ASU Online
Arizona State University

Foundations of Algorithms (CSE 551)

Note: The information and course outline below are subject to modifications and updates.

About this Course

Algorithms, or a step-by-step process to efficiently reach a desired goal, have been part of human history since the 1200's. Algorithms are a fundamental component to any computerized system. In this foundational course, you will learn learn several different algorithms and be able to explain how they work and why they are considered good. This will help you:

(1) Evaluate appropriate algorithmic techniques that can lead to more efficient solutions for a problem, instead of just coding the first idea that comes to mind
(2) Develop sound background knowledge on algorithms that will allow you to navigate the literature, beyond the context of this class.

In order to achieve this, you will have to work through and understand several algorithmic techniques and the mathematical background necessary for analyzing the properties of these techniques and the algorithms based on them.

Specific topics covered include:

- Greedy Algorithms
- Divide-and-Conquer
- Dynamic Programming
- Amortized Analysis
- Graph Algorithms
- Network Flows
- NP-completeness

Required Prior Knowledge and Skills

- Basic understanding of Asymptotic Notation (Big-Oh), recurrence relations, proofs, Recursion, Worst-Case Analysis, and basic discrete math (e.g., sets, functions, logic, graphs, etc.).
- Understanding of basic data structures and algorithms such as Sorting Algorithms, Hash Tables, Binary Search Trees, Heaps, and Red-Black Trees.
- Basic understanding of Greedy Algorithms, Divide-and-conquer, Dynamic Programming.

- Basic understanding of Graph Algorithms such as Depth-First Search, Breadth-First Search, Minimum Spanning Trees (Kruskal's and Prim's algorithms), and Shortest-paths (Dijkstra's algorithm).

Learning Outcomes

Learners completing this course will be able to:

- Identify and apply algorithmic techniques to solve a problem
- Apply knowledge of algorithms in multiple contexts using multiple programming languages
- Evaluate correctness and efficiencies of algorithms

Course Content

Instruction

- Video lectures
- Other videos (animations, demos, etc.)
- Readings
- Live sessions (office hours, webinars, etc.)

Assessments

- Practice activities and quizzes (auto-graded)
- Practice assignments (instructor- or peer-reviewed)
- Team and/or individual project(s) (instructor-graded)
- Midterm or final exam (proctored, auto-and/or instructor-graded)

Major Project

Description: A team project focusing on algorithmic application to a computer programming problem with each student being an individual contributor to the project work. The team will work to fulfill customer expectations by translating user stories into functionality and features. Project will utilize an agile project methodology.

Artifact: Source code for the network and reports documenting the experimental results

Estimated Workload/ Time Commitment Per Week

Approximately 18-20 hours per week.

Technology Requirements

Hardware

TBD

Software and Other

TBD

Course Outline

Unit 1: Stable Matching

Module 1: Solving Stable Matching Problem with Algorithms
Module 2: Well-known Problems in Algorithms

Unit 2: Greedy Algorithms

Module 1: Interval Scheduling and Interval Partitioning
Module 2: Scheduling to Minimize Lateness
Module 3: Optimal Offline Caching
Module 4: Further Examples of Greedy Algorithms

Unit 3: Amortized Analysis and Splay Trees

Module 1: Amortized Analysis
Module 2: Splay Trees

Unit 4: Programming abstractions for the blockchain

Module 1: General Techniques
Module 2: Closest Pair of Points
Module 3: Integer Multiplication and Matrix Multiplication

Unit 5: Blockchain Consensus

Module 1: General Techniques
Module 2: Weighted Interval Scheduling
Module 3: Knapsack

Module 4: Shortest Path: Bellman-Ford

Unit 6: Network Flows

Module 1: Ford-Fulkerson Algorithm
Module 2: Max Flow-Min Cut Theorem
Module 3: Capacity Scaling Algorithm/Edmonds-Karp Algorithm
Module 4: Max Cardinality Bipartite Matching

