Algorithms: Design and Analysis

CS 412 L1

Spring Semester 2023

“An algorithm must be seen to be believed.” – Donald E. Knuth

"Executing algorithms is boring, but designing them is interesting, intellectually challenging, and a central part of computer science." - Allen Downey

Course Information

Class Location: E-003
Class Meeting Time(s): Mon Thurs (11:30 AM-12:45 PM)
This course is part of CS Kernel. It fulfills the “SSE Elective” and “Free Elective” categories for all other students. It also fulfills the requirement for a CS minor.

Instructor Information

Instructor: Waqar Saleem
Title: Associate Professor, CS
Office Location: C-122
Email: waqar.saleem@sse.habib.edu.pk
Office Hours: TBD

Course Description

Computer Science is arguably the inventing, improving, adapting, analyzing, designing, and implementing of algorithms. The study of algorithms provides budding computer scientists like you a glimpse of the ingenuity that is the hallmark of the community you are about to join. It provides you an effective toolset to solve problems and critique solutions.

This course explores certain *classes* of algorithms and provides useful tools to analyze algorithms. The algorithms under study are selected for being useful, instructive, beautiful, or any combination thereof.

This course also marks the culmination and is the crowning glory of the CS Kernel. It will make you conversant in the language of algorithms, which is a chief component of technical interviews and software-related jobs.

Course Aims

This course aims to:

- introduce algorithm design techniques by studying a few representative algorithms from each class
- develop proficiency in the analysis of a given algorithm
- develop proficiency in the design of an algorithm that meets a given set of requirements and constraints
- inculcate comfort with and a high level of reasoning about algorithms

Course Learning Outcomes (CLOs)

By the end of the course, students will be able to:

CLO	Outcome	Learning-Domain Level
CLO 01	Identify commonly used algorithmic techniques	Cog – 2
CLO 02	Apply common algorithmic techniques to standard computational problems	Cog – 3
CLO 03	Design algorithms for different computational problems under given constraints	Cog – 5
CLO 04	Analyze an algorithm to construct proofs of its correctness and time complexity	Cog – 6

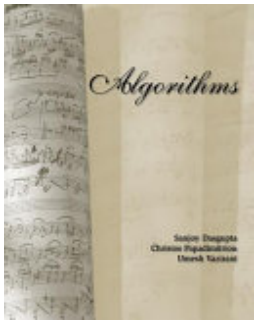
CLO	Outcome	Learning-Domain Level
CLO 05	Collaborate fruitfully on the solution, research, and presentation of problems, proofs, and techniques related to the above topics	Aff – 3

Mode of Instruction

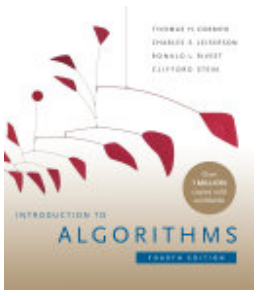
Instruction in higher education all over the world has vacillated unpredictably between in-person and online for more than two years, leading to at least one important lesson. We do not like remote, online learning or instruction. To every extent possible, this course will take place in person. We will meet twice a week for 75-minute lectures and once a week for a 50-minute recitation.

In the unfortunate circumstance where we need to go online, relevant instructions will be shared accordingly. For that contingency, you should have a computer with an internet connection that is capable of running a latest browser version and Zoom.

Required Texts and Materials

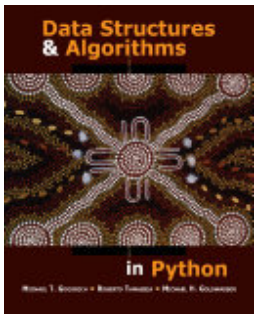


Algorithms
ISBN: 9780073523408
Authors: Umesh Vazirani, Algorithms, Christos H. Papadimitriou, Algorithms, Sanjoy Dasgupta, Algorithms
Publisher: McGraw-Hill Education
Publication Date: 2006-09-13

