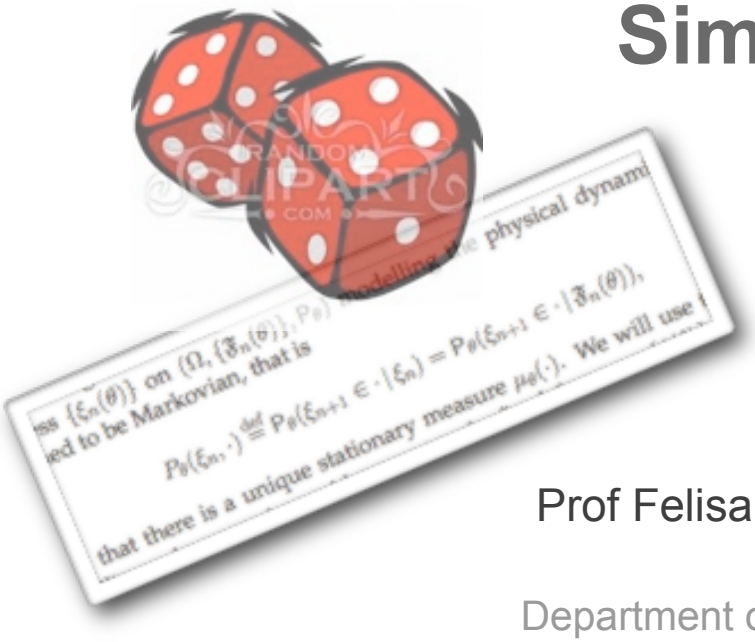
Introduction to Stochastic Processes and Computer Simulation



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Department of Computer Science
Hunter College and Graduate Center
City University New York

City University New York
Edition Fall 2013

Graduate Center: CS 86030
Hunter College: STAT 702

Introduction to Stochastic Processes and Computer Simulation

Learning Objectives

The ability to model systems under uncertainty is an important skill. The ubiquitous nature of Markov Chain applications makes it very important in a diverse range of subjects, such as bioinformatics, industrial engineering, telecommunications, finance, strategic planning and manufacturing.

This course addresses that need by studying fundamental results of Markov chain processes. The focus is on modeling and many examples will be covered. In real problems, often analytical solutions are impossible to obtain, mainly (but not only) due to large state spaces. Simulation is a versatile and popular tool that can provide numerical approximations. This course covers topics of computer simulation and modeling that emphasize statistical design and interpretation of results.

Course Description

This course covers probability models, with emphasis on Markov chains. Theoretical results will be stated, and focus is on modeling. The last part of the course is devoted to techniques and methods of simulation, with emphasis on statistical design and interpretation of results. Students will work in team projects with a programing component.

The students who succeed this course will:

- understand and apply probability models to describe real problems,
- be capable of designing computer simulations for Markov chains,
- understand how to interpret and present the statistical results from simulations, and
- understand the analysis techniques for studying Markov chains.

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Course Schedule

City University New York
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Graduate Center: CS 86030
Hunter College: STAT 702

Venue: Graduate Center,
365 5th Ave, Room 3305.
Time: Thursday 2 - 4 PM.

Lecturer: Prof Felisa Vázquez-Abad

Office Hours: By appointment: felisav"at"hunter.cuny.edu, or Mon, 14h - 16h at Hunter College:
395 Park ave, Room HN 1000 B

References:
•*Introduction to Probability Models*,10th Edition, Sheldon M. Ross.
•Notebook from *University*

Week 1: Concepts of probability: random variables, probability distributions, expectations. Stopping times and examples.

Week 2: Concepts of probability: conditional probability, conditional expectations.

Week 3: Generation of random variables and introduction to simulation.

Week 4: Markov chains introduction, classification of states and properties.

Week 5: Simulation models: tick-based and event-based methods.

Week 6: Simulation models: Reduced models. Examples: Petri nets, aggregated models.

Week 7: Analysis of absorbing Markov chains, examples. Branching processes and time to extinction.

Week 8: Analysis of stationary Markov chains, examples. Reversible chains.

