CS 231: Algorithmic Problem Solving

University of Waterloo

Term and Year of Offering: Spring 2020

Course Number and Title: CS 231, Algorithmic Problem Solving

Lecture Times, Building and Room Number: Online

Instructor's Name, Contact Information, Office Hours: Naomi Nishimura, nishi@uwaterloo.ca, TBA

IA's Name, Contact Information, Office Hours:

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Course Description:

The study of the steps required to solve real-world problems on a computer, including problem specification, choice of algorithm paradigm, analysis, and implementation. Topics include exhaustive search, divide and conquer, greedy, and dynamic programming approaches.

Course Objectives: At the end of the course you should be able to:

- Describe the steps taken in solving a real-world problem on a computer.
- Explain and use the concepts of asymptotic running time, order notation, worst-case, average-case, and best-case complexity, and lower and upper bounds. Given a simple algorithm written in pseudocode, determine and informally justify its asymptotic running time, as expressed in order notation.
- Describe situations in which the greedy paradigm is applicable and situations in which it yields an efficient algorithm. Given a simple problem, be able to form a greedy algorithm, and, when appropriate, form an example input that shows its inefficiency.
- Describe situations in which divide-and-conquer can be applied and those in which it is unsuitable. Given a suitable problem, form an algorithm that uses divide-and-conquer and analyze it using recurrence relations.
- Describe situations in which dynamic programming can be used. Given a suitable problem, form and analyze a dynamic-programming algorithm.
- Explain various methods for exploring the search space, including exhaustive search, backtracking, and branch-and-bound. Given a simple problem, form an algorithm using one of these methods and informally analyze the asymptotic running time, as expressed in order notation.
- Explain the notions of hardness, reduction, and lower bounds.
- Explain how various approaches, such as approximation algorithms and heuristics, can be used on hard problems.
- Write, test, and debug programs in the Python language that incorporate the ideas described above.

Optional Text: Anany Levitin, *Introduction to the Design and Analysis of Algorithms*, 3rd ed. Pearson, 2011.

Readings: Supplementary reading material will be available on the course website.

Topics to be covered in lectures:

Module 1: Introduction

Topics: Introduction, course goals, types of problems, exhaustive search

Module 2: Comparing problems and solutions

Topics: Comparing problems, models of computation, pseudocode, asymptotic notation, analyzing algorithms, analyzing exhaustive search

Module 3: Greedy approach

Topics: Scheduling events, making change, fractional knapsack, single-source cheapest paths, spanning tree

Module 4: Divide-and-conquer

Topics: Binary search, sorting, solving recurrence relations, maximum subtotal, matrix multiplication

Module 5: Dynamic programming

Topics: Matrix-chain multiplication, longest common subsequence, all-pairs cheapest paths

Module 6: Hardness of problems

Topics: Complexity, polynomial time, lower bounds, decision trees, adversary lower bounds, reductions, NP-completeness

Module 7: Compromising on speed

Topics: Search trees, backtracking, branch and bound, fixed-parameter algorithms, Las Vegas algorithms

Module 8: Compromising on correctness

Topics: Approximation algorithms, Monte Carlo algorithms, heuristics

Evaluation:

Marks in the course will be calculated as follows:

- Assignments: 60%
- Quizzes: 20%
- Final assessment: 20%

Students should periodically check recorded marks (using MarkUs) for accuracy.

Notes:

- You must pass the final assessment in order to pass the course.
- Each assignment has the same weight towards the overall mark.

Assignment policies:

All assignments must be completed individually in this course. The solutions you submit must be entirely your own work. Do not look up full or partial solutions on the Internet or in printed sources.

No late assignments will be accepted. We do not accept assignments that are emailed to course personnel.

Assignments consist of written and programming components.

Submit both types of components electronically using MarkUs.