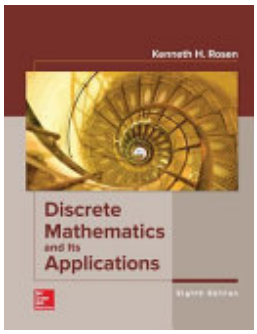


Introduction to Algorithms, fourth edition
ISBN: 9780262046305
Authors: Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, Clifford Stein
Publisher: MIT Press
Publication Date: 2022-04-05

Data Structures and Algorithms in Python
ISBN: 9781118476734
Authors: Michael T. Goodrich, Roberto Tamassia, Michael H. Goldwasser



Publisher: Wiley Global Education
Publication Date: 2013-03-08



Discrete Mathematics and Its Applications
ISBN: 9781259676512
Authors: Kenneth H. Rosen
Publisher: McGraw-Hill
Publication Date: 2018-05-01

Assessments

A breakdown of course grades (minor changes will be made as the semester progresses):

Assessment type	Quantity	Weight (%)	Remarks
Homework Assignments	2	15	Review and practice problems on covered content. These are attempted *in teams*, released and submitted *via GitHub*, and typeset in *LaTeX*.
Quizzes	5	20	Quizzes are attempted *individually* in class on paper. The *best 4* will count toward your grade.
Weekly Challenges	~15	20	A challenge comprises a few questions on recent content. It is attempted *individually* unless specified otherwise. There is a challenge almost every week. These are typically released and submitted *via GitHub*, and typeset in *LaTeX*. The *best 10* will count toward your grade.
Project	01	10	This is a research project to be attempted *in teams*. Your team will *present* its research to the class toward the end of the term and submit a *report*.
Recitation	~15	5	Attendance and participation in weekly recitations.
Midterm Exam	01	15	The exam is cumulative and attempted *individually*.

Assessment type	Quantity	Weight (%)	Remarks
Final Exam	01	15	The exam is cumulative and attempted *individually*.

You may be called in by the course staff for a viva on your submission for any of the assessments. Your performance on the viva will affect your earned score on the assessment.

Late Submission Policy

You must submit all assessments no later than the announced deadline. However, with special approval from your instructor, you may submit late within the faculty's assigned deadline with a 10% late submission penalty.

Grading Scale

Letter Grade	GPA Points	Percentage
A+	4.00	[95-100]
A	4.00	[90-95)
A-	3.67	[85-90)
B+	3.33	[80-85)
B	3.00	[75-80)
B-	2.67	[70-75)
C+	2.33	[67-70)
C	2.00	[63-67)
C-	1.67	[60-63)
F	0.00	[0, 60]

Note: [*a*, *b*) is a range of numbers from *a* to *b* where *a* is included in the range and *b* is not.

Week-Wise Schedule (Tentative)

The schedule may change in view of class progress as the semester proceeds. All indicated chapters under Reading are from the text book. See the Live Syllabus for an updated version.

Week	Start	End	Topic(s)	Reading	Assessments etc.*
1	9-Jan	13-Jan	**Introduction** Course syllabus	CLRS: Chapters 1, 2, 3	

