COMPSCI 550: Introduction to Simulation (Spring 2024)

Teaching Staff:

Instructor: Prof. Peter J. Haas (phaas@cs.umass.edu)
Office hours (hybrid): Wed 1pm-2pm and by appointment in CS 204.
Note: There is another Prof. Peter Haas on campus, in Political Science. Please make sure to send emails to the correct Prof. Haas.
TA: Cen Wang (cenwang@umass.edu)
Office hours: Tues 2:30-3:30 and Thurs 4-5pm, CS 207

Graders:
Arushi Bohra (abohra@umass.edu) Office hour: Fri 10-11am LGRC T220
Kartik Choudhary (kartikchoudh@umass.edu) Office hour: Mon noon-1pm on Zoom

Class Meetings:

TuTh 1pm – 2:15pm in Computer Science Building, Room 142. We will be using the Class Question app (classquestion.com/students) for class polls and questions.

Canvas - Learning Management System

Canvas is the primary platform for this class (replacing Moodle used in previous years). Look there for resources including lecture slides, lecture recordings, handouts, and so on. The main thing we will NOT use it for is discussions and questions - we will use Piazza (see below).

Prerequisites:

Students need to be able to write, run, and debug basic programs in Python; this requires computing competency at the level of CS 187. Sample Python code will be posted at the beginning of the course, and students may adapt and build on this code, if they want, to complete their assignments. Students need to be proficient in basic calculus-level probability and statistics at the level of STAT 515. Knowledge of basic stochastic processes, such as Markov chains, is helpful, but not required; the necessary material will be covered in class. Students will be given a handout that reviews the basic probability and statistics needed for the course. During the first week or so of class, there will be a review session covering the basics of writing, running, and debugging a Python program, and another review session covering probability and statistics.

Number of Credits: 3

Type of course and format: Lecture

Course Goals:

The emphasis will be on understanding the underlying principles and basic techniques of simulation modeling and analysis, so that students can apply simulation in a flexible and intelligent manner to real-world problems and become educated consumers of simulation studies and simulation packages. Students will learn to appreciate the power and scope of simulation in applications drawn from a variety of domains.

Learning Objectives:

Students will be able to

- Use basic Monte Carlo methods to estimate probabilities, expected values, and more, when they are hard to compute analytically or numerically.
- Formulate a mathematically precise stochastic simulation model from a description of an existing or proposed real-world dynamic system.
- Use existing data or theoretical guidance to determine appropriate input distributions for the random components of a simulation model.
- Understand algorithms for generating random variables and for executing a simulation model.
- Efficiently implement the above algorithms on a computer in Python.
- Statistically analyze the output of the simulation program to estimate system properties of interest, and to identify optimal systems designs and operating policies.
- Demonstrate understanding of the mathematical principles underlying simulation methodology.
- Critique someone else's simulation results.

Required Textbook:

A. M. Law, *Simulation Modeling and Analysis*, 5th Edition, 2015, McGraw Hill. ISBN 9780073401324.

ClassQuestion for in-class problems:

We will use the ClassQuestion app for doing in-class problems. Note that questions will be given in the form of a poll, and we will only note whether you have submitted an answer and will not grade it on whether it is correct or not. If you already have a Class Question account, skip to step 2. If you are new, start at step 1.

1. Go to classquestion.com/students and click "Click here to register". This link will allow you to register for the site.
2. Once you have registered, go to classquestion.com/students and sign in.
3. Click "Add Class" at the bottom. Enter the Class Code for this class: **PJCPD** and then click "Add Class".
4. Your class will be added to the dropdown menu at the top. You can now click the "Sign In" button to log into the class.

