CSCI 445

Analysis of Algorithms

Fall 2018 MWF 12:55–2:05 pm SCI 131

http://cs.wheaton.edu/~tvandrun/cs445

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Office: SCI 163 Office hours: MTuWF 3:30–4:30pm; Th 9:30–10:30am and 1:00–3:00pm.

Contents

Catalog description. An introduction to algorithmic efficiency and to techniques for the design and analysis of efficient algorithms. General topics include review of asymptotics, algorithm design techniques (such as divide-and-conquer, dynamic programming, and greedy algorithms), graph algorithms, languages and automata, and NP-completeness.

Textbooks.

Cormen et al. *Introduction to Algorithms*, third edition, McGraw Hill / MIT Press, 2009. (See the course website for a link to solutions to some of the problems as found on the book's official website and a link to lectures by one of the book's authors from a class similar to ours.)

Lewis and Papadimitriou. *Elements of the Theory of Computation*, second edition, Prentice Hall, 1998. (The department owns copies for students to borrow.)

Objectives. The general goal of this course is for students to *improve their ability to devise, evaluate, and implement algorithms*. Specific goals are subdivided into five areas. At the end of the course, students should be able to

(1) devise new algorithms using

   a. the divide and conquer pattern
   b. dynamic programming
   c. the greedy approach

(2) prove the correctness of algorithms using loop invariants

(3) analyze the efficiency of algorithms using

   a. worse-case and expected-case analysis
   b. recurrences and the substitution method
   c. the master method
   d. amortized analysis

(4) articulate known algorithmic results

(5) prove the undecidability or intractability of a problem

In addition to these, together we have the general objective of seeing algorithmic work as a creative expression for God's glory and observing what the limitations of computation tell us about God's creation.

OUTLINE. This course is divided into three parts.

Core. This course is mainly about building on earlier courses—especially CSCI 345—to advance your ability to devise algorithms, prove their correctness, analyze their efficiency, and implement them. The first segment of the course reviews and hones the skills you already have and introduces new techniques, tools of understanding, composing, and analyzing algorithms.

- We review topics of algorithm analysis and correctness proof that students have seen in previous courses and make students' skills in these areas stronger and more rigorous.
- We learn analysis concepts and strategies such as asymptotics and complexity classes (big-theta, etc).
- We consider specific techniques for analyzing divide-and-conquer algorithms: recurrences, the substitution method, and the master method.
- We study sorting algorithms at a level of rigor beyond those in earlier courses; some ideas of computational complexity are anticipated as we consider the lower bound for complexity of comparison-based sorting.
- We revisit the dynamic programming technique to give students the ability to devise their own dynamic programming algorithms.
- We consider greedy algorithms and when they are applicable.
- We learn the amortized analysis technique for evaluating an algorithm's efficiency.

Topics. Each semester I chose a handful of specific topics for study and for applying the ideas covered in the core unit. This year I have chosen

- B-trees
- Fast Fourier transform
- Computational geometry

Computational complexity. We study the theory of computation with the goal that students learn the terminology and concepts of the field, the important results, and how to do reductions as used in proofs of undecidability and intractability.

- We learn the background of formal languages and automata
- We learn the theory of universal Turing machines and the Church-Turing thesis
- We consider the formal definition of undecidability and how to prove a problem is undecidable
- We learn the crucial points of computational complexity, especially $\mathcal{P}$ vs $\mathcal{NP}$.
- We learn the concept of $\mathcal{NP}$-completeness and how to prove a problem is $\mathcal{NP}$-complete.

For a schedule, see the course website.

Course procedures

HOW WE DO THIS COURSE. This course's pedagogical style is collaborative practice guided by the textbooks. For most class periods, students will have a textbook reading and practice problems (referred to as *daily work*). In class we will clarify points in the readings, review solutions to practice problems, and work together on new problems.

Students will have more serious problem sets (referred to as *homework*) for turn-in and grading about every week-and-a-half. There will be three mostly-noncumulative tests, two held during class time, the last during the exam block.

DAILY WORK. For almost every class period students will be assigned a reading and set of exercises. These exercises will be inspected for completeness. Much of our class time will be spent discussing the reading and going over solutions to the assigned exercises.

Students should come to class with their solutions written out in a form that can be inspected by the instructor, shown to classmates, displayed on the document camera, etc. I recommend having a notebook for this class and using for taking notes from the readings and from class, as well as writing solutions for daily work and scratch space for the homework.

HOME WORK (PROBLEM SETS). The bulk of the work in this course will be pencil-and-paper(-and-computer) problem sets, usually from the textbook. You are permitted to work together to a reasonable extent. If you work with another person or two, be your own judge that you are making a grade-worthy contribution and receiving the full benefit of the exercise.

Assignments should be turned in electronically. Code portions of a problem should be turned in as source code files; everything else should be turned in as a PDF. I strongly encourage you to write up your solutions using LaTeX. I will provide some help (such as LaTeX source for some of my notes and solutions) to get you started learning LaTeX.

