

Department of Industrial and Systems Engineering  
Spring 2009

# Simulation and Probabilistic Modeling

(ISyE 320)

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Lecture:	Tuesday and Thursday 11:00AM–12:15PM	1153 Mechanical Engineering Building
Section #1:	Thursday 9:55–10:45AM	3120 Mechanical Engineering Building
Section #2:	Tuesday 3:30–4:20PM	3120 Mechanical Engineering Building
Section #3:	Friday 12:05–12:55PM	3120 Mechanical Engineering Building

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*Analysis of stochastic systems using both analytic methods and computer simulation. Empirical and theoretical models of arrival and service processes. State spaces and state transition probabilities. Simulation of queuing and manufacturing systems. Prerequisite: Stat 311 and Stat 312 or equiv. Math 320 or Math 340.*

## DISCUSSION SECTIONS

Discussions sections and lab play a crucial role in the learning process for this course. As such, your attendance in discussion section class ISyE 321 is *mandatory*. All three discussion sections will be led by the same teaching assistant, Lei Ruan. The main purpose of the lab is to give students hands-on experience with developing discrete-event simulations (in ARENA) and with performing spreadsheet analysis of random systems in Excel.

**Teaching Assistant:** Lei Ruan

**Office:** 3237 Mechanical Engineering Building

**Office Hours:** Monday 4-5PM and Friday 1:30-2:30PM

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**Grader:** Chia-Chun Tsai

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## COURSE MATERIALS

### *Required Texts*

There is one required text.

**Banks, Carson, Nelson, and Nicol.** *Discrete-Event System Simulation*, Fourth (Prentice-Hall, 2005).

### *Recommended Texts*

There are three recommended texts. All three have been placed on reserve at Wendt library.

**D. Kelton.** *ARENA*, 4th Edition (McGraw Hill, 2007). *This book has more details about the Arena modeling language and its use to teach simulation concepts.*

**Frederick Hillier and Gerald Lieberman.** *Introduction to Operations Research*, Fourth Edition (McGraw-Hill, 2005). *The last portion of the course is on applied probability modeling (Markov Chains) and queueing theory. We will use this book to supplement the material on Markov chains and queueing theory*

**Sheldon Ross.** *Introduction to Probability Models*, 9th Edition (Academic Press, 2006). *A great book on an introduction to serious probabilistic modeling. Might be useful for probabilistic modeling module.*

### *Web Site*

The course web site will be available through the the **Learn@UW** system: <https://learnuw.wisc.edu/>. Course lecture notes and solutions to homework exercises will be posted there.

## COURSE OVERVIEW

This course deals with phenomena that are of a stochastic (rather than deterministic) nature: that is, some aspects of the system under study are subject to random variations. Systems with a stochastic component include a wide range of applications such as inventory, reliability, computer, communication, production, and transportation systems. This course provides a unified approach to the modeling, analysis and simulation of stochastic systems. Analytical tools include the Poisson process, Markov chains and queueing theory. In parallel to the mathematical models, we develop the concept of discrete event simulation. The homework problems will sometimes require the use of a spreadsheet such as EXCEL and also the ARENA simulation software.

### *Objectives*

This course is intended to equip you with the following skills and insights:

1. Understand the stochastic nature of real systems
2. Learn modeling techniques and tools for stochastic systems
3. Understand how random events may be modeled via computer
4. Understand the assumptions made in building simulations

5. Apply statistical methods to correctly build input distributions for simulation models.
6. Understand standard analytical models for random events, including Markov Chains and queueing theory
7. Be able to use simulation software tools to model a system and to estimate performance measures of the system
8. Use statistical methods to draw proper conclusions about the output parameters of interest from simulation models
9. Be able to present the results of the modeling process to users in a non-technical presentation

There are other course objectives that will become clear as the course proceeds, but those listed above are the most important. Also, the tests and assignments given in this course are specifically designed to measure your progress in the above areas.

## REQUIREMENTS AND GRADING

### *Lectures*

For instruction, the course will contain twice-weekly lectures and a once-weekly discussion session. Learning is an interactive process. As such, attendance at lectures and discussion is mandatory, and a small portion of your grade will depend on your participation.

### *Homework*

There will be (roughly) weekly homework assignments. The homework assignments are meant to ensure that you have mastered the material from the previous lectures and will help you to learn the skills and concepts listed under course objectives.

### *Exams*

There will be two (in-class) quizzes. The first quiz is scheduled to take place on March 3, the second quiz is scheduled to take place on April 2. The final exam will be held on December 15.

### *Course Project*

A significant portion of this course will be based on a team-based project. You will work with up to 3 other classmates to identify, model, simulate, and draw conclusions about a random phenomenon. More details of the project will be made available later during the semester.

### *Grading Scheme*

- 5% Participation
- 30% Homework
- 15% Course Project

- 12.5% Quiz #1
- 12.5% Quiz #2
- 25% Final Exam

## COURSE STATEMENTS

### *Homework Submission Policy*

Homework exercises will be assigned in most weeks as a means to help you understand the concepts and to give you practice in applying them. They will generally be due on Tuesday morning, and you should bring the assignments to class with you, or ensure that the homework has been submitted to the class dropbox. (The specific assignment will state clearly which method of turning in the assignment is expected). Late homework will not be accepted, but the lowest homework grade score will be dropped when computing the overall average homework score.

