[EE381V/CS395T] Unconventional Computation

Graduate Course :: Spring 2020 :: TTh 3:30-5pm in ECJ 1.214

Instructor

Prof. David Soloveichik [david.soloveichik@utexas.edu]
Office: EER 7.814
Office hours: TBD

Teaching Assistant

Cameron Chalk [ctchalk2@gmail.com]
Office hours: TBD

Description

There is a world of computation outside of electronic devices: in every biological cell, in your head, in cutting-edge laboratories trying to create DNA computers and quantum computers. Such unconventional computation inspires new models of computing beyond traditional models of boolean circuits and automata. This class exposes you to new perspectives on computation: models of highly distributed and unstructured computation such as that occurring in chemical reactions, models in which building is equivalent to computing, models that address the ultimate limits of low energy computation, and models that compute by relaxing to the lowest energy state. If time permits, we will cover the basics of neural computation (not learning), and quantum computing. The course will consist of a combination of lectures, paper discussions, and group projects.

Tentative Topics

1. Extreme distributed computing: Population Protocols, Chemical Reaction Networks
   - deterministic computation and its limitations
   - kinetics and time analysis
   - register machines
   - “analog”/real valued computation, oscillators, chaotic systems

2. “The Simplest Geometry”/“To build is to compute”: Cellular Automata, Algorithmic Tile Assembly Model
   - elementary CAs, game of life
   - complexity of self-assembly, busy beaver Turing machines
   - biological pattern formation

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

4. Basics of Quantum Computing
   - foundations, oracle query model
   - destructive interference: Bernstein-Vazirani Problem, Deutsch-Jozsa Algorithm

5. Other: Mechanical computers, DNA Computing, Hopfield networks, Thermodynamic Binding Networks

Prerequisites

Experience with proofs (e.g., discrete math, algorithms)
Helpful: undergraduate probability/random processes, basic differential equations, automata theory, logic circuits

No physics, biology, or chemistry background is assumed.

Grading

Homework (65%), Final Project (30%), Class participation (5%)

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).

Collaboration policy

You may discuss homework problems with other students, 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 will 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.

Textbook / reading materials

There is no textbook for this course. You are strongly urged to attend all classes and participate during discussions. Where possible, PDF copies of optional reading materials will be provided.

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 provides on request appropriate academic accommodations for qualified students with disabilities. At the beginning of the semester, students who need special accommodations should notify the instructor by presenting a letter prepared by the Service for Students with Disabilities (SSD) Office. Disabilities range from visual, hearing, and movement impairments to Attention Deficit/Hyperactivity Disorder, psychological disorders (bipolar disorder, depression, Obsessive Compulsive Disorder, etc.), and chronic health conditions (diabetes, multiple sclerosis, cancer, etc.). These also include from temporary disabilities such as broken bones, recovery from surgery, etc. For more information, contact Services for Students with Disabilities at (512) 471-6259

[voice], (866) 329-3986 [video phone], via e-mail at ssd@austin.utexas.edu, or visit: http://ddce.utexas.edu/disability/.