November - 17 November	Lecture	Mixture models

Attendance Requirements

Students are strongly encouraged to attend all classes and review lecture recordings.

General Schedule Information

The course schedule provided below is an indicative lecture schedule, subject to minor variations.

Course Resources

Recommended Resources

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

Staff Details

Position	Name	Email	Location	Phone	Availability	Equitable Learning Services Contact	Primary Contact
Lecturer	Sahani Pathi raja		H13 Anita Lawrence Building East - 2070			No	Yes

Other Useful Information

Academic Information

Upon your enrolment at UNSW, you share responsibility with us for maintaining a safe, harmonious and tolerant University environment.

You are required to:

- Comply with the University's conditions of enrolment.
- Act responsibly, ethically, safely and with integrity.
- Observe standards of equity and respect in dealing with every member of the UNSW community.
- Engage in lawful behaviour.
- Use and care for University resources in a responsible and appropriate manner.
- Maintain the University's reputation and good standing.

For more information, visit the UNSW Student Code of Conduct Website.

Academic Honesty and Plagarism

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism.
Further information about referencing styles can be located at https://student.unsw.edu.au/referencing

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits: honesty, trust, fairness, respect, responsibility and courage. At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.

Further information about academic integrity, plagiarism and the use of AI in assessments can be located at:

- The Current Students site,
- The ELISE training site, and
- The Use of AI for assessments site.

The Student Conduct and Integrity Unit provides further resources to assist you to understand your conduct obligations as a student: https://student.unsw.edu.au/conduct

Submission of Assessment Tasks

Penalty for Late Submissions

UNSW has a standard late submission penalty of:

- 5% per day,
- for all assessments where a penalty applies,
- capped at five days (120 hours) from the assessment deadline, after which a student cannot submit an assessment, and
- no permitted variation.

Any variations to the above will be explicitly stated in the Course Outline for a given course or assessment task.

Students are expected to manage their time to meet deadlines and to request extensions as early as possible before the deadline.

Special Consideration

If circumstances prevent you from attending/completing an assessment task, you must officially apply for special consideration, usually within 3 days of the sitting date/due date. You can apply by logging onto myUNSW and following the link in the My Student Profile Tab. Medical documentation or other documentation explaining your absence must be submitted with your application. Once your application has been assessed, you will be contacted via your student email address to be advised of the official outcome and any actions that need to be taken from there. For more information about special consideration, please visit: https://student.unsw.edu.au/special-consideration

Important note: UNSW has a "fit to sit/submit" rule, which means that if you sit an exam or submit a piece of assessment, you are declaring yourself fit to do so and cannot later apply for Special Consideration. This is to ensure that if you feel unwell or are faced with significant

circumstances beyond your control that affect your ability to study, you do not sit an examination or submit an assessment that does not reflect your best performance. Instead, you should apply for Special Consideration as soon as you realise you are not well enough or are otherwise unable to sit or submit an assessment.

Faculty-specific Information

Additional support for students

- The Current Students Gateway
- Student Support
- Academic Skills and Support
- Student Wellbeing, Health and Safety
- Equitable Learning Services
- UNSW IT Service Centre
- Science EDI Student Initiatives, Offerings and Guidelines

School-specific Information

School of Mathematics and Statistics 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 web site starting at: The School of Mathematics and Statistics 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 Initial Handout and Course Home Page. Lack of knowledge about a policy will not be an excuse for failing to follow the procedure in it.

Special Consideration - Short Extension Policy

The School of Mathematics and Statistics has carefully reviewed its range of assignments and projects to determine their suitability for automatic short extensions as set out by the UNSW Short Extension Policy. Upon comprehensive examination of our course offerings that

incorporate these types of assessments, we have concluded that our current deadline structures already accommodate the possibility of unexpected circumstances that may lead students to require additional days for submission. Consequently, the School of Mathematics and Statistics has decided to universally opt out of the Short Extension provision for all its courses, having pre-emptively integrated flexibility into our assessment deadlines. The decision is subject to revision in response to the introduction of new course offerings. Students may still apply for Special Consideration via the usual procedures.

Computing Lab

The main computing laboratory is room G012 of the Anita B.Lawrence Centre (formerly Red Centre). You can get to this lab by entering the building through the main entrance to the School of Mathematics (on the Mezzanine Level) and then going down the stairs to the Ground Level. A second smaller lab is Room M020, located on the mezzanine level through the glass door (and along the corridor) opposite the School's entrance.

For more information, including opening hours, see the computing facilities webpage. Remember that there will always be unscheduled periods when the computers are not working because of equipment problems and that this is not a valid excuse for not completing assessments on time.

School Contact Information

Please visit the School of Mathematics and Statistics website for a range of information.

For information on Courses, please go to “Student life & resources” and either Undergraduate and/or Postgraduate and respective "Undergraduate courses" and "Postgraduate courses" for information on all course offerings.

All school policies, forms and help for students can be located by going to the "Student Services" within “Student life & resources” page. We also post notices in "Student noticeboard" for your information. Please familiarise yourself with the information found in these locations. If you cannot find the answer to your queries on the web you are welcome to contact the Student Services Office directly.

Undergraduate

E: ug.mathsstats@unsw.edu.au

P: 9385 7011 or 9385 7053

Postgraduate

E: pg.mathsstats@unsw.edu.au

P: 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 use your UNSW student email and state your student number in all emails to us.**