Personal Statement

Introduction: The Emergency Room and I have a fair bit of history. One of my earliest appearances happened when I was about six years old. We were eating dinner as a family and my dad decided that I was old enough to cut my own meat. It didn't take very long after being handed the steak knife for me to slice my finger open. I still have the scar from that one. As adults, we often overlook how hard it is to safely perform some tasks that we think are simple. Similar to the knife-wielding, six-year-old me, robots can struggle to perform well on many manipulation tasks when placed in novel circumstances. Fortunately, this is a solvable problem. It is also a problem that we *should* solve. From hospitals to homes, intelligent robots have the potential to bring a lot of good into the world. Imagine how big the impact could be of a robot that could do chores and care for children, elderly, or those with disabilities. But while solvable and societally impactful, this is also a hard problem. These robots would have to operate in proximity to humans in unknown environments. That means we really need to care about the safety of such systems. In order to ensure safety in these robotic systems, they need to be able to reason about *uncertainty*. My goal is, through research, to create robust methods that allow such uncertainty-awareness. I believe I have the skills and aptitude to do that.

To understand how I got those skills, we need to start in Junior high. My school decided to offer its first ever programming class and I figured I'd give it a try. I loved it. I loved it so much that a year later, I taught myself trigonometry while coding a computer game in my free time. By the time I was in high school, I was crazy about computers and math. Despite this, it wasn't until after I had graduated from high school that I started to consider pursuing research. For personal reasons, the year between high school and starting college was a transformative period for me. I realized that a job wasn't really what I wanted out of college. Instead, I wanted to work on interesting problems that gave me a *challenge*. I figured research could provide that. This ultimately led me to enroll at the University of Utah, where I am on track to complete my Honors Bachelor of Science in Computer Science this year. Because I couldn't stand going too long without a math class, I also decided to minor in Mathematics. It was at the University of Utah where I really fell in love with building probabilistic methods for intelligent robots. I plan to follow this passion and pursue a PhD at an R1 research university.

Intellectual Merits: While at the University of Utah, I decided to reach out to some professors to ask about research opportunities. The next semester, I joined the Utah Learning Lab for Manipulation Autonomy (LL4MA) under Dr. Tucker Hermans. The first project I was on attempted to use Graph Neural Networks to reason about occlusion in robotic tabletop scenes. While the efforts were ultimately unsuccessful, I learned a lot from the experience. For example, I learned how to read research papers. I attended the lab's reading group for the first time. I even got to lead the reading group a couple of times. During this project, I also applied for and received the Undergraduate Research Opportunity Program (UROP) grant, which funded two semesters of research totaling over $2000. During those two semesters, I wrote a lot of code. I wrote code to interface with robotic simulators, process meshes, and train neural networks. I also had to debug the code too. It was hard, and I was doing it alongside with taking classes full time and working a part-time job to help pay for college.

Speaking of classes, I have had the opportunity to take some awesome classes as part of my journey to learn more about robotics and adjacent areas. I have taken multiple graduate level courses on things like Optimization, Computer Vision, Algorithms, and others. These have turned out to be my favorite classes I've taken as an undergraduate.

After determining that our approach might not be feasible, Dr. Hermans and I decided to switch gears. We thought about phrasing the problem as a multi-class mapping problem and borrowing some ideas from the mapping literature. I was able to dig up some theorems from previous papers that pointed towards a novel EM algorithm for performing Bayesian softmax regression. Over the course of a few meetings, we also came up with a way to negatively sample along camera rays of a depth camera observation in order to encode the relevant information about the observation. During this time, I experimented with the method,

reconstructing meshes from pre-existing datasets and real world scenes with one of the lab's depth cameras. Then, in fall 2023, Dr. Hermans went on parental leave. Because I strongly wanted to continue working on my research project during this time, I began meeting remotely with a different advisor, Dr. William Zhi, a post-doc at Carnegie Mellon University. After figuring out a few more things, designing and running some experiments, we figured we had enough for a paper.

