CpSc 8400: Design and Analysis of Algorithms

Instructor: Dr. Brian Dean   Spring 2021
Webpage: `http://www.cs.clemson.edu/~bcdean/`   TTh 12:30-1:45
Handout 1: Course Syllabus   Online Class

1 Overview and Course Goals

The study of algorithms is a significant part of the foundation for the discipline of computing. Over the past several decades, research in algorithmic computer science has advanced at a rapid pace its contributions have had a profound impact on almost every area of science and industry. In this graduate-level course, we aim to provide an introduction to the study of algorithms that is both broad and deep. The primary goals of the course are:

- to become proficient in the application of fundamental algorithm design techniques (e.g., divide and conquer, greedy algorithms, dynamic programming),

- to gain familiarity with the main theoretical tools used in the analysis of algorithms (e.g., recurrences, probability theory, etc.)

- to study and analyze different algorithms for many of the most common types of "standard" algorithmic problems (e.g., sorting, searching, graph problems), and

- to introduce students to some of the prominent subfields of algorithmic study (e.g., computational geometry, randomized algorithms, data structures, etc.) in which they may wish to pursue further study.

The final point is particularly worth noting — the instructor intends this course as well as its successor, CpSc 9400, to serve as a "gateway" for new students with interests in theoretical computer science to learn about opportunities for pursuing further research and studies in areas related to algorithms.

This is a *theory* course. We will occasionally discuss implementation-related issues when appropriate, but for the most part all lectures and assignments will involve the analysis of algorithms in a rigorous mathematical fashion. Many of these are quite elegant and draw on a variety of useful techniques that should serve to broaden and strengthen your analytical abilities.

2 Prerequisites

Students should have taken at least one algorithms course at the undergraduate level, and they should have a reasonable amount of mathematical maturity. Familiarity with basic proof techniques (e.g., induction) and fundamental discrete mathematics (e.g., "Big Oh" notation, combinations and

permutations) is assumed. One of the goals of the class is to illustrate the power and simplicity of randomized algorithms, so familiarity with basic probability theory will be helpful; however, we will briefly review most of this material in class.

3 Tentative List of Topics

The field of algorithms includes far too much interesting material than we can hope to cover in just a single course. In order to cover as much ground as possible, we will move at a fairly fast pace through the semester. The following is a preliminary list of topics the instructor plans to cover. It is subject to change, so we may omit some of these topics (or cover them only at a high level) and we may also cover topics not on this list. Fundamental topics often taught in an introductory algorithms course (e.g., basic sorting algorithms and simple data structures) will be covered at a relatively fast pace, since we assume students already have some familiarity with these concepts.

- **Analysis Techniques.** Solving recurrences, expected and "with high probability" analysis of randomized algorithms, amortized analysis of data structures, basic modular arithmetic.

- **Sorting and Selection.** Insertion sort, bubble sort, merge sort, (randomized) quicksort, heap sort, counting sort, radix sort, bucket sort, stable in-place sorting, randomized and deterministic selection in linear time, lower bounds on comparison-based sorting.

- **Data Structures.** Arrays and linked lists, binary heaps, balanced binary search trees, universal hash tables.

- **Divide and Conquer Algorithms.** Merge sort, quicksort, quickselect, repeated squaring, Strassen's fast matrix multiplication algorithm, the Fast Fourier Transform and its applications, in-place matrix reblocking and transposition.

- **Optimization.** Greedy algorithms, dynamic programming, brief introduction to integer and linear programming and convex continuous optimization. Solving linear and nonlinear systems of equations.

- **Graph Algorithms.** Depth-first and breadth-first search, topological sorting, strongly-connected components, shortest paths, minimum spanning trees, possibly flow and bipartite matching algorithms.

- **Computational Geometry.** Convex hulls, half-space intersection, closest pair and diameter of a set of points, sweep line and randomized incremental construction techniques.

- **Hard Problems.** Approximation algorithms for NP-hard problems, heuristics for solving hard problems: branch and bound, neighborhood search, genetic algorithms, simulated annealing.

- **Number Theory and Cryptography.** Euclid's algorithm, primality testing, key exchange, the RSA public-key cryptosystem.

