CSOR W4231 (s. 001, 002, H02): Analysis of Algorithms Sep 3, 2019

Course Information

Instructors: *Alex Andoni, Cliff Stein*

1 Basic Information

Lectures (Cliff Stein, section 001):

- Time: 10:10-11:25am on Tue/Thu.
- Location: 833 Mudd.

Lectures (Alex Andoni, section 002):

- Time: 2:40-3:55pm on Tue/Thu.
- Location: 833 Mudd.

Exams:

- Midterm 1: 10/8. in class.
- Midterm 2: 11/21. in class.
- Final: During finals period. Location TBD.

Staff:

- Instructor for 001: **Cliff Stein** (`cliff@ieor.columbia.edu`).
- Instructor for 002, H02: **Alex Andoni** (`andoni@cs.columbia.edu`).

TAs and office hours will announced on the Courseworks.

Textbook: Introduction to Algorithms, 3rd edition, by Cormen, Leiserson, Rivest, and Stein.

Courseworks: Class announcements, including homeworks and lecture notes will be posted on Courseworks.

Piazza: There is also a Piazza forum setup for the class (accessible through the Courseworks). You are encouraged to discuss class lectures and related topics, as well as ask questions or clarifications. (But you *cannot* discuss homework solutions on Piazza.)

Videos: lectures will be recorded and available online to sections 002 and H02.

2 Course Goals

The main goals of the class are for you to learn what is an algorithm, how to design algorithms, and how to analyze them:

- We will learn some of the fundamental *algorithmic techniques* by going through a few concrete, classic algorithms.
- We will learn to think about the *efficiency and correctness* of the algorithms. In particular you will learn how to formally analyze algorithms using *rigurous* mathematical proofs.
- Overall, we will develop an *algorithmic mindset*: how to think from specification of a given problem to designing an actual algorithm solving it.

3 Syllabus (subject to change)

Lec	Date	Topic	Reading (CLRS)	HW out	HW due
1	9/3	Introduction, big numbers multiplication	Ch. 1,2		
2	9/5	Divide And Conquer, Asymptotic notation	Ch. 2,3	HW1 out	
3	9/10	Recurrences, Merge Sort	Ch. 4		
4	9/12	Heapsort, Loop invariants	Ch. 6		
5	9/17	Deterministic Selection, Randomized Analysis	Ch. 5	HW2 out	
6	9/19	Indicator Random Variables	Ch. 5		HW1 due
7	9/24	Quicksort, Randomized Selection	Ch. 7, 9.2		
8	9/26	Sorting lower bounds, Counting Sort, Radix Sort	Ch. 6		
9	10/1	Dynamic programming	Ch. 15	HW3 out	
10	10/3	Dynamic programming	Ch. 15		HW2 due
	10/8	Midterm 1 (in class)			
11	10/10	Dynamic programming, Greedy algorithms	Ch. 15, 16		
12	10/15	Greedy algorithms	Ch. 16	HW4 out	
13	10/17	Amortized analysis	Ch. 17		HW3 due
14	10/22	Graphs: BFS, DFS	Ch. 22.1-22.4		
15	10/24	Topological Sort, Strongly Connected Components	Ch. 22.4, 22.5		
16	10/29	Minimum Spanning Tree, Disjoint Sets	Ch. 21,23	HW5 out	
17	10/31	Shortest paths: Dijkstra's, Bellman-Ford, DAGs	Ch. 24.1-24.5		HW4 due
18	11/7	All pairs shortest paths	Ch. 25		
19	11/12	Maximum Flows	Ch. 26.1-26.3		
20	11/14	Linear Programing	Ch. 29.1-2, 29.4	HW6 out	
21	11/19	Hardness, reductions between problems	Ch. 34		HW 5 due
	11/21	Midterm 2 (in class)			
22	11/26	NP-completeness	Ch. 34		
23	12/3	NP-completeness	Ch. 34		
24	12/5	Approximation algorithms			HW6 due
	12/?	Final			

4 Prerequisites

Two things are crucial for making the class easier for you:

- being able to read and write **formal mathematical proofs**: mathematical formalism provides a robust method to analyze and verify correctness of algorithms, and hence in this class we place a high emphasis on formal proofs;
- some familiarity with algorithms/data structures or a strong coding background: while we will learn algorithms without assuming that you know algorithms, it will be easier for you to absorb the new material if you have seen, and reasoned about, some examples of algorithms previously.

Formal prerequisites are: COMS W3134, W3136, or W3137, and W3203.

5 Evaluation and Grading

Your grade is based on the following three components:

- 6 Homeworks: 15%;
- Midterm 1: 25%;
- Midterm 2: 25%;
- Final: 35%.

6 Homeworks

Homeworks will be assigned roughly every two weeks and will be posted on Courseworks. They will be due in class on their due date before the lecture starts. Please follow the Homework Submission Guidelines below. Late homeworks will be penalized at the rate of 10%, additively, per late day or part thereof (i.e. fractions of a day are rounded up), for up to 7 days. To allow us to distribute the solutions in a timely fashion, homeworks submitted more than 7 days after the deadline will not be accepted. Exceptions will be made only for exceptional unforeseen circumstances (e.g., serious illness), in which case you will need to provide some additional documentation (e.g., doctor's note). The homework with the lowest score will not count in the grade.

