Applied Viscous Thread Instability for Manufacturing 3D Printed Foams
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Traditional foams are fabricated via stochastic chemical processes that yield homogeneous material properties. Foams can exhibit a wide range of material properties by varying process controls allowing them to be used in many industrial and commercial applications. Previously, additive manufacturing could only produce foam approximations in the form of traditional lattice infill. My work employs viscous thread printing (VTP) of thermoplastic polyurethane (TPU) on a fused filament fabrication (FFF) printer, exploiting the semi-viscous nature of extruded filament to coil producing a new type of printed foam. Specimens were tested under compression to determine uniformity along principal axes and behavior under strain when compared to infill patterns, such as grid and cubic. My work establishes that VTP, using elastic materials, can be used to manufacture programmable stiffness foams as a function of density, suited to a variety of needs and should be considered as an alternative to traditional foams and other printed lattice geometries.

Designing and Building TinyQuad: A Quadcopter That Weighs 1–2 Grams
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Development and testing of sensors and power methods for insect-based robots is a difficult task. Due to the high cost of manufacture with regards to both training time and funds, finding a sustainable and easy-to-produce method to test sensors and power options is essential. Previously, the only option for testing new sensors and power options was using one of the robotic insects, which is risky considering their high costs. Drawing from prior results, we believe a lightweight quadcopter would be faster, easier to produce, more robust, and able to serve as a suitable replacement in sensor testing and development. My goal will be to create the world’s lightest and smallest quad-rotor helicopter, “TinyQuad,” with a target mass of 1–2 g. The new helicopter I have designed will enable the testing of new sensors such as cameras and power options such as radio frequency-based charging. This design allows for testing a variety of sensors and electronics configurations very quickly, with the potential to rapidly speed up the prototyping process. I will demonstrate flight capabilities through utilizing wireless charging, and sensor-based feedback control to improve flight stability and duration. I completed calculations and design of this hardware, and anticipate seeing that the collected flight data supports the utilization of a lightweight quadcopter in insect robotics development. This will allow us to rapidly develop and refine sensors for use onboard the RoboFly robotic insect platform. Creating a working quadcopter would result in accelerated prototyping that allows for more unusual sensor and payload designs, and for further research in developing new sensors and power methods for insect robotics, smaller quadcopters, and improved design of micro aerial vehicles.

Community-Based Data Visualization for Mental Well-being with a Social Robot
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Mentor: Maya Cakmak, Computer Science and Engineering
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Social robots have been used to support mental health, be-
cause they are capable of forming meaningful interactions with humans due to their social intelligence, which boost user engagement with social robots. Thus, social robots can better foster emotional support with mental health data visualization compared to other technologies in collecting and displaying relevant data from humans. In this Human-Robot Interaction (HRI) research work, I explored their potential as community-based tools rendering data visualizations that represent a community’s mood patterns. Collecting and visualizing the mood patterns of a community might help the community members raise awareness about the mental health of the community, and whether there are significant factors negatively impacting the mental health of community members. In a two-day study, twelve participants recruited from a university community engaged with a robot displaying mood data. I created a data visualization template to show random mood data and placed it in a social robot. The design choices (e.g., spectrum of data varieties, data representation) of the template were made hypothetically in a random manner with no evidence basis from any particular community’s moods. During the study, participants were asked questions verbally and through written prompts on paper to express their feelings about robot-rendered visualizations’ usefulness in their lives. Given the feedback from participants, I modified the data visualization on the robot screen with the aim of increasing accessibility, universality, and usefulness of such visualizations. Currently I am implementing a real-time data collection and visualization system in the robot’s end-user-programming tool. In the near future, I plan on conducting studies to assess how interacting with the robot’s automated data collection and visualization software affects users and if it produces an improved experience for them. Eventually, I hope to evaluate how data visualization enhances a sense of belonging and support among community members.

**Computational Design of Passive Grippers**

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*Mentor: Adriana Schulz, CSE*

*Mentor: Jeffrey Lipton, Mechanical Engineering, University of Washington*

This work proposes a novel generative design tool for passive grippers—robot end effectors that have no additional actuation and instead leverage the existing degrees of freedom in a robotic arm to perform grasping tasks. Passive grippers offer interesting trade-offs between cost and capabilities. However, existing designs are limited in the types of shapes that can be grasped. This work proposes to use rapid-manufacturing and design optimization to expand the space of shapes that can be passively grasped. Our novel generative design algorithm takes in an object and its orientation with respect to a robotic arm and generates a 3D printable passive gripper that can stably pick the object up. To achieve this, we address the key challenge by jointly optimizing the gripper shape and the insert trajectory to enlarge the set of objects that can be passively grasped. We evaluate our method on a testing suite of 23 objects, all of which were evaluated with physical experiments to bridge the virtual-to-real gap. Inspired by the true cost of repurposing infrastructures in assembly lines following the recent changes in demand early in the COVID-19 crisis, our work allows a cost effective solution to rapidly generate, fabricate, and deploy custom passive grippers on the existing robot arms for the new products in demand.

