CSC 591: CS Theory Toolkit

Syllabus

Lecture times: Tuesday & Thursday, 10:15-11:30am, starting August 22
Lecture location: EBII 1226

Instructor: Chin Ho Lee
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Office Location: EBII 3292
Office Hours: TBD, or by request

Course Description

This course is intended to equip a student interested in studying theoretical computer science (TCS) with some of the fundamental tools commonly used in this area. We will study several mathematical tools and see how they are used to develop algorithms and prove impossibility results in various areas in computer science.

Objectives

By the end of the course, students should be able to:

- apply several fundamental tools that are used widely in TCS and other areas
- complete some low-level proof details after digesting high-level ideas in research papers
- become aware of some connections between various areas in TCS
- formulate a research problem and carry out independent research

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Prerequisites

Required: MA 305, ST 370, CSC 226, CSC 316, CSC 333. Solid undergraduate background in math (e.g., elementary combinatorics, graph theory, discrete probability, basic linear algebra) and theoretical computer science (running time analysis, big-O/Omega/Theta, P and NP, basic fundamental algorithms). Mathematical maturity is a must.

Students who do not satisfy the prerequisites but wish to enroll in the course should email the instructor. Note that this is a theory-intensive subject.

Required Materials

There are no required textbooks for this class. We will mostly follow the material in Ryan O'Donnell's class (https://www.diderot.one/courses/28). References will be provided.

Course Structure

The main components of the course are as follows:

- **Main class meetings (Tue & Thu 10:15-11:30am):** These will be interactive lectures, with the exposition and discussion guided by student questions and comments, interspersed with occasional problem-solving and brainstorming in small groups.
- **Reading and commenting:** To allow our class meetings to be more interactive, short advance reading will be posted on the social e-reader Perusall before class, and you are encouraged to comment on those readings using Perusall. Your commenting will help us focus our class meetings on the material that you all find most confusing or most interesting, will give you experience in working through advanced material with your peers, and can lead to interesting discussions or project/research ideas.
- **Note scribing:** You may be asked to scribe 1-2 lectures in class.
- **Problem sets:** There will be problem sets due approximately every other week. Some of the problems may require deep thought, so you are strongly encouraged to begin them early and utilize office hours. (See Homework Policy below.)
- **Peer-reviewing:** For each problem set, you will review and comment on a submission by another student on HotCRP. You do not have to give grades in your review.
- **Final exam:** There will be a take-home exam at the end of the semester. (See Final Exam Policy below.)
- **Asynchronous Q&A and discussion:** We will use Ed for Q&A, announcements, and discussions that are not attached to specific readings.

Tentative Topics & Schedule

Week	Topics	
8/21	Introduction, Asymptotics, Factorials and Binomials	
8/28	Tail inequalities	8/31: HW1 out
9/4	Fields and Polynomials, DFT, FFT (Schwartz-Zippel lemma, Polynomial Identity Testing, Lovász's perfect matching algorithm)	
9/11	Coding theory, Secret sharing (Reed-Solomon codes,	9/14: HW1 due, HW2 out

	Hadamard code)	
9/18	Analysis of Boolean Functions (Linearity Testing)	
9/25	Spectral graph theory (Expanders, st-connectivity, expander codes)	9/28: HW2 due, HW3 out
10/2	LP and SDP (Duality, Max-cut, Sparsest cut)	
10/9	Streaming and Sketching algorithms (Frequency moment estimation, Approximate counting)	10/12: HW3 due, HW4 out
10/16	Learning theory (Boosting, VC dimension)	
10/23	Communication complexity (Equality, Disjointness)	10/26: HW4 due, HW5 out
10/30	Communication complexity (Applications)	
11/6	Information theory and Information complexity	11/9: HW5 due, HW 6 out
11/13	Derandomization (k-wise independence, small-bias set)	
11/20	Quantum computing (Grover's search, Shor's factoring algorithm)	
11/27	Buffer or TBD	11/28: HW6 due
12/4	Buffer or TBD	12/4: Final exam out

Topics will be adjusted and rearranged according to the pace and interests of the class.

