INTRODUCTION

The opportunity to apply my drive to investigate questions and satisfy my curiosity has always been important to me since I discovered this passion in high school thanks to my robotics club which provided me opportunities to work hard and to discover how robotics can be used as a tool to impact others. As a result, I am now a senior studying Robotics Engineering at Arizona State University and conducting robotics research in Dr. Dan Aukes' IDEAlab. This undergraduate research experience has, in turn, inspired me to pursue a graduate level degree in computer science and continue conducting research in robotics. I would like to continue this cycle by contributing to the field of educational robotics so that I may impact the next generation.

INTELLECTUAL MERIT

My research has investigated how the material properties and dynamics of origami-inspired, foldable robots can be taken advantage of without increasing the complexity or costs. For first project that I worked on when I joined Dr. Aukes' lab we developed a methodology to leverage the deficiencies of soft, low-cost, informal systems to our advantage to sense contacts in a way that rigid systems cannot. My current work focuses on understanding the unique considerations of laminate robots that need to be accounted for to use informal simulators to develop a high-performance jumping robot.

My research began upon receiving an undergraduate research fellowship to develop a force sensing device that could easily be integrated into an existing foldable robot design as an example of our integrated-sensing methodology for nonrigid systems. My device takes advantage of the inherent flexibility of foldable laminate materials by measuring the deformation and using it to extract the force acting on the device. After building a prototype of this design, I tested its measured force verified against known applied forces to confirm the accuracy of the force measurement. Then I demonstrated an application of this system by utilizing the data in a force-feedback control-loop. My controller takes into account the force measured by the device and uses it to adjust the movement of a motor to maintain a constant force or to prevent the device from exceeding a certain maximum force.

My design is unique because it integrates the soft member into the structure of a mechanism in parallel with more rigid members. This reduces complexity compared with the traditional method of building a completely rigid structure and then going back and adding a soft layer on the exterior. By building the flexibility into the design, there is no need to make a structure completely rigid only to then make it soft again. This type of force-feedback system is necessary for human-robot interactions where robots need to limit the force they are exerting so as not to cause injury.

Following my completion of this force sensing device, I was awarded another fellowship by the Fulton Undergraduate Research Initiative to work on a larger project to construct a bio-inspired laminate robot based on terrestrial birds. While other members of the team have been tackling separate challenges the robot will face, such as gliding and balancing, my role in this project has been to develop simulations to optimize the design of the robot's legs for jumping.

The goal of this work is to understand the limitations and important factors of modeling the nonideal behaviors of laminate systems. I am investigating a more generally available gaming engine that features a physics engine as well as a purpose-built symbolic equation builder based on Kane's method. I could have merely used experimental data to identify trends and follow a data driven approach. Instead, I chose to take the more challenging route of developing a theoretical model that fits the experimental data because it provides more insights into the factors that affect the robot's performance and can be used to make decisions outside of the design space that has been tested.

In order to determine which aspects of the leg needed to be included in the model, I built several leg prototypes, and compared their jumping performance with those of the models at each step. Through this investigation, it became apparent that the flexibility of the laminate materials in the leg was affecting the jumping results and needed to be modeled. To do this, I experimentally examined the force-deflection relationship of the material and found it could be reasonably approximated by a rotational joint with a linear spring. This resulted in a closer fit between the trends of the simulated and the experimental results. To further close the gap, I examined another unmodeled aspect of the leg: the motor dynamics. After collecting data on the motor's electrical and mechanical characteristics, I replaced the linear motor model I had been using with a more complete dynamic model including resistance, inductance, inertia, and damping.

I seek to show how high-performance robots can be made from informal methods. A free game engine is the logical simulator to pair with foldable robotics since both seek to be more affordable and accessible to novices. There has been little investigation into the usefulness of free physics programs such as game engines and Python libraries as means of modeling complex dynamic systems in engineering. However, they are effective means of representing a dynamic system and provide useful insights on the design choices. Knowledge about the design can be gained quickly through the model and then applied to the rapid prototyping of the foldable robot. This allows as much performance as possible to be squeezed out of a cheap laminate mechanism, so that a high-performance device can be made and tested quickly.

BROADER IMPACTS

In college, I have mentored elementary through high school students in robotics so that they may discover the same enthusiasm for engineering that I experienced in high school. I mentored my old high school's robotics team for the past three years and volunteered at all of their competitions. While my inspiration came in high school, many students now are being exposed to engineering as early as elementary school. Many educators are using robotics to do this because it makes engineering concepts fun and practical for students since they can build mechanisms and see these principles in action. I have seen this first-hand as I taught several robotics workshops with elementary-age students. For many students, what they previously considered too boring and abstract becomes hands-on and enjoyable when robotics is used as a tool for learning.

The challenge with implementing robotics in the classroom is that traditional robots are precision machined from metal, which requires significant investment in the materials and machines as well as advanced expertise. Several commercially available robotics kits attempt to solve this issue; however, the limitation of using prefabricated parts inhibits students' creativity and restricts the designs that can be explored. My research in Dr. Aukes' lab developing foldable, origami-inspired robots using unconventional materials and methods to make the development of robots from scratch more accessible to students. My force sensing mechanism encourages the use of these low-cost materials by showing an advantage in the form of sensing capabilities. My dynamics simulation informs our field about what factors affect the design of a foldable robot so that more optimized robots can be made in the future. Both of my projects have contributed to a design methodology centered around laminate materials, understanding their properties, and considering how they can be used advantageously as part of a mechanism.

My research in robots made from informal materials and rapid prototyping seeks to lower the cost, time, and technical skill required to make robots, while still allowing construction from scratch. This makes the process more accessible and opens the doors for more students to experience robotics in their pre-college education. Students don't need to attend a school with a machine shop or be limited by what can be made with kits. They can rapidly make foldable mechanisms from cardboard, test them to discover the motion they produce, and iterate on their design to learn how to produce the desired effect. The goal is to show students that engineering is not beyond them and to inspire these students in the same way I was inspired.

FUTURE GOALS

I discovered my curiosity and passion for investigation when I joined my school's robotics team, so I wish to foster the same love in the next generation through the same tool that inspired me. I plan to increase the accessibility of robots so more people may share in the benefit that I received. To do this I would like to continue researching within the realm of robotics as I get my doctoral degree in computer science. Whereas my undergraduate research has focused on the mechanical design of robots, I would like to move into the design of robotics software. I feel the two main factors preventing the wider proliferation of robotics is their cost and the difficulties involved in programming them to accomplish desired tasks. My undergraduate research has been in the new field of foldable robotics, which is one potential solution to the problem of cost. Now, I would like to work on what I see as the other main issue, intelligent control software. I would like to become a professor and lead a research team in the area of autonomous robotics so that I may continue to advance the country's robotics capabilities and one day become a leader in this field. I am excited to continue working in a close community of fellow scholars who are all mutually interested in robotics and explore the same type of experience in a greater context throughout my doctoral degree.