COMPSCI 550 Introduction to Simulation

Teaching Staff:

Instructor: Prof. Peter J. Haas (phaas@cs.umass.edu)
Office hours (hybrid): Wed 11am-noon and by appointment
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 (Zoom): Tue 2:30-3:30pm & Thur 4-5pm
Graders:
Deepsikha Das (deepsikhadas@umass.edu),
Rishabh Garodia (rgarodia@umass.edu)

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.

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.

Lecture Schedule (Approximate):

Week	Topic	Notes
2/6	Introduction: the power of simulation, simulation challenges; basic Monte Carlo; basic point and interval estimation	
2/13	Probability models for discrete-event systems: simulating Markov chains, simple generation of discrete random variables	
2/20	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
2/27	Input distributions: theoretical guidance; maximum-likelihood parameter estimation; Bayesian parameter estimation	HW 2 due

Week	Topic	Notes
3/6	Generation of non-uniform random numbers: acceptance-rejection, composition, convolution, alias method	Quiz #1 Thurs, 7-9pm, ILCS 140
3/13	Spring Break	
3/20	Generation of uniform random numbers: congruential generators, period length and number theory; pitfalls; modern generators; quality testing	HW 3 due
3/27	Data structures for event lists: linked lists, heaps, hybrid structures	HW 4 due
4/3	Output analysis: Estimating nonlinear functions of means, quantiles, roots of equations	
4/10	No lectures, assignment on agent-based simulation	Quiz #2 Thurs, 7-9pm, ILCS 211
4/17	Steady-state simulation: regenerative and batch-means methods	HW 5 due
4/24	Efficiency-improvement techniques: common random numbers, antithetic variates, conditional Monte Carlo, control variates	
5/1	Intro to experimental design and simulation-based optimization, gradient estimation, Robbins-Monro algorithm	HW 6 due
5/8	Discrete simulation-based optimization	
5/15	Course review	HW 7 due

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: Students are expected to attend all classes 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 2-3 unexcused absences will result in a lowered participation grade.

Homework:

Homework assignments generally will be assigned Thursday and be due Friday of the following week by **11:59pm**. (Some assignments will be due two weeks after they are assigned.)

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.

Pen-and-paper problems: Any problem not explicitly designated as a computing problem 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 within five days of when the homework or quiz is returned.

Online discussion forum: We will be using Piazza for online discussion. 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

Welcoming classroom environment: In both synchronous and asynchronous settings students and teaching staff are expected to uphold and promote a welcoming environment for learning. Politeness and tolerance are expected at all times. Students need to respect others having different academic backgrounds and skills. Similarly, we will not tolerate disrespect for anyone based on their gender, race, ethnicity, disabilities, or sexual orientation. Students should try and be aware of their own biases and avoid micro-aggressions. They should listen to others and let them participate, asking themselves whether they are dominating a conversation and not giving others a chance to contribute.

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 GPTChat 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).

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