You are strongly encouraged to start working on the homeworks *early*: some problems may require you to sit on the problem for a while before you get your "aha" moment. Starting early also gives you time to ask questions and make effective use of the office hours of the teaching staff.

Writing up solutions: precise and formal proofs. Remember that a goal of the class is for you to learn to reason about algorithms, precisely describe them, and formally prove claims about their correctness and performance. Hence, it is important that you write up your assignments *clearly, precisely, and concisely*. Legibility of your write-up will be an important factor in its grading. When writing up (algorithmic) solutions, keep in mind the following:

- The best way for you to convey an algorithm is by using plain English description, or a well-explained pseudocode. A worked example can also help. Generally, give enough details to clearly present your solution, but not so many that the main ideas are obscured.
- The analysis of the algorithm has to include both 1) proof of correctness, and 2) upper bound on performance (usually runtime, but sometimes space as well).

- You are encouraged (but not required) to type up your solutions using LaTeX. Latex is the standard package for typesetting and formatting mathematically-rich content. Since LaTeX knowledge is a good life skill, now may be a good chance to learn it. A short mini-course on LaTeX is available here: `http://www.ctan.org/tex-archive/info/lshort/english/lshort.pdf`. Macros to format pseudocode are available at `http://www.cs.dartmouth.edu/~thc/clrscode/`
  You are encouraged to use the template available on Coursework (the files `homework.tex, homework.cls`).

For examples of the expected level of rigorousness in your write-up, please consult the textbook and the proofs in it. Note that our lectures will generally be at a lower level of formalism (in lectures we will focus on intuition and main ideas; you will use the textbook to learn the formal details and proofs).

Clarity points. To encourage clarity (and conciseness), for each problem, 20% of the points are given for the *clarity* of your presentation. In particular, you will be awarded a default 20% of the points for an *empty solution* (note that, if you submit no coversheet whatsoever, you get only 0%). Note that you can *lose these 20%* if you write something that is unintelligible, does not lead to a solution, or is excessively long (including scoring a 0%). Clarity points policy does not apply to the exams.

7 Collaboration and Academic Honesty

You are expected to abide by the policies of academic honesty. The CS department web page lists the department's academic honesty policies: `http://www.cs.columbia.edu/education/honesty`.

Collaboration: you are permitted to discuss the homework *assignments*. If you do collaborate, you must write the solutions *individually* (without looking at anybody else's solutions), and acknowledge anyone with whom you have discussed the problems. It will be considered an honor code violation to consult solutions from previous years, from the web or elsewhere, in the event that homework problems have been previously assigned or solutions are available elsewhere. Honor code violations will be treated harshly and can lead to a score of 0, grade reduction, and/or a report to the Academic Committee (which may decide on further penalties that can permanently affect your academic record).

The main goal of the homework assignments is education, not evaluation. We must also be mindful of rules regarding academic honesty and plagarism. To facilitate these goals, we will use the following policy.

- All work submitted for credit must be your own.
- You may discuss the homework problems with your classmates, the teaching assistant(s), and the instructors. For each problem, you must acknowledge the people with whom you discussed your work, and you must independently write up your own solutions.
- Any written sources used (apart from the text) must also be acknowledged; however, you may not consult any solutions from previous years' assignments whether they are student or faculty generated.
- Solutions to problems may be available somewhere on the web. Do not use these solutions. If you do use them, cite them. If you do choose to copy another student's work, or to copy from some other source, please state this in writing on your homework assignment.

Please ask if you have any questions about this policy. Violations will be treated harshly. This means that if you violate the policy, even once, your grade on homework for the entire semester will be 0, and the infraction will be reported to the dean. THERE ARE NO EXCEPTIONS TO THIS POLICY. Every semester, several students are caught violating this policy and they are reported to the dean. Typically, students use unacknowledged sources on the web. Do not do this. If a homework problem is too hard, start earlier, ask for help, or don't answer the question. If you can't answer some of the questions, you are still a good person who can go on and have a productive life. Academic dishonesty is never the correct solution. Note that allowing someone else to copy your solution is just as serious as copying someone else's solution.

8 Homework Submission Guidelines

- You can submit your homeworks electronically via Courseworks *in pdf format*. You may write solution by hand, in which case you should either scan or photograph your solutions (and transform into the pdf format).
- Homeworks are due on the specified due date at 12:01am (i.e., in practice the day before).
- Please identify yourself and each problem clearly at the top of the page. Write your name and UNI, and the problem number. This will make it easier for the TAs to grade the homeworks and ensure that everything gets recorded properly. Collaborators must be mentioned for each problem.

9 Students with Disabilites

We encourage students with disabilities, including invisible disabilities such as chronic diseases and learning disabilities, to discuss with the instructor any appropriate accommodations that we might make on their behalf.