

CSCI 688 ★ APPLICATIONS OF MARKOV CHAINS

Spring 2023

Welcome to Applications of Markov chains! I hope we all have a great time together, and that we all learn from each other this semester. Below you will find all the relevant information about this class and the assessment. While going through the rest of this document, note that everything written in **maroon** contains a link.

1 General Information

- Schedule: Monday, Wednesday and Friday 11:00-11:50 am
- Modality: In person
- Classroom: ~~Boswell Hall, room 2~~ Jones 113
- Instructor: Daniela Hurtado-Lange
- Office hours:
 - Monday, Wednesday and Friday 12:00-1:00 pm in person at my office
 - By appointment in my virtual office (Zoom meeting) or in person
 - If you want to meet virtually, please set up an appointment via email

2 Description

This course aims to explore some of the (many) applications of Markov chains, focusing on queueing theory and Markov decision processes. The course will be oriented to modeling techniques, analytically computing performance measures, and algorithms to help us estimate these measures when the analysis become intractable.

Specifically, we will learn some of the foundations of reinforcement learning and queueing theory. Our goal this semester is to acquire a broad understanding of these two areas of knowledge and develop intuitions about the performance of various systems and algorithms. We will start the semester reviewing probability and Markov chains, and we will then move on to applications.

Prerequisites: A calculus-based class in probability. I expect you to know the definition of pdf, pmf, cdf, expectation and conditional probability along with some of the most popular distributions, such as uniform, exponential, normal, Bernoulli, binomial and Poisson.

3 Textbooks

This course is a survey of applications of Markov chains, so we will use three textbooks. I will provide lecture notes to complement what we do in class, so the books are optional. The following list is in alphabetical order. In Section 10 I specify when we'll be using each book (approx).

- [1] Harchol-Balter, M. (2013). *Performance Modeling and Design of Computer Systems: Queueing Theory in Action*. Cambridge University Press.
* Available in hard copy at this [link](#).
- [2] Ross, S.M. (2014). *Introduction to Probability Models*. Academic Press.
* Available in hard and soft copies at this [link](#).
- [3] Sutton, R.S. & Barto, A.G. (2018). *Reinforcement Learning: An Introduction*. MIT Press.
* Free soft copy available at this [link](#).

4 Learning Objectives

By the end of the semester you will be able to:

1. Understand the basics of reinforcement learning and queueing theory
2. Use reinforcement learning in applied problems
3. Understand the main issues with applying reinforcement learning techniques to real-life problems
4. Use queueing theory ideas to predict performance in real-life systems

5 Assessment and Grading Structure

This is a letter-grade course, under the grading scale presented below:

Letter grade	A	A-	B+	B	B-	C+	C	C-	D+	D	D-	F
Total score	> 94	> 90	> 87	> 83	> 80	> 77	> 73	> 70	> 67	> 63	> 60	≤ 60

I might curve the grades in your favor at the end of the semester.

There will be multiple opportunities for lower-stake assessment, with the goal of preparing you for the exams and the final. Some of these will be graded, and some will not. I encourage you to use all these opportunities to learn what you know well and what needs practice before the exam.

Below you will find a brief description of each graded assignment:

- **Homework (average 20%):** Sets of problems to be solved individually. You will have 1 week to solve them, and they will be released biweekly (approx.). Collaboration is encouraged subject to the “empty hands policy,” described in Section 6.
 - Where do I find the questions? They will be posted on Gradescope, and I will send an announcement to let you know when they are available.
 - Submission: You should submit your homework to Gradescope in a **single pdf** file and **mark in which page(s) you answered each question** using the Gradescope feature. Following these simple rules saves a lot of time in grading. Let’s be empathetic! If you fail to follow these rules, you automatically lose 5 points on the corresponding homework.
 - Due dates: You will have until 11:59 pm of the due date (always a Friday) to submit your homework, or you may use some “late days.” I invite you to check Section 6 to learn what these are.
 - Grading: Each homework will be graded from 0 to 100 points. A subset of problems will be graded with a rubric, and the rest by completion.
 - Solutions: I will provide the solution to the problems after the days of lateness or after everybody submits (whichever happens first).
- **Help sessions and participation (average 5%):** I believe that the best way to learn is getting your hands dirty and discussing with classmates. We will use one lecture to work on the homework problems together. You may work in groups, discuss with your classmates out loud, and ask me questions.
 - When? Wednesday before the homework submission dates.
 - Grading: Attendance gives you a 100, so make use of this opportunity!
 - Are they mandatory? No. I encourage you to participate, but they only affect your grade if they help.
- **Midterm I and II (20% each):** Take-home exam to be solved individually in, at most, 48 hours. The dates and (tentative) contents are provided in Section 10. Observe they are scheduled on **Thursday and Friday**. There is no class whenever we have a Midterm. Instead, I will hold office hours.
 - Where do I find the questions? I will post them on Gradescope at 12 am of the corresponding Thursday.

