Final Project

Overview

For your final project, you are going to study algorithms of your choice. The goals are for you to learn about new algorithms (e.g., history, applications, and run-time complexity) and how they compare to other algorithms, implement the algorithms, and demonstrate your working implementation. Your final project will be divided into three components: first, an initial project proposal report that entails researching three algorithms; second, a presentation focusing on one of the three algorithms, complete with a demonstration of its functionality; and the third part will involve integrating entrepreneurial thinking into the practical application of algorithms to address real-life problems.

You may work in teams for this project. You should indicate all partners in your research report.

Algorithm Research Report

Choose your top 3 algorithm choices. You can use the list below for ideas on classical algorithms, but you can also choose algorithms that are not in the list.

If you don't currently have any ideas or ongoing side projects, such as a potential startup or a project that heavily relies on algorithms for its success, you can opt to implement a classical algorithm from scratch (no other libraries used) as part of your initial project proposal. This algorithm will serve as one of the topics for your project. For the subsequent entrepreneurial aspect, you'll be tasked with envisioning a real-world business scenario where an algorithm can be applied and presenting it as part of your final project presentation. This presentation will complement the classical algorithm topic. In this scenario, you won't be required to actually implement the "second" algorithm for the business application. Instead, your focus would be on presenting the underlying concept and idea behind it.

If you already have business concepts or have been actively engaged in side projects that demand the use of algorithms for their success, you have the flexibility to choose that specific algorithm as the sole subject of your final project proposal. In this case, you'll be permitted to utilize libraries for implementation, provided that you write additional code to customize the algorithm or approach for solving a particular task. This approach will also contribute to the entrepreneurial aspect of the project, allowing you to combine the algorithm and its business application into a single topic for your final project presentation. If you have an idea that encompasses both algorithmic and entrepreneurial elements, please indicate it within the project proposal document.

You will write a research report consisting of maximum 3 pages. The proposal should list your three chosen algorithms (ranked in order of preference). For each of your chosen algorithms

a. State the computational problem solved by each algorithm. Give an example of a problem instance.

b. List 2 applications for the algorithm with a brief description (2-3 sentences) of each application

c. Describe the worst-case and average-case asymptotic time complexity for the algorithm.

d. Determine if there are other well-known algorithms for the same computational problem.

e. Compare and contrast with those algorithms in terms of run-time complexity, complexity of the algorithm itself, and other factors. (e.g., Fibonacci heaps allow merging of heaps in O(1) time but are much more complicated to implement than binary heaps like the one we implemented as a lab.)

f. Estimate how easy or difficult it would be to implement the algorithm. Indicate what you might need, including any potential data sets. If you do need to use a data set, provide a link to a data set that you would use and a description.

g. Please specify whether you intend to utilize the same algorithm for the entrepreneurial component of the project.

Your instructor will review you research report and provide feedback. Included in the feedback will be a suggestion on which algorithm to use for your presentation (to avoid duplication across groups). Once you have received approval from your instructor, you should begin working on the second part of the project.

Submission: submit your report as a PDF through Canvas

Rubric:

Description of computational problem (x3)	20%
Applications (x3)	20%
Time Complexity (x3)	20%
Comparison to competing algorithms (x3)	20%
Project Estimation (x3)	20%

Classical Algorithm List

- String comparisons: Minimum Edit Distance / Levenstein, Knuth-Morris-Pratt string search, Needleman-Wunsch global string alignment algorithm, Smith-Waterman local string alignment algorithm, Rabin–Karp algorithm, Boyer–Moore string-search algorithm.

- Graph algorithms: A*, Dijkstra's shortest path algorithm, Dijkstra's algorithm for adjacency list representation, Bellman–Ford algorithm, Floyd Warshall algorithm, Johnson's algorithm for all-pairs shortest paths, shortest path in directed acyclic graph, shortest path with exactly k edges in a directed and weighted graph.
- Clustering: K-means, K-medoids, hierarchical clustering, mean-shift clustering, density-based spatial clustering of applications with noise (DBSCAN), expectation–maximization (EM) clustering using Gaussian mixture models (GMM).
- Optimization: gradient descent, stochastic gradient descent, momentum, Adagrad, RMSprop, Adadelta, Adam, evolutionary algorithms / genetic algorithms, linear programming.
- Data Structures: Red-Black trees, Skip lists, B-Trees, Fibonacci heaps, disjoint sets, segment trees, tries.

