Course Syllabus

ISYE 6644

Simulation and Modeling for Engineering and Science

Summer 2019

Professor: Dr. David Goldsman

Course Description

This course covers modeling of discrete-event dynamic systems and introduces simulation-based methods for using these models to solve engineering design and analysis problems.

Prerequisites

- You will be expected to come in knowing a bit of basic calculus, probability, and statistics. But don't worry too much – we'll provide bootcamps on that material so as to make the class pretty much self-contained. In addition, this course will involve extensive computer programming, so it would be nice to have at least a little experience in something like Excel, just to bring back the programming memories.

Course Goals

- Learn how to develop simulation models and conduct simulation studies.
- Become familiar with the organization of simulation languages. In particular, we will do a great deal of modeling with Arena, a comprehensive simulation package with animation capabilities.
- Review statistical aspects including input analysis, random variate generation, output analysis, and variance reduction techniques.

Grading Policy

- There will be two midterms and one final exam.
- There will be 10 Homework assignments (not as bad as it sounds).
- You must achieve an overall weighted average of 60% to pass the course.
- Breakdown
    - Homeworks 10%
    - Midterm Quiz 1 30%
    - Midterm Quiz 2 30%
    - Final Quiz 3 30%

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    Total 100%

Homework and Quiz Due Dates

All homeworks and quizzes will be due at the times in the table at the end of this syllabus. These times are subject to change so please check back often. Please convert from Eastern Daylight Savings Time (EDST) to your local time zone using a Time Zone Converter.

Timing Policy

- The Modules follow a logical sequence, so they (mostly) need to be done in order.
- Homework Assignments should be completed by their due dates.
- Quizzes must be completed during the time allotted on the schedule.
- You will have access to the course content for the scheduled duration of the course.

Quiz Policy

- For Quiz *x* (*x* = 1,2,3), you are allowed to use *x* sheets of paper, either 8.5"x11" or A4, with handwritten notes (both sides of the sheet, 2*x* sides total).
- For all quizzes, you are allowed a blank sheet of paper for scratch work. (All OMS Analytics degree students will be proctored; you will have to show the front and back of the blank sheet while you are being proctored.)
- You are also allowed to bring any reasonable calculator.

Attendance Policy

- This is a fully online course.
- Login on a regular basis to complete your work, so that you do not have to spend a lot of time reviewing and refreshing yourself regarding the content.

Plagiarism Policy

- Plagiarism is considered a serious offense. You are not allowed to copy and paste or submit materials created or published by others, as if you created the materials. All materials submitted and posted must be your own.

Student Honor Code

All OMS Analytics degree students should abide by the Georgia Tech Student Honor Code.

- Review the Georgia Tech Student Honor Code: www.honor.gatech.edu.
- You are responsible for completing your own work.
- Any OMS Analytics degree student suspected of behavior in violation of the Georgia Tech Honor Code will be referred to Georgia Tech's Office of Student Integrity.

Communication

- Please contact your instructor, teaching assistants, and fellow learners via the Piazza discussion forums. Often, discussions with fellow learners (and your highly engaging and enthusiastic prof) are the sources of key pieces of learning.

Netiquette

- Netiquette refers to etiquette that is used when communicating on the Internet. Review the Core Rules of Netiquette. When you are communicating via email, discussion forums

or synchronously (in real-time), please use correct spelling, punctuation, and grammar consistent with the academic environment and scholarship[1].

- We expect all participants in Georgia Tech's MS in Analytics program, (learners, faculty, teaching assistants, staff) to interact respectfully. Learners who do not adhere to this guideline may be removed from the course.

[1]Conner, P. (2006–2014). Ground Rules for Online Discussions, Retrieved 4/21/2014 from http://teaching.colostate.edu/tips/tip.cfm?tipid=128

Course Topics and Sample Pacing Schedule

The table below contains a course topic outline and homework due dates. [Note that some topics below are marked as OPTIONAL. You will not be given homework nor will you be tested on those topics; but we have nevertheless included this material in case you need additional review or would like to delve into a topic further.]

Weeks	Course Topics	Release Dates
Week 1	Module 1: Whirlwind Tour of Simulation • Lesson 1: Getting to Know You • Lesson 2: Syllabus • Lesson 3: Whirlwind Tour • Lesson 4: Whirlwind Tour – History • Lesson 5: What Can We Do For You • Lesson 6: Some Baby Examples • Lesson 7: More Baby Examples • Lesson 8: Generating Randomness • Lesson 9 [OPTIONAL]: Simulation Output Analysis	May 13, 2019 at 8:00 a.m. EDST
Week 1 Homework	Homework 1	May 17 at 8:00 a.m. EDST – May 24 at 11:59 p.m. EDST
Week 2	Module 2: Bootcamps • Lesson 1 [OPTIONAL]: Calculus Primer • Lesson 2 [OPTIONAL]: Saved By Zero! Solving Equations • Lesson 3 [OPTIONAL]: Integration • Lesson 4 [OPTIONAL]: Integration Computer Exercises • Lesson 5: Probability Basics • Lesson 6: Simulating Random Variables	May 20, 2019 at 8:00 a.m. EDST