Week 9: Statistical analysis of simulation output. Confidence intervals, stopping tests.

Week 10: Continuous Time Markov Chains and Regenerative Processes.

Week 11: Simulation efficiency and variance reduction methods.

Week 12: (optional) Markov Chain Monte Carlo methods and random search methods.

Readers. Order here.
•*An Introduction to Stochastic Modeling*, 3rd Edition, H. M. Taylor and S. Karlin.
•*Simulation*, 4th Edition, Sheldon M. Ross.
• See Course Materials for more details

Week 13: (optional) Markov Decision Processes and Dynamic Programming.

Week 14: Student presentations.

Week 15: Final Exam.

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Workload:

In addition to the midterm and final examinations, there will be student presentations of research projects, and five homework assignments.

It is highly recommended that students use at least one hour per week for team work and two hours per week for homework. Homework assignments can be solved by teams (only one copy per team).

Assessment:

☑ Project Presentation	10%
☑ Project Report	30%
☑ Homework assignments	35%
☑ Exams	25%

Threshold: in order to pass the course, a minimum of 55/100 in the exams is required.

Research Projects:

Research projects will be assigned to teams of 2 to 3 students. These projects will involve:

- modeling a situation of interest and stating a research question,
- application of theoretical results, and/or
- experimental design for computer simulations. The students will program the simulations and analyze the results.

Dates on calendar are closer than they appear to be!

Useful Documentation:

We have adapted Prof Natashia Boland's documents to provide guidance on how to prepare the report and the

presentation of your research project.

Please visit also the Course Material in this site.

A word of advise:

Start working on your research project early on.

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Homework Assignments

- Series1.pdf, due by week 3: 19 September.
- Series2.pdf, due by week 5: 3 October. Source file (in latex).
- Series3.pdf, due by week 9: 31 October.
- Series4.pdf due by week 14: 12 December. Source file.

Project Assignments

Guideline for project management

- **Week 2:** Define your teams (3-4 people)
- **Week 4:** Choose a project and start your simulation
- **Week 6:** State your research goals and verify your simulation model
- **Week 10:** Submission of first report with goals, objectives and methodology
- **Week 15:** Hand out final report.

Bike Share (2013)

Project 1: Include maintenance and perhaps re-distribution algorithms

Project 2: Include a central controller with routing and “reservations”

Project 3: Include pricing schemes and economic model

Performance evaluations may include availability studies, customer satisfaction, overall cost of

operation, overall profits, sustainability indicators, etc.

Task 1: Set up the SSJ Libraries from Pierre L'Ecuyer's site. Try the current working code.
Task 2: All to change arrival streams per o-d (origin-destination) pair. On week 5 we will discuss alternatives and choose the best of them for everyone.
Task 3: Design the necessary classes and modules to be added to the current program (weeks 4 to 6).
Task 4: Define your project's research questions to compare results with current NYC system (due on week 6)

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Reading Guide

[1] Taylor and Karlin, *An Introduction to Stochastic Modeling*, 3rd Edition
[2] Ross, *Introduction to Probability Models*,10th Edition
[3] Ross, *Simulation*, 4th Edition
[4] Cassandras and Lafortune, *Introduction to Discrete Event Systems.*
[5] Alexopoulos and Seila, Chapter 7: "OutputAnalysis-HandbookOfSimulation.pdf", of Handbook of Simulation.
[6] Boyle, Broadie and Glasserman, "MC Methods for security pricing", JEDC 1996.
[7] Study guide for exam: Quiz.

University readers has prepared a package with relevant chapters from [1], [3] and [4] into a single document. To purchase this material follow the instructions:

Step 1: Log on to https://students.universityreaders.com/store/.
Step 2: Create an account or log in if you have an existing account to purchase.
Step 3: Choose the correct course pack, select a format and proceed with the checkout process.
Step 4: After purchasing, you can access a digital copy of the first few chapters (if you selected a print format) by logging into your account and clicking "My Digital Materials" to get started on your reading right away.