As a culmination of these efforts, I was able to get a first-authored conference paper accepted into the 2024 IEEE/RSJ International Conference on Intelligent Robots and Systems. We showed how our method could provide principled uncertainty measurements that were high in heavily occluded areas of the scene. I was also able to present this work in a workshop at the 2024 IEEE International Conference on Robotics and Automation (ICRA). Going to ICRA was a fun and exciting experience that convinced me even more that I wanted to continue doing research in robotics. The research for the paper was challenging and ultimately very rewarding. I found the actual writing of the paper to be a great learning experience as well.

Since then, I have continued to work with Dr. Zhi and Dr. Hermans and the LL4MA lab. Altogether, I believe my experience as an undergraduate researcher indicates that I am capable of further novel research. I am excited to continue to develop novel methods that allow robots to have uncertainty-awareness and increased robustness.

Broader Impacts: A secondary goal of mine is to inspire and mentor younger students who are interested in STEM. If my school had never decided to start a programming class, I might've never fallen in love with computer science. I want to make sure that each student has the opportunity to be exposed to the beauty of mathematical problem-solving in an exciting way, just like I was. Critical to this goal are improved science communication and outreach. In the past, I have been involved in both outreach, communication of scientific ideas, and helping teach younger students mathematical concepts. I would like to continue these activities and believe that pursuing a doctorate will give me opportunities to engage more effectively in each of these.

In high school, I was able to participate in an outreach program where we went to a local elementary school to teach 5th grade students block code and programming fundamentals. We went to the elementary school twice a week for an entire semester. A few of us high school students would be assigned to a class. We would give a quick lesson, then let each student try out block codes exercises on their computers. We would help out students who got stuck, confused, or needed assistance. We covered topics from conditional statements, different types of loops, and variables. It was really cool to see the spark in some students eyes as they tried to solve the programmatic challenges.

In college, I was able to be a Teacher's Assistant for a probability and statistics class, where I had various responsibilities. Multiple times a week I would hold office hours and help students with the material. I would also help students during weekly labs for the class, where they would get into groups to run statistical tests and analyses on prepared data. Being a TA helped me not only get a better grasp on the fundamentals of probability and statistics, it also helped remind me how much I enjoy teaching and helping those learning mathematical concepts. It was fun to watch students connect the dots on the central limit theorem or what a confidence interval meant.

I also enjoy communicating science and research. As mentioned above, I have led multiple lab reading groups. I have also given a presentation of my work to collaborators of my advisor from Oregon State University. Afterwards, I answered questions, and we had a discussion of the method. I also was able to discuss my research during the poster session of the ICRA workshop I participated in. During the conference, I was able to talk with lots of people about their research, which was similarly enjoyable. These experiences have helped me be a better communicator of complicated research. I hope to be able to also discuss this research with people outside of robotics as well.

While I have an interest in continuing both outreach and science communication, I don't think that is the only broader impact of my efforts. As mentioned in the introduction, my research has broader impacts as well. A lot of effort is spent caring for people who don't have the means to care for themselves. Being able

to deploy intelligent robots to do such tasks can alleviate a large burden that is currently placed on caretakers. For such robotic systems to be deployed, uncertainty-awareness and robustness is crucial to ensure necessary safety. That's where robust, probabilistic methods can really make a difference. By advancing both the theory and methods of probabilistic robotics, my work has the potential to ensure safety and deployability of impactful robotic systems at large.

Overall, I think there is not only broader impacts of my research, but also of my efforts to communicate and teach younger students. With the NSF-GRFP during my PhD, I would be able to engage even more in outreach and impactful research.

Future Goals: After graduating with my bachelors, I intend to pursue a PhD at an R1 research university. During my PhD, I will conduct research developing uncertainty-aware robotic methods. Following the completion of my PhD, I want to continue conducting similar research. Ideally, this would be as a professor at a research-focused university, but this could also come in the form of a having a research scientist position. Regardless of where I end up, I want to continue to develop robust, uncertainty-aware methods for robotic manipulation tasks. Eventually, I want to combine various probabilistic methods to create an efficient robust framework to solve general manipulation tasks with uncertainty-awareness. I also want to continue to conduct outreach to help expose younger students to robotics and STEM in general both during and after my PhD. Being awarded the NSF-GRFP would be a great first step on this path.