Course Syllabus for IEDA4130 (Spring 23-24)

System Simulation

Simulation builds a bridge between the actual world and some mathematical models whose analysis is tractable. With the continuing improvement of processor speed , it enables us to model the phenomenon as faithful as possible. Such that, we can rely on a simulation study to study a real phenomenon. This course will cover the basic simulation techniques, such as generate random variables, simulate process. By continually generating of a model, how to achieve estimators of desired quantities of interest and a variety of ways in which one can improve on the usual simulation estimators are presented.

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Class sessions: Monday, 3pm–4:50pm, Room 2504

Lab sessions: Tuesday, 1:30pm–4:20pm, Room 3207

Each session will build in some time for in-class practices. Students are encouraged to bring their own laptops for such practices.

Prerequisites: Basic understanding of probability and mathematics statistics.

Course objectives: Upon successful completion of this course, students will be able to

- Determine an appropriate simulation techniques to address the relevant scientific questions.
- Implement the chosen simulation techniques using good programming practice.
- Evaluate the efficiency of the implementation and apply certain instruments to achieve improvement.

Recommended Course materials:

(2012) Simulation by Sheldon Ross, Academic Press

Assessment: Assessment of student progress will be based on a final exam (40%), an in-class midterm exam (30%), and several take-home assignments (30%).

The above exams and assignments include coding and written tasks.

Midterm Exam: The midterm exam will be held in class on March 25th, 2024.

Programming assignments: All the simulation techniques are implemented by programming. Thus, one of the core part of this course is writing code. You may expect 4–6 such assignments throughout the semester and to have about two weeks to complete each one. `Python` is the required programming language for these assignments.

The write-up should be completed in `Jupyter Notebook`. Students must submit their projects in a *single document* through `Canvas`. All the files should be in `.ipynb` format and written at a level such that a student who has similar academic background could understand:

- A general description of the approach taken, along with some justification for the direction taken;
- Conclusions, along with supporting output (typically including graphics);
- The complete code.

Code will be gone through when the homework is graded. Therefore, enough information (including, for instance, random seeds used, where appropriate) must be provided such that the result is reproducible. Assignments are due at midnight on the date assigned. NO Late assignments will be accpted. Projects will be evaluated based on the following criteria:

Functionality	50%	Does the program do what it's supposed to do? Does it interface well?
Efficiency	20%	Are there unneeded variables or function arguments? Is there repeated code that could be consolidated into a function or subroutine? Is the code itself efficient (e.g., there's no need to store variables that are accessed only once, the same computations shouldn't be repeated, loops should be consolidated where possible, etc.)
Documentation and readability	15%	Are proper conventions of indentation followed? Are variable names and arguments informative? Is the interface clearly described? Is the documentation sufficient for anyone to understand what each step does?
Writeup	15%	Is the description of the procedure and its application correct, complete, and understandable?

Part 0: PROBABILITY REVIEW

Part 1: GENERATING RANDOM VARIABLES

Topics:

- Generate random variables from continuous distributions
  - inverse cumulative distribution function method
  - acceptance/rejection sampling
- Generate random variables from discrete distributions
- Monte Carlo integration

Part 2: EFFICIENCY IMPROVEMENT

Topics:

- Statistical analysis of simulated data
  - sample mean and sample variance
  - confidence interval
- Variance reduction techniques
  - control variates
  - conditional Monte Carlo
  - antithetic variates

Part 3: SIMULATING PROCESS

Topics:

- Poisson processes
- Discrete-event simulation
- Queueing System
- Insurance Model