Student Responses to RENEWAL Questions

The following apply only for renewal applications. Please consider these responses in making your assessment of the application.

1. Please describe how successful you were in achieving the intended outcomes of and adhering to the plan/timeline of your original proposal.

I was very successful in adhering to the timeline listed in my proposal. The weekly meetings I had with my mentor helped me stay on track the most. There has been no significant changes to the project.

2. Please describe how successful you think your relationship with your mentor was during your first semester of UROP.

Dr. [redacted] was always available to help me with my project. We had weekly meetings to make sure that we adhered to the timeline and whenever I was faced with an obstacle, he was more than happy to lend a hand. He included me as part of his Robotic Systems and Control lab and with that, resources to facilitate the project. He also provided an opportunity for me to attend an ASME conference in Park City as a volunteer.

3. Please explain what you think the impact of an additional semester in UROP would be to your educational and career goals.

An additional semester is vital for me to continue my research from Fall 2019. The architecture I am building is almost finished and once it is, I can focus on publishing a paper under my name. That is a foot in the door of the research community. I have also gained multiple useful technical skills such as soldering, wiring, coding in both C and C#, and more. I would love to gain more knowledge to increase my worth in the robotics world.

UROP Proposal

Title of Proposal

Distributed Sensing in Multi-Bladder Network within Football Helmet for Impact Detection

Problem/Topic of Research or Creative Work

Data collected by Duhaime et al. (2012) from 450 athletes from Dartmouth College, Brown University, and Virginia Tech recorded 486,594 head impacts [1]. Following the frequency of head impacts, Langlois et al. (2006) reports an estimate of 1.6 to 3.8 million cases of mild traumatic brain injury in sports and recreation each year [2]. The injuries sustained by athletes in the United States has raised public health concern leading to research has been done on head impact detection, prediction, and analysis but few has explored concussion mitigation in helmets. Dr. [redacted] and his collaborators envision a combination of impact detection and concussion mitigation in a football helmet by implementing soft robotics. In Figure 1, the Smart Helmet consists of pneumatic bladders molded by silicone rubber (Mold Max 40, Smooth-On, Inc) attached to the helmet wall. The bladders are designed to dissipate impacts to reduce forces transmitted to the head that can cause brain injury. The bladders are controlled by small circuit boards (1"x1") with microcontrollers, sensors (bladder pressure, bladder compression, and bladder acceleration) and valves that control airflow in/out of the bladders. All of these components are currently embedded in the base of the bladders, but since the helmet will have many bladders, ongoing research aims to use one board (e.g. the Parent Board) to control groups of bladders (left side, right side, top, front, and back) for each region of the helmet. Air flow in the bladders in each region of the helmet will be coupled and controlled by one bladder in each region with the board embedded in it. The other bladders in that region, termed "Daughter Bladders" will be assumed to behave similarly to the instrumented bladder, termed the "Parent Bladder".

The proposed project focuses on providing sensing in the Daughter Bladders in each region of the helmet so the Parent Board can better monitor and control the bladder array. The challenge, however, is that the sensors are borrowed from cell phone technology so only one sensor of each type can be connected to the Parent Board. Hence, this proposal will research and develop "Daughter Boards" that will collect pressure and distance data in each Daughter Bladder and then relay that data to the Parent Board. The Daughter Boards will be equipped with a microcontroller to read data from a proximity sensor and a barometric pressure sensor. The Daughter Boards in each bladder array will communicate with the Parent Board over a data bus. Future work for Spring 2020 involves combining multi-bladder networks and their integration into the Smart Helmet.

Relevant Background/Literature Review

Distributed sensing is applied in robotics for a robot to achieve a certain level of awareness towards its environment. Rennekamp et al. (2006) utilized a distributed camera network mounted around an office space and onboard mobile robots to optimize motion planning while predicting the path of moving obstacles [3]. Specifically, distributed pressure sensing allows for monitoring the fluid dynamics surrounding a robot. Cellucci et al. (2018) introduced a robust, adaptable self-estimation scheme using a distributed pressure sensing strategy with 74 pressure sensors mounted on the wings of an aerial vehicle [4]. Biorobotics utilize distributed pressure sensing to mimic the sensory system of fish and further understand changes in behavior according to fluid flow as demonstrated by the work of Haehnel-Taguchi (2018) and Kahn (2012) [5], [6]. For this research however, the fluid flow observed is within the pneumatic bladders.