Lecture and Quiz Schedule (Approximate):

Week	Topic	Notes
1/29	Introduction: the power of simulation, simulation challenges; basic Monte Carlo; basic point and interval estimation	
2/5	Probability models for discrete-event systems: simulating Markov chains, simple generation of discrete random variables	
2/12	Probability models for discrete-event systems: simulating Markov, semi-Markov and generalized semi-Markov processes; variable time advance mechanism; inversion method for generating continuous random variables	HW 1 due
2/19	Input distributions: theoretical guidance; maximum-likelihood parameter estimation; Bayesian parameter estimation	
2/26	Generation of non-uniform random numbers: acceptance-rejection, composition, convolution, alias method	HW 2 due
3/4	Generation of uniform random numbers: congruential generators, period length and number theory; pitfalls; modern generators; quality testing	Quiz #1 Thurs, 7-9pm, ILCS131
3/11	Data structures for event lists: linked lists, heaps, hybrid structures	HW 3 due
3/18	Spring Break	
3/25	Output analysis: Estimating nonlinear functions of means, quantiles, roots of equations	HW 4 due
4/1	No lectures, assignment on agent-based simulation	
4/8	Steady-state simulation: regenerative and batch-means methods	HW 5 due
4/15	Efficiency-improvement techniques: common random numbers, antithetic variates, conditional Monte Carlo, control variates	Quiz #2 Thurs, 7-9pm, ILCS211
4/22	Intro to experimental design and simulation-based optimization, gradient estimation, Robbins-Monro algorithm	HW 6 due
4/29	Discrete simulation-based optimization	
5/6	Course review	HW 7 due

Quiz dates and times: Quiz 1 will be on Thursday, March 7, 7-9pm, ILCS131; Quiz 2 will be on Thursday, April 18, 7-9pm, ILCS211.

Course Policies:

Grading: Grades are based on participation (10%), seven homework assignments (50%), and two noncumulative quizzes (20% each). Participation is judged by both in-class behavior and participation in Piazza discussions and office hours. Assignment #7 will serve as a "final project" in lieu of a final exam. The lowest homework score (except for Assignment #7) will be dropped. Grading requirements are the same for both undergraduate and graduate students. Individual homework assignments will be weighted by their length and complexity.

Tentative grading scale (all numbers are percentages): For graduate students, any score below a 72.5 is an F.

A	92.5-100	C+	77.5-80	F	Below 60
A-	90-92.5	C	72.5-77.5		
B+	87.5-90	C-	70-72.5		
B	82.5-87.5	D+	65-70		
B-	80-82.5	D	60-65		

Attendance policy and missing a quiz:

Please try to attend every class to participate in class discussions and exercises. In the past, there has been a strong link between regular attendance and a good course grade. Students who cannot attend class are responsible for any material covered during their absence. Late arrivals must enter the classroom quietly and discreetly. More than three unexcused absences from class will result in a lowered participation grade.

With a doctor's note and/or legal documents that comply with the University's Class Absence Policy, you will be able to take a make-up quiz and/or miss more than three classes.

Homework:

Homework assignments generally will be assigned Thursday and be due in two weeks, on Friday by **11:59pm**.

Turning in Assignments: We will be using Gradescope for grading homeworks and quizzes. You will need to set up a Gradescope account if you don't have one. Then you will need to enroll in CS 550 using code **VB77EK**. When turning in assignments, you will need to upload

them to Gradescope as images or a pdf file; ask one of the teaching team or go to the Gradescope help page. Assignments must generally be submitted by 11:59pm on the day that they are due. **It is a very bad idea to wait until the last minute to upload, since a computer or internet glitch can cause your assignment to be late; try to submit at least 30 minutes before the deadline.**

Computing problems: These problems are designated explicitly as "Computing Problems" on the homework assignment. For such problems, students may work in teams of two. Each individual student or student team should hand in a report that contains (1) The solutions to any parts of the computing problem that require a writeup, (2) a printout of the computer program, and (3) a summary of the resulting output. If you submit as a pair, use the group submission feature of Gradescope to make sure that both students receive credit.

We also request that your programs use the **rngStream** pseudorandom number generator found on the course site rather than any of the built-in Python random number generators, for reasons that will be explained later. The easiest way to do this is from within the Google Colab environment; see the readme-install.txt file that comes with the generator.

Pen-and-paper problems: Any problem not explicitly designated as a "computing problem" (even if some computation is required) is considered a pen-and-paper problem. Such problems are to be done individually and handed in as an individual solution.