**Laser Processing of Polyimide for Flexible Electronics and Wearable Sensors**

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Laser-induced graphene’s (LIG) simple and rapid fabrication has led to the development of flexible sensors with various applications in wearable electronics. LIG is produced in ambient air through CO\(_2\) laser scribing on a polyimide film. Although LIG has been incorporated into flexible chemical and strain sensors, its sensitivity to resistance changes under deformation and instability prevents it from being fully utilized as a flexible conductor. This work presents a versatile technique to increase the electrical conductivity of LIG and enhance its structural stability so that it can be used as flexible conductors in printed electronics. This is achieved by the deposition and activation of functionalized liquid metal (LM) nanoparticles on LIG traces. To overcome the repulsion of LM on LIG’s surface, the CO\(_2\) laser’s settings are adjusted to create LIG traces with a superhydrophilic inside and superhydrophobic border. Additionally, the adhesion between the LIG and LM was improved through surface functionalization of the liquid metal droplets. Our results show the resistance of LM-LIG traces to be 3 orders of magnitude smaller than that of LIG traces. Electromechanical characterization of the LM-LIG traces demonstrate low resistance changes under large bending deformations. The combination of the liquid-phase conductor and 3D structure of graphene enables the fabrication of customizable, solder-free, flexible circuits with high mechanical stability. We demonstrate this technique with the fabrication of flexible light-dependent resistor circuits that serve as a basis for further flexible sensor and biosensor exploration.

**Dynamic Cadaveric Test Bed for Biomechanical Studies of Hand and Wrist Function**

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*UW Honors Program*

*Mentor: Scott Tefler, Orthopaedics and Sports Medicine*

Wrist and hand motion is continuously present and necessary in daily life, making it important that we understand
the biomechanics of the joints along with the effects of injury. The use of cadaveric studies is crucial in understanding the biomechanics of the wrist and hand. Currently, most cadaveric studies on wrists are performed statically, which can fail to represent the complexity of dynamic wrist motion. To address the inaccuracy of static testing, we designed, constructed, and tested a system capable of dynamic testing of the wrist under prescribed loads. The dynamic cadaveric test bed utilizes a robotic pulley system to load the tendons that actuate the wrist and hand along with a fuzzy logic control system to recreate physiologically accurate wrist motions. Biomechanical data, such as tendon forces and joint kinematics, are collected simultaneously during motion to provide wholistic insight on the biomechanics of the wrist and hand. To validate the cadaveric test bed, a 3D printed wrist model was used to ensure accurate control of the control system and robust data collection. The wrist model consisted of a model forearm, palm, and wrist joint that simulated wrist motion using string in lieu of tendons. After successful trials using the hand model, the test bed is now being utilized for biomechanical wrist and hand cadaveric studies, including studies regarding surgery effectiveness and injury analysis. The dynamic cadaveric test bed’s ability to more accurately study wrist and hand motion could lead improved treatment practices for wrist injuries.

Operational Effects of the One-Sided Diverging Diamond Interchange Design

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Mentor: Yinhai Wang, Civil And Environmental Engineering

The conventional signalized diamond interchange provides numerous essential freeway-to-arterial connections. However, it tends to become operationally inefficient when high traffic demands exist on the arterial or off-ramps. To address this problem, diverging diamond interchanges (DDIs) have been implemented at many sites to replace conventional diamond interchanges (CDIs). While DDIs have been shown to outperform CDIs under high left-turn demands, their operational performance diminishes when through demands on the arterial become heavy. In this work, I proposed a new service interchange design named the “one-sided diverging diamond interchange” (one-sided DDI) as a replacement for congested CDIs and DDIs. Through a comprehensive series of microscopic simulation tests with the software PTV Vissim, I analyzed and compared the operational attributes of the one-sided DDI to those of the CDI and DDI over a range of traffic demands. Overall, the results from the simulation tests indicate that the one-sided DDI significantly outperforms both the CDI and DDI in vehicle travel time and throughput when through demands on the arterial are dominant. On the other hand, the one-sided DDI tends to modestly outperform the traditional DDI in travel time when handling moderate to high proportions of left-turning traffic.