	• Lesson 7: Great Expectations • Lesson 8: Functions of a Random Variable • Lesson 9: Jointly Distributed Random Variables • Lesson 10 [OPTIONAL]: Conditional Distributions / Expectation • Lesson 11: Covariance and Correlation • Lesson 12: Probability Distributions • Lesson 13: Limit Theorems • Lesson 14 [OPTIONAL]: Introduction to Estimation • Lesson 15 [OPTIONAL]: Maximum Likelihood Estimation • Lesson 16 [OPTIONAL]: Confidence Intervals	
Week 2 Homework	Homework 2	May 24 at 8:00 a.m. EDST – May 31 at 11:59 p.m. EDST
Week 3	Module 3: Hand Simulations • Lesson 1: Stepping Through Differential Equation • Lesson 2: Monte Carlo Integration • Lesson 3: Monte Carlo Integration Demo • Lesson 4: Making Some Pi • Lesson 5: A Single-Server Queue • Lesson 6: An (*s*,*S*) Inventory System • Lesson 7: An (*s*,*S*) Inventory System Demo • Lesson 8: Simulating Random Variables • Lesson 9: Simulating Random Variables Demo • Lesson 10: Spreadsheet Simulation Module 4: General Simulation Principles • Lesson 1: Steps in a Simulation Study • Lesson 2: Some Useful Definitions • Lesson 3: Time-Advance Mechanisms • Lesson 4: Two Modeling Approaches • Lesson 5: Simulation Languages	May 27, 2019 (Memorial Day) at 8:00 a.m. EDST
Week 3 Homework	Homework 3	May 31 at 8:00 a.m. EDST – June 7 at 11:59 p.m. EDST

Week 4	Module 5: The Arena Simulation Language • Lesson 1: Introduction • Lesson 2: Process-interaction • Lesson 3: Let's Meet Arena! • Lesson 4: The Arena Basic Template • Lesson 5: Create-Process-Dispose Modules • Lesson 6: The Process Module • Lesson 7: Resource, Schedule, and Queue Spreadsheets • Lesson 8: The Decide Module • Lesson 9: The Assign Module • Lesson 10: Attribute, Variable, and Entity Spreadsheets • Lesson 11: Arena Internal Variables • Lesson 12: Displaying Stuff	June 3, 2019 at 8:00 a.m. EDST
Week 4 Homework	Homework 4	June 7 at 8:00 a.m. EDST – June 14 at 11:59 p.m. EDST
Midterm Exam 1	Midterm Exam 1 [Covers up to and including Week 3 material + maybe a tiny bit of Arena material from Week 4]	June 7 at 8:00 a.m. EDST – June 16 at 11:59 p.m. EDST
Week 5	Module 5 (cont.): More Arena • Lesson 13: Batch, Separate and Control • Lesson 14: Run Setup and Control Lesson 15: Two-Channel Manufacturing Example • Lesson 16: Fake Customers • Lesson 17: The Advanced Process Template • Lesson 18: Resource Failures + Maintenance • Lesson 19: The Blocks Template • Lesson 20: The Joy of Sets • Lesson 21: Description of Call Center • Lesson 22: Call Center Demo • Lesson 23: An Inventory Model • Lesson 24: One Line vs Two Lines? • Lesson 25 [OPTIONAL]: A Re-entrant Queue	June 10, 2019 at 8:00 a.m. EDST

	• Lesson 26 [OPTIONAL]: SMARTS Files + Rockwell Demos • Lesson 27: A Manufacturing System Demo	
Week 5 Homework	Homework 5	June 14 at 8:00 a.m. EDST – June 21 at 11:59 p.m. EDST
Week 6	Module 6: Random Number Generation • Lesson 1: Introduction • Lesson 2: Some Lousy Generators • Lesson 3: Linear Congruential Generators • Lesson 4: Tausworthe Generators • Lesson 5: Generalization of LCGs • Lesson 6: Choosing a Generator – Some Theory • Lesson 7: Choosing a Generator – Statistics Test, Intro • Lesson 8: Choosing a Generator – Goodness of Fit Tests • Lesson 9: Choosing a Generator – Independence Tests, I • Lesson 10 [OPTIONAL]: Choosing a Generator – Independence Tests, II	June 17, 2019 at 8:00 a.m. EDST
Week 6 Homework	Homework 6	June 21 at 8:00 a.m. EDST – June 28 at 11:59 p.m. EDST
Week 7	Module 7: Random Variate Generation • Lesson 1: Introduction • Lesson 2: Inverse Transform Method • Lesson 3.1: ITM – Continuous Examples • Lesson 3.2: ITM – Continuous Examples DEMO 1 • Lesson 3.3: ITM – Continuous Examples DEMO 2 • Lesson 4: ITM – Discrete Examples • Lesson 5 [OPTIONAL]: ITM – Empirical Distributions • Lesson 6.1: Convolution Method • Lesson 6.2: Convolution DEMO • Lesson 7: Acceptance-Rejection Method • Lesson 8 [OPTIONAL]: Proof of the A-R Method • Lesson 9.1: A-R Method – Continuous Examples	June 24, 2019 at 8:00 a.m. EDST