4 Instructor Information

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Web: http://cs.clemson.edu/~bcdean/
Office Hours: Tuesday 2:00-3:30pm or by appointment

5 Grading

The following items contribute to your grade in this course:

- **Homework (35%).** Assignments will be issued weekly. Homework problems range from simple exercises to more challenging questions asking you to design and analyze new data structures. Each homework problem is worth a certain number of points, indicated on the problem. Homework solutions must be *typeset*, and turned in electronically as a single PDF file via handin.cs.clemson.edu prior to the start of class on the day they are due.

- **2 Quizzes (20% each).** Two quizzes will be given, one in the middle of February and the other near the end of March.

- **Final Exam (25%).** A final exam will be held Monday, April 26, from 3-5:30. The final exam is cumulative, covering all material from the entire course.

Final letter grades are not assigned according to an absolute scale. Based on final numeric scores, the instructor will draw cutoffs between letter grades as deemed appropriate. Plus/minus grading is not used in this course.

As a general policy, an assignment submitted late or lack or participation in a quiz/exam will result in a grade of zero for that particular item. However, the instructor acknowledges that due to the unique circumstances of this semester, additional flexibility may be required in some situations (e.g., if a student encounters technical difficulties during an exam, or if a medical issue arises). Please contact the instructor (as far in advance as possible) in the event of an exceptional circumstance in which you may require special accommodation.

If you feel work graded by a TA has been graded incorrectly, you may request a re-grade from the instructor. However, note that the entire assignment will be re-graded, which could potentially cause your grade to drop.

6 Course Materials

There is no required text for this course. The instructor may post excerpts from a draft of an algorithms textbook he is currently writing (not to be redistributed outside this course). This book is a "dual-media" textbook, presenting high-level concepts in printed text and explanations of technical low-level details using animated multimedia "whiteboard lectures". Lecture slides and videos will also be posted on the course website.

For additional reference material, students may want to consult other prominent algorithms texts (e.g., the book of Cormen, Leiserson, Rivest, and Stein, or the book by Kleinberg and Tardos). One can also find a great deal of useful material on the web, typically in the form of slides and course notes from other universities.

7 Technology Requirements and Course Delivery

A personal computer with a functioning webcam and microphone are required for participation in this course. You will need a reliable internet connection for participating in the remote delivery aspects of the course; if your internet is unreliable, you should email `ithelp@clemson.edu` for assistance.

We will use Canvas for posting all course materials. You are responsible for checking Canvas on a daily basis to stay up-to-date on all assigned work. We will use Zoom for synchronous online course discussions, online labs, and office hours. We might use Slack as an online discussion server for additional course communication between students and the course staff. Zoom (and possibly Slack) links are provided on Canvas. We will use the `handin` website for electronic submission of assignments.

You may not record class meetings without prior permission (most class meetings are already being recorded and posted by the instructor).

8 Course Conduct

- **Attendance.** Although attendance is not mandatory, you are generally expected to arrive on-time for every class meeting. Class attendance and participation will be considered as a "tie breaker" for those with borderline grades. Students may leave class after 15 minutes if the instructor does not arrive by that time. If a student cannot attend class, it is his or her responsibility to obtain notes and other information on the material that was missed.

- **Academic Integrity.** The official university policy on academic integrity is as follows: "As members of the Clemson University community, we have inherited Thomas Green Clemson's vision of this institution as a "high seminary of learning". Fundamental to this vision is a mutual commitment to truthfulness, honor, and responsibility, without which we cannot earn the trust and respect of others. Furthermore, we recognize that academic dishonesty detracts from the value of a Clemson degree. Therefore, we shall not tolerate lying, cheating, or stealing in any form." The instructor of this class values academic integrity *very* highly, and will report any infractions for further disciplinary action. Please ask the instructor if you have any questions on matters of academic integrity (e.g., what constitutes plagiarism).

- **Use of Previous Course Material.** Since some problems are re-used from year to year in this course, it is strictly forbidden to consult any homework solutions from previous years (written by the instructor or by students who have taken the course in previous years). Do not ask students having previously taken the course for specific details on individual homework problems.

- **Use of Web Content.** Please feel free to consult the web for *general* information (e.g., useful mathematical formulae, definitions, supplemental reading on course material). However, you

are not to go looking on the web for information *specifically* related to any particular homework problems. The purpose of the homework is to help you develop your skills at problem-solving, not web searching. Use your best judgment as to what is acceptable and what is not, or if there is any question, you can always ask the instructor.

