# Course Syllabus

## Course Description

This is a graduate level class on advanced computer simulation technique: a statistical sampling technique that uses the power of computers to study complex stochastic systems when analytical or numerical techniques do not suffice. 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. Techniques introduced in this class have strong applications in realistic problems in service systems, health-care, manufacturing planning, production scheduling, and financial mathematics.

This course is not based on a particular software (such as Arena, Simio and R). 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

July 8– July 23. Room: 3-134

## Instructor

**Yunan Liu**
Office: Email: yunan.liu@gmail.com
Office hours: Right after class, or by appointment.

## Textbooks

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

(ii) A. M. Law, *Simulation Modeling and Analysis*. Mc-Graw Hill, 2015. (Recommended)

## Prerequisites

This course is intended for graduate students in industrial engineering, mathematics, operations research and related fields. Student are expected to have completed a Ph.D. level class on probability theory and stochastic models. For simulation homework or projects a working knowledge of a programming language (such as MatLab, R, Python) will be needed.

## Homework

- Students are encouraged to collaborate with other students in the class, as long as each person writes his/her own solutions and codes.
- Copying homework from another student (past or present) is **forbidden**.
- Late homework will **NOT** be accepted.

## Exams

- There will be no exam.

## 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

- submitting a project report (by the last day of class).

Potential project topics include (but not limited to)

- insurance models,
- pricing and sensitivity analysis of financial derivatives,
- online trading systems,
- service systems (e.g., banks, gyms, call centers, supermarkets, restaurants),
- health care (e.g., hospitals, clinics),
- communication and social networks (e.g., facebook, twitter),
- sports, etc.

## Evaluation

- Homework assignments (3–4); weight 60%.
- Term Project (due July 27); weight 30%
- Class Attendance will account for part of the "final examination", where arrangements will be made for anyone who has a verifiable conflict with class make-up sessions; weight 10%

## Tentative Course Topics

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
3. 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) Gaussian

4. Generating paths of stochastic processes

   - Poisson process: homogeneous, nonhomogeneous and compound
   - Continuous- and discrete-time Markov chains
   - Brownian motions

5. Simulation via discrete events

   - A single-server queueing system
   - A queueing system with two servers
   - A Uber traffic model
   - A supermarket model with customer jockeying
   - An inventory model
   - A production system
   - An insurance risk model
   - A repair problem
   - A bitcoin blockchain
   - A limit order book model

6. Output data analysis

   - Transient and steady-state behavior of a stochastic process
   - Statistical analysis for terminating simulations
   - Statistical analysis for steady-state parameters

7. Variance reduction techniques

   - Antithetic variables
   - Control variates
   - Variance reduction by conditioning
   - Importance sampling
   - Common random numbers

8. Selecting input probability distributions

   - Sample independence
   - Hypothesizing families of distributions
   - Estimation of parameters
   - Goodness of fit tests

9. Advanced topics (dependent on time)

- Markov-chain Monte Carlo
- Simulation optimization
- Simulation-based reinforcement learning