	• Lesson 9.2: A-R Method – Continuous Examples DEMO	
Week 7 Homework	Homework 7	June 28 at 8:00 a.m. EDST – July 5 at 11:59 p.m. EDST
Week 8	Module 7 (cont.): More RV Generation • Lesson 10: A-R Method - Poisson Distribution • Lesson 11 [OPTIONAL]: Composition • Lesson 12: Box-Muller Normal RVs • Lesson 13: Order Statistics Other Stuff • Lesson 14: Multivariate Normal Distribution • Lesson 15 [OPTIONAL]: Baby Stochastic Processes • Lesson 16.1: Nonhomogeneous Poisson Processes • Lesson 16.2: Nonhomogeneous Poisson Processes DEMO • Lesson 17.1 [OPTIONAL]: Time Series • Lesson 17.2 [OPTIONAL]: Time Series DEMO • Lesson 18 [OPTIONAL]: Queueing • Lesson 19.1: Brownian Motion • Lesson 19.2: Brownian Motion DEMO	July 1, 2019 at 8:00 a.m. EDST
Week 8 Homework	Homework 8	July 5 at 8:00 a.m. EDST – July 12 at 11:59 p.m. EDST
Midterm Exam 2	Midterm Exam 2 [Covers up to and including Week 7 material, but with emphasis on more-recent stuff]	July 5 at 8:00 a.m. EDST – July 14 at 11:59 p.m. EDST
Week 9	Module 8: Input Analysis • Lesson 1: Introduction • Lesson 2: Identifying Distributions • Lesson 3: Unbiased Point Estimation • Lesson 4: Mean Squared Error • Lesson 5: Maximum Likelihood Estimators • Lesson 6: MLE Examples	July 8, 2019 at 8:00 a.m. EDST

	• Lesson 7: Invariance Property of MLEs • Lesson 8 [OPTIONAL]: The Method of Moments • Lesson 9: Goodness of Fit Tests • Lesson 10: Exponential Example • Lesson 11: Weibull Example • Lesson 12: Still More Goodness-of-Fit Tests • Lesson 13: Problem Children • Lesson 14: Demo Time	
Week 9 Homework	Homework 9	July 12 at 8:00 a.m. EDST – July 19 at 11:59 p.m. EDST
Week 10	Module 9: Output Analysis • Lesson 1: Introduction • Lesson 2 [OPTIONAL]: Mathematical Interlude • Lesson 3: Finite-Horizon Analysis • Lesson 4: Finite-Horizon Extensions • Lesson 5: Simulation Initialization Issues • Lesson 6: Steady-State Analysis • Lesson 7 [OPTIONAL]: Properties of Batch Means • Lesson 8: Other Steady-State Methods Module 10: Comparing Systems • Lesson 1: Introduction • Lesson 2: Confidence Interval for the Mean • Lesson 3: CIs for the Difference in Two Means • Lesson 4: Paired CI for the Difference in Two Means • Lesson 5: CIs for the Mean Difference in Simulations	July 15, 2019 at 8:00 a.m. EDST
Week 10 HW	Homework 10	July 19 at 8:00 a.m. EDST – July 26 at 11:59 p.m. EDST
Week 11	Module 10: Comparing Systems (cont'd) • Lesson 6: Common Random Numbers • Lesson 7 [OPTIONAL]: Antithetic Random Numbers • Lesson 8 [OPTIONAL]: Control Variates	July 22, 2019 at 8:00 a.m. EDST

	• Lesson 9: Ranking and Selection Methods • Lesson 10: Normal Means Selection • Lesson 11: Single-Stage Normal Means Procedure • Lesson 12 [OPTIONAL]: Normal Means Extensions • Lesson 13: Bernoulli Probability Selection • Lesson 14 [OPTIONAL]: Bernoulli Extensions • Lesson 15: Multinomial Cell Selection • Lesson 16 [OPTIONAL]: Multinomial Procedure + Extensions • Lesson 17: Summary	
Week 11 HW	Homework 11	July 26 at 8:00 a.m. EDST – August 2 at 11:59 p.m. EDST
Final Exam	Final Exam [Covers everything, with emphasis on more-recent stuff]	July 26 at 8:00 a.m. EDST – August 4 at 11:59 p.m. EDST

Course Materials

- All content and course materials can be accessed online.
- There is no required textbook for this course, though students are encouraged to find copies of the following references:
  - Law, A. M., Simulation Modeling and Analysis, 5th edition, McGraw-Hill Education, New York, 2015. [This textbook is most for the "theory" aspects of the course.]
  - Kelton, W. D., Sadowski, R. P., and Zupick, N. B., Simulation with Arena, 6th edition, McGraw-Hill, New York, 2015. [This book covers the Arena simulation language.]

Technology/Software Requirements

- Internet connection (DSL, LAN, or cable connection desirable)
- R statistical software (free download; see cran.r-project.org)
- Arena simulation software (free student download; see www.arenasimulation.com/academic/students)
- Adobe Acrobat PDF reader (free download; see https://get.adobe.com/reader/)