Course syllabus

Faculty of Technology
Department of Mathematics and physics

4MA510 Monte Carlo-metoder, 7,5 högskolepoäng
Monte Carlo methods, 7.5 credits

Main field of study
Mathematics

Subject
Mathematics

Level
Second cycle

Progression
A1N

Date of Ratification
Approved 2025-06-25.
The course syllabus is valid from spring semester 2026.

Prerequisites
1MA501 Probability Theory and Statistics 7.5 credits or equivalent course in mathematical statistics, and 15 credits in mathematics at G2F level.

Objectives

After completing the course, the student should be able to:
Knowledge and Understanding

- A.1 Demonstrate understanding of the fundamental results in probability theory on which Monte Carlo methods are based, such as the law of large numbers and the central limit theorem, and justify the use of these methods.
- A.2 Describe the principles behind, derive basic properties of, and explain the theoretical foundations of central algorithms and methods for generating random variables from different probability distributions, simulating stochastic

processes, variance reduction, and Markov chain Monte Carlo (MCMC).
- A.3 Describe and identify general situations and types of problems for which different Monte Carlo methods are appropriate and efficient.

Skills and Abilities

- B.1 Implement and apply basic and advanced algorithms for generating random variables from different univariate and multivariate distributions.
- B.2 Implement and apply methods for simulating basic stochastic processes.
- B.3 For given problems, propose, implement, and apply suitable variance-reduction techniques to increase the efficiency of Monte Carlo simulations.
- B.4 Implement basic Markov chain Monte Carlo algorithms.
- B.5 Use and justify the choice of techniques for validating, analysing, and interpreting results from Monte Carlo simulations.

Judgement and approach

- C.1 Critically compare and evaluate the suitability, strengths, and weaknesses of different variancereduction methods in relation to specific problems and computational conditions.
- C.2 Demonstrate the ability to assess the reliability and precision of simulation results.

Content

The course provides a thorough overview of the central theoretical and practical aspects of Monte Carlo methods. This includes methods for generating random variables and other probabilistic models, and performing simulations using Markov chain Monte Carlo (MCMC). The course also covers techniques for analysing and validating simulation results, as well as methods for increasing simulation efficiency through variance reduction.
The following topics are covered:

- Basic principles and theoretical background
- The law of large numbers and the central limit theorem in the context of Monte Carlo simulation.
- Basic complexity theory for Monte Carlo methods.
- Generation of univariate random variables
- General methods for generation from probability distributions:
- Inverse transform method
- Acceptance–rejection method
- Composition method
- Generation from specific discrete distributions: Poisson, binomial, and geometric distributions.
- Generation from specific continuous distributions: uniform, exponential, and normal distributions.
- Generation of multivariate random variables and stochastic processes
- Methods for generating multivariate normal random variables (including Cholesky decomposition and eigenvalue decomposition).
- Generation of multivariate random variables using copula models.
- Simulation of basic stochastic processes (such as Poisson processes and Gaussian processes) in one and several dimensions.
- Variance-reduction techniques
- Antithetic variates

- Control variates
- Conditioning
- Stratified sampling
- Importance sampling (unnormalised and normalised)
- Latin hypercube sampling
- Markov chain Monte Carlo methods (MCMC)
- The Metropolis–Hastings algorithm
- Gibbs sampling
- Analysis and validation of simulation results
- Estimation of mean squared error, unbiasedness, and variance of estimators.
- Construction of confidence intervals for means.
- Techniques for validating simulation models and results.

Type of Instruction

Lectures, presentations, and supervision.

Examination

The course is assessed with the grades A, B, C, D, E or F.

The course is assessed with the grades A, B, C, D, E, Fx, or F. Grade A is the highest grade. The remaining grades follow in descending order, where grade E is the lowest passing grade. Grade F indicates that the student’s performance has been assessed as fail.
The course is examined through:

1. Graded individual written and oral assignments (4.0 credits), grading system A–F
2. Written individual project work (1.5 credits), grading system A–F
3. Oral presentation of a project (1.5 credits), grading system A–F
4. Opposition on another student’s project (0.5 credits), grading system U/G (Fail/Pass)

To pass the course, a passing result is required for all examination elements. The final grade is determined by a weighted average of the grades.

Resit examination is offered in accordance with Linnaeus University’s Local regulations for courses and examination at the first- and second-cycle levels. In the event that a student with a disability is entitled to special study support, the examiner will decide on adapted or alternative examination arrangements.

Course Evaluation

A course evaluation should be conducted during the course or in connection with its conclusion. The results and analysis of the completed course evaluation should be promptly communicated to students who have completed the course. Students participating in the next course instance should be informed of the results of the previous course evaluation and any improvements that have been made, no later than at the start of the course.

Overlap

The course cannot be included in a degree along with the following course/courses of which the content fully, or partly, corresponds to the content of this course:

4MA206 Monte Carlo Methods, 7.5 credits, and 4MA506, 7.5 credits.

Other Information

Assessment criteria for the A–F grading scale are communicated to the student via a separate document. The student is informed of the course assessment criteria no later than in connection with the start of the course.

Required Reading and Additional Study Material

Required Literature

- Ross, Sheldon M.: Simulation, Academic Press, latest edition. Approx. 300 pages.

Recommended Reading

- Asmussen, S.ren & Glynn, Peter: Stochastic Simulation: Algorithms and Analysis, Springer, latest edition.
- Robert, Christian & Casella, George: Monte Carlo Statistical Methods, Springer, latest edition.
- Robert, Christian; Casella, George: Introducing Monte Carlo Methods with R, Springer, latest edition.