KTH Electrical Engineering

Electric Power Systems Lab

EG2080 MONTE CARLO METHODS IN ENGINEERING

Autumn 2012

Project Assignment

In the project assignment, you will yourself define a system, and then investigate how it can be simulated using Monte Carlo methods. The project assignment is presented in a written report.

The project assignment is to be solved individually. The major part of your report must be the result of your own work. It is of course allowed to use models, methods and ideas from textbooks and scientific papers, or to ask a friend or the lecturer for advice, *but the source must then be clearly stated*!

Problems

The main task of this project assignment is to select a system and simulate it using Monte Carlo simulation.

Formulate a simulation problem

You may select any kind of system that can be simulated using the methods described in the course. It is preferable if you can find a problem that is relevant to your studies or your own research. However, if Monte Carlo simulation is not applicable to your field you may use a completely fictitious system (such as the Ice-Cream Company that has been described during the lectures).

It should be noticed that although it is desirable that your findings from the project assignment are useful in other courses or in your research, the main objective of the project assignment is that you should put Monte Carlo methods into practice. Hence, it is more important that you study a system that is interesting to simulate, not that you are using a realistic model or realistic data. If systems from your field are too complex to be treated in a project assignment like this, it is recommended that you scale down the problem to a manageable size, or that you consider a fictitious system.

Analyse simulation methods

You should analyse which simulations method are applicable and efficient for your simulation problem. Start with a theoretical analysis, i.e., describe to which inputs you may apply complementary random numbers and dagger sampling, if you can find a suitable control variate, and if you can find scenarios for the input values, which are likely to be of particular interest, and which

therefore should be the target for importance sampling or stratified sampling.

After the theoretical analysis, you should set up the necessary software to simulate the system, and test those simulation methods that you have identified as suitable for your problem. Try to estimate the accuracy of the different simulation methods by investigating the variance of the estimates.

Report

The main objective of the written report is of course that you present your findings from the project assignment. However, the report writing is also a good practice for future reports (for example your master thesis) and you are encouraged to write the report so that the text can be reused in a thesis or a scientific paper.

Contents

Below follows an outline of the contents of the written report. The chapters and sections mentioned below are mandatory and must be included in the report, unless they are preceded by an asterisk *****. However, you are of course welcome to add further chapters or sections to the report if you find it necessary.

Introduction

The introduction chapter should give the reader of the report an overview of what you have been doing and why you choose to study this particular problem.

- **Background.** Short description of the background of your simulation problem. You can for example briefly describe the scientific field from which your problems comes. If you are using a fictitious system which you have invented just for this project assignment, then it is sufficient to mention this in the background section.
- **Problem Definition.** Short overview of the system to be studied, and the objective of simulating it. Present the inputs and outputs of your system, but leave the mathematical details for *Modelling* chapter.
- ***Related Research.** If you have studied this problem before then it is valuable if you can provide a short overview of what others have done in this field, and what your contribution is.
- **Overview of the Report.** Include a short overview (one or two sentences is sufficient) of the contents of each chapter in the report.

Modelling

The modelling chapter should be as general as possible, i.e., avoid to include numeric data in this chapter.

- **Assumptions.** Before you describe the mathematical model you should describe how the model relates to the real system. Which simplifications have you made? Are there any special cases which cannot be considered in the model?
- **Symbols.** Define the symbols that you are using in the mathematical model. It should also be clear if the symbols denote input variables, output variables or parameters within the model.
- **Mathematical Model.** Describe the mathematical model, i.e., how are the outputs X calculated given the value of the inputs, Y. The description should be understandable to anybody with a general engineering background, which means that you must include all relevant formulae and some explanatory text for each formula. Any special background theory that is necessary to understand this section can be put in an ap-

pendix.

Variance Reduction Techniques

This chapter should have one section for each of the six variance reduction techniques which have been described in this course. For each technique you should analyse its possible usage on your simulation problem. Notice, that all techniques may not be suitable to your problem; in that case you should explain why the method cannot be used or why it would be inefficient. Concerning those techniques that can be applied to the simulation problem, you should describe how the technique is implemented. In particular, you should investigate if there are some tricks that can be applied in order to improve the efficiency of the variance reduction technique.

Finally, you should also have a section where you discuss the possibilities to combine several variance reduction techniques to further improve the efficiency of the simulation.

Case Study

Now it is time to apply the model and simulation methods described in the previous chapters. Your report should include at least one case study. If you have the time, you may include extra case studies. For example, you can start with a simple test system, which is so small that it can be analysed without Monte Carlo simulation; this test system can be used to verify that your simulation methods provide correct results. Then, you can study a larger system, where Monte Carlo simulation is the only viable method to study the expectation value of the outputs.

