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
Office hours: 446 Daniels, Monday/Wednesday 4:30-5:30
Email: yliu48@ncsu.edu
Homepage: http://yunanliu.wordpress.ncsu.edu

Teaching Assistant
Kyle Hovey
Office hours: 444 Daniels, TBD.
Email: kahovey@ncsu.edu

Textbooks

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