# Graduate Research Plan Statement

# Introduction/Motivation

Robots revolutionized the manufacturing industry. Today, robots play a role in producing most things we use; however, robots that play a personal role in our individual lives are far less common. Industrial robots, while being highly precise and capable, have a relatively high inertia which severely limits how quickly they can move around humans to mitigate collision and high contact forces. Development of robotics that are lightweight (lower inertia), compact, and inherently safe around humans will enable robots to play a much more personal role in our lives. Robots like this will be able to interact with their environment with unplanned impacts without hurting humans or breaking. They could play a major role in living assistance, rehabilitation, search and rescue, and space exploration, to name a few.



*Figure 1: Five degree of freedom soft robot developed by Pneubotics*

I recently began my graduate degree in the Robotics and Dynamics (RaD) Lab at Brigham Young University (BYU). The RaD Lab does research into inflatable pneumatically actuated robots that are inherently lighter and safer around humans than current robotic technology. My research will focus on dual arm bimanual manipulation using the soft robot shown in *Figure 1*.

# Background

Many tasks such as opening a bottle, lifting heavy and bulky objects, or even folding clothes are difficult, if not impossible with only one arm. This fact has sparked a large amount of research into dual arm manipulation. One of the difficulties in dual arm manipulation with traditional robots is that small deviations in end effector position (or orientation) from either arm while holding a rigid object results in large stresses on both the object and internally on the arm. Many researchers have proposed hybrid force/position control schemes in order to control the desired position of an object in task space while maintaining interaction and/or internal forces below a desired threshold.

One approach to mitigate buildup of high internal forces is to use a robot with flexible links [1]. Inflatable, pneumatically actuated robots have no rigid structure and are inherently compliant. This means that small deviations in relative position during a dual arm task will not result in high stresses.

# Hypothesis

I propose that dual arm manipulation can realistically (and usefully) be implemented on an inflatable, pneumatically actuated robot with the following research questions/goals in mind:

* Implement coordinated bimanual manipulation for impact tasks with rigid objects (such as sweeping)
* Implement coordinated bimanual manipulation with a nonrigid object like a blanket
* Some tasks require more stiffness than soft, pneumatically actuated arms inherently have. Can these tasks become more feasible by grasping one arm with the other (forming a closed kinematic chain increasing the rigidity)?
* One of the challenges with soft, pneumatically actuated robots is repeatability. The fabric doesn’t fold on itself the same way with each movement, so the dynamics of the arm change regularly. What type of control scheme will result in the highest task space repeatability?

In order to answer these research questions, there are many intermediate steps I will work on as described in the following section.

# Research Plan

To get started, I will perform a manipulability analysis on the robot in *Figure 1*. I recently finished moving all of the electronics/sensors from the inside of the arm to the outside to improve robustness and make troubleshooting easier. As a part of this, I removed the faulty elbow joints in each arm. So, the robot currently has only four degrees of freedom. In order to perform coordinated bimanual manipulation tasks, I will need to accurately command each end effector in 6 degrees of freedom (for example, with the impact task of sweeping with a broom, each end effector will need to have a certain task space position as well as being parallel to the other manipulator in orientation). This likely means I will need to add additional degrees of freedom to improve the manipulability of the arm.

Next I will design a controller to accurately and repeatably command a single arm to a position and orientation in task space. Previous students in the lab have designed a model predictive controller that can accurately command the arm in joint space. I’ll start by using this work to develop a hybrid controller, in which I will use inverse kinematics to determine the desired joint angles to send to the model predictive controller. Since the dynamic model is not perfect and changes regularly as the fabric folds in different ways, this control will not alone result in accurate task space positions. I will use visual servoing to close the distance between the desired position and actual position. The lab currently has a highly precise motion capture system that I will use initially; however, this can only be used inside the lab. Ultimately, the system will need to be usable outside the lab. We recently acquired an HTC Vive which is accurate enough to replace the motion capture system. An undergraduate is currently working on getting the Vive working in Linux and the Robot Operating System (ROS).

After I am able to accurately command one arm, I will develop a path planner and control scheme for dual arm manipulation as well as a grasping one arm with the other in a closed kinematic chain.

# Broader Impacts of Proposed Research

The inherent broader impact of my research to society is one of the main reasons I chose to do my master’s degree in the RaD lab. Soft, pneumatically actuated robots (already inherently safe around humans) with dual arm manipulation capabilities will have the potential to play a major role in living assistance, stroke rehabilitation, search and rescue, and even space applications (due to the lightweight nature and small footprint of these robots). In addition, all of my development will be made publicly available on git, so other researchers can utilize and build on my discoveries.

I will also focus on getting younger students excited about engineering. I have already participated in multiple outreach opportunities as a part of the RaD lab. Additionally, I plan on demonstrating our robots and my research for younger students throughout my graduate degree. During these demonstrations, I will give younger students a chance to interact with the robots. For many students, especially those from a disadvantaged background, these interactions will motivate a desire to pursue a STEM education. Finally, I will give undergraduates the opportunity to assist me in my research and with writing multiple conference papers. During my undergraduate degree, having the opportunity to participate in research and write a conference paper inspired me to pursue a graduate degree. It would thrill me to similarly inspire younger students.

[1] Mitshiro, Y., et al. "Cooperative control of a 3D dual-flexible-arm robot."*Journal of Intelligent and Robotics Systems* (2004): 1-15