IOE 574. Simulation Analysis
Winter 2010
Time TuTh 1:30PM - 3:00PM in Room 2717 IOE

Revised 4-13-10

Course Website: http://vanoyen.engin.umich.edu/

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Office Hours: As determined in class(Monday 4-5 and Fri 2-3); other times by appointment

Detailed Description: A course in discrete-event simulation for graduate students. The course covers system modeling, simulation design (including mechanisms for efficiency), analysis of output, and programming in general-purpose languages (such as Visual Basic for Applications in Excel or C++). Proper design and analysis of discrete-event simulation experiments is emphasized. Applications are drawn primarily from manufacturing, service systems, and healthcare. Includes fundamentals as well as the more advanced concepts that allow students to model and to analyze systems using custom simulations at a deeper level than courses based on off-the-shelf simulation packages. Topics include stochastic models for simulation, statistical methodology for designing simulations and output analysis, randomvariable and process generation, and efficiency improvement techniques.

Notes:

- IOE 474 is a more basic course than IOE 574. 474 emphasizes the use of ProModel as a simulation package. It is not necessary to have IOE 474 prior to IOE 574.
- *IOE grad students may choose to take a qualifying exam on Simulation*

Text: A. M. Law 2007. *Simulation Modeling and Analysis*, 4th Edition, McGraw-Hill. (We previously used the 3rd edition, which has ISBN: 0070592926 and 3rd Edition website http://www.mhhe.com/engcs/industrial/lawkelton/).
Note that it is not necessary to have "Expertfit" software included with the book. We will have Statfit available via CAEN.

Prerequisites: IOE 515 is listed as a prerequisite in the catalog, but it is not really required. You need some background on the course's 3 supporting elements, listed below. My experience is that most students feel that one or two of the following areas are a challenge.

1. Statistics. You should be familiar with the normal distribution and estimation of sample standard deviation, student's t distribution, confidence level, confidence interval

2. Probability and stochastic models. You should be familiar with the Central Limit Theorem, Law of Large Numbers, conditional probabilities, conditional expectation, Poisson processes

3. Programming. You should be familiar with computer programming in some programming language (for example, VBA, C, Java, or Matlab). VBA, which is Visual Basic embedded in Excel, will be emphasized in this course, and materials will be made available to help you learn it.

Note that background in Markov chains and queueing is helpful, but not required; Graduate standing is recommended, but undergraduates with IOE 316, a good understanding of statistics, and comfort with programming have the essential background.

Grading: (tentative)

Homework & mini-projects: 25%
Test 1: 25%
Test 2: 25%
Major Project: 20% *For a description, see project IOE 574.doc*
Class Participation: 5%

The simulation "*homeworks, mini-projects*, and final project" may be done individually or in a team of 2 students. When a homework or project is done as a team, the group writeup must be submitted as a single copy bearing the names of both group members (who generally share the same grade unless there are extenuating circumstances). The midterm and final examination will be open book and notes.

Course Schedule (tentative): Note that only the near-term material is available on the website, and the resources will be progressively uploaded.

Module	Topic	Reading & Homework (L. = Law)	Other
1	Discrete Event Simulation modeling	L. Chapter 1 introduction.pdf Get familiar with VBA (see Intro to VBA & Excel-MVO .ppt and IOE574-startup.xls) Homework #1: hw1.pdf due Tue 1/19 [I encourage you to start from the file DiscreteTTFhw1-starter.xls]	Note that the Ctools websitehttps://ctools.umich.edu/portal has Assignment functionality to upload .xls or .c attachments to the website, and the grader and I can view your work through that mechanism. FYI: For those without a background in queueing - A light Intro to Queueing with some operations management principles: 574queue-lec-A.ppt 574queue-lec-B.ppt Lecture notes: (to be posted AFTER they are delivered) lec2-formulationSimModels.pdf mm1-queue-sim.pdf
	Program-ming simulations	L. Ch 2 Homework #2: hw2.pdf due Thur Feb. 4	The Basic sim. examples [(1) a queueing system and (2) an inventory system]: Basic_Simulation_Modeling.xls Lecture Notes: 4-lec-inventory-sim.pdf Problem discussed in class:InClassPracticeFormulation.doc
3	Developing Simulations & using "Simlib"	L. Chapter 5 - Building Credible Sim's. Homework #3: hw3.pdf due [Thur Feb 11]	More complex examples with all simlib VBA routines embedded: Modeling_Complex_Systems.xls (contains "TandemWalk" example from class) Lecture Notes: 6-Intro to RV Generation & Event Scheduling.pdf 8-verification.pdf 9- Simulation of a CTMC.pdf 11-WalkTandem-verification.pdf
4	Input modeling; Simulation	L. Chapter 6 L. Chapter 4.3 and 4.6 **Mini-Project**	Read L. Chapter 4 only to the extent you need the review. Lecture notes:

	as a stochastic process	**#1:**CallCenterProject.html (CallCenter-quickstart.xls) due [Delayed to Tue Feb 23]	12-input modeling.pdf 13B-Poisson-complete.pdf (replaces 13A-Poisson.pdf)
5	Random-number generation	L. Chapter 7.1-7.3.2 L. Chapter 8.1-8.2 Project Proposal Due [Thur Feb. 25] in class - hardcopy. Homework #4: hw4.pdf (handed out in class) due [_Tue Mar 9_], 2 days prior to midterm because of Winter Break.	Lecture notes (filenames changed 2/25) 14-Unif-RanNumberGenerators.pdf; 15-RV Generation.pdf
March 11	***TEST 1 Thur Mar. 11***	in class test covering up through Module 5 and hw4. I will have to provide you with solutions to HW 4 so you can be ready for the test. (open notes and book)	
7	Output analysis	L. Chapter 9 assignment: hw5.pdf due [March 25] MeanPlots.ppt = example from class Discussion of Batch means (lag-1 process)	Take note that the (old) file Modeling_Complex_Systems_BLN_MVO.xls (which is linked above in Module 3) is helpful for hwk5 because of the worksheet "test" and the distributions generated in BLNDriver() Lecture notes: 16-1-Sim-as-Stoch-Proc.pdf = Stochastic Process view of sim. output analysis, part 1. 16-2-Sim-as-Stoch-Proc.pdf = Stochastic Process view of sim. output analysis, part 2. 18-steady state analysis.pdf 19-batch-means.pdf
8	Common Random Numbers, Comparison, ranking, and selection of alternatives	L. Chapter 10 assignment: hwk6.pdf due Saturday, April 6 at noon via CTOOLS Brief intro to comparisons:Comparisons Example.ppt	Lecture notes: 20-CRN-Comparisons.pdf 21-Mult-Comparisons.pdf (updated 4-6)
	TEST 2 Thursday, April 15	in class test (not intended to be cumulative in nature - emphasis on material since the first test; open notes and book) Note that it is not possible to have the	

		test be completely disconnected from the earlier part of the course.	
9	Application of Simulation to Research	Simulation and its role in research.	IOE Research and Simulation.ppt Examples of operations papers where simulation was essential: Flexibility-Iravani-VanOyen-Sims.pdf chaining-MS010829-0072.pdf Example: Need for CRN's to tackle a research question: W10 XP-PR.ppt
10	Optional: Choosing distributions for Modeling; Conduct of effective sim. projects		Making Models Statistically Valid and Fitting.ppt (a resource with some very basic material in addition to useful perspective)
	Variance reduction	L. Chapter 11 through section 11.3	
No Class April 20	Course Project Due and Presentations in Class	A written report of your course project is due Tuesday, April 27, 4:00 pm. **We will have 2 hours for your presentations of 25 minutes each. Email the presentations and project files to me in advance of class.**	This is the same time as the regularly scheduled Final Exam (which we don't have)

Interpretation of the Honor Code for this class:

You may obtain help from others in doing the homework and projects (unless an assignment explicitly disallows teamwork), but the purpose of teamwork is to help *you* to fully comprehend the material. While you may discuss assignments with multiple people, actual completion of an assignment must be *limited to a team of at most two (2) members*. A homework assignment or

project that is prepared as a team should be submitted as a single copy containing the names of all group members (and all members will share the grade given).

Supplementary Resources - For Your Information Only:

- sim-probability-facts.pdf = Helpful details on computing sample variance, arrival counting processes, parameterizing a Poisson process, timing diagrams for queues, and generating pseudo-random numbers (for illustrative purposes, not practical)
- Tutorial: intro to statistical issues and Stat::Fit: Making Models Statistically Valid.ppt
- Inventory Management (basic intro.): Chapter02-SSmodel.ppt (see the latter half, emphasizing The Single Product (Q,r) Model)
- Tips for Success with Simulation: Sim Pro Model Introduction.ppt
- C and Fortran code for Law and Kelton is available from http://www.mhhe.com/engcs/industrial/lawkelton/
- From John O. McClain of Cornell University: FREE simulation package called **CellSim.xls** that runs from a Microsoft Excel spreadsheet using Visual Basic macros. It comes packaged in a self-extracting zip file, together with a Word document and a number of sample factory files (also Excel files). You can now simulate to explore multiple processes, Kanban-type control, setup time reduction, low-inventory factories, and a bunch of other things. Download from http://forum.johnson.cornell.edu/faculty/mcclain/Software/Software.htm
- Random number generation from a hardware and software perspective. http://pre.plt-scheme.org/docs/html/srfi/srfi-27.html Excerpt: This uses Pierre L'Ecuyer's MRG32k3a generator which is combination of two recursive generators of degree three, both of which fit into 54-bit arithmetics. The MRG32k3a generator also passes DIEHARD and in addition, has desirable spectral properties and a period in the order of 2^191. As a matter of fact, multiple recursive generators (MRGs) are theoretically much better understood than special constructions as the COMBO generator. This is the reason why the implementations provided here implements the MRG32k3a generator. When implemented in floating point arithmetics with sufficient mantissa-width, this generator is also very fast.