Academic Integrity, Intellectual Property, Grievance, Discipline, Discipline, Avoiding Academic Offices, Appeals, and Note for Students with Disabilities: see www.uwaterloo.ca/current-undergraduate-students/academic-integrity-and-students-disabilities The text for this web site is listed below:

Academic Integrity

In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. Check the Office of Academic Integrity's website for more information.
All members of the UW community are expected to hold to the highest standard of academic integrity in their studies, teaching, and research. This site explains why academic integrity is important and how students can avoid academic misconduct. It also identifies resources available on campus for students and faculty to help achieve academic integrity in — and out — of the classroom.

Intellectual Property

Students should be aware that this course contains the intellectual property of their instructor, TA, and/or the University of Waterloo. Intellectual property includes items such as:

- Lecture content, spoken and written (and any audio/video recording thereof)
- Lecture handouts, presentations, and other materials prepared for the course (e.g., PowerPoint slides)
- Questions or solution sets from various types of assessments (e.g., assignments, quizzes, tests, final exams)
- Work protected by copyright (e.g., any work authored by the instructor or TA or used by the instructor or TA with permission of the copyright owner).

Course materials and the intellectual property contained therein, are used to enhance a student's educational experience. However, sharing this Intellectual property without the intellectual property owner's permission is a violation of intellectual property rights. For this reason, it is necessary to ask the instructor, TA and/or the University of Waterloo for permission before uploading and sharing the intellectual property of others online (e.g., to an online repository).
Permission from an instructor, TA or the University is also necessary before sharing the intellectual property of others from completed courses with students taking the same/similar courses in subsequent terms/years. In many cases, instructors might be happy to allow distribution of certain materials. However, doing so without expressed permission is considered a violation of intellectual property rights.

Grievance

A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70 — Student Petitions and Grievances, Section 4. When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline

A student is expected to know what constitutes academic integrity, to avoid committing academic offenses, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offense, or who needs help in learning how to avoid offenses (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course professor, academic advisor, or the Undergraduate Associate Dean. For information on categories of offenses and types of penalties, students should refer to Policy 71 — Student Discipline. For typical penalties, check Guidelines for the Assessment of Penalties.

Avoiding Academic Offenses

Most students are unaware of the line between acceptable and unacceptable academic behaviour, especially when discussing assignments with classmates and using the work of other students. For information on commonly misunderstood academic offenses and how to avoid them, students should refer to the Faculty of Mathematics Cheating and Student Academic Discipline Policy.

Appeals

A decision made or a penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 — Student Appeals.

Note for students with disabilities

The AccessAbility office is located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.

Mental Health: If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support.

On-campus Resources

- Campus Wellness https://uwaterloo.ca/campus-wellness/
- Counselling Services: counselling.services@uwaterloo.ca / 519-888-4567 ext 32655 / Needles Hall North 2nd floor, (NH 2401)
- MATES: one-to-one peer support program offered by Federation of Students (FEDS) and Counselling Services: mates@uwaterloo.ca
- Health Services service: located across the creek from Student Life Centre, 519-888-4096.

Off-campus Resources

- Good2Talk (24/7): Free confidential help line for post-secondary students. Phone: 1-866-925-5454
- Here 24/7: Mental Health and Crisis Service Team. Phone: 1-844-437-3247
- OK2BME: set of support services for lesbian, gay, bisexual, transgender or questioning teens in Waterloo. Phone: 519-884-0000 extension 213

Diversity: It is our intent that students from all diverse backgrounds and perspectives be well served by this course, and that students' learning needs be addressed both in and out of class. We

recognize the immense value of the diversity in identities, perspectives, and contributions that students bring, and the benefit it has on our educational environment. Your suggestions are encouraged and appreciated. Please let us know ways to improve the effectiveness of the course for you personally or for other students or student groups. In particular:

- We will gladly honour your request to address you by an alternate/preferred name or gender pronoun. Please advise us of this preference early in the semester so we may make appropriate changes to our records.
- We will honour your religious holidays and celebrations. Please inform of us these at the start of the course.
- We will follow AccessAbility Services guidelines and protocols on how to best support students with different learning needs.