Extra credit: Some assignments will have extra-credit problems. The goal is to give a chance to those who want to try and raise their grade, while not pressuring those who are doing well in the course to do extra work if they don't want to. Your final letter grade will first be computed ignoring extra credit. Then an extra-credit score will be calculated. If you have a good extra-credit score and your initial grade is near a boundary (say you have a B- but your score is almost enough to get a B) then you will get the higher letter grade. I will do more upward pushing for those with lower grades, so that people who are doing well in the course will not be penalized for not doing the extra credit.

Late homework and regrading: Students are allowed a total of up to **four** late days for the semester; **at most one late day can be used for any given assignment**. A late homework without compensating late days will get zero credit. Each late day for a team project will count against the allotments of all the team members. Students must contact the teaching staff with grading questions on homework or a quiz within **five working days** of when the homework or quiz is returned. Do **not** give us an excuse for a late homework until **after** you have used up your 4 late days. Try and save your late days for later in the term.

Online discussion forum:

We will be using Piazza (not Canvas or email) for online discussion and communication. We will add student names and send out a test message after the first lecture; let the teaching staff know if you do not receive it.
If you have any problems or feedback for the developers, email team@piazza.com .

The ground rules for using Piazza are as follows:

- You must converse respectfully with each other and with the instructors.
- Posts are restricted to topics directly related to the class.
- You may post anonymously (to other students), but do not abuse this privilege
- You may ask for hints or clarifications, but do not simply ask for answers to the questions or post such answers. We will endeavor to answers questions within 24 hours; weekend responses may be slower.
- You are encouraged to help other students via posting (subject to the above restrictions).
- Rather than emailing the instructor or a TA, we strongly recommend that you post privately on Piazza so that anyone on the teaching staff can respond; this will shorten the response time.

Pass/fail options:

For *undergraduate student*s, we will follow UMass policy:

- Students may elect up to three P/F courses
- They have until the last day of classes to elect P/F
- Courses passed with P's can be used for Gen Ed and major requirements
- Departments may use the hidden real grades to enforce prerequisites (CICS intends to do this)

For *graduate students*, the class policy is as follows:

- Students may elect SAT/Fail with threshold grade X
- X is between C and A
- If true letter grade G is higher than X, then grade is recorded as G
- If G is in range of C to X, then grade is recorded as SAT
- If G is less than C, then grade recorded as Fail
- They have until the last day of classes to elect this option

Equity and inclusion statement:

We are committed to fostering a culture of diversity and inclusion, where everyone is treated with dignity and respect. This course is for everyone. This course is for you, regardless of your age, background, citizenship, disability, education, ethnicity, family status, gender identity, geographical origin, language, military experience, political views, race, religion, sexual orientation, socioeconomic status, or work experience. We bring different skills to the course and we will all be learning from and with each other. We respect

everyone's right to be addressed by the name and pronouns that they choose. You can indicate your preferred/chosen first name and pronouns on SPIRE, which appear on class rosters. A student's chosen name and pronouns are to be respected at all times in the classroom.

In both live and online settings, we all are expected to uphold and promote a welcoming environment for learning. Politeness, kindness, and tolerance are expected at all times. Respect that people have differences of opinion, and work and approach problems differently. Please keep unstructured critique to a minimum and make sure that any criticism is constructive. Try and be aware of your own biases and avoid micro-aggressions. Listen to others and let them participate; ask yourself whether you are dominating a conversation and not giving others a chance to contribute. Disruptive behavior is not welcome, and insulting, demeaning, or harassing anyone is unacceptable. We follow the university's guidelines for classroom civility. In particular, we don't tolerate behavior that excludes people in socially marginalized groups. If you feel you have been or are being harassed or made uncomfortable by someone in this class, please contact a member of the course staff immediately, or if you feel uncomfortable doing so, contact the Dean of Students office.