- **System Description.** Describe the background of your case study, i.e., if it is a real or fictitious system, how did you obtain the data, whether there is some special properties of this system that makes it more interesting, etc. Present the numerical data of the system in tables and figures.
- **Simulation Method.** Comment on which simulation methods that you have tested, and the software that you have used. If possible, you can include the code in an appendix. You should also describe the necessary preparations before the simulation, as for example how you have calculated the expectation value of control variates, stratum weights, etc.
- **Results.** Present your simulation results in tables or graphs and discuss if the results correspond to your expectations. Do the results seem reasonable or could there be any error in the simulation software? Is it possible to verify the results? Which simulation methods seems most efficient, considering both accuracy and computation time? Do you see any possibilities to improve the efficiency by using better software, other algorithms, etc.?

Conclusions

This chapter gives the reader a summary of your results. Try to write this chapter so that it can be understood even if the reader has skipped the previous chapters.

- **Effectiveness.** Is Monte Carlo simulation appropriate to simulate your system? Have you identified any variance reduction techniques that are more efficient than others? Which possibilities are there to combine different variance reduction techniques?
- ***Conclusions from the Case Study.** Are there any interesting results from the case study which may not be applicable in a general case, but which you still would like to comment upon?
- ***Future work.** Have you identified any topics which would be interesting to study in more detail?

References

Alphabetical list of the sources that you have used in the report.

Layout

Instructions for the layout of the report are given below.

Page Layout

The keywords for the page layout are neat and clear; the layout should make reading as comfortable as possible. Therefore, the layout should fulfil the following requirements:

- The report should be in A4 format, with a single column and single line spacing. Leave at least 2 cm margin around the text.
- Headings should be aligned to the left, whereas body paragraphs should normally be justified (exceptions can be made for tables and figures).
- The font must be easy to read, i.e., not too small and not too large. The recommended font size is 12 points for normal text.
- Chapters should be numbered using arabic numbers. Subsections should also be numbered, so that 1.1 is the first subsection of chapter 1, and 1.1.2 is the second subsection of section 1.1. Avoid using more than three levels in the section numbering.
- There should be page numbers on every page (except for the title page if you include one). Use roman numbers (i, ii, …) for the preamble and arabic numbers (1, 2, …) for the main text and any appendices. If possible, the page numbers should consequently be located in the same place of the page.

Equations

Complex equations can be difficult to typeset, but it is important that equations are complete and readable. The following requirements should be fulfilled:

- All mathematical symbols must be italicised both in the text and in equations. Units should be used according to SI and may not be italics.
- All equations should be numbered, so that they can be easily referred to. Preferably, the number should include the chapter number and a counter. If the software used to write the report cannot easily manage chapter numbers it is possible to exclude them and just use a counter. The equation number should appear near the right margin after the equations, as in the example below:

$$\textit{Equation} \tag{1.1}$$

- Refer to equations only by their number, for example "(1.1)" and not "Eq. (1.1)" or "equation (1.1)", except at the beginning of a sentence: "Equation (1.1) shows…".

Tables and Figures

Tables and figures should assist the reader in understanding the report; hence, you should always ask yourself what the main message of the table and figure is. Do not add tables and figures unless you refer to them and discuss them in the main text. Moreover, you should fulfil the following requirements:

- The font must be easy to read, i.e., not too small and not too large. The recommended font size is 10 points for figure captions and tables. Do not forget that text inside figures should also be readable—if possible, use a 10 points font here as well.
- Tables and figures should be located as closely as possible to the paragraphs where they are first mentioned.
- Table and figures should also be numbered using the chapter number and a counter, for example as follows:

Table 1.1 Table caption.

Figure 1.1 Figure caption.

If the software used to write the report cannot easily manage chapter numbers it is

Table 1 Format for references.

Type of publication	Format
Journal paper	[1] First author, second author, … & last author, "Paper Title", *Journal Name*, volume, number, date.
Conference paper	[2] First author, second author, … & last author, "Paper Title", *Proceedings of* …, volume, conference location, date
Report	[3] First author, second author, … & last author, "Report Title", type of report (internal report, master thesis, doctoral dissertation, etc.), publisher, place of publication, date.
Book	[4] First author, second author, … & last author, *Book Title*, publisher, place of publication, date.
Interview	[5] Name, organisation, personal communication.

possible to exclude them and just use a counter.

- Refer to tables and figures as "table 1.1" and "figure 1.1",. i.e., do not use capital letters except at the beginning of a sentence.
- You may use colour in figures, but remember that the report should also be readable when printed in black-and-white.

References

The references should fulfil the following requirements:

- Avoid references to web pages, because you never know if the a web site is going to be changed or disappear; thus, your reference might no longer be valid. If an electronic version of a publication is available on the internet, you may indicate that by adding the address within brackets after the reference.

  Example:

  [1] "Nordel Annual Report 2008", Nordel, 2008. [Available at https://www.entsoe.eu/]

- The format of different types of references are shown in table 1.
- Refer to literature references by their number in square brackets, for example [1]. The sentence punctuation follows the brackets. If there are multiple references then each reference is put in a square bracket, for example [1], [3]. Multiple references which are numbered in a sequence can be referred to as an interval, for example [1]-[3]. Do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] shows…".