- What is allowed during the exam? You may use your notes, the textbook and everything posted on Blackboard, but **collaboration is not allowed**. Not even under the “empty hands” policy. I encourage you to prepare a couple of pages summarizing the contents to enhance your learning process and facilitate searching what you may need for the exam.
- Submission rules: By Friday at 11.59 pm, you need to upload your exam to Gradescope, marking which page(s) correspond to each question.
- Conflicts with schedule: If you have a schedule conflict with the exams, please let me know by **Friday, February 3rd** via email.
- Grading: Each Midterm will be graded from 0 to 100 points. After the grades are released, you will have 1 week to request a regrade in case I made a mistake. The regrading requests must be submitted on Gradescope, and you should explain where and why you believe there is a mistake.
- Opportunity for bonus points: After each Midterm, you will have 1 week to fill a survey with the following questions:
 1. What was easy in the Midterm?
 2. What was hard in the Midterm?
 3. What has the instructor done well so far?
 4. How can the instructor improve?
 5. What have I (as a student) done well so far?
 6. How can I improve for the next assessment?

I deeply care about the feedback you can provide, so I will give you 5 bonus points in the corresponding midterm for answering the survey (yes, you can end the semester with 105 points in each midterm if you answer these questions!). Please be as concrete as possible with your answers.

- **Final exam (35%):** Take-home exam at the end of the semester (dates available in Section 10). Topics may include everything we did in class. Except for the duration and the survey, the same rules of the Midterms apply.

How to compute my final grade?

The help sessions can only improve your grade. In other words, if you do not participate, your grade will not be affected. The final grade will be computed as follows:

$$\text{Grade} = \max \left\{ 0.05 \times \text{Help sessions} + 0.2 \times \text{Homework} + 0.2 \times \text{Midterm I} + 0.2 \times \text{Midterm II} + 0.35 \times \text{Final} , \right. \\ \left. \frac{0.2 \times \text{Homework} + 0.2 \times \text{Midterm I} + 0.2 \times \text{Midterm II} + 0.35 \times \text{Final}}{0.95} \right\}$$

6 Some Ground Rules

- **Attendance to class and participation:** I highly encourage you to attend the lectures and participate to create an active learning environment. If you have to miss a class, no worries! I invite you to check Section 7 to see how we will handle it.
- **Collaboration:** Collaboration in solving the homework and preparing for the exams is encouraged, under the “empty hands policy” described below. The exams are individual, and no collaboration in solving them is allowed. I understand that you may use similar methods to solve the problems, but you must submit your own answers.
- **Empty hands policy¹:** Two or more students may enter a room (for example, a room with a whiteboard) and may together solve some or all of the problems on a homework assignment on the board. Each student must leave the room without any written or electronic materials describing these solutions. Students are to leave such a problem-solving session with only the solutions to the problems in their heads. Each student must perform their own individual write-up of the homework solutions sometime after the problem-solving session and submit their solutions individually.

¹Based on policy created by Prof. Steve Park

- **Use of AI:** The use of AI-interactive software (such as ChatGPT) is allowed in homework and exams as long as you report it. You may include a screenshot of the answer(s) provided by the AI, and you must explain why you think it is correct (or not). This software is not fully tested for the topics we cover in this class and, hence, it may not give you correct answers.
- **Late work:** You will have 5 days of ‘lateness’ to use at your convenience when submitting your homework, to be spent in integer numbers. This means that you can submit your homework late by at most five days in the entire semester and your grade will not be affected. For any additional day of ‘lateness’ you will lose 5 points of the corresponding homework. For example, you may submit homework 1 two days late, homework 2 eight hours (hence, one day) late and homework 3 two days late and you qualify to the maximum grade. However, if you submit all three homeworks two days late, your third homework will have a maximum of 95 points.
- **Academic integrity:** I expect you to be familiar with the Honor Code and behave accordingly.
- **Student-faculty expectations:** I expect you to participate in class and ask questions during the lectures, via emails or in office hours. My job is to do my best to keep you interested in the class, transmit the content in the lectures and answer your questions. I know we all may work on weekends, but I will not reply to any email and I do not expect you to submit any work during weekends.
- **Accommodations for students with disabilities:** If you need any type of accommodation, please make an appointment with the Office of Disability Services to get an Accommodation Letter (steps in this [link](#)). I am happy to provide any accommodation, but you need to let me know as soon as possible (hopefully by the beginning of the semester).

