ST407-15 Monte Carlo Methods

26/27

Department
Statistics
Level
Undergraduate Level 4
Module leader
Adam Johansen
Credit value
15
Module duration
10 weeks
Assessment
Multiple
Study location
University of Warwick main campus, Coventry

Description

Introductory description

This module will provide students with the tools for advanced statistical modelling and associated estimation procedures based on computer-intensive methods known as Monte Carlo techniques.

Pre-requisites

- Statistics UG Students:
    - ST230 Mathematical Statistics.
- Non-Statistics UG Students:
    - ST232/ST233 Introduction to Mathematical Statistics or ST352 Introduction to Mathematical Statistics (for Finalists).
- MSc in Statistics Students:
    - ST961 Statistical Methods and Practice.

Module web page

Module aims

When modelling real world phenomena statisticians are often confronted with the following

dilemma: should we choose a standard model that is easy to compute with or use a more realistic model that is not amenable to analytic computations such as determining means and p-values. We are faced with such choice in a vast variety of application areas, some of which we will encounter in this module. These include financial models, genetics, polymer simulation, target tracking, statistical image analysis and missing data problems. With the advent of modern computer technology we are no longer restricted to standard models as we can use simulation-based inference. Essentially we replace analytic computation with sampling of probability models and statistical estimation. In this module we discuss a variety of such methods, their advantages, disadvantages, strengths and pitfalls.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

Introduction and Examples: The need for Monte Carlo Techniques; history; example applications.
Basic Simulation Principles: Rejection method; variance reduction; importance sampling.
Markov chain theory: convergence of Markov chains; detailed balance; limit theorems.
Basic MCMC algorithms: Metropolis-Hastings algorithm; Gibbs sampling.
Implementational issues: Burn In; Convergence diagnostics, Monte Carlo error.
More advanced algorithms: Auxiliary variable methods; simulated and parallel tempering; simulated annealing; reversible jump MCMC; Metropolis-adjusted Langevin algorithms.

Learning outcomes

By the end of the module, students should be able to:

- demonstrate knowledge of a collection of simulation methods including Markov chain Monte Carlo (MCMC) and understanding of Monte Carlo procedures.
- develop and implement an MCMC algorithm for a given probability distribution
- evaluate a stochastic simulation algorithm with respect to both its efficiency and the validity of the inference results produced by it.
- use Monte Carlo methods for scientific applications.

Indicative reading list

Specific reading list for the module

Subject specific skills

- Demonstrate facility with rigorousMonte Carlo methods.
- Evaluate, select and apply appropriate Monte Carlo techniques.
- Demonstrate knowledge of and facility with formal Monte Carlo concepts, both explicitly and by applying them to the solution of problems.
- Create structured and coherent arguments communicating them in written form.

- Construct logical mathematical arguments with clear identification of assumptions and conclusions.
- Reason critically, carefully, and logically and derive (prove) mathematical results.

Transferable skills

- Problem solving: Use rational and logical reasoning to deduce appropriate and well-reasoned conclusions. Retain an open mind, optimistic of finding solutions, thinking laterally and creatively to look beyond the obvious. Know how to learn from failure.
- Self awareness: Reflect on learning, seeking feedback on and evaluating personal practices, strengths and opportunities for personal growth.
- Communication: Present arguments, knowledge and ideas, in a range of formats.
- Professionalism: Prepared to operate autonomously. Aware of how to be efficient and resilient. Manage priorities and time. Self-motivated, setting and achieving goals, prioritising tasks.

Study

Study time

Type	Required
Lectures	30 sessions of 1 hour (20%)
Practical classes	9 sessions of 1 hour (6%)
Private study	81 hours (54%)
Assessment	30 hours (20%)
Total	150 hours

Private study description

Weekly revision of lecture notes and materials, wider reading, practice exercises and preparing for the examination.

Other activity description

Revision support equivalent to approximately 2 hours.

Costs

No further costs have been identified for this module.

Assessment

You do not need to pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

Assessment group D8

	Weighting	Study time	Eligible for self-certification
Assignment 2	10%	15 hours	No

The assignment will contain a number of questions for which solutions and / or written responses will be required.
The study time noted refers to the amount of time in hours that a well-prepared student who has attended lectures and carried out an appropriate amount of independent study on the material could expect to spend on this assignment. Your ST407 Assignment 2 should not exceed15 pages in length.

