ORIE 4580/5580: Simulation Modeling and Analysis
ORIE 5581: Monte Carlo Simulation

Syllabus

Fall 2020

> *All models are wrong but some are useful [...] there is no need to ask the question "Is the model true?". If "truth" is to be the "whole truth" the answer must be "No". The only question of interest is "Is the model illuminating?".*
>
> — G. E. P. Box. "Robustness in the Strategy of Scientific Model Building".

TL;DR

Intro to Monte Carlo techniques and stochastic simulation.
Topics include: random variable and process generation; data-driven distribution learning; input and output analysis; modeling and optimization of complex systems under uncertainty. Emphasis on 1. understanding how to use simulation to answer 'what-if' questions, 2. tools and techniques needed in practice, in particular, modeling and simulation in Python.

Grading based on 9 assignments (in groups of 1-2), one 'semi'-final, a final project (groups of 4-5), in-class polls.
Requires comfort with basic probability and coding in Python. Prerequisites: CS 2110/ENGRD 2110, ORIE 3500 (ORIE 3500 may be taken simultaneously).

Instructor: Sid Banerjee (229 Rhodes Hall, email: `sbanerjee@cornell.edu`)

Lectures: TR 11:30am-12:45pm, Statler auditorium (room 185)

Recitation Sessions: There are four in-person and one online recitation sessions

3. Friday: 9:10am-11:05am, Rhodes 571
4. Friday: 4:15pm-6:10pm, Rhodes 453
1. Monday: 11:30am-1:25pm, Rhodes 571
2. Wednesday 4:15pm-6:10pm Rhodes 453
5. Wednesday: 7:30pm-9:25pm, online

Recitation cycle starts on Wednesday. The first recitation is on 9^{th} September (Wednesday).

Important links:
Website: https://people.orie.cornell.edu/sbanerjee/courses/orie4580f20/
Canvas: https://canvas.cornell.edu/courses/22758/
Piazza: https://piazza.com/cornell/fall2020/orie458055805581combined
CMSx: https://cmsx.cs.cornell.edu/web/auth/?action=viewCUmemb&courseid=689
Online lectures: Zoom link (Password: metropolis)
Please ensure you have access to **all of these** sites.

Course Logistics

This syllabus is for Simulation Modeling and Analysis (ORIE 4580/5580), as well as Monte Carlo Simulation (ORIE 5581). ORIE 4580 and 5580 are exactly the same (4 credits) course, ORIE 5581 is a *half semester* (7 week, 2 credits) course with its last class on 16^{th} October. The material of ORIE 5581 is the same as the first 7 weeks of ORIE 4580/5580, and so all lectures and recitations are shared between the three courses in the first 7 weeks of the semsester.

If you are an undergraduate student, you (usually) want to enroll in ORIE 4580 (or ORIE 5580 for online only); if you are an MEng student, you should to enroll in ORIE 5580 for the full semester course, or in ORIE 5581 for the half semester course.
Note: October 28th is the last day to drop the class for full semester classes like ORIE 4580/5580; *the last day to drop ORIE 5581 is earlier* (usually end September; check with registrar).

Course Description

There are many different simulation techniques across different fields; the focus of ORIE 4580/5580 is *stochastic simulation*: in particular, we will cover two topics:

- *Monte Carlo estimation*: How can we use randomness to speed up complex computations.
- *Discrete-event simulation*: How can we use models for *counter-factual analysis* (i.e., answering 'what-if questions') in complex real-world systems.

Our focus will be on *data-driven engineering* – going beyond learning from data ('data-science') to using data to design and improve complex systems. Such techniques find use across many disciplines: for modeling factory staffing, automated vehicles, and supply chains; to model fleet logistics and traffic in airlines and transportation systems; to model data transmission and processing in communication and computer systems; to model medicine and staff levels and placement in hospitals and pharmacies; to simulation to model spread of diseases; to model police, fire fighting, ambulance and judicial systems; in various problems in financial, marketing and information systems. We will try to see some of these throughout the course.

Prerequisites:

The foundations of simulation are probability and statistics, and computer programing. The course will assume you are comfortable with these topics – it is up to you to ensure this is true.

Familiarity with the topics covered in **ENGRD 2700** and **ORIE 3500/5500** is required, but ORIE 3500/5500 may be taken concurrently. The initial part of the course includes a short review of probability and statistics, which is in essence the material in Chapter 2 Elements of Probability - of the suggested textbook by Ross (available online through the Cornell library). If this material is unfamiliar to you, then you should study it from any introductory probability textbook (for example, Chapters 1 through 4 of Introduction to probability by Bertsekas and Tsitsiklis, or Chapters 1 through 6 of Introduction to probability and statistics by Ross).

The course involves a fair amount of coding, and some prior programming experience is essential. For the first part of the course, our preference is that students use **Python**, and submit their assignments as **Jupyter notebooks** with annotated code and plots. The first recitation section will provide a brief introduction to these tools; the first assignment will also make sure everyone is up to scratch on requirements. The second half of the course will also mainly be based on Python; time permitting, we will also briefly look at **Simio**, a commercial simulation package, to get a sense of how simulation works in industry.

Course communication

The Canvas site (https://canvas.cornell.edu/courses/22758) will contain all the information you need. Lecture notes (blank and annotated slides) will be posted here. Over time, you can also find staff information, office hours, homework assignments and solutions, exam preparation material and course announcements and your homework and exam grades on this site. Make sure that you are enrolled on the course Canvas site and that you **check the site regularly** for updates, announcements, and new material.

