

# Syllabus: CSC 488/288 Fall 2022

*This syllabus is subject to change.*

**Course:** CSC 488/288: Analytic Methods in Computer Science

**Instructor:** Kaave Hosseini                      [kaave.hosseini@rochester.edu](mailto:kaave.hosseini@rochester.edu)

**Lecture:** MW 3:25 PM - 4:40 PM Location: Lechase Room 181

**Office hours:** M 4:50 PM - 6:00 PM Location: Wegmans 2507

**Course description** In this course, we introduce a number of tools with analytic flavor that have an impressive range of applications in computer science and discrete mathematics. Although the objects we are dealing with (such as graphs, sets, boolean functions, and various models of computation) are discrete in nature, it turns out that an analytic point of view—as opposed to a purely combinatorial one—provides a powerful lens to study these objects.

We start with elementary tools such as probabilistic concentration bounds and then move on to more advanced material such as spectral graph theory, discrete Fourier analysis, and pseudorandomness. Applications of these tools in areas such as algorithms, dimension reduction, coding theory, complexity theory, discrete mathematics, and machine learning will be discussed.

**Course material** Here is a tentative list of topics.

- Introduction to spectral graph theory and Laplacian of a graph
- Cheeger's inequality
  - Sparsest cut problem
  - Spectral clustering and image segmentation
- Spectral dimensionality reduction
  - Principal Component analysis
  - Random projections and Johnson-Lindenstrauss theorem
  - Sparse recovery
  - Further applications in machine learning

- Expanders
  - Random walks on graphs
  - Error-correcting codes
  - Error reduction of randomized algorithms
- Introduction to discrete Fourier analysis
  - Property testing
  - Coding theory
  - Computational social choice theory
  - PAC learning
- Small bias spaces
  - Constructing error-correcting codes
  - Derandomization
  - Pseudorandom generators
  - Construction of Ramsey graphs
  - Design of Approximation algorithms and hardness of approximation
- Structure vs Randomness
  - Roth's theorem

**Objectives** Obtain knowledge to model and solve various combinatorial and algorithmic problems that are amenable to an analytic approach.

**Prerequisites** Students are expected to have familiarity with undergraduate-level discrete mathematics, graph theory, linear algebra, and probability. Students interested in theoretical computer science and/or discrete mathematics are welcome.

**Resources** We will be using a number of resources for this class, some of which are the following.

1. Techniques in Combinatorics, Tim Gowers. <https://gowers.files.wordpress.com/2014/11/techniques2014notes.pdf>
2. Analysis of Boolean Functions, Ryan O'Donnell. <https://arxiv.org/pdf/2105.10386.pdf>
3. Analysis of Boolean Functions, Tom Sanders. <https://people.maths.ox.ac.uk/~sanders/abf/notes.pdf>
4. Extremal Combinatorics with applications in Computer Science, Stasys Jukna.
5. Fourier analysis of Boolean functions, Shachar Lovett. <http://cseweb.ucsd.edu/~slovett/teaching/WI17-CSE291/>

**Assessment** Evaluation will be based on homework assignments(70%) and a final project(30%).

**Homework assignments** There will be an assignment roughly every other week. Students can solve each assignment in groups of size at most two, however, each student should write down their final solution individually. Every student should submit their solutions to Piazza. Late assignments are not permitted unless in urgent situations. Groups can change for every assignment.

**Final Project** The final project is done individually. There are a number of options for a final project. The first option is to choose a related paper/topic and give a nice presentation of it towards the end of the semester. The second is to write a report on some important recent paper(s). The third is a programming project, related to implementing/experimenting with some of the algorithms that will be discussed during the course. Forth is a research project, by working on an open theoretical or experimental problem and give a talk about your progress towards the end of the semester (this forth item can be done in groups of at most two.)

**Communication** Announcements, homework assignments, discussions, etc will be posted on Piazza. Here is the sign-up link for the course: [piazza.com/rochester/fall2022/csc488288](https://piazza.com/rochester/fall2022/csc488288)

**Academic Integrity** Students must follow UR's Code of Academic Integrity: <https://www.rochester.edu/college/honesty/policy/index.html>

**Disability resources** The University of Rochester respects and welcomes students of all backgrounds and abilities. In the event you encounter any barrier(s) to full participation in this course due to the impact of a disability, please contact the Office of Disability Resources. The access coordinators in the Office of Disability Resources can meet with you to discuss the barriers you are experiencing and explain the eligibility process for establishing academic accommodations. You can reach the Office of Disability Resources at: [disability@rochester.edu](mailto:disability@rochester.edu); (585) 276-5075; Taylor Hall; [www.rochester.edu/college/disability](http://www.rochester.edu/college/disability).