[ECE381V/CS395T] Unconventional Computation

Graduate Course :: Spring 2025 unique: 18120, 51460

Last year's lecture notes and homework (check if this class is right for you): [link]

Lectures

Tue/Thu 5pm to 6:30pm in GLT 1.102

Instructor

Prof. David Soloveichik [david.soloveichik@utexas.edu]
Research website: https://solo-group.link

TA

Aditi Awasthi [aditiawasthi@utexas.edu]

Description

There is computation outside of digital electronics: in every biological cell, in your brain, in cutting-edge laboratories trying to create DNA computers and quantum computers. For decades prior to digital electronics, analog mechanical and electric computers reigned. This class exposes you to a variety of perspectives on computation, focusing on proving important properties of the various models, and on how to use the models to achieve desired computational behavior. If you enjoy solving puzzles, proving theorems, and designing computers out of seemingly inadequate parts, this class may be for you.

Topics

1. **Computation gets real: analog/real-valued computation**
   - (GPAC) general purpose analog computer
   - dynamical systems: oscillators, chaos
   - chemical reaction networks
   - mechanical computation with linkages

2. **Almost anything can compute everything: cellular automata, counter machines**
   - Turing machines and Minsky's counter machines
   - CA-like models: Conway's game of life, rule 110, algorithmic tile-assembly
   - the uncomputable: Kolmogorov complexity, halting problem
   - natural but not Turing universal: population protocols

3. **Computing without using energy: reversible computing**
   - reversible Turing machines
   - Bennett's simple and space-efficient constructions
   - optimality of the reversible pebble game

4. **Computing by interference: quantum computing**
   - foundations, oracle query model
   - destructive interference: Bernstein-Vazirani Problem, Deutsch-Jozsa Algorithm
   - Quantum Fourier Transform and Shor's factoring algorithm

Prerequisites

Experience with proofs (e.g., discrete math, algorithms)

Helpful: automata theory (Turing machines), logic circuits, undergraduate probability, basic differential equations

No physics, chemistry, or biology background needed

Textbook / reading materials

There is no required textbook for this course, but the following book does a great job in covering the nature of computation inside and outside of electronic computers:

> Cristopher Moore and Stephan Mertens. *The Nature of Computation.* Oxford University Press 2011

You are strongly urged to attend all classes and participate during discussions. Where possible, PDF copies of optional reading materials will be provided.

Grading

Homework (65%), Projects (30%), Class Participation (5%)

Normal grading scale: 93–100 A ; 90–92 A- ; 87–89 B+; etc

Projects

Over the course of the semester, you will do two (2) projects on a paper or model related to the topics covered in the class. The projects will involve a class presentation and a written “homework” problem / solution. Projects will be done in groups of 1-4 students (depending on class size).

Homework policy

Homework must be typed and submitted to Gradescope. “Star” homework problems are not extra credit. These problems are less well-defined than the others/ closer to a research problem (this is a graduate class!) Use your judgement to understand the bigger picture. Feel free to reach out to me or to the TAs.

Late homework will be accepted only until the time when solutions are posted. The penalty will be –20% per 24 hour period. This penalty is assessed after normal grading and is cumulative with any points lost (e.g. a homework that would normally receive 80% of total points would receive only 40% if handed in within 48 hours).

Homework sets and solutions may not be shared online or with anyone outside of the class unless you have my explicit, written permission. Unauthorized sharing of materials promotes cheating. It is a violation of the University’s Student Honor Code and an act of academic dishonesty. Any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students. These reports can result in sanctions, including failure in the course.

Collaboration policy

You may discuss homework problems with other students (indeed it's encouraged and expected). But the solutions turned in must be written entirely by you. **You must write the names of all the students you collaborated with at the top of your homework.** Copying on homework assignments could result in an automatic zero for the assignment for both students as well as other consequences (e.g., failure and disciplinary action). Close collaboration is expected for group projects, with all students meaningfully contributing.

University policies

Religious holy days. By UT Austin policy, you must notify me of your pending absence at least fourteen days prior to the date of observance of a religious holy day. If you must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, I will give you an opportunity to complete the missed work within a reasonable time after the absence.

Students with Disabilities. The University of Texas at Austin provides, upon request, appropriate academic adjustments for qualified students with disabilities. If you have a disability that warrants such adjustments, please give the instructor a letter from the Dean of Students describing what needs to be done. You should do this during the first week of classes.