CS 6810: Theory of Computing, Fall 2023

1 Essential information

- Instructor: Eshan Chattopadhyay
  - Email: eshan@cs.cornell.edu
  - Website: https://www.cs.cornell.edu/~eshan/
- Course webpage: https://courses.cs.cornell.edu/cs6810/2023fa/
- Lecture
  - Timing: TR 1:25pm-2:40pm
  - Location: Hollister Hall 306
- Office Hours
  - Timing: Thursdays 3-4pm
  - Location: Gates Hall 319

2 Course description and resources

Computational complexity theory is devoted to understanding the limitations of efficient computation (with respect to computational resources such as time, space and randomness). This course will be a graduate level introduction to various aspects of complexity theory.

Resources: While we will not follow a single book for this course, the following references will come in handy.

- *Computational Complexity: A Modern Approach* by Sanjeev Arora and Boaz Barak. You can find a draft of the book here.
- *Computational Complexity: A Conceptual Perspective* by Oded Goldreich. You can find a draft of the book here.
- *Mathematics and Computation* by Avi Wigderson. You can find a draft of the book here.

3 Prerequisites

Any of CS 4810, CS 4820 or CS 4814; or permission of instructor. In general, some mathematical maturity is expected. Familiarity with basic notions of algebra (such as finite fields, basics of vector spaces, polynomials), linear algebra, and discrete probability will be useful.

4 Credit and Credit Hour Options

4 credits. The course can be taken for a letter grade or S/U grade. In addition to scheduled lectures and accompanying homework, this course has an independent project requirement with a final presentation that will require work throughout the semester. (This is described in more detail in the evalution section.)

5 Topics to be covered

A brief overview of topics that will be covered:

- Introduction
  - Turing Machines, Robustness of model,
  - Reductions and NP-completeness.
  - Diagonalization: applications (Undecidability, Time Hierarchy theorem, Ladner's Theorem) and limitations (Relativization and Oracle Turing Machines).
- Space Complexity
  - PSPACE completeness, Savitch's theorem
  - Log-space reductions, NL=coNL.
- Polynomial Hierarchy and Alternations
- Boolean Circuits
  - Karp-Lipton Theorem
  - Circuit Lower Bounds
  - Natural Proof barrier
- Randomness and Derandomization
  - Hardness vs Randomness
  - Space-bounded derandomization
- Interactive Proofs
- Probabilistically Checkable Proofs and Hardness of Approximation

6 Homeworks

There will be 4 homeworks spread evenly across the semester. Solving problems will require original thinking, and it will be a good idea to start early. You will be required to use LaTeX to typeset your solutions.

We encourage you to discuss with your peers in the course to brainstorm ideas for how to get through homework. However, your solution must be written up completely on your own; you are not allowed to share digital or written notes or images of your work in any form with each other. Just like in research, your work must also include acknowledgements of all students with whom you collaborated. Both the physical or digital distribution of information about solutions and the failure to acknowledge collaborators are serious violations of academic integrity.

7 Evaluation

Your performance will be evaluated based on the following components:

- Homeworks: 40%.
- Scribe notes: 15%. Students are required to scribe lecture notes. You will be required to send in an initial draft of the scribed notes by 48 hours after the lecture. that you can use.
- Final project: 40%. You are expected to pick a topic and send a project proposal by October 28. The expectation is that students work in groups (up to 2 members) to write a high quality survey based on a topic (that is relevant to this course) and give a final presentation. We encourage students to start thinking about potential project topics quite early into the semester. This could be about a general area of research (e.g., sublinear algorithms, quantum complexity theory etc) or an in-depth report about a specific result (e.g., proof of the PCP theorem).
- Class participation: 5%.

8 Grading

Typically the median grade is A, and 80-90% of the students receive grade of A- or better.