Faculty of Engineering

Department of Management Sciences

MSCI 333 Fall 2018: Simulation Analysis and Design

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Time & Place

Lecture	Tuesdays	01:00 – 02:20 pm	CPH 3681
	Thursdays	01:00 – 02:20 pm	CPH 3681
Lab	Wednesdays	01:30 – 02:50 pm 03:00 – 04:20 pm	CPH 4333
Tutorial	Fridays	01:30 – 02:20 pm	MC 4042

Course Description

This course introduces the use of discrete event simulation as an approach for understanding and analyzing complex management systems. Topics include an introduction to simulation modelling, general purpose and special purpose simulation languages, designing valid and credible simulation models, input data analysis, output analysis and experimental design.

Prerequisites: *Calculus, Linear Algebra, Probability and Statistics.*

Simulation program: ARENA and Microsoft Excel.

Recommended Textbook	Banks, J., Carson II, J.S., Nelson, B.L., and Nicol, D.M. (2010), **Discrete-Event System Simulation**, *5th Edition, Prentice Hall, New York.* ISBN-13: 978-0-13-606212-7 ISBN-10: 0-13-606212-1
Other Textbook	Rossetti, M. (2015). **Simulation Modeling and ARENA**. *2nd Edition, Wiley Publications.* ISBN-13: 978-1118607916 ISBN-10: 1118607910

Course Materials

1. UW-Lean: Lecture notes, Assignments, Tutorials other supplementary materials.
2. Textbook.

Intended Learning Outcomes

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

1. Identify probability distributions and performance measures or metrics. [KB]*
2. Implement a thorough analysis of the performance metrics of interest. [PA]*
3. Use statistical methods to find the type of distributions, estimate the parameters, and implement goodness-of-fit tests. [Tools]*
4. Design and build simulation models for stochastic systems. [Des]*
5. Verify and validate simulation models using statistical methods and software (e.g., Excel and Arena). [Tools]*
6. Investigate costs and benefits in relation to a model of interest from simulation results. [Inv]*

** Abbreviations in brackets are Graduate Attributes required for Accreditation, see appendix.*

General Course Instructions

- **Lectures** will be used to introduce simulation modelling techniques to model real-life systems, and methods to analyze those models.
- **Lab sessions:** Concepts discussed in the lectures will be applied to develop working simulation models using ARENA and Microsoft Excel. Often new modelling and analytical techniques will be introduced in Lab sessions.
- **Tutorials:** Objective is to illustrate the concepts discussed in the lecture through examples and to answer student's queries. However, new or supplementary materials may be discussed in tutorials if necessary.
- It is highly recommended to attend all three sessions. Assignments, projects and exams will require an in-depth understanding of the material discussed in lecture, lab and tutorial.
- Group discussion of assignment problems is encouraged. However, every student must complete his/her assignments independently.
- Students are encouraged to use programming languages other than ARENA or EXCEL for modelling. However, it is student's responsibility to get access to them.
- All assignments and projects must be submitted online via UW-learn Dropbox before the deadline. Late submissions will not be accepted unless a strong reason is presented.
- An acceptable project, whether late or not, must be submitted to pass the course.
- All announcements related to the course will be made through UW-learn or email.
- Your questions, comments and suggestions will be greatly appreciated. Please talk to the instructors directly or use the email addresses provided.

Marking Scheme

Assignments	20 %
Project	20 % (Final Submission Due: December 3, 2018)
Mid-term (Open book)	30 %
Final (Open book)	30 %

Assignments

Assignment	Start Date	Due Date
1	September 07, 2018	11:59 pm September 28, 2018
2	October 02, 2018	11:59 pm October 26, 2018
3	October 17, 2018	11:59 pm November 08,2018

4	November 06, 2018	11:59 pm November 23, 2018
5	November 14, 2018	11:59 pm November 30, 2018

Guidelines for Assignments submission

Unless otherwise specified, all assignments must be submitted online (UW – Learn Dropbox will be created) in two parts: Report File and Program File.

Report File: Your findings and statistical inference for the given problem should be presented in your report, submitted online as a single file (PDF/word format). It may include several components.

- A brief description of the model to be studied or the problem to be solved.
- List of parameters, their definitions and their initial values (should be declared always).
- Introduce the problem to be solved and state your assumptions explicitly.
- A brief description of the solution methodology or steps.
- Computational details of the solution process.
- Results, with discussions on their significance.
- Inferences and/or conclusion.

Note: An outline of the program or code (pseudo-code and/or flowchart) must be included in the report explaining your program. Report file should be self-explanatory without your program file.

Program File: Students are encouraged to use ARENA, Excel or other programming languages (C++, C#, R, Python, JAVA or other) to develop their simulation model. Program files must be submitted to have your problems marked unless otherwise specified.

