Engineering Student Services
Virtual Undergraduate Research Poster Session

Tuesday, November 17th
4-5:30pm

Ailin Chen, Komal Thind, Kahraman Demir & Grace Gu. ***BioInspired Fish scales: A Kinematic and Numerical Approach for Flexible Armor Design***

Research Area: Mechanical Engineering; Material and Design

Abstract: Fish scales serve as a natural dermal armor with remarkable flexibility and puncture resistance. Through biomimetic scales, researchers are able to acquire these properties and tune them by adjusting their design parameters. Overlapping scales, as seen in elasmoid scales, can lead to complex interactions between each scale. These interactions are able to maintain stiffness while improving flexibility. Hence, it is important to understand these interactions in order to design biomimetic fish scales. As the scaled substrate deforms and the scales start to engage, modeling the flexibility requires accounting for nonlinear relations. Current studies focus on characterizing these kinematic linear and nonlinear regions but fall short in modeling the kinematic phase shift. Here we propose an approach that will predict when the transition from linear to nonlinear will occur, allowing for more control of the substrate's overall behavior. Using a kinematic analysis of the interacting scales, we can model the flexibility at the transition point where the scales start to engage in a nonlinear manner. The validity of these kinematic predictions will be investigated through finite element analysis. The results of this investigation could allow for an efficient optimization method for scale-like designs that can be applied to various applications.

Sasha de Frondeville. ***Benefits of HVAC Electrification for Rural Electric Cooperatives.***

Research Area: Building Energy Use

Abstract: Buildings, as a whole, take up approximately 40% of U.S energy consumption and well over half of U.S. electricity consumption. As a mechanism for reducing climate change impacts driven by electricity production, buildings have high potential for decarbonization, specifically through increased use of more energy efficient lighting, appliances, and HVAC technology. In some areas of the U.S., residents are served electricity through electric cooperatives, which are “private, independent electric utilities, owned by the members they serve, ” and provide key utility services to rural Americans. 90 million people in the U.S. receive electrical service from municipal or cooperative utilities. Non-profit Post Road Foundation has used the National Renewable Energy Laboratory ResStock Analysis Tool to predict the economic and environmental impacts of heat pump adoption by cooperative members. End-use load profile (EULP) outputs from ResStock have been combined with data on fossil fuel costs, electricity costs, and region-specific emissions factors to produce forecasts of adoption impact. Specifically, our work shows that an upgrade from fuel oil/propane combusting furnaces + AC configuration to heat pump technology can result in a trifecta of benefits: increased revenue in electricity sales to the rural cooperative, decreased annual energy bills to the customer, and decreased annual HVAC related CO2 emissions. The magnitude of these benefits, and whether or not they can be realized, are functions of many different variables, most importantly the efficiency of the heat pump, the type of heat pump, and the local weather. PRF has conducted these studies for five different communities to date, with plans to expand analyses to other regions. Goals include communication of results to community stakeholders, utilities, and policymakers in order to provide insight regarding programs that incentivize heat pump adoption and make it affordable.

Sharjeel Laeeq, Hayden Taylor, Brian Salazar, Parham Aghdasi, Levi Seidel, Michael Herrmann, Claudia Ostertag & Zane Schemmer. ***Optimizing the placement of steel in flexural beams.***

Research Area: Composite Topology Optimization and Manufacturing; Mechanical Engineering

Abstract: As concrete is a brittle material, it is typically reinforced with steel for use in building applications. The steel reinforcement often takes the form of a 1-D bar or 2-D cage. However, these reinforcements are not optimized for specific loading scenarios. The amount of steel reinforcement in a concrete structure is dictated by the loads it must withstand and building codes and other regulation. Concrete structures typically do not have a steel reinforcing ratio greater than 6%. Our goal is to optimize the placement of both steel and concrete within the overall structure. We use a topology optimization software to inform the optimal steel placement within the concrete structures, the loading scenario considered is a beam undergoing four-point bending. A total of 5 beams were casted which included one optimized steel, once conventional, two unoptimized, and a control specimen made of just the concrete. The last beam had both the steel reinforcements and concrete optimized. In four-point bending tests, we found that the optimized beam outperformed all the other specimens. It had a toughness 2.5 times the toughness of the control specimen. When we compared it with the beam in which both the steel reinforcement and concrete was reinforced, the peak load was reduced by only 18%, and the toughness was reduced by only 26%. These results suggest that optimizing the placement of steel reinforcement within concrete structures can have a significant improvement in the overall mechanical properties

Kathy Min & Neilabjo Maitra. ***Designing Shape Morphing Piezoelectric Materials.***