Unit 7: Polynomial Time Reductions and NP-Completeness

Module 1: Polynomial-Time Reductions
Module 2: Classes P and NP
Module 3: NP-Completeness

Unit 8: Introduction to Approximation and Randomized Algorithms

Module 1: Traveling Salesman Problem
Module 2: List Scheduling
Module 3: Knapsack
Module 4: Skiplists

Creators

Professor **Andréa Richa** joined Arizona State University (ASU) in 1998. She is currently affiliated with the Biomimicry Center at ASU, and the Biosocial Complexity Initiative in general. Prof. Richa's main areas of expertise are in distributed/network algorithms and computing in general. More recently she has focused on developing the algorithmic foundations on what has been coined as programmable matter, through her work on self-organizing particle systems (SOPS) (see sops.engineering.asu.edu). Her work has been widely cited, and includes, besides SOPS, work on bio-inspired distributed algorithms, distributed load balancing, packet routing, wireless network modeling and topology control, wireless jamming, data mule networks, underwater optical networking, and distributed hash tables (DHTs). Dr. Richa received the 2017 Best Senior Researcher award from the School of Computing, Informatics, and Decision Systems Engineering (CIDSE). She was the recipient of an NSF CAREER Award in 1999, an Associate Editor of IEEE Transactions on Mobile Computing, and the keynote speaker and program\general chair of several prestigious conferences. In particular, Prof. Richa was the Program Committee Chair of the 31st International Symposium on Distributed Computing (DISC), 2017, one of the top two conferences in distributed computing. Prof. Richa has also delivered several invited talks both nationally and internationally. For a selected list of her publications and other accomplishments, CV, and current research projects, please visit www.public.asu.edu/~aricha or sops.engineering.asu.edu.

About ASU

Established in Tempe in 1885, Arizona State University (ASU) has developed a new model for the American Research University, creating an institution that is committed to access, excellence and impact.

As the prototype for a New American University, ASU pursues research that contributes to the public good, and ASU assumes major responsibility for the economic, social and cultural vitality of the communities that surround it. Recognizing the university's groundbreaking initiatives, partnerships, programs and research, U.S. News and World Report has named ASU as the most innovative university all three years it has had the category.

The innovation ranking is due at least in part to a more than 80 percent improvement in ASU's graduation rate in the past 15 years, the fact that ASU is the fastest-growing research university in the country and the emphasis on inclusion and student success that has led to more than 50 percent of the school's in-state freshman coming from minority backgrounds.

About Ira A. Fulton Schools of Engineering

Structured around grand challenges and improving the quality of life on a global scale, the Ira A. Fulton Schools of Engineering at Arizona State University integrates traditionally separate disciplines and supports collaborative research in the multidisciplinary areas of biological and health systems; sustainable engineering and the built environment; matter, transport and energy; and computing and decision systems. As the largest engineering program in the United States, students can pursue their educational and career goals through 25 undergraduate degrees or 39 graduate programs and rich experiential education offerings. The Fulton Schools are dedicated to engineering programs that combine a strong core foundation with top faculty and a reputation for graduating students who are aggressively recruited by top companies or become superior candidates for graduate studies in medicine, law, engineering and science.

About the School of Computing, Informatics, & Decision Systems Engineering

The School of Computing, Informatics, and Decision Systems Engineering advances developments and innovation in artificial intelligence, big data, cybersecurity and digital forensics, and software engineering. Our faculty are winning prestigious honors in professional societies, resulting in leadership of renowned research centers in homeland security operational efficiency, data engineering, and cybersecurity and digital forensics. The school's rapid growth of student enrollment isn't limited to the number of students at ASU's Tempe and Polytechnic campuses as it continues to lead in online education. In addition to the Online Master of Computer Science, the school also offers an Online Bachelor of Science in Software Engineering, and the first four-year, completely online Bachelor of Science in Engineering program in engineering management.