Introduction

This past summer, I’ve been working in the Chemical Engineering department of USC’s Viterbi School of Engineering as part of Dr. Muhammad Sahimi’s team. His research is mainly focused on modeling and simulation of porous media, and a specific application of this that I’ve been working on is called percolation theory.

Percolation theory can be defined in many ways, but the simplest explanation is that it describes the behavior of connected clusters in a random graph. For instance, if you look at Figure 1 on the right, you’d see that there are points that are connected to one another and other points that are disconnected. These groups of connected points represent the aforementioned “clusters” because they are adjacent to other connected points, and percolation theory applies because they were generated randomly.

My project was to write a program that simulates corrosion in metals using a function called “random walk,” in which the computer generates a series of points, always moving one unit in a random direction. In my program, once the computer has passed over a certain point four times, that point is no longer accessible to the walker and it must move in a different direction. Once the program has taken a specified number of steps in the random directions, it stops and analyzes the shortest path from one side to the other, which is supposed to represent a crack forming. Once that part is finished, the program analyzes the distribution of the sizes of the “islands” of non-corroded nodes (see Figure 2), which represents the molecules of the metal that are not yet corroded. There are data that suggest that the size distribution of these “islands” changes significantly at the time of the crack, so the purpose of my project is to show this phenomenon using mathematical modeling.

Objectives & Impact of Dr. Sahimi’s Research

A large part of Dr. Sahimi’s research focuses on mathematical modeling and simulations of porous media on a wide range of scales, from microscopic nanotubes to large hydrocarbon reservoirs. This type of research is done entirely on computers, as it is merely a simulation, and this is the area that I spent most of my time learning about this summer.

Aside from the computer simulation of porous media, Dr. Sahimi also has done a great deal of experimental work on membrane and nano-scale materials. His research has provided important insight into a wide variety of fields, including but not limited to, the development of percolation theory and our understanding of hydrocarbon reservoirs through mathematical analytical techniques, such as Fourier transform, wavelet transform, etc. He has also published many papers on diffusion and convection in porous media, and he’s found ways to optimize the design and fabrication of nano-porous membranes.

Skills Learned

This project required extensive knowledge of computer programming, so I learned Matlab (short for Matrix Laboratory), which is a computer language widely used by engineers due to its vast libraries that simplify codes that would be very difficult to write in other languages, like the more standard C++. I learned how to create both codes and functions in Matlab, the difference being that you can use a function in any code, but not the other way around. Also, I became familiar with all kinds of different matrix operations since Matlab was designed to handle matrices, and they make large sets of numbers easier to store and work with.

My project was mainly based on concepts in chemical engineering, so I spent time learning about the different ways chemical engineers model porous materials. Some of these include a node and connection model, in which each pore is represented by a node, and a connection between nodes means that there is a passage between the two pores that the nodes represent (see Figure 1). A particularly interesting application of the node and connection model is used in GPS navigation, in which each node represents a major city and each highway between cities is modeled by a connection between the cities it runs through.

Another concept used to model the shapes of pores or islands within a given material is that of fractality. Chemical engineers calculate a large amount of random numbers by assuming that each island of molecules has a similar shape to those around it, so the computer saves time instead of actually computing each individual random number and taking a long time to run.

Relation to My STEM Coursework

The SHINE program has given me invaluable experience in both computer science and chemical engineering. Since chemical engineering is not a course that my school offers, I am really lucky to have been able to get some insight into a few of the field’s main concepts.

Aside from the very specialized concepts that I learned about, the main thing I’ll bring to the table from my SHINE experience will be my ability to troubleshoot and solve problems. Multiple times in my development of the code, I ran into certain errors that took up to a few days to get rid of, but I learned how to look at my code in different ways and with different mindsets until I found the problem.

Also, these errors taught me a valuable lesson in being methodical and patient, as I had to literally examine my code line by line at times to make sure it was working properly. Whenever I ran into a problem, I was able to fix it as long as I didn’t get frustrated and didn’t give up, so I hope to bring this mindset back to my STEM courses this year, so that I keep trying until I get results.

My Next Steps

I plan on continuing to do research once I become an undergraduate, and I think it’s safe to say that I will explore, and maybe even major in, either chemical engineering or computer science. Thanks to SHINE, I now have experience in both of these fields, so I already know that I’d enjoy doing research in either of them. In the meantime, during my senior year of high school, I plan on learning even more about programming and computer science, both through classes at my school and through personal projects. I am also signed up for a general engineering course, so I will be able to get experience in getting my hands dirty and building, which will be very interesting for me. I don’t currently have plans for after college, but I will definitely try to continue this sort of research in some way, shape, or form either at a university or in industry.

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