
Lamar University

COSC 5340-03, Spring 2004

Computational Complexity

TTH 12:30 AM ~ 1:45 PM, Maes 106

Instructor: Dr. Chung-Chih Li
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Office Hours: MWF 9:30 ~ 10:30 AM or by appointment

Course Description and Topics:

Ever since Leibniz suggested that we could sit down and compute to end all disputes, what could be reasoned by way of mechanical computation had been the central theme of modern rationalism as well as a compelling force in the development of the foundation of mathematics in the late nineteenth century. Unfortunately, after Gödel announced his famed *incompleteness theorem* in 1931 stating that it is impossible to have a formalism that can help us to reach all truths and only truths, we finally realized that we had gone a long way in fighting a battle that was impossible to win. Mathematicians and later computer scientists, however, did not retreat from the battle but instead advanced the front line in a different direction. Alan Turing converted the episode into a firm chapter in mathematics – *the theory of computability* – and provided a tool – *Turing Machine* (an abstract computer) – for computer theorists to characterize the problems that can be computed. The question then interested us was no longer that “can problem A be solved?” but that “how fast can problem A be solved?” Consequently, a better revision of Leibniz’s call shall be something like “Sir, let’s sit down and see how fast we can compute.”

In this class, we start with an introduction to some necessary setups and formalisms including the Turing machine and its variants. Then, we will go back to the origin of the theory of computability – Logics. We will survey first-order logic and its completeness, undecidability in logic, axiomatic systems, theorem proofs, second-order logic, and Gödel’s incompleteness theorem.

After entering the main course of the theory, we will formalize the notion of complexity classes and then review the questions around **P** vs. **NP**. The central topics include relations between complexity classes, reductions between problems, the completeness of complexity classes (for example, **NP**-complete), co-**NP**, and randomized computation. Also, relative intractability will be introduced in terms of the polynomial hierarchy, which is an interesting structure based on the assumption that $\mathbf{P} \neq \mathbf{NP}$, which means that the entire hierarchy will collapse if **P** and **NP** turn out to be the same class. If time is allowed, some important digressions such as computational number theory and the intertwined relation between complexity theory and cryptography will also be covered in the class.

Prerequisites:

Discrete Mathematics, Algorithms, Foundations of CS.

Textbook:

Computational Complexity
by Christos H. Papadimitriou, Addison Wesley Longman; 1994

NOTE: No Xerox copy of the textbook is allowed to bring to the class and tests.

Reference Books:

1. *The Complexity Theory Companion*
by Lane A. Hemaspaandra and Mitsunori Ogihara, Springer-Verlag, 2002.
2. *Computability and Complexity Theory*
by Steven Homer and Alan L. Selman, Springer-Verlag, 2001.
3. *Theory of Computational Complexity*
by Ding-Zhu Du and Ker-I Ko, John Wiley & Sons, 2000
4. *Classical Recursion Theory – Volumn II*
by P.G. Odifreddi, North Holland – Elsevier, 1999

Tests: (400 points)

Two midterms (100 points for each) and one final (200 points). All tests are open book and accumulative. You will receive 0 point for any absent test. No makeup test will be given. These rules also apply to quizzes.

Tentative dates:

Midterm I	100 points	Feb. 17 (6th week, Tuesday)
Midterm II	100 points	Mar. 23 (11th week, Tuesday)
Final Exam	200 points	May 11 (18th week, Tuesday)

NOTE: No early or late final exam will be given for any personal travelling plan.

Pop quizzes: (200 points)

Ten pop quizzes will be given impulsively. Each quiz carries 20 points towards your tally. The coverage of every quiz is also accumulative, including the materials covered in the class right before the quiz. A typical quiz takes about 10 minutes.

Attendance: (50 points)

About 10 attendances will be taken randomly. An attendance on a day when the roll is checked contributes 5 points towards the tally. In other words, an absence may cost 5 points if attendance is taken, or cost as many as 20 points if a quiz is given.

Grading Policy: Based on 650 points, your grade will be given according to the following table.

Points	Grade	
540 ~ 650	A	Excellent
420 ~ 539	B	Good
300 ~ 419	C	Satisfactory
200 ~ 299	D	Passing
0 ~ 199	F	Failure

Academic Honesty:

Cheating, plagiarism, collusion, abuse of resource materials, and their consequences are defined and described under the section of Academic Affairs in the *Student Handbook*.

Students giving away academic works for assignment offered for credit to other students working on the same assignment will be considered as guilty as academic dishonesty, and will receive the same penalty.

Tentative Topics and Schedules for COSC 5340-03

Week	Topics	Reading
1: Jan. 12	(01/14, semester begins, 01/15 1st class), introduction to problems and algorithms	syllabus, chapter 1
2: Jan. 19	(01/19 Monday, MLK's birthday, no class), Turing machines, speedup theorem, and bounds	2.1 ~ 2.5
3: Jan. 26	Random access machines, universal Turing machines, halting problems, undecidability	2.5 ~ 3.4
4: Feb. 2	Boolean logic, first-order logic, models, validity	4.1 ~ 5.3
5: Feb. 9	Completeness theorem, second-order logic, undecidability, incompleteness theorem	5.4 ~ 6.4
6: Feb. 16	(Midterm 1, 02/17 Tuesday) , complexity classes, hierarchy theorem, gap theorem	7.1, 7.2
7: Feb. 23	Savitch's theorem, reduction, completeness, Cook's theorem	7.3, chapter 8
8: Mar. 1	NP -complete problems	chapter 9
9: Mar. 8	(Spring break, no class)	catch up
10: Mar. 15	co- NP problems	chapter 10
11: Mar. 22	(Midterm 2, 03/23, Tuesday) , randomized algorithms, randomized complexity classes: PP and BPP	11.1, 11.2
12: Mar. 29	Random sources, circuit complexity, interactive proofs, zero-knowledge proofs	11.3, 11.4, 12.2
13: Apr. 5	P vs NP , (04/09, Good Friday, no class)	14.1, 14.2
14: Apr. 12	Oracle Turing machine, relative computation,	14.3, 14.4
15: Apr. 19	Parallel Computation, NC , RNC , P -completeness	chapter 15
16: Apr. 27	The polynomial hierarchy, $\mathbf{P}^{\mathbf{NP}}$, $\Delta_i\mathbf{P}$, $\Sigma_i\mathbf{P}$, $\Pi_i\mathbf{P}$,	chapter 17
17: May 3	(May 4, last class day) Prepare for the final	
18: May 11	Final Examination, May 11 Tuesday, 11:00 AM ~ 1:30 PM	