- Program files should have the student's name, course number, date and short description of the program at the beginning of each program; and guides to execute if required.
- Please name your program files appropriately and submit them separately uncompressed.
  Eg: "MSci333_StudentID_Asg*_P**"
  (*Assignment Number; ** Problem Number)
- *Excel:* Label the columns and make comments appropriately.
- *ARENA:* Name the entities, variables, attributes and modules appropriately and in a self-explanatory manner.
- *Coding (C#, R, Python, JAVA or other):* Apply indentation and comment your comment clearly. Name all your variables relevant to your problem or simulation model.
- Program files must be supported with a pseudocode and/or flowchart in your '***report file***' explaining your program logic.

Note: In addition to ARENA and MS Excel, students are highly encouraged to use other open programming languages for simulation modelling such as *python, R, JAVA, C# or C++*.
BONUS POINTS (up to 10%) will be awarded for the efficient models, with good programming style.

Guidelines for Course Project

This course project will be done by a team of 4 members. The deadline for final project submission is December 3, 2018. Guideless for assignments submission applies for the project as well. Each project team is expected to meet the three milestones given below for complete acceptance of their project before corresponding deadlines.

1) **Project team enrolment:** 11:59 pm September 12, 2018.
   Students are expected to form a team with a maximum of 4 members and enrol themselves via UW-Learn.
2) **Problem Description (one page report):** 11:59pm October 05, 2018.
   Define your problem, in-scope, out-scope, data collection procedure, performance metric(s) and simulation modelling language.
   Project team shall proceed with modelling if the problem is accepted, or else will be intimated for revision.
3) **Revised problem definition (one-page report):** 11:59 pm October 23, 2018.
   Meet-up with the course instructor or TA if required to revise your problem definition and finalise your problem definition before the given deadline.

Suggested outline for the project, not mandatory.

Model introduction: Introduce your model clearly with some discussion on the assumptions, important features of the model and cases to be studied.
Issues of interest: Define the issue(s) to be investigated and justify why it is important to study.
Problem definition: Define your problem(s) to be studied explicitly. Define the performance measures and introduce necessary notations.
Development of a simulation model: Define the simulation model and its components explicitly.
Development of a simulation program: Show how statistics are collected in the simulation program. Use pseudocode(s) and/or flowchart(s) to explain your simulation program or model logic. Show the details of simulation program implementation.
Validation of the simulation model: Justify your simulation model using any method(s).
Numerical experimentation: Run the simulation program with different input distributions. Present simulation results and provide your inferences.
Output analysis: Carry out a thorough analysis of the performance metric(s) of interest. This part may include the construction of confidence intervals, statistical comparison of models, hypothesis testing, etc. In short, try to justify simulation results.
Insights into the model of interest: Learn more about the model of interest from simulation results.

Marking scheme

1. Clear problem definition and introduction (maybe the using flowchart like techniques) – 10%
2. Definition of simulation components – 15 %
3. Input modelling – 15 %
4. Logical flowprocess chart and/or pseudo code expressing the simulation model logic – 15 %
5. Simulation model implementation in ARENA or other programming languages – 10 %
6. Results: Statistical analysis, inferences and conclusion – 30 %
7. Overall presentation of report and program files with adequate supporting information – 5 %
8. **BONUS POINTS:** Efficient modelling, reporting and programming style – 10%

Correctness: A project with an ***incorrect*** simulation program (model) will be rejected and must be redone in order to pass this course (start your project with a flowchart and pseudocode, validate them with course instructor or TA if required before modelling). | **Completeness:** You must do output analysis and gain insights into the model to make your project complete. | **Clearness:** Organization, presentation, etc. | **Beyond**: The more you learn about the model of interest using your simulation program, the better.

