COMP 585:
Probabilistic Toolkit for Learning and Computing

Time: Tuesdays Thursdays 9:25 - 10:40 am
Place: Keck Hall 107
Webpage: https://maryamaliakbarpour.com/courses/S25/index.html

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Office hour: Tuesdays 11:00 am-12:00 pm, Duncan Hall 3098

Course Description

Randomness is one of the strongest tools which enables designing efficient algorithms. The applications of randomness in computer science spans machine learning algorithm, cryptography, networks, distributed systems. In this course, we study a variety of probabilistic tools and techniques that allow us to harness the power of randomness and apply it in algorithm design and learning theory.

Course Objectives

The ultimate objective of this course is to equip students with an arsenal of probabilistic methods that are advantageous for conducting research in theoretical computer science and learning theory. Throughout the lectures, we will introduce these methods and explore their applications in fundamental questions in learning theory and theoretical computer science. Homework assignments are designed to allow students develop a strong proficiency in utilizing these techniques. Furthermore, the class project has been designed to enable students to explore state-of-the-art research within the field and practice applying these methods in their own research.

Prerequisites

This course is intended for graduate students and very strong undergraduates with mathematical maturity. Students are expected to have a solid undergraduate background in probability (random variables, PDF, expectation, variance, and conditional probabilities), algorithms (running time analysis and big-O/Omega/Theta notation), as well as the basics of graph theory.

Course content

Here is a tentative list of topics:

- Probability foundation:
  - Review of Basics: Events, Conditional Probabilities, Independent Random Variables, Law of Total Probability, Bayes' Law
  - Tail Bounds: Markov, Chernoff. Distances between Distributions. Application: Property Testing of Distributions
  - Sub-Gaussian and Sub-Exponential Random Variables
- Computational learning theory:
  - Linear Regression, Sparsity,
  - Dimensionality Reduction, Johnson-Lindenstrauss Embedding
  - PAC Learning
  - VC Dimension and the Fundamental Theorem of PAC Learning
  - Representation and Computational Hardness of Learning
  - Decision Trees
- Special topics:
  - Differential privacy

Textbooks

No textbook is required for this course. However, below is a list of suggested textbooks where the lecture notes are based on.

- An Introduction to Computational Learning Theory, by Michael Kearns and Umesh Vazirani
- High-Dimensional Probability: An Introduction with Applications in Data Science, by Roman Vershynin
- Introduction to Property Testing, by Oded Goldreich
- Probability and Computing: Randomization and Probabilistic Techniques in Algorithms and Data Analysis, by Michael Mitzenmacher and Eli Upfal
- Understanding Machine Learning: From Theory to Algorithms, by Shai Shalev-Shwartz and Shai Ben-David

Logistics and format

This is a 3-credit hour course with standard letter grade. The course consists of two lectures per week for roughly 14 weeks during the semester, four assignments, and a class project. The assignment and project report should be submitted to canvas; For questions about the course content or assignments, students may attend office hours or reach out to the instructor or TAs via email.

Grading Policy

The students' grades are computed based on their performance on the following tasks:

Task	**Grade percentage**
Class participation	5%
Scribed notes	10%
Assignments	50%
Project	35%

Class participation: Active and engaged participation in class is strongly encouraged as it enriches the learning experience. Please be aware that the use of laptops during class is only permitted when used for note-taking, to ensure focused interaction with course content and fellow classmates.

Scribing two lectures: Students are required to produce high-quality notes for two lectures (depending on the number of students in the class). These notes will be available on the course website online.

Homework assignments: We will have five problem sets during the semester, including one review problem set. Each of the four main assignments will account for 12% of the grade, while the review problem set will account for 2% of the grade.

Late submission policy: There is a penalty for late submission: If you submit your assignment within 24 hours after the deadline, the grade will be multiplied by **0.75**. If you submit your assignment between 24 to 48 hours after the deadline, the grade will be multiplied by **0.5**. Unfortunately, we will not be able to accept any assignments after two days since we make the solutions available to the class.

The same late submission policy applies to class project assignments. You may also use your two "free days" for project-related submissions. However, the total allowance of two days applies to all submissions combined.

We understand that life happens, and students may face situations that prevent them from submitting their assignments on time. We give all of students a total of **two** "free days" for late submission. In other words, students will not be penalized for two days of late submissions. Students are not required to contact us regarding the usage of these late dates; we will automatically allocate them to maximize their score.

Class Project: The class project can be an exploratory research project or a high-quality survey of four relevant papers. Depending on the project, a few milestones will be defined for the students during the semester so they can track their progress and organize accordingly:

- Project proposal
- Mid-point evaluation
- Final report
- Final presentation

The late submission policy for class project assignments is the same as homework assignments. You may use your two **two** "free days" for project related submission as well. However, your budget remains two days in total.

Reading Assignments (optional): During the semester, we provide students with references to a textbook that explains the materials in the next lecture (if available). While this is not required, we recommend that students read the provided material in preparation for the lectures.

Other course policies

The members of our community at Rice come from many different backgrounds and views. Our goal is to ensure that everyone feels safe, respected, and empowered to be their best selves. We kindly ask our students to treat each other with care and respect.

Rice Honor Code

Students are expected to adhere to the Rice Honor Code. You are encouraged to collaborate and find resources online. However, all the material to be graded is expected to be original unless properly recognized and cited. This policy includes the use of large language models (such as chat-gpt). It is permissible to apply such software for spell/grammar checks to your original text. However, these tools are prohibited for generating content that is not deemed to be yours, including rephrasing others' work and producing summaries.

Disability Resource Center

If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with the Disability Resource Center (Allen Center, Room 111 / adarice@rice.edu / x5841) to determine the accommodations you need; and 2) Email the instructor to discuss your accommodation needs in the first two weeks of class.

Wellbeing and Mental Health

The wellbeing and mental health of students is important; if you are having trouble completing your coursework, please reach out to the Wellbeing and Counseling Center. Rice University provides cost-free mental health services through the Wellbeing and Counseling Center to help you manage personal challenges that threaten your personal or academic well-being. If you believe

you are experiencing unusual amounts of stress, sadness, or anxiety, the Student Wellbeing Office or the Rice Counseling Center may be able to assist you. The Wellbeing and Counseling Center is located in the Gibbs Wellness Center and can be reached at 713-348-3311 (available 24/7).

Title IX Responsible Employee Notification

At Rice University, unlawful discrimination in any form, including sexual misconduct, is prohibited under Rice Policy on Harassment and Sexual Harassment (Policy 830) and the Student Code of Conduct. Please be aware that all employees of Rice University are "mandatory reporters," which means that if you tell me about a situation involving sexual harassment, sexual assault, dating violence, domestic violence, or stalking, we (the course staff) must share that information with the Title IX Coordinator. Although we have to make that notification, you will control how your case will be handled, including whether or not you wish to pursue a formal complaint. Our goal is to make sure you are aware of the range of options available to you and have access to the resources you need. To report sexual harassment, please contact the Title IX Coordinator at titleix@rice.edu. To explore supportive measures and other resources that are available to you, please visit the Office if Interpersonal Misconduct Prevention and Support at safe.rice.edu.