KTH Electrical Engineering

Electric Power Systems Lab

EG2080 MONTE CARLO METHODS IN ENGINEERING

1 November 2013

Syllabus autumn 2013

The latest news of the course can be found on the KTH course web (www.kth.se/social/course/ EG2080). It is also possible to contact the lecturer:

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Objectives

The topic of this course is methods for solving complicated mathematical problems using sample surveys. Applications of Monte Carlo methods can be found in many fields, from opinion polls to simulation of technical systems. The focus of this course is going to be on the latter.

To pass the course, the students should show that they are able to

- state basic definitions concerning probability theory, random variables and sampling techniques,
- apply computation methods for random number generation, simple sampling and variance reduction techniques.

To receive a higher grade (A, B, C, D) the students should also show that they are able to

- formulate mathematical models appropriate for Monte Carlo simulation,
- choose efficient variance reduction techniques for a specific simulation problem.

Learning Activities

As a student, you will have to put some effort into the course in order to fulfil the objectives. This is an advanced level course, and you will be expected to be able to study on your own, but you will of course also get guidance and assistance from the lecturer. The most important learning activities are lectures and home assignments.

Lectures and Lecture Assignments

There are seven lectures in the course, as listed in the schedule on the last page. The lectures are organised around "themes" (one theme per lecture). Slides for each theme are on the course web pages. The students are expected to read the slides before coming to the lecturer, because time is not sufficient to present all slides in the lecture—the focus will be on the lecturer highlighting the most important concepts and answering questions from the students. The remainder of the lecture time will be spent on lecture assignments. Each lecture assignment consists of a simple question addressing a central topic in the course. The assignment is solved during the lecture, and there is no grading or bonus points awarded. The objective of the lecture assignment is that the students should *learn* not that they provide correct answers (in fact, students who initially gives a wrong answer and then learn the right answer from own reflection and discussion with the other students has probably gained more from the assignment than the students who were right from the beginning).

Home Assignments

There are twelve home assignments in the course. The home assignments consists of small problems, which either are solved by hand or with a computer program. The students are free to choose which software they use, but Matlab is probably the most suitable choice. The problems can be found on the course web pages.

The home assignments is a mandatory part of the course. The problems do not have to be solved individually—you can cooperate with fellow students if you think you will learn more that way. However, each student must be able to explain and motive how the problems are solved. You will not be allowed to write the exam if you do not have at least eight home assignment points. The preferred method to obtain home assignments points is to attend the home assignment seminars (see the schedule on the last page). At the beginning of the seminar, each participant will state which problem he or she is prepared to present. However, all students who have prepared a presentation of a particular problem will not actually have to present it; one student will be randomly selected to give the presentation at the seminar. You will receive one home assignment point for each problem that you have prepared to present. If you cannot give a good presentation at the seminar although you claim to be prepared then you will loose two home assignment points. Please notice that at good presentation does not necessarily mean that you have solved the problem correctly (some of the problems do not even have a single correct answer). Since the home assignments are meant for learning, it is sufficient that you have done a sincere attempt to solve the problem.

If you for some reason cannot attend the home assignment seminars or if you fail to get enough home assignment points during the seminars, you can get additional home assignment points by submitting a written report to the lecturer. Once the report has been marked, you will have a meeting with the lecturer, where you give a short presentation of the problem. As for the seminars, the report and the presentation to the lecturer do not have to be absolutely correct as long as you have made a sincere effort.

Literature

The main topics of the course are covered by the themes (see above). Students are also advised to look for relevant in the KTH library or the internet when preparing for lectures, solving home assignments or writing the project assignment. Here are a few suggestions on literature that might be of interest:

[1] W. G. Cochran, *Sampling Techniques*, 3rd edition, John Wiley & Sons, 1977.

[2] B. V. Gnedenko, *The Theory of Probability*, Chelsea Publishing Company, New York 1962.

[3] G. R. Grimmet & D. R. Stirzaker, *Probability and Random Processes*, 2nd edition, Oxford University Press, Oxford 1992.

[4] J. M. Hammersley & D. C Handscomb, *Monte Carlo Methods*, Methuen & Co, London 1964.

[5] F. S. Hillier & G. J. Lieberman, *Introductions to Operations Research*, 7th edition, McGraw-Hill, 2001.

[6] H. Kumamoto, K. Tanaka, K. Inoue & E. J. Henley, "Dagger Sampling Monte Carlo for System Unavailability Evaluation", *IEEE Transactions of Reliability*, Vol. R-29, No 2, June 1980.

