Previous Research Experience

Throughout the majority of my undergraduate experience I was involved in research of one form or another, and it is now my job to develop research robots. I believe hands-on experience results in the best understanding. Doing well in class can provide a solid foundation of problem solving tools, but an appreciation for the complexity of problems and solutions cannot be gained without pushing your limits by trying to solve hard problems. I found these invigorating challenges in internships, and by pursuing research with the CMU Robotics Club Colony project and the Robotics Institute Biorobotics Lab's Modular Snake Robot project. In each I grew as an engineer and researcher by honing my technical skills, gaining valuable project organization experience, and contributing to original research. I was also able to give back to the engineering community by being a mentor in these projects, participating in several outreach events, and publishing my work.

Before being involved in undergraduate research, I learned several technical skills from an internship at National Instruments. I worked in the motion control products group on a motor controller module for reconfigurable input-output system. This module had an FPGA with a soft CPU core instantiated on it. My project for the summer was to write VHDL to simulate the EEPROM chip used to configure the FPGA to verify the design of the entire module in simulation. I successfully implemented the interface based on their design specification, and produced documentation of my own for the simulation and automated test suites I developed. From this internship I learned the development toolchains for both the FPGA and the processor core instantiated on it. I also became proficient with debugging tools such as logic analyzers and oscilloscopes, and how to unit test hardware designs.

From the start of my university experience, I was excited about engaging in robotics research. The Carnegie Mellon robotics club provided the perfect opportunity with the Colony project. The project was conceived in 2004 by a team of undergraduate students as a research platform for exploring emergent behaviors using a low cost mobile robot architecture. Each of the tabletop differential drive robots has wireless connectivity and a variety of sensors. Colony operates by proposing new behaviors or technologies to explore on our robots each semester. Small Undergraduate Research Grants (SURGs) primarily fund the project. These grants award up to $1000 to the most competitive grant proposals submitted to CMU's Undergraduate Research Office each semester. We share the results of this ongoing research via poster and oral presentations at the annual undergraduate research symposium to fellow student researchers, university faculty and staff, and judges invited from industry and professional organizations.

Working with the Colony project was an excellent introductory experience because I learned how to propose, carry out, and disseminate robotics research. This was especially exciting since the team of undergraduates formulated our research questions and decided how best to answer them with minimal involvement from faculty mentors. Each of the six SURGs I participated in with Colony proposed a behavior or technique that has significant application to real world problems that are specifically suited to multi-robot solutions. I progressed from being responsible for small technical paragraphs in the proposals to forming an entire research outline to align with the goals of the project. From a technical standpoint the Colony project served as a crash course in mobile robot programming and an introduction to robot architectures designed around microcontrollers with limited resources. I now have experience with writing embedded C code to implement navigation and search algorithms, interface with several types of sensors and actuators, and how to implement effective wireless mesh networks. Aside from the technical knowledge, I also learned good coding practices for large group projects such as API specification, effective commenting, and version control. Finally, I helped publish the results of our research in several forms. I personally presented one of our research posters at the undergraduate research symposium, and gave an award winning oral presentation. My Colony experience culminated in co-authoring a paper on the development of the robots that was published in the AAAI[1] symposium on intelligence in distributed systems. I attended the conference to help present our robots and enjoyed seeing the work of several experts in the field of mobile robotics.

With everything I had learned from student-led projects, I felt ready to make a more significant contribution to academic research. The modular snake robots (modsnakes) I help develop in the Biorobotics lab explore control techniques and applications for hyper-redundant robotic mechanisms. The robots are composed of a series of identical modules with alternating joint axis alignments. This configuration allows for useful and unique modes of locomotion, collectively called gaits, which would be impossible with other types of robots. The modsnakes are especially suited to navigating cluttered, complicated, and dangerous environments that would stop conventional robots in their tracks. Improving the effectiveness of urban search and rescue by being able to reach survivors under rubble is one the lab's long-term goals. Another potential application that aims to keep people out of dangerous environments is high-voltage power line inspection. Snake robots could be deployed on insulator towers to navigate the scaffolding and automatically inspect insulators for defects. By removing humans from this operation, hundreds of thousands of dollars could be saved per year in training, line shut downs, and power outages from failure, not to mention keeping human inspectors out of harm's way.

Because of my experience with Colony I was able to jump right in to a major design change for the snake robot mechanism and electronics. A primary goal of this design was to use Shape Memory Alloy (SMA) to actuate a module brake mechanism, allowing the modules to hold position indefinitely without power expenditure. I worked closely with senior staff and graduate students to perform the preliminary research on the feasibility of the SMA brake unit, produce a design specification, design the circuit board under tight size constraints, and write the embedded processor code to run the SMA actuator and motor to keep them operating safely. This design is in all of the latest generation snake modules, and we have begun the process of collecting our findings to publish on the design and applications of the brake module.

More recently an important part of my lab work is assisting graduate students with their research. A major thrust of my work this past year has been improving the communication protocol architecture we use for the modsnake processors to coordinate their motion and report sensor values. By making the protocol more flexible while still guaranteeing precise scheduling of sensor readings I am enabling research to progress faster while trying more approaches. This work also lets me work closely with grad students, requiring me to learn the analytical tools such as Kalman filtering, Bayesian techniques, and high-dimensional parameter optimization so that I can ensure the robots and software tools are up to the tasks they require. This experience has also motivated me to study the improvement of computational hardware available to roboticists.

By immersing myself in varied research projects I enhanced my technical knowledge, team problem solving skills, and perspective. I am confident in my abilities to design and build robotic systems and stay abreast of emerging technologies. I also have a good understanding of how complex systems interact, including people in research teams, which makes me an effective member of a team at multiple leadership levels. Finally, the perspective on robotic problems I have gained through trying to solve many different types so far allows me to think about the broader problem of the tools and techniques at the disposal of engineers.

Publications

1. F. Duvallet, A. Buchan, et al. "Developing a Low-Cost Robot Colony." Association for the Advancement of Artificial Intelligence: Fall Symposium. Arlington, VA. 2007.