### *Schedule Conflicts*

Sometimes students have legitimate conflicts that prevent them from taking an exam at the scheduled time. In accordance with University policy, I request that you notify me of any such conflicts within the first two weeks of class. If for some reason you become aware of such a conflict after the first two weeks of class, I request that you notify me as soon as you become aware of the conflict. In such cases, I will work with you to schedule a make-up exam, provided that you have made a reasonable effort to give me advance notice of your conflict.

### *Computing*

You will need to make use of the Microsoft Excel spreadsheet program throughout the course, and you will also need to use the ARENA software for PC-compatible machines. The ARENA software is available in CAE computing lab, and a student version can be made available to you. Arena is only available for Windows-Compatible computers.

### *Academic Integrity*

You are encouraged to share ideas with each other on class assignments **orally**. However, you must ultimately demonstrate your understanding of the material by writing up your own solutions without the help of other students or their written work, including source code and spreadsheets. **AT NO TIME ARE YOU ALLOWED TO OBTAIN, LOOK AT, OR CUT AND PASTE FROM THE SPREADSHEET, SOURCE CODE, OR WRITE-UP/PROBLEM SET OF ANY OTHER INDIVIDUAL, WHETHER THEY ARE IN THE CLASS THIS SEMESTER OR NOT. THIS INCLUDES GETTING SOURCE CODE FROM THE INTERNET. YOU ARE EXPRESSLY FORBIDDEN FROM SHARING ELECTRONIC FILES OF ANY TYPE BY ANY MEANS WITH ANYONE.**

### *Use of External Sources*

Extensive materials related to the topics we will be covering in this class are available on the Internet. You may use supplementary material to enhance your understanding of the course material. If you use external references of any kind, even if they are not quoted verbatim, **YOU MUST CITE THEM!** This rule will be strictly enforced and violations will be dealt with harshly. Again, I encourage you to seek outside sources, but **you must acknowledge the source of any ideas that are not your own.**

You are all grown-ups. **Do not cheat.** If you have any question or concern about what constitutes cheating or improper collaboration, *please* contact me. If I suspect that you are cheating, you will make me sad. Then you will make me mad. Do not do this. If you don't think that I will know if you are copying or inappropriately using other people's work to do your assignments, you are wrong.

As to quizzes and exams, you are all grown-ups. **Do not cheat!** Improper behavior during quizzes and exams will be dealt with in the

Academic misconduct will be dealt with under the disciplinary penalties set forth in the University of Wisconsin Policy for Academic Misconduct: (<http://www.wisc.edu/students/saja/misconduct/UWS14.html>). Also, be aware that academic integrity requires you to let the instructor know if you think you see incidents of misconduct.

## (TENTATIVE) CHRONOLOGICAL SYLLABUS

There is some flexibility in the schedule, depending on our progress through the various chapters and my assessment of your mastery of the material. I currently anticipate that the homework due dates and the dates for the exam and quizzes will not change. A more detailed schedule is available on the course web site and will be updated to more accurately reflect our progress, including detailed homework assignment listings.

### Part I: **Introduction to Simulation**

*January 20–January 29*

*Motivation for Simulation. Brief probability review). Estimation of mean of random variable via sampling. Examples of Simulation.*

**Readings:** Chapters 1, 2, 11.3

**Homework #1:** Due: Feb. 3

### Part II: **Generating Random Variables**

*February 3–February 10*

*Generating (Pseudo)-Random Numbers. Tests for Randomness. Review of Probability Distributions. Inverse-Transform and Accept-Reject techniques*

**Readings:** Chapters 5, 7, 8

**Homework #2:** Due: Feb. 10

**Homework #3:** Due: Feb. 17

Part III: **Input Analysis**

*February 12–March 3*

*Identifying distributions, Parameter Estimation, Goodness of fit tests, multivariate models*

**Readings:** Chapter 9

**Homework #5:** Due: Feb. 24

**Quiz #1:** March 3

Part IV: **Probabilistic Modeling**

*March 5–April 2*

*Discrete Time Markov Chains, Continuous Time Markov Chains, Poisson Processes, Queueing Theory*

**Readings:** Chapter 6, Course Supplements

**Homework #6:** Due: March 24

**Homework #7:** Due: March 31

**Quiz #2:** April 2

Part V: **Output Analysis**

*April 7–April 21*

*Confidence intervals on output statistics. Termination simulations. Initialization bias. Replications and batch means.*

**Readings:** Chapter 11

**Homework #8:** Due: April 14

**Homework #9:** Due: April 21

Part VI: **Comparing Systems**

*April 23–April 28*

*Paired t-tests, common random numbers, comparing multiple systems*

**Readings:** Chapter 12

**Homework #10:** Due: April 28

Part VII: **Project Presentations and Final Review**

*April 30–May 7*

*Student will do their project presentations. May 7 will be reserved for a final exam review*