Algorithm Presentation

For the second part of the project, you will be expected to give a presentation on one algorithm. Your presentation should be 10-15 minutes in length. Your presentation should include the information about the algorithm from your research report. You must also demonstrate a working implementation of the algorithm. **You must demo your algorithm implementation as part of your presentation.**

You will have flexibility with the medium you use for your presentation. For example, you may use PowerPoint or a Jupyter notebook. You must include all of the requested information, however. Presentations will be given during the lecture times in class.

Entrepreneurial Minded Learning

The objective of this project is to empower you with not only a strong foundation in algorithms but also the entrepreneurial mindset and skills required to apply algorithmic knowledge in real-world contexts. You will develop problem-solving abilities, creativity, and an understanding of how algorithms can be used to solve practical business and societal challenges.

You will work in teams to identify a problem, design a solution, and build a prototype (bonus) using algorithms. You are required to create a business plan, approximate financial projections, and a presentation on how your algorithm-based solution can address real-world challenges and provide value to potential investors, partners, and stakeholders.

Students who have a pre-existing startup concept where an algorithm could be harnessed to generate revenue, or who are presently involved in a startup or side project, can employ the algorithm chosen in Part 1 of the project to expound upon its business applications.

For those who do not have an existing startup idea, envision yourselves as members of a startup company tasked with the creation, development, testing, marketing, and sale of a product with algorithmic components. The evaluation of the presentations will consider the following criteria: (1) the depth of algorithmic integration, (2) feasibility, (3) innovation, and (4) your familiarity with the technology involved. See the grading rubric for more details.

Your business plan should outline your potential company's mission, vision, and goals, as well as your target market and competitive analysis. Financial projections can include approximate revenue forecasts, expense estimates, and a potential path to profitability. The presentation should effectively communicate your innovative approach, the problem you're solving, the market opportunity, and the potential for growth. It's essential to demonstrate a compelling case for investment and showcase how your algorithm-based solution can make a significant impact on real-world challenges while delivering a strong return on investment.

Below are some resources you might find helpful:

Short lectures on the topic of 'How to Launch a Successful Startup Company'

Watch the following short lecture series from the MIT Open Courseware: https://ocw.mit.edu/courses/15-390-new-enterprises-spring-2013/video_galleries/video-tutorials/

Business plan

You have the option to utilize freely available business plan template from the internet, and customize them as much as feasible. Feel free to even brainstorm a name for your company! The following are some links you might find useful. Feel free to use other related materials that you can find.

- https://www.nerdwallet.com/article/small-business/business-plan
- https://www.sba.gov/business-guide/plan-your-business/write-your-business-plan
- https://www.forbes.com/advisor/business/how-to-write-a-business-plan/

Pitch Deck

- Pitch Deck Examples: https://venngage.com/blog/best-pitch-decks/
- Presentation Tips for Pitching to Investors: https://secondnatureuk.co.uk/blog/presentation-tips-for-pitching-to-investors/
- Why knowing your audience will make a profound difference to the impact of your presentations: https://secondnatureuk.co.uk/blog/using-the-audience-in-presentations/
- How to Pitch a New Idea at a Business Meeting: https://secondnatureuk.co.uk/blog/how-to-pitch-a-new-idea-at-a-business-meeting/

- How To Create Engaging & Memorable PowerPoint Slides for Your Presentation: https://secondnatureuk.co.uk/blog/create-engaging-powerpoint-slides/
- 25 Persuasive Power Words to Use in Your Next Sales Pitch: https://secondnatureuk.co.uk/blog/power-words-for-sales-pitches/
- How to handle questions during a presentation: https://secondnatureuk.co.uk/blog/how-to-handle-questions-during-a-presentation/
- "Feedback Is The Breakfast Of Champions": https://secondnatureuk.co.uk/blog/using-feedback-for-better-presentations/
- Pitch Deck: How To Create The Perfect Funding Proposal: https://www.slideheroes.com/pitch-deck

Please keep in mind that your entrepreneurial idea should have some algorithmic content to it. Make an attempt to verify the novelty of your idea, perhaps by conducting a search on Google or checking the United States Patent and Trademark Office (USPTO). Share the source of inspiration that led to the creation of your most innovative idea.

Submission: You should submit a zip file containing the presentation materials (e.g., PowerPoint slides, PDF/HTML output from Jupyter Notebooks) and any source code to Canvas.