Assignment 1	10%	15 hours	No

The assignment will contain a number of questions for which solutions and / or written responses will be required.
The study time noted refers to the amount of time in hours that a well-prepared student who has attended lectures and carried out an appropriate amount of independent study on the material could expect to spend on this assignment. Your ST407 Assignment 1 should not exceed15 pages in length.

Centrally-timetabled examination (On-campus)	80%		No

The examination paper will contain four questions, of which the best marks of THREE questions will be used to calculate your grade.

- Answerbook Pink (12 page)
- Students may use a calculator

Assessment group R5

	Weighting	Study time	Eligible for self-certification
In-person Examination - Resit	100%		No

The examination paper will contain four questions, of which the best marks of THREE questions will be used to calculate your grade.

	Weighting	Study time	Eligible for self-certification

- Answerbook Pink (12 page)
- Students may use a calculator

Feedback on assessment

Assignments are marked and given feedback online within 20 working days of the submission deadline. Where appropriate, model solutions will be provided.

Solutions and cohort level feedback will be provided for the examination.

Past exam papers for ST407

Availability

Courses

This module is Optional for:

- Year 1 of TMAA-G1PE Master of Advanced Study in Mathematical Sciences
- Year 1 of TMAA-G1PD Postgraduate Taught Interdisciplinary Mathematics (Diploma plus MSc)
- Year 1 of TMAA-G1P0 Postgraduate Taught Mathematics
- TMAA-G1PC Postgraduate Taught Mathematics (Diploma plus MSc)
    - Year 1 of G1PC Mathematics (Diploma plus MSc)
    - Year 2 of G1PC Mathematics (Diploma plus MSc)
- TESA-H1B1 Postgraduate Taught Predictive Modelling and Scientific Computing
    - Year 1 of H1B1 Predictive Modelling and Scientific Computing
    - Year 2 of H1B1 Predictive Modelling and Scientific Computing
- Year 1 of TSTA-G4P1 Postgraduate Taught Statistics
- Year 4 of USTA-G300 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics

This module is Option list A for:

- TSTA-G4P1 Postgraduate Taught Statistics
    - Year 1 of G40B Statistics with Data Science (Taught)
    - Year 1 of G40A Statistics with Probability (Taught)
- Year 4 of USTA-G1G3 Undergraduate Mathematics and Statistics (BSc MMathStat)
- Year 5 of USTA-G1G4 Undergraduate Mathematics and Statistics (BSc MMathStat) (with Intercalated Year)

This module is Option list B for:

- Year 1 of TSTA-G4P1 Postgraduate Taught Statistics

- Year 4 of USTA-G304 Undergraduate Data Science (MSci)
- Year 4 of UCSA-G4G3 Undergraduate Discrete Mathematics
- Year 5 of UCSA-G4G4 Undergraduate Discrete Mathematics (with Intercalated Year)
- UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
    - Year 3 of G106 Mathematics (MMath) with Study in Europe
    - Year 4 of G106 Mathematics (MMath) with Study in Europe
- Year 3 of USTA-G1G3 Undergraduate Mathematics and Statistics (BSc MMathStat)
- Year 4 of USTA-G1G4 Undergraduate Mathematics and Statistics (BSc MMathStat) (with Intercalated Year)

This module is Option list C for:

- UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
    - Year 4 of G105 Mathematics (MMath) with Intercalated Year
    - Year 5 of G105 Mathematics (MMath) with Intercalated Year
- UMAA-G103 Undergraduate Mathematics (MMath)
    - Year 3 of G103 Mathematics (MMath)
    - Year 4 of G103 Mathematics (MMath)
- Year 4 of UMAA-G107 Undergraduate Mathematics (MMath) with Study Abroad

This module is Option list D for:

- Year 5 of USTA-G301 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics (with Intercalated

This module is Option list E for:

- Year 5 of USTA-G301 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics (with Intercalated

This module is Option list F for:

- Year 4 of USTA-G300 Undergraduate Master of Mathematics,Operational Research,Statistics and Economics