CS 6810: Theory of Computing, Fall 2021

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/cs6810/2021fa/`
- Lecture
  - Timing: TR 11:25am-12:40pm
  - Location: Statler Hall 351

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 come in handy.

4 Tentative topics

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

5 Evaluation

- Homeworks: 40%. There will be 4 homeworks spread evenly accross 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.
- 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. Here is template 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%.