[7] R. Y. Rubinstein, *Simulation and the Monte Carlo Method*, John Wiley & Sons, 1981.

[8] R. Y. Rubinstein & B. Melamed, *Modern Simulation and Modeling*, John Wiley & Sons, 1998.

A compendium on Monte Carlo methods is under development. An incomplete draft version of the compendium will be available on the course web page together with the themes. Student are most welcome to suggest improvements to the compendium! For example, if some part of the course is difficult to understand in the slides of that theme, further explanations and examples can be added to the compendium. It is also appreciated if students report corrections and need for clarification.

Examination

The course gives 6 credits and is examined by a written exam and a written project report.

Exam

The written exam consists of short, basic problems, and can give a total score of 40 points. Solutions should include sufficient detail that the argument and calculations can be easily followed. Exams are given twice a year. Only students who have received at least eight home assignment points can write the exam. It is also required that the student registers in advance using KTH My pages, which can be accessed from the student web (http://www.kth.se/student).

The duration of the exam is four hours. The following aids are allowed in the exam:

- Calculator without information relevant to the course.
- Formulae sheet.

The formulae sheet will be appended to the exam. A preliminary version of the formulae sheet is available on the course web pages. You are welcome to contact the course coordinator and suggest improvements of the formulae sheet!

KTH has from autumn 2013 a central coordinator for students with disabilities:

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Project assignment

The objective of the project assignment is that the students should be able to apply the methods taught during the lectures on a larger simulation problem. It is free for each student to decide which system that will be simulated. It is recommended that students consider systems that are relevant for their intended master thesis project or Ph.D. research, but if that is not possible or would result in an overwhelming work load, students can create their own fictitious systems similar to the

Ice-cream Company in Theme 1 or the Product Company in part II of the home assignments.

The result should be presented in a written report. Detailed instructions for the report writing can be found on the course web pages.

The project assignment is to be solved individually. It is of course acceptable to ask a friend for advice, and it is possible to ask questions to the lecturer. However, plagiarism is not allowed and the reports will be checked using the turnitin tool.

Project assignments can be submitted twice a year in connection with the exams. The reports should be submitted as a pdf file by e-mail to the lecturer. It is optional if the students want to submit a preliminary report. Students who use this opportunity will get written feedback which they can use to improve the final report. Deadlines for report submission are given in below.

Table 1 Deadlines for report submission.

Period	Preliminary report (optional)	Final report
2	Wednesday 18 December 2013, 11:00	Monday 20 January 2014, 11:00
June re-exam	Thursday 5 June 2014, 11:00	Friday 29 August 2014, 11:00

Grading

The requirement to pass the course is that the student has passed the written exam and submitted the project assignment. In addition to the score on the written exam, the student will receive scores for three different aspects of the written report. The grading matrix in table 2 below shows which scores that are necessary to receive a certain grade. Please note that in order to get a certain grade, the student must have received the stated or a better score for each of the aspects. This means that only students who have passed the exam and received the scores *Good problem formulation, Analysis above expectation* and *Good presentation* can receive the grade A. A student who passes the exam and receives the scores *Good problem formulation, Analysis above expectation* and *Some flaws in presentation* will receive the grade C, although the students for some aspects fulfils the requirements for a higher grade.

Table 2 Grading

Score on the written exam	Project report			Grade
	Problem formulation	Analysis	Presentation	
33–40	Good	Above expectation	Good	A
33–40	Good	As expected	Good	B
33–40	Good	As expected	Some flaws	C
33–40	Some flaws	As expected	Some flaws	D
33–40	Some flaws	Below expectation	Some flaws	E
31–32	Some flaws	Below expectation	Some flaws	Fx
0–30	Insufficient	Insufficient	Inferior	F

If a student receives the grade F in the exam, the student will have to attend a re-exam. If a student receives the grade Fx in the exam, the student will be offered to write a complementary test to pass the exam without taking a re-exam. If any aspect of the report receives the grade F then the student will have to submit *a new report on a new topic*—it is not possible to complement the report after it has been submitted for marking.

More details about what is evaluated for the different aspects and what is meant by the reviews in the grading matrix are given below.

Problem formulation

Students are required to find a simulation problem that is suitable for Monte Carlo simulation using the methods presented in the course. The simulation problem must also be described well enough to allow a reader without any previous knowledge about the specific problem to understand the model.