For pressure sensing in an elastomer bladder, prior work can be directed to the research of a former graduate student, [redacted] in the University of Utah under Dr. [redacted] himself. Wang (2014) introduced a Smart Shoe to mimic terrain features such as uneven ground and stones by controlling the pressure within a pneumatic bladder system attached to sole of the shoe in a virtual environment. The pressure sensor in each bladder detects increase in pressure as the user steps on the shoe to allow for deflation. The swing phase of the gait decreases in pressure triggering the inflation of the shoe [7]. The difference between the proposed work and Wang's work is that in the Smart Shoe, each bladder is controlled by a separate parent board, whereas the helmet uses a single parent board to control multiple bladders. Distributed sensing in this research will allow the parent board to better monitor the bladders in the region of the helmet that it controls.

The Parent Boards used in the Smart Helmet and this research are identical to those from Wang's Smart Shoe. I have been working in the lab to prepare Parent Boards for the helmet. This requires soldering all components on the Parent Boards (e.g. resistors, capacitors, diodes, sensors, microcontrollers, connectors, etc). Once populated, the Parent Boards will be programmed to control the regions of the helmet and tested. This will be done in Summer 2019.

Specific Activities to be Undertaken and Timeframe for Each Activity

The first step is to research and select the Daughter and Parent Board architecture (two weeks). Based upon this research, a prototyping board (e.g. an Arduino Nano or Teensy) will be selected for making a Daughter Board prototype (one week). Pressure and distance sensors will be integrated with the Daughter Board, which will include electrical connections, physical mounting, and programming (three weeks). The next step would be to establish communications between the Daughter Board and the Parent Board, which will require electrical connection via a data bus and programming the communication protocols on both the Parent and Daughter boards (two weeks). Multiple Daughter Boards will then be connected to the Parent Board to form a group of boards sufficient for a bladder array for a side of the helmet (three weeks). In the next step, the Daughter and Parents Boards will be embedded into the base of a bladder array provided by other researchers to form a side of the helmet (two weeks). The performance of the integrated multi-bladder network will be tested and evaluated (two weeks). The final step will be writing a report summarizing the work. See Figure 2 for a timetable for the proposed project with expected durations of each step.

The timeline for Spring 2020 continues research from the previous semester starting with sensor recalibration which involves data conversion and noise filtering (three weeks). The next step would be to improve data communications between Parent and Daughter boards (8 weeks). This step is divided into data synchronization (4 week) and Graphic User Interface (GUI) re-design (4 weeks). After Step 10, the Parent- Daughter architecture will be complete and ready for testing and evaluation (4 weeks). A month is allocated to focus on writing a research paper for publishing (4 weeks).

Relationship of the Proposed Work to the Expertise of the Faculty Mentor

Dr. [redacted] is an Associate Professor in the Department of Mechanical Engineering at the University of Utah. He supervises the Robotics Systems Lab where he works on all things robotic including wearable robots, climbing robots, terrain adaptable mobile robots, and autonomous ground vehicles [9]. Dr. [redacted] is the PI for the Smart Helmet project, leading research on the helmet bladder network. He demonstrates expertise to the proposed work as he advised and published the Smart Shoe project featuring the control of pneumatic bladders with pressure sensing [7], [8]. I was first acquainted with Dr. [redacted] through RoboUTES in which he was the faculty advisor. I worked under his PhD student, [redacted] with the Smart Shoe project. Currently, I am a research assistant for the study of multi-sensory startle response in a virtual reality environment, reporting to Dr. [redacted]. I have been involved in multiple projects under Dr. [redacted] for over a year and I believe he will be the perfect mentor.

Relationship of the Proposed Work to Student's Future Goals

I am in my senior year of obtaining a Mechanical Engineering B.S. with an emphasis in Robotic Systems and Control in which I will be finishing in Spring 2020. My long-term objective is to become an engineer specializing in robot control. Ideally, Boston Dynamics is the company I want to commit to where I can experiment and expand the limits in robotics. To increase my chances of realizing that goal, I will attend graduate school and obtain a PhD. This research opportunity is integral to this plan as it will lead to my appreciation for research and prepare me for graduate school. It will also enhance my programming skills as there will be extensive coding for the circuit boards and communication protocol. Receiving a research designation under Dr. [redacted], a name well recognized in the field of robotics, widens my opportunity to work in this field.

References

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