Grading Information

The final grades for the course will be determined by roughly the following breakdown:

10% Lecture note-scribing and class participation
10% Peer-reviewing (1 submission for each homework assignment)
60% Homework (6 problem sets)
20% Final exam (Take-home)

The following grade scale will be used: A+ (97-100), A (93-96), A-(90-92), B+ (87-89), B (83-86), B-(80-82), C+ (77-79), C (73-76), C-(70-72), D+ (67-69), D (63-66), D-(60-62), F (below 60).

Homework Policy

You are required to typeset your solution using LaTeX. Overleaf (https://www.overleaf.com/) is a popular online LaTeX editor.

Each student has 8 late days for homework submission throughout the semester, of which you can use up

to 5 days on any problem set. Any extension beyond the 8 late days will be subject to Academic Absence Verification (https://dasa.ncsu.edu/support-and-advocacy/find-help/absence-notification/).
When late days are used up and a problem set is submitted **L** days late, the grade for that problem set will be multiplied by $\mathbf{0.9^L}$.

You are allowed to discuss homework questions with others in the class, only after spending some time on them on your own. You must write down your own solutions, without consulting others while you are writing them.

Final Exam Policy

You are **not** allowed to discuss the final exam with others and must work on the final exam on your own.

There is no late day for final exam submission. Any extension request will be subject to Academic Absence Verification (https://dasa.ncsu.edu/support-and-advocacy/find-help/absence-notification/).

Regrading Policy

Any re-grade request must be submitted within 1 WEEK after the graded homework/exam is returned to you. After that point, you cannot appeal your grade.

Resources

Here are some courses with a similar title offered at other universities.

https://www.diderot.one/courses/28, taught by Ryan O'Donnell
https://www.youtube.com/playlist?list=PLm3J0oaFux3ZYpFLwwrlv_EHH9wtH6pnX, video lectures by Ryan O'Donnell
https://ocw.mit.edu/courses/18-409-topics-in-theoretical-computer-science-an-algorithmists-toolkit-fall-2009/download/, taught by Jonathan Kelner
https://tifr-2023-tcs-tools.bitbucket.io/, taught by Prahladh Harsha and Piyush Srivastava
https://www.cs.princeton.edu/~arora/pubs/toolkit.pdf, taught by Sanjeev Arora
https://www.cs.purdue.edu/homes/hmaji/teaching/Spring%202023/CS-58500-Spring-2023.html, taught by Hemanta K. Maji and Paul Valiant
https://yuanz.web.illinois.edu/teaching/B609fa16/, taught by Zhou Yuan
https://home.ttic.edu/~madhurt/courses/toolkit2018/index.html, taught by Madhur Tulsiani

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Academic Integrity

All students are expected to maintain traditional standards of academic integrity by giving proper credit for all work. All suspected cases of academic dishonesty will be aggressively pursued. You should be aware of the University policy on academic integrity found in the Code of Student Conduct (https://policies.ncsu.edu/policy/pol-11-35-01/).

Class Communications and Course Evaluations

You can email the instructor at **chinho.lee@ncsu.edu**

All communication to the class will be conducted via Ed. It is the student's responsibility to contact the instructor with their email, in order to join that group.

Disabilities

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 919-515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation(REG 02.20.01).

NC State Rules and Regulations

Students are responsible for reviewing the PRRs which pertain to their course rights and responsibilities. These include:

- http://policies.ncsu.edu/policy/pol-04-25-05 (Equal Opportunity and Non-Discrimination Policy Statement)
- http://oied.ncsu.edu/oied/policies.php (Office for Institutional Equity and Diversity)
- http://policies.ncsu.edu/policy/pol-11-35-01 (Code of Student Conduct), and
- http://policies.ncsu.edu/regulation/reg-02-50-03 (Grades and Grade Point Average).