The following criteria are used to evaluate the student's problem formulation:

- **Good.** The student has given a clear background for the simulation problem. Assumptions, mathematical model and input data are well described.
- **Some flaws.** The background, assumptions and input data are unclear or there are small errors or missing formulae in the mathematical model.
- **Insufficient.** The student has chosen a too trivial simulation problem that is not suitable for application of variance reduction techniques, or there are essential errors or unclear parts in the background, mathematical model or input data.

Analysis

The main part of the project assignment is to analyse which variance reduction techniques that can be applied to the simulation problem and then to test those simulation methods in practice. It is important that the analysis is supported by good arguments—especially when the student is claiming that a variance reduction technique is not suitable for the problem in question.

The following criteria are used to evaluate the student's analysis:

- **Above expectation.** The student has investigated all variance reduction techniques considered in the course. In addition to that, the student has either tested other techniques or tricks (either found in the literature or invented by the student) or provided a very detailed and educational analysis.
- **As expected.** The student has investigated all variance reduction techniques considered in the course.
- **Below expectation.** The student has investigated all variance reduction techniques considered in the course, but there are minor errors in the analysis.
- **Insufficient.** The student has not investigated all variance reduction techniques considered in the course or there are significant errors in the analysis.

Presentation

The review of the report is depending both on how well the student describes the work performed and the conclusions, as well as language and format. Good language means that the report does not contain language errors that makes the reading difficult, i.e., occasional spelling errors or grammatical errors are acceptable. Format refers to the rules for report described in the instructions for the project assignment.

The following criteria are used to evaluate the report:

- **Good.** The report is well-written, i.e., it has a clear structure, the presentation of the work and the results is easy to follow and the conclusions are supported by results from the report. Moreover, good language is necessary and the format must have been followed correctly.
- **Some flaws.** The report as a whole gives the reader a good understanding of the work that has been done, although some parts of the report do not fulfil the requirements for a good report.
- **Inferior.** The report does not provide the reader with sufficient information of the work that has been done, or the report does not follow the format stated in the instructions.

Course Evaluation Committee

To evaluate and improve the course, we need a few students who are willing to participate in the course evaluation committee. The committee is meeting shortly after the ordinary exam. In connection with this meeting, the Electric Power Systems Lab will treat the participants to lunch. Students who are interested in participating can contact the course coordinator by e-mail or in connection to a lecture.

Preliminary Schedule

The notion **2:4** refers to the fourth teaching occasion in period 2. The seminar room is located at Teknikringen 33, 1st floor (former lecture room H21). The conference rooms are located at Teknikringen 33 in the corridor for the Electric Power Systems lab. *Please notice that the doors to this corridor are locked, and the lecturer can only let you in if you come in time!* Teaching occasions marked "Reserve" will not be used unless another occasion has been cancelled. Information about changes in the schedule can be found on the course web page.

2:1 *Tuesday 5 November, 10–12, the seminar room*
L1: Introduction. Monte Carlo simulation.

2:2 *Wednesday 6 November, 13–15, the seminar room*
L2: Random variables. Random number generation.

2:3 *Thursday 7 November, 8–10, the seminar room*
L3: Simple sampling. Home assignments part I.

2:4 *Monday 11 November, 13–15, large conference room*
L4: Complementary random numbers. Dagger sampling.

2:5 *Wednesday 13 November, 8–10, large conference room*
L5: Control variates. Correlated sampling.

2:6 *Thursday 14 November, 10–12, large conference room*
L6: Importance sampling. Stratified sampling. Home assignments part II-IV.

2:7 *Tuesday 19 November, 8–10*
Reserve.

2:8 *Wednesday 20 November, 8–10, large conference room*
L7: Simulation design. Project assignment.

2:9 *Monday 25 November, 13–15, the seminar room*
Home assignment seminar part I and II.

2:10 *Wednesday 27 November, 8–10*
Reserve.

2:11 *Monday 2 December, 10–12*
Reserve.

2:12 *Friday 6 December, 10–12, the seminar room*
Home assignment seminar part III and IV.

2:13 *Monday 9 December, 10–12*
Reserve.

2:14 *Tuesday 10 December, 13–15*
Reserve.

2:15 *Monday 16 December, 10–12*
Reserve.

2:16 *Tuesday 17 December, 13–15, large conference room*
L8: Repetition.

Wednesday 15 January, 9–13, the seminar room
Exam. Last day to register for the exam is *Wednesday 1 January.*