			Basics of algorithm analysis Computational tractability A refresher on asymptotic notations	Dasgupta: 0.2, 0.3 DSAP: 3.2.1, 3.3 Rosen: 3.2	
2	16-Jan	20-Jan	**Searching and Sorting** A lower bound on Sorting Solving linear recurrences	CLRS: 8.1, 4.3, 4.4, 4.5 Rosen: 8.2 DSAP: 12.4.1	Quiz 1
3	23-Jan	27-Jan	**Searching and Sorting** A lower bound on Sorting Solving linear recurrences	CLRS: 8.1, 4.3, 4.4, 4.5 Rosen: 8.2 DSAP: 12.4.1	
4	30-Jan	3-Feb	**Divide and Conquer algorithms** Analysis of Merge Sort Proof of Master Theorem and solving recurrences Maximum Subarray Problem other problems.	CLRS: 2.3, 4.1, 4.6 Dasgupta: 2.2, 2.3 DSAP: 12.2 Rosen: 8.3	HW 1 out
5	6-Feb	10-Feb	**Divide and Conquer algorithms** Analysis of Merge Sort Proof of Master Theorem and solving recurrences Maximum Subarray Problem other problems.	CLRS: 2.3, 4.1, 4.6 Dasgupta: 2.2, 2.3 DSAP: 12.2 Rosen: 8.3	Quiz 2
6	13-Feb	17-Feb	**Graph algorithms-I** Directed acyclic graphs Topological ordering Connected and strongly-connected components. Planar graphs	CLRS: 22.1 - 22.5 Dasgupta: 3.4 DSAP: 14.1, 14.5	HW 1 due
7	20-Feb	24-Feb	**Graph algorithms-I** Directed acyclic graphs Topological ordering Connected and strongly-connected components. Planar graphs	CLRS: 22.1 - 22.5 Dasgupta: 3.4 DSAP: 14.1, 14.5	
8	27-Feb	3-Mar	**Graph algorithms-II** Maximum Flow Problem Ford-Fulkerson method Max-Flow-Min-Cut algorithm	CLRS: 26.1, 26.2 Dasgupta: 7.2	Midterm Exam
9	6-	10-	**Dynamic Programming-I**	CLRS: 15.1 - 15.4	

	Mar	Mar	Matrix-Chain multiplication Longest Common Subsequence and related problems.	Dasgupta: 6.5, 6.2	
10	13-Mar	17-Mar	**Dynamic Programming-II** Finding the shortest path in dags Edit distance and related problems. Knapsack problem	CLRS: 25.1, 25.2 Dasgupta: 6.1, 6.3, 6.4	Quiz 3
11	20-Mar	24-Mar	**Greedy algorithms-I** Dijkstra's algorithm Finding minimum spanning trees	CLRS: 24.3, 23.1, 23.2 Dasgupta: 4.4, 5.1 DSAP: 14.6.2, 14.7 Rosen 10.6	
12	27-Mar	31-Mar	**Greedy algorithms-II** Knapsack problem Huffman Coding [optional]	CLRS: 16.1, 16.2 CLRS: 16.3 (optional) Dasgupta: 5.2 (optional)	HW 2 out
13	3-Apr	7-Apr	**Randomized algorithms** Analysis of Quickselect Analysis of Quicksort	CLRS: 7, 9.2 Dasgupta: 2.4 Rosen 6, 7	
14	10-Apr	14-Apr	**Randomized algorithms** Analysis of Quickselect Analysis of Quicksort	Dasgupta: 2.4 Rosen 6, 7	Quiz 4
15	17-Apr	21-Apr	Project presentations		HW 2 due
15.5	24-Apr	28-Apr	Project presentations		Quiz 5
		Exam Period			Final exam

* - a weekly challenge will take place on most weeks.

Academic Integrity

Each student in this course is expected to abide by the Habib University Student Honor Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work.

Scholastic dishonesty shall be considered a serious violation of these rules and regulations and is subject to strict disciplinary action as prescribed by Habib University regulations and policies.

Scholastic dishonesty includes, but is not limited to, cheating on exams, plagiarism on assignments, and collusion.

a. Plagiarism: Plagiarism is the act of taking the work created by another person or entity and presenting it as one's own for the purpose of personal gain or of obtaining academic credit. As per University policy, plagiarism includes the submission of or incorporation of the work of others without acknowledging its provenance or giving due credit according to established academic practices. This includes the submission of material that has been appropriated,// bought, received as a gift, downloaded, or obtained by any other means. Students must not, unless they have been granted permission from all faculty members concerned, submit the same assignment or project for academic credit for different courses.
b. Cheating: The term cheating shall refer to the use of or obtaining of unauthorized information in order to obtain personal benefit or academic credit.
c. Collusion: Collusion is the act of providing unauthorized assistance to one or more person or of not taking the appropriate precautions against doing so.

All violations of academic integrity will also be immediately reported to the Student Conduct Office.

