Course Syllabus

Course Description

This is a **Ph.D. level class on computer simulation:** a statistical sampling technique that uses the power of computers to study complex stochastic systems when analytical or numerical techniques do not suffice. This course is a sequel to ISE/OR 760 *Stochastic Models* which serves as a prerequisite. Course topics include random number generator, techniques of generating random objects, design and implementation of discrete-event simulation experiments, output analysis, variance reduction techniques, estimation of steady-state performance, Markov-chain Monte Carlo, simulation optimization.

This is NOT a software based course! Students who are looking for a class on simulation software, such as Arena and Simio, are recommended to take ISE 562 (master-level simulation class). Simulation algorithms will be taught in the format of pseudo codes. Students will design and implement relevant simulation procedures in a script-based programming language, such as MatLab.

Time and Place

Monday and Wednesday 1:30–2:45. Room: Daniels 353.

Instructor

Yunan Liu
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Teaching Assistant

Kyle Hovey
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Textbooks

(i) S. M. Ross, *Simulation.* 5th Edition, Academic Press, 2014. (Required)

(ii) A. M. Law and W. D. Kelton, *Simulation Models and Analysis.* 5th Edition, McGraw-Hill, 2014. (Recommended)

Prerequisites

This course is intended for graduate students in industrial engineering, operations research and related fields. Student are expected to

- have completed a first course on stochastic models at the level of the first-year doctoral course ISE 760 (at least ISE 560);

- have knowledge of a programming language such as MatLab.

Homework

There will be approximately 8 assignments. Graded assignments will be returned in class.

- Students are encouraged to collaborate with other students in the class, as long as each person writes his/her own solutions and codes.
- But any such collaboration should be clearly **noted** (If some ideas of your solutions come from the discussion with another person, write his/her name on your solution).
- Copying homework from another student (past or present) is **forbidden**.
- Late homework will **NOT** be accepted.

Exams

All exams are closed book and notes. You are allowed to bring a one-page cheat sheet.

- Midterm: March 14 (temporary).
- Final: April 30 (Monday).

Project

The group project has both modeling and coding components. Each group will be composed of at most two students and will be responsible for

- choosing a topic (after the midterm);
- submitting a project report (by the last day of class);
- giving a project presentation (during the last week of class).

Potential project topics include (but not limited to)

- service systems (e.g., banks, gyms, call centers, supermarkets, restaurants),
- health care (e.g., hospitals, clinics),
- communication and social networks (e.g., facebook, twitter),
- manufacturing systems (e.g., machine workshops, production lines),
- transportation systems (e.g., trains, airports, highways),
- financial processes (e.g., stock prices),
- sports, etc.

See moodle page for a sample project report.

Grading

Define the following random variables:
$HW \equiv$ homework, $M \equiv$ midterm, $F \equiv$ final exam, $P \equiv$ project and $G \equiv$ overall grade.
Then the overall grade is given by

$$G \equiv HW \times 20\% + M \times 30\% + P \times 20\% + F \times 30\%.$$

Tentative Course Topics

The course topics include:

1. Introduction to simulation
   - Discrete event simulation
   - Monte Carlo simulation
2. Review of basic probability and statistics
   - Random variables and their properties
   - Estimation of means, variances, and correlations
   - The strong law of large numbers and central limit theorems
   - Confidence intervals and hypothesis tests for the mean
3. Random number generators and numerical integration
4. Generating copies of random variables
   - Inverse transform, acceptance-rejection, composition
   - Generating discrete random variables:
     (i) geometric; (ii) binomial; (iii) Poisson; (iv) discrete uniform.
   - Generating continuous random variables
     (i) exponential; (ii)uniform; (iii) Erlang; (iv) Gamma; (v) Gaussian
   - Dependent random variables and copulas
5. Generating paths of stochastic processes
   - Poisson process: homogeneous, nonhomogeneous and compound
   - Random recursions
   - Continuous- and discrete-time Markov chains
   - Brownian motions and pricing path-dependent options
   - Jump diffusion models
   - Random permutations
6. Simulation via discrete events
   - A single-server queueing system

- A queueing system with two servers
- An inventory model
- An insurance risk model
- A repair problem
- A limit order book model
- Exercising a stock option

7. Output data analysis
    - Transient and steady-state behavior of a stochastic process
    - Statistical analysis for terminating simulations
    - Statistical analysis for steady-state parameters
8. Variance reduction techniques
    - Antithetic variables
    - Control variates
    - Variance reduction by conditioning
    - Stratified sampling
    - Importance sampling
    - Common random numbers
9. Selecting input probability distributions
    - Sample independence
    - Hypothesizing families of distributions
    - Estimation of parameters
    - Goodness of fit tests
10. Advanced topics (dependent on time)
    - Markov-chain Monte Carlo
    - Simulation optimization
    - Rare event simulation