Interdisciplinary Research at the Boundary of Hardware and Software

The field of robotics is interdisciplinary by nature. Studying both Mechanical Engineering and Computer science has allowed me to position myself at this interdisciplinary boundary between the hardware and software of robotics and control systems. Consequently, both of my two significant past research experiences have utilized my skills along this boundary, where I can employ my computer science skills to solve engineering problems and use my algorithmic knowledge to influence the design of mechanical systems.

The University of Maryland: Micro-Robotics Lab

In the University of Maryland Micro-Robotics Lab, I have worked as an undergraduate researcher on robotics applications since February of 2011. Specifically, I've led the controls design of a project to develop a **centimeter-scale robotics platform**. These robots, which our lab named the TinyTeRP (Tiny Terrestrial Robotic Platform), are designed from commercial off-the-shelf components [1]. Envisioned as a research platform, these miniature mobile robots also have many potential uses in search-and-rescue missions and other environments where small volumes are necessary. This incredibly resource-constrained system introduced **enormous computational challenges**. With only an incredibly small, 8-bit microcontroller, I was able to develop, test, and implement a controls algorithm to drive the platform toward a continuously stable state. I **solved** these problems by drawing on my interdisciplinary background.

Since the TinyTeRP was developed as a whole integrated system, I was able to use my knowledge of both hardware and software computer interfaces while writing code and designing the circuitry. As opposed to attempting to include an analog sensor, which would have added a significant computational load to our system, our team used the distance measurements from RF communications to trilaterate each robot's position [1]. In writing the controls software for this embedded microcontroller, the Texas Instruments MSP430, I was able to actively consider the mechanical operation of the onboard motors and adjust the code accordingly. Similarly, I wrote the statistical algorithms for measuring distance with a whole-system perspective. As one member of the multi-disciplinary TinyTeRPs team, I worked independently on some specific sub-systems such as low-level software research of both controls and RF communications, and very collaboratively with the rest of the team on others, such as the circuit design. In the paper that our group submitted to the 2012 IEEE International Conference on Robotics and Automation [1], I wrote the sections on the controls algorithm and system testing.

Additionally, this research led to a number of **broader impacts** at the University of Maryland**.** I had the opportunity to use my communication skills by giving a presentation on the TinyTeRPs at the University of Maryland Robotics Day [2], a 500+ person event focused on inspiring middle-school and high-school students to careers in engineering. This research was also included Maryland's publications about our robotics programs, and thus our contributions were disseminated to the wider academic community.

Through this unique combination of breadth and depth in systems design, I learned significant amounts about embedded microcontroller circuitry and software, as well as resource-constrained systems. The hands-on experience of physically assembling these robots has given me laboratory experience with multiple fabrication techniques.

US Army Corps of Engineers: Engineering Research and Development Center

At the US Army Corps of Engineers Research Lab during the summer of 2011, I was able to assist in wireless sensor networks research from this same systems perspective. The lab has been working to develop a system of networked sensor-buoys for efficient water quality testing, which will rely on the software and hardware of long-range, low-power communications. In order to perform the design and testing that was required on the prototype system during my time at the Corps, I had to think critically about the effect of environmental variables on the system's digital signal response. This research posed multiple **challenges** due to the sensor's aquatic environment, including calibrating temperature and humidity sensors, designing an appropriate antenna, and preventing the buoy container from leaking. **I addressed these challenges** by creating a set of standard operating procedures for handling the buoy, redesigning the antenna gasket, and taking a wide range of calibration data. Along with the design and testing of this system, I wrote the software to dynamically re-calibrate these sensors using the recorded data, as well as configure the low-level hardware settings on each network node.

The research environment at the Corps included the same type of interdisciplinary teams as the Micro-Robotics Lab at Maryland. Independently, I used specific previous knowledge to build the system software. I similarly used my own communication skills to present my research to a review panel of Corps of Engineers managers [3]. However, I worked as part of a larger team during the design of the system. While interacting with that team, my knowledge of communications technology increased, as did my teamwork skills and experience with testing. This research had a range of **broader impacts,** including improving access to clean water in remote communities, and thereby preventing disease.

Future Research Aspirations:

In all of these research experiences, I have been able to utilize my skills along the hardware-software boundary, as well as my communication and leadership skills, all while increasing my engineering knowledge. Continuing my education in graduate school, with the assistance of the NSF Graduate Research Fellowship, would allow me to leverage my knowledge and unique skillset in future research settings.

Publications and Presentations:

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