You are encouraged to study together and to discuss information and concepts covered in lecture and the sections with other students. You can give "consulting" help to or receive "consulting" help from such students. However, this permissible cooperation should never involve one student having possession of a copy of all or part of work done by someone else, in the form of an e-mail, an e-mail attachment file, a diskette, or a hard copy.

Should copying occur, the student who copied work from another student and the student who gave material to be copied will both be in violation of the Student Code of Conduct.

During examinations, you must do your own work. Talking or discussion is not permitted during the examinations, nor may you compare papers, copy from others, or collaborate in any way. Any collaborative behavior during the examinations will result in failure of the exam, and may lead to failure of the course and University disciplinary action.

Penalty for violation of this Code can also be extended to include failure of the course and University disciplinary action.

Program Learning Outcomes (For Administrative Review)

Upon graduation, students will have the following abilities:

- PLO 1: Analysis: Analyse a given situation and reduce it to one or more problems that can be solved via computer intervention.

- PLO 2: Design: Design one or more computer-based solutions of a given problem and select the solution that is best under the circumstances.
- PLO 4: Implementation: Design and implement software systems of varying complexity.
- PLO 6: Self-learning: Research, learn, and apply requirements needed to implement a solution for a given high level problem description.
- PLO 8: Communication and Teamwork: Work effectively in inter-disciplinary teams.

Program Learning Outcomes (PLOs) mapped to Course Learning Outcomes (CLOs)					
	CLOs of the course are designed to cater following PLOs: PLO 1: Analysis PLO 2: Design PLO 4: Implementation PLO 6: Self-learning PLO 8: Communication and Teamwork				
	Distribution of CLO weightages for each PLO				
	CLO 1: Identify	**CLO 2: Apply**	**CLO 3: Design**	**CLO 4: Analyze**	**CLO 5: Collaborate**
PLO 1					
PLO 2					
PLO 4					
PLO 6					
PLO 8					

Mapping of Assessments to CLOs

Assignments	**CLO 1: Identify**	**CLO 2: Apply**	**CLO 3: Design**	**CLO 4: Analyze**	**CLO 5: Collaborate**
Homework Assignments					
Quizzes					
Weekly Challenges					
Project					
Recitations					

Midterm Exam					
Final Exam					

Recording Policy

Only asynchronous and synchronous online sessions will be recorded and uploaded on our Video Management System (Panopto). Link to the folder of recordings will be available to all students. Hyflex classes might be recorded if faculty deems it appropriate.

Accommodations for Students with Disabilities

In compliance with the Habib University policy and equal access laws, I am available to discuss appropriate academic accommodations that may be required for student with disabilities. Requests for academic accommodations are to be made during the first two weeks of the semester, except for unusual circumstances, so arrangements can be made. Students are encouraged to register with the Office of Academic Performance to verify their eligibility for appropriate accommodations.

Inclusivity Statement

We understand that our members represent a rich variety of backgrounds and perspectives. Habib University is committed to providing an atmosphere for learning that respects diversity. While working together to build this community we ask all members to:

- share their unique experiences, values and beliefs
- be open to the views of others
- honor the uniqueness of their colleagues
- appreciate the opportunity that we have to learn from each other in this community
- value each other’s opinions and communicate in a respectful manner
- keep confidential discussions that the community has of a personal (or professional) nature
- use this opportunity together to discuss ways in which we can create an inclusive environment in this course and across the Habib community

Attendance Policy

You are expected to attend and participate in all lectures. Under extenuating circumstances, you may miss up to 04 lectures. Missing recitations will lead to a loss of marks in them. In case of a missed session, you must inform the relevant instructor. Failing to do so may raise an early academic alert with the Office of Academic Performance (OAP). Excessive absences will lead to an automatic withdrawal from the course.

Office Hours Policy

Every student enrolled in this course must meet individually with the course instructor during course office hours at least once during the semester. The first meeting should happen within the first five weeks of the semester but must occur before midterms. Any student who does not meet with the instructor may face a grade reduction or other penalties at the discretion of the instructor and will have an academic hold placed by the Registrar’s Office.