Schedule for MSCI 333 Fall 2018

Week	Day	Theme	Topics
1	06-Sep (Th)	Lecture	Introduction to Simulation Modelling
	07-Sep (F)	Tutorial	No tutorial
	11-Sep (T)	Lecture	Single server modelling & statistics
	12-Sep (W)	Lab	ARENA: Single server modelling
2	13-Sep (Th)	Lecture	Multi-server modelling & statistics
	14-Sep (F)	Tutorial	Multi-server modelling & statistics collection
	18-Sep (T)	Lecture	Newspaper vendor Modelling & statistics
	19-Sep (W)	Lab	ARENA: Multi-server Modelling
3	20-Sep (Th)	Lecture	Simulation Principles: Single-server Modelling
	21-Sep (F)	Tutorial	FEL simulation: Single server modelling & stats
	25-Sep (T)	Lecture	Simulation Principles: Two-server Modelling
	26-Sep (W)	Lab	ARENA: Inventory (M, N) modelling
4	27-Sep (Th)	Lecture	Simulation Principles: Two-server Modelling & statistics collection
	28-Sep (F)	Tutorial	FEL simulation: Multi-server Simulation components definition & flowchart
	02-Oct (T)	Lecture	Simulation Principles: Inventory Modelling & statistics collection
	03-Oct (W)	Lab	ARENA: Inventory modelling with multiple servers
5	04-Oct (Th)	Lecture	Simulation Principles
	05-Oct (F)	Tutorial	FEL simulation: Multi-server Modelling & stats
Mid-term Study Break (9-Oct & 10-Oct)			
6	11-Oct (Th)	Lecture	Simulation Principles
	12-Oct (F)	Lab	Lecture: Probability distribution review
	16-Oct (T)	**Lecture**	**Mid-Term**
7	17-Oct (W)	Lab	ARENA: Basic & Advanced modules
	18-Oct (Th)	Lecture	Queuing Models
	19-Oct (F)	Tutorial	Queuing Models
	23-Oct (T)	Lecture	Queuing Models
8	24-Oct (W)	Lab	**ARENA simulation Modelling**
	25-Oct (Th)	Lecture	Queuing Models Vs simulation
	26-Oct (F)	Tutorial	Queuing Models - computation
	30-Oct (T)	Lecture	Input modelling: Data Visualization
9	31-Oct (W)	Lab	**ARENA simulation Modelling**
	01-Nov (Th)	Lecture	Input modelling: Distribution fitting
	02-Nov (F)	Tutorial	Input Modelling: Distribution fitting
	06-Nov (T)	Lecture	Random Numbers & Random-Variate Generation
10	07-Nov (W)	Lab	**ARENA simulation Modelling**
	08-Nov (Th)	Lecture	Random numbers & Random-variate generation
	09-Nov (F)	Tutorial	Random numbers & Random-variate generation
	13-Nov (T)	Lecture	Verification & Validation
11	14-Nov (W)	Lab	**ARENA simulation Modelling**
	15-Nov (Th)	Lecture	Verification & Validation
	16-Nov (F)	Tutorial	Verification & Validation, Hypothesis testing

Week	Day	Theme	Topics
	20-Nov (T)	Lecture	O/P Analysis: Estimation of Absolute Performance
12	21-Nov (W)	Lab	ARENA process analyzer
	22-Nov (Th)	Lecture	O/P Analysis: Estimation of Relative Performance
	23-Nov (F)	Tutorial	Confidence intervals
	27-Nov (T)	Lecture	Meta-modelling approach
13	28-Nov (W)	Lab	**Other programming languages implementation**
	29-Nov (Th)	Lecture	Final exam review
	30-Nov (F)	Tutorial	Final exam review – Sample Questions

University Policies

Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo are expected to promote honesty, trust, fairness, respect and responsibility. (Check www.uwaterloo.ca/academicintegrity for more information.)

Discipline: A student is expected to know what constitutes academic integrity, to avoid committing academic offences, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course professor, academic advisor, or the Undergraduate Associate Dean. When misconduct has been found to have occurred, disciplinary penalties will be imposed under Policy 71 – Student Discipline. For information on categories of offenses and types of penalties, students should refer to Policy 71 - Student Discipline.

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70 - Student Petitions and Grievances, Section 4.

Appeals: A student may appeal the finding and/or penalty in a decision made under Policy 71 - Student Petitions and Grievances (other than regarding a petition) or Policy 71 – Student Discipline if a ground for an appeal can be established. Read Policy 72 - Student Appeals.

Turnitin: Text matching software (Turnitin®) will be used to grade and screen assignments in this course. Students' submissions are stored on a U.S. server, therefore students must be given an alternative, if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.
It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit alternate assignment.

Note for students with disabilities: The Accessibility Services office, located in Needles Hall Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the AS office at the beginning of each academic term.

Appendix

All engineering programs are reviewed by the Canadian Engineering Accreditation Board (CEAB). One of the required accreditation criteria is that institutions ensure students have sufficient knowledge and proficiency with respect to the 12 Graduate Attributes (GAs) listed below. These attributes are mapped to the learning objectives in each course for assessment, as shown in the brackets. This allows the program to both comply with CEAB requirements and continuously improve.

#	Acro-nym	Attribute Name	Attribute Definition
1	KB	Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.
2	PA	Problem analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.
3	Inv	Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.
4	Des	Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.
5	Tools	Use of Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.
6	Team	Individual and team work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.
7	Comm	Communication skills	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.
8	Prof	Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.
9	Impact	Impact of engineering	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.
10	Ethics	Ethics and equity	An ability to apply professional ethics, accountability, and equity.
11	Econ	Economics and project management	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.
12	LL	Life-long learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.