QBIO 570 Introduction to data structures and algorithms for science

Units: 4
Fall 2024 Semester
Lecture: Mondays and Wednesdays, 10:00-11:20 am
Discussion: Thursday, 10:00-10:50 am
Location: RRI 301

Instructor: Tsu-Pei Chiu, PhD
Office: RRI 413J
Office Hours: Fridays, 3:00-5:00 pm, or by appointment
Contact Info: tsupeich@usc.edu

Instructor: Jinsen Li, PhD
Office: RRI 413G
Office Hours: TBD
Contact Info: jinsenli@usc.edu

Teaching Assistant: Yibei Jiang
Office: RRI 413K
Office Hours: Mondays, 11:30-12:30 am, or by appointment
Contact Info: yibeijia@usc.edu

Short Description

An introduction to scientific data analysis; fundamentals of data structures and algorithms; specialized algorithms used in the sciences; challenges posed by large data sets.

Course Description

This course covers fundamental techniques in data structures and algorithms. Topics include sorting and searching, basic to advanced data structures, greedy algorithms, dynamic programming, graph algorithms, NP-completeness. Through this course students will learn how to reason about computing problems that arise in scientific data analysis, and how to overcome the challenges presented by modern large-scale scientific data sets.

Learning Objectives

Through this course students will develop conceptual tools to reason about performance of existing software and code libraries or packages that are used for large-scale data analysis. On completion of this course, students will be able to design efficient and correct solutions when programming for scientific data analysis by understanding a broad set of data structures and algorithmic techniques. Students will gain a foundation of knowledge to support deeper understanding of more specialized algorithms used in areas of the sciences. Additionally, students will be able to use theoretical methods to guide the selection of data analysis approaches and problem formulations, including when to leverage parallelization, apply randomness, or aim for approximations.

Prerequisite(s): None
Co-Prerequisite(s): None
Concurrent Enrollment: None
Recommended Preparation: No previous coursework in data structures or algorithms is required.

Course Notes
Letter grade, 4 credits. Lectures and sample material posted on Brightspace.

Technological Proficiency and Hardware/Software Required
Assignments require access to a personal computer and network connection.

Suggested Readings and Supplementary Materials
Texts below are indicated with a code used in the schedule.
Primary text:
[CLRS] Cormen, T. H., Leiserson, C. E., Rivest, R. L., & Stein, C. (2022). Introduction to algorithms. MIT press. (online through USC libraries)

Additional texts for specific topics:
[S] Skiena SS (2020). The Algorithm Design Manual (3rd edition). Springer International Publishing. (online through USC libraries)
[AHU] Aho AV, Hopcroft JE & Ullman JD (1974). The design and analysis of computer algorithms. Addison Wesley Pub. Co.
[HSR] Horowitz E, Sahni S & Rajasekaran S (1997). Computer Algorithms. Macmillan.

Background:
Discrete mathematics: Graham R, Knuth D, Patashnik O (1994). Concrete Mathematics: A Foundation for Computer Science (2nd edition). Addison-Wesley Professional. (online through USC libraries) - Graphs: Harary F (1999). Graph theory. Perseus Books. (online through USC libraries)

Description and Assessment of Assignments
Assignments will be a combination of theoretical written exercises and problems sets, and programming assignments. Students will not need a background in any specific programming language to be capable of completing the assignments. Written exercises will be assessed on correctness and clarity. Programming assignments should be fulfilled by pseudocode and will need to be accompanied by a demonstration that the implementation correctly solves the required problems.

Grading Breakdown

Assessment	Points	% of Grade
Homework (5)	40	40
Midterm	30	30
Final	30	30
Total	100	100

Assignment Submission Policy
Written assignments are due at the beginning of lecture on the due date. Electronic reports are due by midnight on the due date and must be submitted via Brightspace.

Grading Timeline
Homeworks and tests will be graded within one week of submission.

Academic Integrity
The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the USC Student Handbook. All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Course Content Distribution and Synchronous Session Recordings Policies
USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relationship to the class, whether obtained in class, via email, on the internet, or via any other media. (Living our Unifying Values: The USC Student Handbook, page 13).

