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CSPB 3112

Final Project Report

Introduction: This semester I aimed to improve my performance on Leetcode problems. This is a critical skill for career progression in the software and programming profession. Leetcode problem style questions are commonly asked in technical interviews, and represent a good strategy to retain basic coding proficiency. At the start of my final semester I realized how underprepared I was to solve these problems off the top of my head, so I deemed it critical to practice them.

As a potential portfolio piece and future venture, I also planned to research the techniques required to simulate neural tissue. I planned to do this on the side as a potential portfolio project.

Background: In my project proposal I aimed to complete twenty five easy and twenty five medium Leetcode problems. The criteria for completion would be that the problem was solved with a time limit. Additionally I would not be able to use any external resources like looking up syntax, data structure properties, etc. I identified time management as the largest risk to completion of the project, and proposed mitigating this risk with scheduling software. I decided on this constraint to prepare for the pressure of a technical interview.

Brain emulation is relevant to my professional development, because I have always found the field of computational biology fascinating. While the current capabilities of neural network architectures are incredible, they have drifted far from their original biological inspiration. I think a promising avenue for further breakthroughs is to replicate brain processes in ML models. If I could build my own digital piece of brain tissue this would be a great portfolio addition. For this I knew going in I wanted to recreate a human cortical column as a graph data structure. I also planned on making the graph functional, in the sense that each node would be a neuron with its own model of neural activity. As a more speculative problem I wanted to know how to simulate an environment or sensory signals for the network to process. This setup would allow for potential new insights into the functioning of the human brain. Emulations like these are being constructed professionally at a much larger scale. The largest human connectome dataset is 1.4 petabytes and includes 183 million synapses. Simulating that on your laptop might take a while, and is outside of the scope of this class.

Methodology: My initial methodology was to repeatedly attempt Leetcode problems. I also made use of the resources algomap.io, the GeeksforGeeks website and Gregg Hogg's youtube channel. I found that the most useful resource of all of these was the

youtube channel. He gave clear and concise explanations of the data structures and algorithms best suited for particular problems. He also explained counter intuitive strategies to bring time complexity down. I also tried to memorize basic patterns with respect to specific algorithms. This became my main focus for the first several weeks, and I focused heavily on trees and graphs given their relevance to the side project. I used the youtube videos as a jumping off point.

In terms of the neural simulation, the easy part is converting the data into a graph. You can use a wide array of implementations like adjacency lists, adjacency matrices and incidence matrices. The difficult part is properly simulating neural activity and sensory signals, or environmental interactions that produce sensory signals.

Results: I ended up abandoning some of the initial evaluation criteria in my proposal. I decided that time limits weren't ideal for making progress. I also heard the advice that memorizing a few basic patterns can be extremely helpful. If you can implement them off the top of your head it is much easier to then adapt them to the specific problem being solved, so I moved in that direction. I also used more external resources than I had initially planned but found that to be helpful. I did not solve fifty problems under a time limit without using external resources. I only completed problems under those criteria a handful of times. I instead decided that I needed to increase the volume of repetitions, even if I had to look at solutions or guides for help. I spent the most time focused on binary search, binary trees, search algorithms like DFS and BFS, sorting algorithms like mergesort and quicksort, and some dynamic programming. I did mostly easy problems with some mediums.

From these exercises my approach to solving the problems has improved. For example, comparing my initial idea for solving the classic "invert a binary tree" problem to the solution was very helpful. My first idea was to do an in order traversal of the tree, reverse the output, and then rebuild the tree from there. A much simpler solution was to recursively swap child nodes. After I read that solution I felt I understood recursive operations on binary trees much better, and it influenced future problems. I didn't end up using scheduling software but this wasn't a major problem. I found that I was able to keep my schedule effectively with paper.

Towards the end of the semester I found the software tool NEURON that is designed to simulate neural activity and networks of neurons. I am currently learning how to use it and plan on moving forward with this tool. It even includes a library for simulating neurotransmitter receptor interactions. I think it will allow me to make progress much more quickly.

Reflection: Overall I think that while I missed some targets, this project has helped me clarify my professional goals a great deal. I will continue to practice Leetcode problems in the hope of landing an interview, but I will probably shift focus to the brain project full

time. I did make progress in Leetcode, but there is much more to practice. In the future increasing the number of repetitions will be key and will take time. I will be able to dedicate much more time to practice post graduation. The project also helped me realize how exciting computational biology is, and has clarified that I want to pursue it professionally. My other future goal is to put a disproportionate amount of time into the brain simulation work. In retrospect I would have probably made that the main focus of this project at the beginning of the semester, had I been aware of the tools that are available.

Conclusion: I started with the narrow scope of solving Leetcode problems under time constraints, with the secondary goal of examining the plausibility of a more complex biological simulation. Over time my focus has shifted to informal practice, and a plausible roadmap to completing the second project with the NEURON software. The culmination of this process has led me to more concrete career goals. Moving forward I will focus my efforts on computational biology with respect to the nervous system. I will convert roughly 100 neurons into a graph, and then model signal propagation through that graph with the NEURON software, potentially down to neurotransmitter interactions at the synapse level.

References:

Largest public human connectome:
https://h01-release.storage.googleapis.com/landing.html

Complete fly connectome:
https://flywire.ai/

Neural activity simulation software:
https://www.neuron.yale.edu/neuron/

Leetcode supplement:
https://algomap.io/

Gregg Hogg's youtube channel:
https://www.youtube.com/@GreggHogg

General programming website:
https://www.geeksforgeeks.org/