

System Simulation

Course Code: IEDA 4130

No. of Credit: 3

Prerequisites: Basic understanding of probability, equivalent to IEDA 2520.

Course Description: 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.

Instructor: Nian Si (email: niansi@ust.hk, office #5559F)

TAs:TBD

Class sessions: Tuesdays, 15:00–16:50pm, Room 4579

Lab sessions: Thursdays, 15:00–16:50, Room 3207

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

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: March 24th tentatively.

You're allowed to bring a one-page, two-sided A4 sheet of notes for the midterm and final exams.

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

The programming assignments 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. 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?

Assignment Submission Policy:

Due Date: All assignments must be submitted by 11:59 PM on the specified due date.

Late Submission Policy:

- You are allocated a total of five (5) late days for the entire term, which you can use across different homework assignments without incurring a penalty.
- A homework assignment is considered “ d days late” if it is submitted d days past the due date.
- We allow a maximum of 2 late days ($d = 2$) per homework assignment. Submissions will not be accepted if they are more than 2 days late.
- Once you have used all your allocated five late days, any submissions past the due date will not be accepted, regardless of the circumstances.

Participation Bonus Policy: Participation is defined as any interaction with the instructor during class, including asking questions, providing answers, or making comments. You are encouraged to actively engage in the lecture, as this not only enhances your learning experience but also provides an opportunity to earn up to 2 bonus points toward your final grade. These points will be awarded at the discretion of the teaching team based on the quality and frequency of your participation.

Part 0: PROBABILITY REVIEW

Topics:

- Probability space
- Random variables
- Conditioning and independence

- Examples of well-known random variables

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

Detailed course schedule:

- Week 1 (2.3): Introduction and probability review
- Week 2 (2.10): Probability review
- Holiday (2.17)
- Week 3 (2.24): Generate random variables
- Week 4 (3.3): Monte Carlo integration
- Week 5 (3.10): Statistical analysis
- Week 6 (3.17): Variance reduction
- Week 7 (3.24): Midterm
- Week 8 (3.31): Poisson process
- Mid-term break (4.7)
- Week 9-10 (4.14 & 4.21): Queueing system
- Week 11 (4.28): Markov chain
- Week 12 (5.5): Review and advanced topics (TBD)

Remark: The above schedule may be adjusted due to the progress of the course.