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 long after being handed the steak knife for me to slice my finger open. I still have a 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 of a robot that could do chores and care for children, elderly, or those with disabilities could be. 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. Such proximity means we really need to care about the safety of the systems. In order to ensure safety in these robotic systems, they need to be able to reason about *uncertainty*, especially when things are unknown. My aspiration is, through research, to create robust methods that allow such uncertainty-awareness in robots. I believe I am in a position where I have the potential to do that.

To understand how I got in such a position, 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. Around this time, I would also spend much of my free time learning new mathematical concepts by watching online videos separate from schoolwork. 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 just getting 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 saw 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.

While I was interested in math and computer science since I was young, it was at the University of Utah where I really fell in love with building probabilistic methods for intelligent robots. I fell in love for many of the reasons previously mentioned: it is impactful, thought-provoking, and challenging. It also lies at the intersection of my broad interests. My experience as an undergraduate researcher also played a big part of how I developed a passion for probabilistic, uncertainty-aware robotics methods. I plan to follow this passion and continue my research by pursuing a PhD at an R1 research university next fall. The NSF-GRFP fellowship would allow me to conduct the best research that I can while in graduate school.

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, where I have been an undergraduate researcher for over two years. My first project 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 part-time to pay for college.

After determining that our approach might not be feasible, Dr. Hermans and I decided to switch gears. We thought about phrasing creating a 3D representation of a tabletop scene 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 the fall of 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. While I wrote the most of the paper, Dr. Zhi provided invaluable insight on the writing style, figures, motivation, and other important parts of the final draft.

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 as part of 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 during my PhD and beyond.

Apart from research, I have also 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 topics such as Optimization, Computer Vision, Algorithms, and others. These have turned out to be my favorite classes I've taken as an undergraduate. Perhaps one of the most relevant classes to my research goals was a robotic algorithms class, where I had to implement various robotics motion planning, perception, and control algorithms like probabilisitic roadmaps, particle filters, and model predictive control for steering. For the final project in the class, a few other students and I put everything together to have a toy car with a depth sensor not only localize itself, but also plan and drive to designated goal locations inside one of the engineering buildings.

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 both improved science communication and improved 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. One of my favorite experiences as part of this program was when the kids used block code to programmatically "paint" something cool by using rotate, move, and draw block code instructions. They were very proud of their drawings and kept wanting to show them to me

or the other high school volunteers. I hope the experience helped interest some of them in pursuing further education in computer science.

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 reminded 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 previously, I have led multiple lab reading groups. As part of a graduate level optimization seminar class, I gave a presentation on a Variational, Bayesian gradient descent method. Preparing for that presentation was a blast. 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. More recently, I was able to give a presentation of my work during the University of Utah's robotics seminar, where I fielded questions afterwards. While I was perhaps a bit nervous at first, these experiences have helped me be a better communicator of cutting-edge research and other complicated topics. I hope to be able to discuss this research with people outside of robotics as well. In the future, I would like to try creating accessible online resources, like videos, that teach robotics concepts to a general audience. In a way, similar online videos acted as a catalyst to my love of math as a kid. I hope that I can similarly inspire younger students through developing such online resources.

While I have an interest in continuing both outreach and science communication, this is not 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, there is not only broader impacts of my research, but also of my efforts to communicate science and teach younger students. With the NSF-GRFP during my PhD, I would be able to engage even more in both 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 robotics methods. My plan is to work towards three main aims during my PhD: extending my previous work to be more accurate, developing a method for active learning with my existing method, and incorporating dynamics models into my previous work. 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 would like 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. Part of the reason I would like to have a role as a professor or senior researcher is because it would provide many opportunities for me to engage in mentoring younger students. Being awarded the NSF-GRFP would be a great first step on this path.