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

Syllabus

Fall 2017

Essential Course information:

- *Lectures*
  Class time: TR 1:25am-2:40pm
  Class location: Hollister B14

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

- *Recitation Sessions*
  There are four recitation sessions:

  1. Monday 12:20-2:15, 571 Rhodes Hall
  2. Monday 2:30-4:25, 571 Rhodes Hall
  3. Friday 11:15-1:10, 571 Rhodes Hall
  4. Friday 2:30-4:25, 571 Rhodes Hall

  You are free to attend whichever recitation you desire for the time being. If one of the sessions gets too crowded, then we will ask you to attend the session for which you registered. Recitations are not graded, but a strong attendance record can help in tie-breaking situations.

  Monday Sept 4th is Labor Day. For that week only we will run special recitations on Thursday Aug 31st 10:10-12:05 and Tuesday Sept 5th 10:10-12:05, both in 453 Rhodes.

- *Website and Piazza*
  Website: http://people.orie.cornell.edu/sbanerjee/ORIE4580/orie4580f17.html
  Blackboard page: http://blackboard.cornell.edu
  Piazza page: https://piazza.com/cornell/fall2017/orie45805580combined
  Please ensure you are signed up for both Blackboard and Piazza. For Blackboard, you should use the course website titled *ORIE 4580 Simulation Modeling & Analysis Banerjee,S* even if you are taking ORIE 5580/5581.

  Instructor
  Prof. Siddhartha Banerjee
  Office: 229 Rhodes Hall
  email: sbanerjee@cornell.edu
  Students should post questions as much as possible on Piazza instead of mailing me; I will respond faster to those before my mail.

Teaching Assistants

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Office hours: To be announced on Piazza

Course description:

Simulation is a general technique for answering 'what-if questions' about complex real-world systems using computer-generated models. 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 that evolve over time, primarily using Simio a widely used simulation package.

Stochastic simulation deals with predicting certain aspects of the behavior of some system through approximate models. Manufacturers use simulation to model work cells, 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 switching. Health care providers use simulation to model resource levels and placement in health care systems. 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:

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 4 Review of Probability and Statistics - of the suggested textbook by Law (see below). If this material is unfamiliar to you, then you might study Chapters 1 through 6 of Introduction to Probability and Statistics for Engineers and Scientists, 2nd ed., by Sheldon Ross, or Chapters 1-5 and Chapter 7 of Probability and Statistics for Engineering and the Sciences, 8th ed., by Devore. This material is very standard, and can be found in other books at a similar level.

The course involves some coding, and some prior programming experience is useful. The programming in the first part of the course can be done using any high-level language of your choice (in particular, MATLAB, R, Julia, C++ or Java); our preference is that students use **Python**, and submit iPython notebooks with annotated code and plots. There will be a recitation section introducing these for interested students, and students can use them in the lab computers in 571 Rhodes Hall and 453 Rhodes Hall. The second half of the course will be based on Simio, a commercial simulation package, which we will teach in class.

Course communication

The course website will only have the syllabus and useful links; all course material will be uploaded on Piazza. All announcements for the class will also be made 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 as an online discussion forum for all course-related questions. This is the most effective way to communicate with course staff; please avoid email if Piazza will do. You are encouraged to post any questions you might have about the course material. The course staff will monitor Piazza closely and you will usually get a quick response. If you know the answer to a question, you are encouraged to post it. 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. You can also post anonymously if you wish. If you post privately, we reserve the right to make your question public if we think the class will benefit.

Everyone who preregistered for the course should automatically be signed up for both Blackboard and Piazza. If you have never used Piazza before, or if you did not preregister for the course, visit the Piazza ORIE 4580 page to sign up.

Resources:

- **Course notes** - These will be uploaded on Piazza a week before the class – you are encouraged to bring copies to annotate them.
- **iClicker** or iClicker App. (Required): See the course webpage for full details.
- **Textbook** (Suggested) The textbook for the course is A. M. Law, Simulation Modeling and Analysis. We will recommend reading so that you will know which section to read if you buy the book. Feel free to purchase older editions of the textbook if you can find a more reasonably priced copy. The contents of the textbook change very little from one edition to the next.
- Other **references** (on reserve at Uris):
  - J. Banks, J.S. Carson II, B.L. Nelson, D.M. Nicol, Discrete-Event System Simulation (Similar level to this class.)
  - S.M. Ross, Simulation (Similar level to this class. Available online on the Cornell library website)
  - B. L. Nelson. Foundations and Methods of Stochastic Simulation: A First Course (Slightly higher level than this class, but very readable. Available online on the Cornell library website)
  - J. Banks, Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice (Slightly higher level than this class, but very readable. Available online on the Cornell library website)
  - 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. Available online on the Cornell library website)

- **Software** (Suggested) The assignments in the first half of semester can be done in any high-level language; our recommendation is for using Python and iPython/Jupyter notebooks. These will be available in 571 Rhodes Hall and 453 Rhodes Hall, and instructions for installing them on your personal computer will be posted on the course website.

  For the second half of semester, we will use a commercial simulation package, Simio, which only operates on PCs, or on Macs running Windows. Simio 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), which will enable you to do the homework assignments at home. 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.

Homework:

There will be approximately weekly homework assignments. You should expect to have approximately 10 assignments throughout the semester.

Typesetting and submission: *All assignment solutions must be submitted online* – in particular, we will use CMS for assignment submissions (instructions in first homework). We encourage all students to *typeset* their solutions, with scans of hand-drawn figures if required. 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. You should use Piazza to find homework and project partners.

Late submissions and drops: You have *four late days* 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 (so submission by Saturday 1pm). *You do not need to inform the instructor or TAs if you are using late days* – it is your responsibility, however, to make sure you do not run out.

We will drop the *two lowest homework grade* (for ORIE 4580/5580) or *one lowest grade* (for ORIE 5581).

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

In addition to the above, students enrolled in ORIE 4580 and 5580 also have to do a project, in teams of 4 or 5 students (not less than 4 and not more than 5) that you select. More details on the project will follow later in the course.

The course also has one prelim (October 12, 7.30pm) and one final exam (December 8, 2:00pm); ORIE 5581 students only do the prelim. For the prelim you may bring one sheet of notes; for the final you can bring in two sheets.

Course Grading

Your grade will be determined as per the following table, depending on whether you are registered for ORIE 4580/5580 or ORIE 5581:

Component	4580/5580	5581
Clicker responses	4	4
Homeworks	25	35
Project	20	-
Prelim (Oct 12)	20	61
Final	30	-
Course Eval	1	-

You must get a certain minimum grade in the final exam to pass this course. That grade depends on how hard the final exam is, but is usually around 50%.

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.

Topics Covered

Below is a list of topics that we will cover throughout the semester, along with the approximate number of lectures we are going to spend on each topic and the corresponding chapter in the textbook. For some of the topics, we will post supplementary reading assignments.

Topic	# of lectures	Chapter in book
Introduction to simulation	1	Ch 1
Review of probability and statistics	1-2	Ch 4
Basic Monte Carlo Simulation	2	
Uniform random variable generation	2	Ch 7
Non-uniform random variable generation	2-4	Ch 8
Estimation and input modeling	2-3	Ch 6
Variance reduction	2-3	Ch 11
Prelim		
Intro to discrete-event system simulation	1	Ch 1
Modeling in Simio (flipped classroom)	4	
Output analysis	2-3	Ch 9
Comparing alternative systems	2	Ch 10
Verification, validation, project mgmt	1	Ch 5
Other topics [1]	2-3	
Review	1	

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.