University policies on classroom civility can be found at

https://www.umass.edu/dean_students/campus-policies/classroom

Academic honesty statement:

Since the integrity of the academic enterprise of any institution of higher education requires honesty in scholarship and research, academic honesty is required of all students at the University of Massachusetts Amherst. Academic dishonesty is prohibited in all programs of the University. Academic dishonesty includes but is not limited to cheating, fabrication, plagiarism, and facilitating dishonesty. Appropriate sanctions may be imposed on any student who has committed an act of academic dishonesty. Instructors should take reasonable steps to address academic misconduct. Any person who has reason to believe that a student has committed academic dishonesty should bring such information to the attention of the appropriate course instructor as soon as possible. Instances of academic dishonesty not related to a specific course should be brought to the attention of the appropriate department Head or Chair.

The following discussion pertains to academic honesty from the perspective of this course.

Unless specifically stated otherwise, use of AI systems such as ChatGPT is prohibited. (Note: we have tried feeding both pen-and-paper math problems as well as simulation programming assignments into ChatGPT, and all answers had serious errors, so such systems would probably not work for this course in any case.)

All work submitted must be your own **in presentation**. How much outside help is allowed depends on the course component.

- For quizzes, no outside help or use of materials online or from prior years is allowed. **Any** cheating on a quiz is grounds for a failing grade in the course.
- You **may** discuss homework with other students, in fact we encourage this as a learning experience. But again, the writeup must be your work. Copying is not allowed, and collaboration so close that it **looks like** copying is not allowed. In general, if we receive two identical homeworks we will accept neither of them (i.e., both get F's) and will give you a stern warning that could lead to formal action the next time. A good practice is to divide your work into an "ideas phase" where you collaborate and a "writeup phase" where you work alone -- enter the writeup phase with notes, but not written solutions.
- If you make use of a printed or on-line source for the homework, other than specific course materials such as the textbook or website, you must mention it in your writeup. Of course, copying a solution to a problem from the web is cheating, and this is easier for us to detect than you might think.
- As per CICS policy, no student shall post course materials online without explicit permission of the instructor. Nor shall a student provide course materials to a third party such as Chegg or StudySoup.

For more information about what constitutes academic dishonesty, please see the Dean of Students' website for the general UMass academic honesty policy. Since students are expected to be familiar with this policy and the commonly accepted standards of academic integrity, ignorance of such standards is not normally sufficient evidence of lack of intent. You can take a quick online quiz to check your "academic integrity quotient (AIQ)".

Disability statement: The University of Massachusetts Amherst is committed to making reasonable, effective and appropriate accommodations to meet the needs of students with disabilities and help create a barrier-free campus. If you are in need of accommodation for a documented disability, register with Disability Services to have an accommodation letter sent to Prof. Haas. It is your responsibility to initiate these services and to communicate with Prof. Haas ahead of time to manage accommodations in a timely manner. For more information, consult the Disability Services website.

Title IX statement: UMass is committed to fostering a safe learning environment by responding promptly and effectively to complaints of all kinds of sexual misconduct. If you have been the victim of sexual violence, gender discrimination, or sexual harassment, the university can provide you with a variety of support resources and accommodations
If you experience or witness sexual misconduct and wish to report the incident, please contact the UMass Amherst Equal Opportunity (EO) Office (413-545-3464 | equalopportunity@admin.umass.edu) to request an intake meeting with EO staff. Members

of the CICS community can also contact Erika Lynn Dawson Head, director of diversity and inclusive community development (erikahead@cics.umass.edu | 860-770-4770).

Copyright: Lectures and course materials, including slides, videos, assignments, tests, outlines and similar materials, and all course recordings, are protected by U.S. copyright laws and by university policy. The instructor is the exclusive owner of the copyright in materials they create. Students may take notes and make copies of course materials for your own use in this class. They may also share those materials with another student who is registered and enrolled in this course. They may not reproduce, distribute, upload, or display any lecture notes or recordings or course materials in any other way — whether or not a fee is charged — without my express written consent. If you do so, you may be subject to disciplinary action under the UMass Code of Student Conduct. Similarly, students own the copyright to your original papers and exam essays. If the instructor is interested in posting a student's answers or papers on the course web site, they will ask the student for their written permission.