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

Syllabus

Fall 2018

> *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 discrete-event simulation. Topics include: random variate and process generation; data-driven distribution learning; input and output analysis; modeling and optimization of complex systems under uncertainty. Emphasizes tools and techniques needed in practice; in particular, modeling and simulation in Python, as well as commercial discrete-event simulation software.

Grading based on 9 assignments (in groups of 1-2), one final project (groups of 4-5), midterm and final. 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 1:25am-2:40pm, Kimball B11

Recitation Sessions: There are four recitation sessions (all in 571 Rhodes Hall)

1. Monday: 11:15am-1:10pm, 2:30pm-4:25pm
2. Friday: 12:20pm-2:15pm, 2:30pm-4:25pm

Attendance at both lectures and one recitations is expected. You are responsible for being aware of announcements and content.

Website: `http://people.orie.cornell.edu/sbanerjee/ORIE4580/orie4580f18.html`
Blackboard page: `http://blackboard.cornell.edu`
Piazza page: `https://piazza.com/cornell/fall2018/orie458055805581`
Please ensure you are signed up on **both** the Blackboard and Piazza sites for the course. For Blackboard, you should use the course website titled *ORIE 4580 Simulation Modeling & Analysis Banerjee,S* even if you are taking ORIE 5580/5581.

Course Description

Simulation is a general technique of using computer-generated models for *counter-factual analysis* (i.e., answering 'what-if questions') of complex real-world systems. In other words, our focus will be on *data-driven engineering* – going beyond learning from data ('data-science') to using data to design and improve complex systems.

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 simulation*: for the first part of the course, we will focus on simulating systems in which time does not play a substantive role.
- *Discrete-event simulation*: in the second half, we will model systems with uncertainty that evolve over time.

Stochastic simulation deals with predicting certain aspects of the behavior of some complex system through approximate models. Manufacturers use simulation to model factory staffing, conveyors, automated guided vehicles, storage and retrieval systems. Airlines and transportation companies use simulation to model fleet logistics and traffic. Designers of communications networks and computer systems use simulation to model data transmission and processing. Health care providers use simulation to model medicine and staff levels and placement in hospitals and pharmacies. Epidemiologists use simulation to model spread of diseases. The defense community uses simulation to model aircraft readiness and combat strategy. In public services, simulation is used to model police, fire fighting, ambulance and judicial systems. Many aspects of financial, marketing and information systems can be studied using simulation.

Prerequisites:

The foundations of simulation are probability and statistics, and computing. 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 iPython 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 be based both on Python as well as **Simio**, a commercial simulation package, which we will teach in class. All programming tools will be available in the lab computers in 571 Rhodes and 453 Rhodes.

Course communication

The course website will only have the syllabus and useful links; all course material will be uploaded on Piazza. All announcements will also be through Piazza, and it is your responsibility to ensure that you are enrolled and receiving the announcements. Please contact the TAs if you have any issues.

Finally, we will also use Piazza for all course-related questions. Please avoid emailing the instructor or the TAs. We will monitor Piazza closely and you will usually get a quick response. By default, your posts are visible to the course staff and other students; however, you can post privately so that only the course staff can see your question, and should do so if your post might reveal information about a solution to a homework problem. If you post privately, we reserve the right to make your question public if we think the class will benefit.

Homework:

There will be 9 assignments throughout the semester (approximately one per week).

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 *iPython notebooks* with *typeset* answers, executable code and labeled plots; additional files can be included, but are discouraged. Homework assignments will be due on Thursday at 1pm (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 *two lowest homework grade* (for ORIE 5581, *one lowest grade*).

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 has one prelim (October 11, 7.30pm) and one final exam (as announced by registrar); ORIE 5581 students only do the prelim. For the prelim you may bring *one sheet of handwritten notes*, which must be attached to the paper; for the final you can bring in *two handwritten sheets*.

Course Grading

The tentative grading scheme is as follows:

Component	**4580/5580**	**5581**
Clicker responses	4	4
Homeworks	25	35
Project	20	-
Prelim (Oct 12)	20	61
Final	30	-
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.

Academic integrity:

Every student is expected to abide by the Cornell University Code of Academic Integrity. All work you hand in should be your own, with the following exceptions: you may discuss the homework assignments with other students, but only at the level of a discussion in a corridor. When you are writing down or typing your homework assignment, please make sure you are by yourself (or with your homework partner if working in a pair). Sharing computer code or spreadsheet calculations is not allowed. You cannot get help in any way from students that have completed this course in the past. We believe that homework is a learning experience, and will grade as easily as possible, as long as you put in an honest effort. Projects should be done in your teams, with no collaboration between different teams.

If you violate this policy, you risk having your entire homework/project grade set to 0 or even failing the course. If you have any questions about this policy, then please contact the instructor beforehand. Please see http://cuinfo.cornell.edu/Academic/AIC.html for more information on the university code of academic integrity.