- **Collaboration.** Collaboration on homework is encouraged to the extent that it is carried out appropriately — with all students involved contributing equally to a discussion of how a concept works or how a problem should be solved, then working independently on writing up solutions. Solution write-ups and code must always be your own individual work. If you do use some material from external sources like books or web pages, you must include appropriate citations for your sources. In addition, on every assignment please list any students with whom you have collaborated.

- **Disabilities.** It is University policy to provide, on a flexible and individualized basis, reasonable accommodations to students who have disabilities. Students are encouraged to contact Student Disability Services to discuss their individual needs for accommodation.

- **Title IX.** Clemson University is committed to a policy of equal opportunity for all persons and does not discriminate on the basis of race, color, religion, sex, sexual orientation, gender, pregnancy, national origin, age, disability, veteran's status, genetic information or protected activity (e.g., opposition to prohibited discrimination or participation in any complaint process, etc.) in employment, educational programs and activities, admissions and financial aid. This includes a prohibition against sexual harassment and sexual violence as mandated by Title IX of the Education Amendments of 1972. The University is committed to combatting sexual harassment and sexual violence. As a result, you should know that University faculty and staff members who work directly with students are required to report any instances of sexual harassment and sexual violence, to the University's Title IX Coordinator. What this means is that as your professor, I am required to report any incidents of sexual harassment, sexual violence or misconduct, stalking, domestic and/or relationship violence that are directly reported to me, or of which I am somehow made aware. There are two important exceptions to this requirement about which you should be aware: Confidential Resources and facilitators of sexual awareness programs such as "Take Back the Night and Aspire to be Well" when acting in those capacities, are not required to report incidents of sexual discrimination. Another important exception to the reporting requirement exists for academic work. Disclosures about sexual harassment, sexual violence, stalking, domestic and/or relationship violence that are shared as part of an academic project, a research project, classroom discussion, or course assignment, are not required to be disclosed to the University's Title IX Coordinator. This policy is located at `http://www.clemson.edu/campus-life/campus-services/access/title-ix/`. Ms. Alesia Smith is the Executive Director for Equity Compliance and the Title IX Coordinator. Her office is located at 223 Holtzendorff Hall, phone number is 864.656.3181, and email address is `alesias@clemson.edu`.

9   Accessibility

Clemson University values the diversity of our student body as a strength and a critical component of our dynamic community. Students with disabilities or temporary injuries/conditions may require accommodations due to barriers in the structure of facilities, course design, technology used for curricular purposes, or other campus resources. Students who experience a barrier to full access to

a class should let the professor know, and make an appointment to meet with a staff member in Student Accessibility Services as soon as possible. You can make an appointment by calling 864-656-6848 or by emailing `studentaccess@lists.clemson.edu`. Students who receive Academic Access Letters are strongly encouraged to request, obtain and present these to their professors as early in the semester as possible so that accommodations can be made in a timely manner. It is the student's responsibility to follow this process each semester. You can access further information here: `http://www.clemson.edu/campus-life/campusservices/sds/`

10   Technical Difficulties and Inclement Weather

If the instructor has technical difficulties, students should use the available class time to review the lecture content and work on assignments. If the problems persist, the instructor will then try to make a recording of the missed lecture available on Canvas. If you have technical difficulties with an online session involving a graded exercise, inform the instructor/TAs as soon as possible via email and/or our online chat server; take a screen shot of the issue if possible for documentation. For general technical issues, try contacting `ithelp@clemson.edu` for assistance.

Any exam that was scheduled at the time of a class cancellation due to inclement weather, University power outage, etc. will be given at the next class meeting unless otherwise noted by the instructor.

11   Feedback

Please feel welcome to ask for feedback on your performance in the class at any time. In addition, please feel welcome to send constructive feedback to your instructor at any time — your instructor places a great deal of value on the ability to present challenging material in manner that is clear, well motivated, and fun, and he appreciates any feedback you can offer on how to improve the quality of the course.

12   Syllabus Modifications

Lecture topics and course delivery details are subject to change, particularly given the uncertainties inherent in this semester due to the global pandemic. The course syllabus is a general plan for the course. Should deviations be necessary, they will be announced to the class and posted on Canvas.