7 Absence to class, help sessions or exams

- **To class (students):** If you are ill, please do not come to class. I will post all the lecture notes, so you will know exactly what I did in class. Additionally, I encourage you to ask as many questions as you need to in office hours, or setting up an appointment. Remember that “can you explain this section to me?” is a perfectly valid question.
- **To class (instructor):** If I need to miss an in-person class, I will post videos with the contents. I understand that videos are not interactive, and you cannot ask questions during the class, but we always have office hours. If I am ill, I will let you know and the office hours will be held virtually.
- **To help sessions:** Help sessions are not mandatory, and the grade only reflects attendance and participation. I understand that if you are ill you may want to join, but you won’t be able to. If that’s the case, **send me an email before it ends** and I can excuse your absence. You may use this resource at most **once** in the semester.
- **To exams:** If you need to miss an exam (including the midterms and the final), please let me know as soon as you know you will miss it. You will have 48 hours after the exam to email me explaining what happened, and we will find another time for a make-up exam. If you fail to contacting me withing 48 hours, you will get a 0 in the corresponding exam.

8 Software

Most of the time we will solve problems on paper (or e-paper). However, an important part of understanding algorithms is putting them in practice, so we will do some coding. You may use your favorite programming language/software, but I can only help if you use Python or Excel.

9 Mental and Physical Well-Being

William & Mary recognizes that students juggle different responsibilities and can face challenges that make learning difficult. There are many resources available at W&M to help students navigate emotional/psychological, physical/medical, material/accessibility concerns. **Asking for help is a sign of courage and strength.** If you or someone you know is experiencing any of these challenges, we encourage you to reach out to the following offices:

- W&M Counseling Center: Click [here](#) or call (757) 221-3620. Services are free and confidential.
- W&M Health Center: Click [here](#) or call (757) 221-4386.
- For additional support or resources, please contact the Dean of Students by submitting a Care Report at this [link](#), calling (757)221-2510, or by emailing deanofstudents@wm.edu.
- For other resources available to students, see [Health and Wellness Resources for Students](#), or this [link](#). The last link can also be reached through the following QR code:



As your instructor this semester, I also ask you to reach out to me if you are facing challenges inside or outside the classroom. I am happy to grab a cup of coffee together, make accommodations if you need any, or guide you to appropriate resources on campus if necessary.

10 Tentative Schedule

Below you will find a schedule based on the chapter numbers of the textbook. These may not match the chapter numbers in the lecture notes.

Date	Topics	Tasks
1. Wed Jan 25th	Welcome and introduction	
2. Fri Jan 27th	Part I: Review of probability and Markov chains. * Based on book [2]	
3. Mon Jan 30th		
4. Wed Feb 1st		
5. Fri Feb 3rd		<ul style="list-style-type: none"> • Homework 1 posted • Email me if conflicts with exams
Last day of add/drop		
6. Mon Feb 6th	Part I (cont.)	
7. Wed Feb 8th	Help session 1	
8. Fri Feb 10th	Part I (cont.)	Homework 1 due by the end of the day
9. Mon Feb 13th		
10. Wed Feb 15th	Part II: Markov Decision Processes and Reinforcement Learning * Based on book [3]	
11. Fri Feb 17th		Homework 2 posted
12. Mon Feb 20th		
13. Wed Feb 22nd	Help session 2	
14. Fri Feb 24th	Part II (cont.)	
15. Mon Feb 27th		<ul style="list-style-type: none"> • Homework 2 due by the end of the day • Homework 3 posted
16. Wed Mar 1st		
17. Fri Mar 3rd	Part II (cont.)	Help session 3
18. Mon Mar 6th		Homework 3 due by the end of the day
19. Wed Mar 8th		
20. Mar 9-10th: Midterm I (take home) – Contents: Lectures 1-17		
Mar 11-19th: Spring break – No class, no office hours		
21. Mon Mar 20th	Part II (cont.)	
22. Wed Mar 22nd		
23. Fri Mar 24th		Homework 4 posted

24. Mon Mar 27th		
Withdraw deadline		
25. Wed Mar 29th	Help session 4	
26. Fri Mar 31st	Part II (cont.)	Homework 4 due by the end of the day
27. Mon Apr 3rd		
28. Wed Apr 5th	Part III: Queueing Theory * Based on book [1]	
29. Fri Apr 7th		Homework 5 posted
30. Mon Apr 10th		
31. Wed Apr 12th	Help session 5	
32. Fri Apr 14th	Part III (cont.)	Homework 5 due by the end of the day
33. Mon Apr 17th		
34. Wed Apr 19th		
35. Apr 20th-21st: Midterm II (take home) – Contents: Lectures 18-32		
36. Mon Apr 24th	Part III (cont.)	
37. Wed Apr 26th		
38. Fri Apr 28th		Homework 6 posted
39. Mon May 1st		
40. Wed May 3rd	Help session 6	
41. Fri May 5th	Review session	Homework 6 due by the end of the day
42. Final exam: Mon May 8th to Fri May 12th – Contents: Lectures 1–41		