Course Schedule

	Topics/Daily Activities	Readings/ Preparation	Deliverables
Week 1	**Introduction to Algorithms:** Basics of algorithms, complexity and asymptotic analysis, models of computation, implementing algorithms and experimentation.	[CLRS] chapter 1, 2, and 3; [AHU] selections from chapter 1; [HSR] selections from chapter 1.	
Week 2	**Sorting and Divide and Conquer I** Insertion sort, merge sort, recurrence relations and the Master Theorem	[CLRS] chapters 2.1, 6, 7 and 8.	
Week 3	**Sorting and Divide and Conquer II** Quick sort, selection sort, counting sort, radix sort	[CLRS] chapters 4, 6, 7 and 8.	Assignment #1
Week 4	**Data Structures** Contiguous and linked data structures, linked lists, stacks, queues, dequeues, circular buffers, hashing and hash tables	[CLRS] chapters 10, 11, and 12	
Week 5	**Advanced Data Structures and Searching** Introduction to trees, binary trees, binary search trees, Red-Black and AVL trees	[CLRS] chapter 12, 13;	Assignment #2
Week 6	**Graph Algorithms I** Graph terminology and representations, depth-first search (DFS), breadth-first search (BFS), topological sorting	[CLRS] chapter 20; [S] chapter 5	
Week 7	**Graph Algorithms II** Kruskal's, Prim's, Dijkstra's, and Bellman-Ford algorithms	[CLRS] chapter 22, 23.	Assignment #3
Week 8	**Review and Midterm**		
Week 9	**Greedy Algorithms** Introduction, simple problems, Huffman encoding, Set cover, minimum spanning tree revisited	[CLRS] chapter 15;	
Week 10	**Dynamic Programming I** Introduction, Fibonacci numbers, Matrix chain multiplication, Longest common subsequence	[CLRS] chapter 14 [S] chapter 10	
Week 11	**Dynamic Programming II** 0/1 knapsack, traveling salesman problem, edit distance, bellman-ford algorithm revisited	[CLRS] chapter 14 [S] chapter 10	Assignment #4

Week 12	**String Algorithms** Introduction, naive string matching, Knuth-Morris-Pratt (KMP) algorithm, Rabin-Karp algorithm	[CLRS] chapter 32	
Week 13	**NP-Completeness** Introduction, P vs NP problem, polynomial-time reductions, Cook-Levin theorem	[CLRS] chapter 34 [S] chapter 11	
	Linear Programming Introduction, simplex algorithm	[CLRS] chapter 29	
Week 14	**Advanced Graph Algorithms:** Network flow: Introduction, Ford-Fulkerson method, max-flow min-cut theorem, Edmonds-Karp algorithm	[CLRS] chapter 23, 24 [S] chapter 8.5	Assignment #5
	All-pairs shortest paths: Floyd-Warshall algorithm, Johnson's algorithm	[S] chapter 8.3	
Week 15	**Selected topics:** **Parallel Algorithms:** Introduction, parallel sorting algorithms, parallel graph algorithms	[CLRS] chapter 26	
	Randomized Algorithms Introduction, randomized quick sort, Monte Carlo and Las Vegas algorithm, randomized algorithms for graph problems	[CLRS] chapter 5.3 [S] chapter 6	
	Approximation Algorithms Introduction,primal-dual method, local search heuristics, approximation schemes	[CLRS] chapter 35 [S] chapter 12	
Final	**Final exam**		

Statement on Academic Conduct and Support Systems

Academic Integrity:
The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, compromises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - *(213) 740-9355 – 24/7 on call*
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - *988 for both calls and text messages – 24/7 on call*
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services

(though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - *(213) 740-9355(WELL) – 24/7 on call*
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - *(213) 740-5086*
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - *(213) 740-5086 or (213) 821-8298*
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - *(213) 740-0776*
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - *(213) 740-0411*
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - *(213) 740-2101*
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - *UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call*
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - *UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call*
Non-emergency assistance or information.

Office of the Ombuds - *(213) 821-9556 (UPC) / (323-442-0382 (HSC)*
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - *(323) 442-2850 or* otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health promoting habits and routines that enhance quality of life and academic performance.