KTH Electrical Engineering

Electric Power Systems Lab

EG2080 MONTE CARLO METHODS IN ENGINEERING

15 November 2012

Syllabus autumn 2012

The latest news of the course can be found on KTH Social (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

There will be no lectures for this course in the academic year 2012/13. As a student, you are expected to study on their own, but you will of course also receive guidance and assistance from the lecturer.

Lectures

In earlier course rounds, the lectures have been a possibility to ask questions on the lecture notes

Table 1 Overview of learning activities and examination.

Theme	Exercises	Home assignment problems	Examination
1 Monte Carlo Simulation	1	–	Project assignment
2 Random Variables and Random Numbers	2–5	1	Exam problem 1
3 Simple Sampling	6–8	2	Exam problem 2, project assignment
4 Complementary Random Numbers and Dagger Sampling	9–11	3, 8, 10	Exam problems 1, 5, project assignment
5 Control Variates and Correlated Sampling	12, 13	4, 5, 11	Exam problem 5, project assignment
6 Importance Sampling and Stratified Sampling	14–16	6, 7, 9, 12	Exam problems 3–5, project assignment
7 Simulation Design	–	–	Project assignment

and to do exercises. Unfortunately, the start of this course round has been delayed to an extent that it not reasonable to reschedule the lectures. Therefore, the lectures are cancelled and replaced by open exercise sessions, where students may come to work on exercises and home assignments, and ask questions about anything that is unclear. The schedule of the exercise sessions will depend on the interest from the students in the course, but there should be at least one hour of assistance per week starting from Monday 19 November. More details will be be published on KTH Social (go to "Schedule" in the menu on the right hand side).

Literature

There is not yet a compendium available for this course. The main topics of the course are covered by lecture notes, which can be downloaded from the course web page on KTH Social (go to the heading "Themes" in the menu on the right hand side). You can ask questions on KTH Social or attend the exercise sessions (see the schedule below).

Students are also advised to look for relevant in the KTH library or the internet. 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.

Exercises

There are seven themes in the course, as listed in the table above. For most of these themes there are simple problems which you can use to test your understanding of the basic concepts. Students are encouraged to discuss the exercises with each other, for example using the course web page on

KTH Social. The exercises are not graded and no bonus points are awarded—the objective of the exercises is that the students should *learn* not that they provide correct answers (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). The answers to the exercises are not published, but can be obtained in the exercise sessions.

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 page on KTH Social.

The home assignments is a mandatory part of the course. You will not be allowed to write the exam if you do not have at least eight home assignment points. Your answers to the home assignments should be described in a written report, which must be submitted at least two workdays before the exam. One home assignment point is awarded for each problem that has been analysed sufficiently. Please notice that a sufficient analysis does not necessarily mean that the problem has been solved 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.

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. This means that students must formulate their reports on their own—no copying is allowed! In case two or more reports are too similar, the involved students will have to meet the lecturer and give short presentations of their solutions. No home assignments points will be awarded if these presentation are not approved.

Examination

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

Exam

The exam of the course is scheduled for 11 December 2012, 9:00–13:00 in L31. There is also going to be a re-exam in June 2013 (exact time an place will be given later). Due to the delayed course start in autumn 2012, there will also be a possibility to schedule an extra exam in January or February 2013. This will be decided upon agreement between the examiner and the interested students.

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 *at least two weeks 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!

Project assignment

The objective of the project assignment is that the students should be able to apply the methods taught in the course 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, 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 Lecture 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 reports should be submitted as a pdf file by e-mail to the examiner. Students are allowed to submit the report twice: first as a preliminary report and then the final report. After submitting the preliminary report, students will receive a short, written feedback. Reports can be submitted anytime until Wednesday 5 June 2013 (deadline for preliminary reports) and Friday 30 August 2013 (deadline for final reports) respectively. Students who cannot meet these deadlines will have to complete the project assignment in the academic year 2013/2014. Please notice that the rules for the project assignment may change then!

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.

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.