Personal, Background, and Future Goals Statement

He was my best friend and my bully, my confidant and my rival. My older brother suffered a stroke in his first year of college, paralyzing the left side of his body. Watching him in recovery for 6 months, I knew he would never fully use his left hand again. Yet this injury that would typically have hindered his engineering studies was instead overcome through the application of years of artificial intelligence research; namely, a speech-to-text app. Today, my brother is a medical student finishing his dissertation. Seeing how new natural language processing technologies alleviated aspects of his physical ailments was awe-inspiring, and I embraced my acceptance to the engineering program at the Ohio State University in hopes of researching and one day building new technologies that would help others like my brother. Over the past four years, I have had the pleasure of undertaking interesting projects and working in both a mathematical immunology and computer systems lab. These experiences were eye-opening, and have reinforced my passion for research and my commitment to pursuing a Ph.D. in machine learning.

Intellectual Merit

My journey into solving open-ended problems began in freshman year with the Honors Engineering Robotics competition. Despite minimal prior experience in hardware and software design, my team was tasked with building a robot to precisely navigate an obstacle course and complete complex motor tasks. In the process, I learned to write bills of materials, plan design schedules, and embrace the software challenges of programming a robot. While the technical knowledge I gained was valuable, I was surprised to find the social aspects of the work just as meaningful. Learning to collaborate effectively with my peers taught me the importance of communication and flexibility when working as a team. To balance everyone's outside time commitments and rigorous coursework meant building flexible schedules that still met deadlines and addressing the technical needs of the project while being sensitive to everyone's personal needs required compassion and tact in managing group messages and communication. Through this process, I realized that it was not only the technical skills of each individual on our team that drove our progress, but also, and perhaps equally as important, our collaboration. Though the final Robotics competition was canceled due to the onset of the Covid-19 pandemic, I still finished the work with a deep sense of fulfillment: We fully constructed and programmed our robot to complete the obstacle course and accomplish all bonus objectives, meaning I got to both challenge myself and tackle open-ended problems with teammates who later became friends.

I continued my journey of working on open-ended problems through a summer internship at the Ohio State tech startup, Converge Technologies. Working with mechanical and electrical engineers, I collaborated across a multitude of interdisciplinary projects. From computing optical specifications for long-range camera systems, testing prototype sensors, and writing firmware for industrial freezers, I initially understood very little of the technical lingo thrown around in group meetings. As painfully uncomfortable as it was to confront my lack of understanding, there was no excuse for doing a poor job. Soon, Google became my best friend, and teaching myself online about a new topic each day became the norm. Eventually, months passed, and my discomfort with the words "I don't know" subsided. Towards the end of my internship experience, I had learned various aspects of industrial design, the fundamentals of embedded programming, as well as written firmware that improved the power efficiency of high-powered motors for industrial freezers. Though I had many sleepless nights of self-doubt, my success boosted my self-confidence in my ability to learn anything given the right resources and amount of time. Deeply empowered from this period of self-growth, my desire to continue challenging myself with novel and interesting problems grew.

With this newfound drive, I started my first research experience in Dr. Jayajit Das' lab within the Battelle Center for Mathematical Medicine. One method for understanding biological systems is building mechanistic models of cellular processes through systems of differential equations. Such models contain any number of unknown parameters that need to be estimated given data. During my time in Dr. Das' lab, I worked on developing parameter estimation software for single-cell models. Parameter estimation of single-cell data is a challenging problem as data is often noisy and protein abundances can vary widely on many orders of magnitude. Initially, we started analyzing simulated noisy time snapshot data using a set of known parameters but later applied our method to immunological systems, specifically measured CD8 T cell data. Through optimizing a cost function derived from the generalized method of moments with particle swarm optimization, we reproduced tight and unbiased confidence intervals around model parameters embedded in differential equations fitting the means and variances of experimental data. Based on this work, we submitted a manuscript (bioRxiv 10.1101/2022.03.17.484491) that is currently under review in the Bioinformatics journal (Oxford Academic, Impact factor 6.931), and I presented a poster at the 2022 q-bio conference. In the process, I furthered my understanding of various statistical and computational techniques, especially ones related to optimization in cellular biology. Additionally, working with immunologists daily has shown me that computational research is valuable not only for augmenting the lives of others through its applications but also can explain biological processes that may one day provide insights on how to better treat diseases that affect those like my brother.

I am confident that I am prepared for graduate school. From my time presenting in group meetings, I understand the value of effective communication. By experiencing major setbacks in my research projects, I now understand the value of resiliency as well as the lessons that come from failure. I believe I have the skillset and growth mindset required for success in research. It is from these fulfilling yet challenging experiences that I am emboldened today to pursue a Ph.D. in machine learning.

Broader Impacts and Future Goals

For my ongoing honors senior thesis, I am exploring the idea of a model-data commons with Dr. Christopher Stewart's ReRout lab. Working with another undergraduate student, we benchmarked vision models and optimization heuristics such as Particle Swarm Optimization against multiple datasets, showing that model performance and their respective rankings are heavily data dependent. Thus far, we have submitted a benchmarking paper on arXiv, which aims to justify why a model commons is necessary as artificial intelligence expands into other fields. We hope to continue exploring many other interdisciplinary machine learning related questions during my last year at Ohio State, especially ones related to cell modeling.

My time in Dr. Das' cancer research lab and Dr. Stewart's ReRout lab has furthered my interest in machine learning model interpretability and explainability, especially around its interdisciplinary application towards the physical sciences. As datasets drastically increase in dimension and scale as seen in Imaging Mass Cytometry datasets, conventional mechanistic modeling techniques may not fully discern the complex relationships embedded within them. On the other hand, machine learning techniques are well-suited for discovering high-dimensional patterns within datasets, but often due to their "black box" nature, fail to provide the explainability needed for scientific progress. Pursuing a Ph.D. in machine learning would allow me to pursue this interest at the highest level and build the framework for interpretable artificial intelligence in the biological sciences. Specifically, I would love to work with Dr. Jian Ma at Carnegie Mellon University and his work in model interpretability, especially in uncovering hidden and higher-order interactions in human genomics with the use of graph neural networks. I would also be honored to work with Dr. Ameet Talwalkar and his studies in model interpretability, as defined in his recent ACM paper *Interpretable Machine Learning: Moving From Mythos to Diagnostics*. In a more general sense, I am very excited about the applications of machine learning, and more specifically deep learning, in interdisciplinary fields.

In addition to my research interests, my experiences as a teaching assistant and an undergraduate ambassador for high school STEM outreach efforts have instilled a desire to pursue further opportunities in mentorship. As the famous physicist Richard Feynman shared, "If you cannot explain something in simple terms, you don't understand it." Breaking down complex coding concepts into digestible chunks for first-time coders was not only emotionally fulfilling but also refined my basic coding skills. Similarly, presenting the amazing applications of machine learning research in front of high schoolers and seeing their eyes light up has reinforced my desire to pursue a Ph.D. After graduate school, I hope to one day mentor others while pursuing research in an academic setting toward professorship.