Material covered in lectures

Lecture Notes

W1 and W2: Probability concepts.
W3: Generation of Random Variables.
W4: Introduction to Markov Chains.
W5 and W6: Simulation Models.
Game of Craps with Change of Measure.
W9: MCMC and Random Search optimization.
W10: MDP's and Dynamic Programming.
W11: Output analysis.
W12: Simulation efficiency and variance reduction

Weeks 1, 2: Probability
[1] Chapters 1, 2 (except 2.5).
[2] Chapters 1,2, 3 (except 2.6).

Week 3: Generation of Random Variables
[3] Chapters 4, 5, SimSpiders

Week 4: Introduction to Markov Chains
[1] Chapters 3, 4 (except 3.7, 3.9, 4.5).
[2] Chapter 4.1 to 4.3.

Weeks 5,6: Simulation Models
[3] Chapter 6.
[4] Chapter 10.

Material covered in lectures

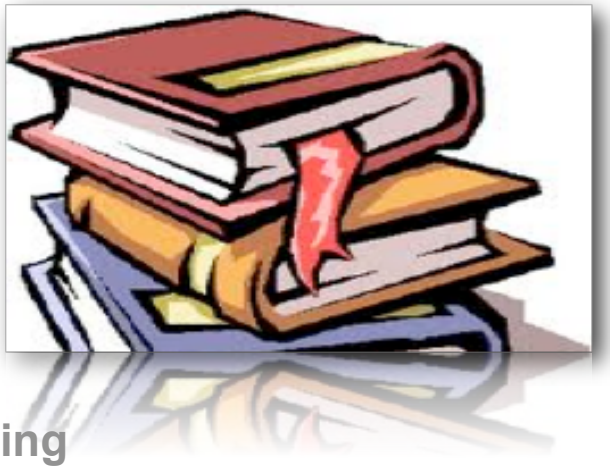
Week 7, 8: MC Analysis
[1] Chapter 3.4, 3.5, and Chapter 4.
[2] Chapter 4.5, 4.6, 4.7, 4.8

Weeks 9, 10:
[2] Chapter 4.9, 4.10.
[3] Chapter 10.

Week 11:
[5] and SimSpiders.
[3] Chapter 7.

Week 12:
[3] Chapter 8, and [6].

Weeks 13, 14:
[2] Chapters 5, 6, 7.
[1] Chapters 5. 6, 7.



Required Reading

Weeks 1-2:
[2] examples in section 3.6.
[1] section 1.5 contains useful formulas.
Familiarize yourself with these useful sections for future reference.

Week 3:
[3] chapters 4 and 5.

Weeks 5,6:
[4] sections 10.1, 10.2, 10.3, 10.4, 10.5
[4] sections 6.3, 6.4, 6.5, 6.6

Weeks 4, 7, 8:
[1] examples in section 3.3.
[1] section 3.5 details modeling special Markov Chains.
[1] examples in section 4.2.
[2] examples in section 4.5.
[2] sections 4.8.

Weeks 9, 10:
[2] Chapter 4.9, 4.10.
[3] Chapter 10.

Weeks 13, 14: CTMC and Renewal Processes
[2] examples 5.5, 5.6, 5.10, 5.15, 5.20 and 5.27.
[1] examples in Chapter 5.
[1] Chapter 6.2.2, and examples on pages 361, 372 and 388.
[2] examples 7.8, 7.12, 7.16, 7.17, 7.26.
[1] examples in section 7.2, and examples in section 7.5.3.

Sample LaTeX Files for Projects

- Sample source file for report. This file uses the basic format for LaTex. You are welcome to define your own font style or layout, if you already know how to typeset files. Otherwise this can help you produce a good quality report. Please check the guidelines for report.

- Sample beamer file for presentation: source, figures. This was used at a conference for a 15 minute presentation. You may have to re-place some figures in your working directories (it will help you understand the system). Styles in beamer are very easy to change, as well as color schemes, please look at the guides available for free from the internet to individualize your presentation. You can use PowerPoint (if you do not have many equations), if you can deliver a high quality output. Please check the guidelines for the presentation.