A problem marked as **complete** indicates your solution must include

- a code solution
- unit tests demonstrating the correctness of your solution
- a correctness proof for the algorithm
- a formal analysis of the algorithm's efficiency

See the course website for further details.

GRADING. There will be three mostly-noncumulative tests, currently scheduled for Friday Oct 5, Friday Nov 1, and Wednesday Dec 19, which is our final exam block.

Your *participation score* consists mainly in doing the daily work, with additional points for contributions to class discussion.

Your *homework score* is the sum of your scores on the individual homework assignments plus your participation score (so, your participation score essentially counts as one homework assignment).

Your *semester score* is the geometric mean of your homework score and your scores on the three tests, with homework score counted twice. That is, your semester score is

$$\sqrt[5]{HW^2 \cdot Test1 \cdot Test2 \cdot Test3}$$

The geometric mean is used because it is self-normalizing: the individual tests have different numbers of total points but affect the semester score equally. Note in particular that test 3 is not worth more than the other tests, even though it is held during the exam block.

Letter grades are determined by score clustering. An estimation of semester grade will be given after each test (or more frequently on request).

Policies etc

ACADEMIC INTEGRITY. Collaboration among students in the class is permitted on most assignments.

Many problems you will be assigned are discussed or solved in the computer science literature or on the Internet. Here are the policies for these resources:

- *Using any resource that specifically serves as a solution to exercises in Cormen et al is not permitted on homework.* Students will receive a 0 on the entire assignment for a first violation of this policy.

- Using any outside resource for homework is discouraged. If a student gets ideas, partial solutions, or other help from an outside resource, that resource should be cited as it would be in a research paper. Students will receive a 0 on the assigned problem for a first violation of this policy
- Students are discouraged from using outside resources for help on daily work until after the student has made a fair, independent attempt.

Repeated offenses will be handled through the college's disciplinary procedures and may result in failing the course.

The official website for the textbook includes solutions to selected exercises. The homework sets won't include any problems that have posted solutions there, but the daily work is. As suggested above, it's reasonable to check the solution found there *after* you've made your best attempt.

Late homework. Homework normally will not be accepted late. If an assignment is not complete by the deadline, turn in what you have at that time for partial credit.

Attendance. Students are expected to attend all class periods. It is courtesy to inform the instructor when a class must be missed.

Examinations. Students are expected to take all tests, quizzes, and exams as scheduled. In the case where a test must be missed because of legitimate travel or other activities, a student should notify the instructor no later than one week ahead of time and request an alternate time to take the test. In the case of illness or other emergency preventing a student from taking a test as scheduled, the student should notify the instructor as soon as possible, and the instructor will make a reasonable accommodation for the student. The instructor is under no obligation to give any credit to students for tests to which they fail to show up without prior arrangement or notification in non-emergency situations. The final exam block is Wednesday, Dec 19, at 1:30 PM. Students are not allowed to take the final exam at a different time (except for urgent reasons, approved by the department chair, as per the college's policy), so make appropriate travel arrangements.

Special needs. *Institutional statement:* Wheaton College is committed to providing reasonable accommodations for students with disabilities. Any student with a documented disability needing academic adjustments is requested to contact the Academic and Disability Services Office as early in the semester as possible. Please call 630.752.5941 or send an e-mail to `jennifer.nicodem@wheaton.edu` for further information.

My own statement: If you have a documented need for accommodations, I will have received a letter on your behalf from the Disability Services Office. But *please talk to me* about what accommodations are most useful to you. In particular, if you desire accommodations for test-taking, talk to me a reasonable amount time in advance (say, at least two class periods) so arrangements can be made.

Gender-inclusive language. The college requires the following statement to be included on all syllabi: *For academic discourse, spoken and written, the faculty expects students to use gender inclusive language for human beings.*

Confidentiality and mandatory reporting. I'm committed to help maintain a safe learning environment on campus. As a faculty member I am required to share with College authorities any information about sexual misconduct that may have occurred on Wheaton College's campus. Confidential resources available to students include Confidential Advisors, the Counseling Center, Student Health Services, and the Chaplain's Office. More information on these resources and the college's policies is available at `www.wheaton.edu/sexualassaltresponse`.

Office hours. I try to keep a balance: Stop by anytime, but prefer my scheduled office hours. Any time my door is closed, it means I'm doing something uninterruptible, such as making an important phone call. Do not bother knocking; instead, come back in a few minutes or send me an email.

Dress and deportment. Please dress in a way that shows you take class seriously—more like a job than a slumber party. (If you need to wear athletic clothes because of activities before or

after class, that's ok, but try to make yourself as professional-looking as possible.) If you must eat during class (for schedule or health reasons), please let the instructor know ahead of time; we will talk about how to minimize the distraction.

ELECTRONIC DEVICES. My intent is for class to be an electronic-device-free zone. Please keep all laptops, tablets, phones, etc, silenced and put away. If you absolutely need to check your phone for something, please discreetly step out in to the hall. **NO TEXTING IN CLASS.**