We will use Piazza as a place to ask and to answer questions about the course content and the homework. Please post your questions to this site and feel free to answer other students' questions there. If you often answer other students' questions (correctly) throughout the course, this will be taken into account when determining your letter grade for this course. To contact course staff, **please only send us private messages via Piaza** (no email).

If you are not enrolled on the course Canvas site, or Piazza, please email one of the TAs to help you enroll.

Homework:

There will be 10 assignments throughout the semester (approximately one per week); 5581 students will do the first 5.

Typesetting and submission: *All assignment solutions must be submitted online* – we will use CMS for submissions (instructions in first homework). Students should submit solutions as *Jupyter notebooks* with *typeset* answers, executable code and labeled plots; additional files can be included, but are discouraged. Homework assignments will be due on Tuesday at 11am (before class).

Collaboration: You may do the homework individually or in pairs. If doing it as a pair, please submit a single solution with **both of your names and netids on the solution**; you will both receive the same grade. You may have a different homework partner for each homework if you wish. Failure to acknowledge collaborators is a violation of academic integrity.

Late submissions and drops: You have **four late days** (two late days for 5581) which you can use across assignments; these will be automatically recorded by CMS. Late submission will be graded only if you are within your late days – once you exhaust them, your late assignments will not be graded. You can use at most two late days per homework (i.e., till Saturday 1pm).

You do not need to inform the instructor or TAs if you are using late days – this is automatically recorded by CMS. It is your responsibility, to make sure you do not miss deadlines or run out of late days. We will not entertain any request to change the CMS records.

We will drop the *lowest homework grade* for all students, and in addition, *the second lowest homework grade* for students who submit all homeworks.

Grading: Homeworks will be graded and returned through CMS. You may request a regrade on any work within one week of the graded work being returned, along with a note that explains your request for a regrade. The entire homework/project/exam will be regraded.

Project and Exams

Students enrolled in ORIE 4580 and 5580 also have to do a *final project*, in teams of 4 or 5 students (not less than 4 and not more than 5). More details on the project will follow later in the course.

The course prelim and final details, as well as exact grading scheme, will be finalized soon once the registrar finishes scheduling.

Course Grading

The tentative grading scheme is as follows:

Component	**4580/5580**	**5581**
Clicker responses	4	4
Homeworks	45	35
Project	20	-
Prelim + Final	30	61
Course Eval	1	-

Your clicker response grade comes from responding to in-class clicker questions. Points are for participation, not correctness. Your clicker score is given by $4 \times \min(1, 1.333x/n)$, where n is the total number of clicker questions and x is the number to which you respond. We will also take into account your participation on Piazza (responding to other students questions) when setting grades.

Note for ORIE Affiliates:

If you are an ORIE major, then you must get a grade of C or better in this course. If you fail to meet this requirement, then you must repeat the course to graduate, even if that means staying another year. There will be no follow-up exams or extra work for credit offered after the course.

Resources:

- **Course notes** - These will be uploaded on Piazza a week before the class – you are encouraged to bring copies to annotate them.
- **Textbook** (Suggested) The textbook for the course is S. Ross, Simulation . An e-copy of the book is available on the Cornell library website.
- Other **references** (available online on the Cornell library website):
  - J. Banks, J.S. Carson II, B.L. Nelson, D.M. Nicol, Discrete-Event System Simulation (Similar level to this class.)
  - A.M. Law, Simulation Modeling and Analysis (Similar level to this class.)
  - B. L. Nelson. Foundations and Methods of Stochastic Simulation: A First Course (Slightly higher level than this class, but readable.)
  - J. Banks, Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice (Slightly higher level than this class, but readable.)
  - P. Glasserman, Monte Carlo Methods in Financial Engineering (This book is for advanced students, and while focused on financial engineering, is excellent reading in general.)
- **Software** (Suggested) The coding assignments can be done in any high-level language; our recommendation is for using Python and Jupyter notebooks. These will be available in 571 Rhodes Hall and 453 Rhodes Hall. You can also use online collaborative coding environments like Google Colaboratory

  For the second half of semester, we will spend a few classes looking at a commercial simulation package, Simio. This will be available in 571 Rhodes Hall and 453 Rhodes Hall. Students may consider obtaining the student version of Simio ($25, link posted on the course website). The student version of Simio imposes limits on the size of the models. These should not be a problem for the homework or project. The Simio software includes documentation.

Academic integrity:

Cornell's Code of Academic Integrity can be found at cuinfo.cornell.edu/aic.cfm.

Your work on the written homework, programming exercises and exams should be your own. For the homework, you may discuss approaches to problems with other students, but as a general guideline, such discussions may not involve taking notes and should be in groups not exceeding three people. You must write up solutions on your own or with one partner, and acknowledge anyone with whom you discussed the problem. You may not discuss exam problems with other students.

For the recitation exercises, you should work with a partner, and you and your partner should turn in a single assignment.

Buying, selling, or reposting course materials on external websites will be considered an academic integrity violation.

If you have any concerns about your learning, grades, or progress in the course, or if you have other difficulties, feel free to talk to me or any of the TAs. Other resources at Cornell are also available (caringcommunity.cornell.edu).