Research Area: Mechanical Engineering; Piezoelectric Materials

Abstract: Mechanical devices rely heavily on discrete actuators in order to generate desirable geometries. However, from robotics to aerospace, such actuation methods lack full control over the geometry of surfaces, resulting in inefficiencies. Shape morphing materials in which users have complete and immediate control over surface contours would alleviate these shortcomings. Numerous developments in the field currently employ thermal expansion or solvent absorption in order to achieve shape morphing behavior. Developing a fully electrically actuated system with significantly more degrees of freedom, however, would allow greater control in creating desired shapes. Piezoelectric materials are suitable for such systems – with applied electric fields, these materials exhibit predictable strain. A model with a bulk piezoelectric polymer flanked by conductive plates was developed, in an attempt to ultimately have full control over curvatures in two dimensions. Parametric analysis was conducted on a simplified version to optimize for greatest unidirectional curvature, resulting in an optimized radius of curvature of 2.02 meters. Carbon fiber reinforcements were also implemented in the model to enhance stiffness, but with the increase in stiffness, there was a drastic reduction in curvature, proving shape-morphing to be much more difficult – instead, a method of applying voltages to counter loads was developed. In addition, the model has been expanded to two dimensions in an effort to gain full control over shape morphing behavior; work is still in progress.

Reet Mishra. ***Assessing GAA mutation predictions from the CAGI Challenge to improve understanding of Pompe Disease.***

Research area: Plant & Microbial Biology/Bioengineering; Computational Biology; Variant Interpretation

Abstract: Pompe disease (PD) is an autosomal recessive metabolic disorder resulting from the progressive accumulation of glycogen in tissue. It is caused by pathogenic variation in the lysosomal acid alpha-glucosidase (GAA), leading to partial or complete loss of the enzyme's activity. PD is fatal to patients with infantile onset and causes patients of later onset to develop muscular dystrophy and respiratory dysfunction. Early detection is key to treatment. However, many mutations causing PD remain unknown.

CAGI is a community experiment that aims to assess computational predictions of the genotype-phenotype relationship. In the GAA CAGI challenge, participants were asked to predict the effect of single nucleotide variant changes on GAA enzymatic activity as measured in an in vitro assay. Here, we evaluated these

predictions and those obtained from a set of untrained algorithms (dbNSFP), using a range of statistical analyses. In vitro assays offer a limited scope on understanding disease, which typically takes place in the context of compound heterozygotes and often involves additional alleles that can act to modify the clinical phenotype. Additionally, protein overexpression and other experimental artifacts can complicate interpretation of pathogenicity. To address these limitations, we curated the literature and collected genotype and phenotype information from 750 PD patients. Using these data, we plan to calculate the phenotype-genotype variance in PD and use it to obtain more reliable estimates of predictor performance.
Overall, we hope this work will lead to a greater improvement of our understanding of PD, ultimately translating to earlier detection and better management.

Mahmoud Morsy & Dr. Antoine Wojdyla. *Speckle Based Position Monitoring.*
Research area: Mechanical Engineering; Controls and Metrology
Abstract: Many industries as well as research, cannot exist without a reliable method of high-precision positioning systems. Motivated by our research questions, the research group proved the viability of a new precision monitoring technique based on speckle analysis, SuPreMe. This technique is substantial for the fact it only requires three parts and is easy to set up. SuPreMe setup is as follows: a laser light passes through a weak-optic diffuser to form a speckle on the object's surface. Then, a camera acquires the data (speckle image) for processing. From the rings that arise in the power spectrum density of Fourier transform of (a simulated) speckle image, the research group extracted distance measurements. Our results demonstrated that the SuPreMe method can extract absolute displacement measurement of 100 μm with a precision range of 7 nm-rms. Based on this experiment, we concluded that SuPreMe device is a viable option of metrology, and we are preparing experimental demonstrations

Arnav Raha, Andrew Saintsing & Robert Full. *Effects of Limb Loss on Cockroach Locomotion.*
Research Area: Integrative Biology; Biomechanics
Abstract: Arthropods regularly lose limbs, but it is unclear what the consequences are. We hypothesized that limb loss would destabilize cockroaches and force them to compensate by taking shorter, faster steps at a given speed. Reduced ground contact time would require the cockroaches to develop supportive forces more quickly over the course of a stride and, consequently, to expend more energy and tire more quickly.
Discoid cockroaches (Blaberus discoidalis) were run to exhaustion at a range of speeds on a treadmill equipped with a respirometer to measure O2 consumption. Average stride frequency and average ground contact time were also calculated by analyzing videos recorded during the trial. After an intact individual completed its trials, we removed one of its hind limbs at the trochanter and repeated the experiment. We removed its other hind limb and again repeated the experiment. There was no significant effect of limb loss on O2 consumption, average stride frequency, or average ground contact time. There was, however, a significant impact on the time to exhaustion. Across the range of speeds included, cockroaches with 2 limbs removed ran for noticeably shorter times than those with 0 or 1 limb removed. Although an animal's total energetic expenditure was unchanged after limb loss, its weight was distributed among fewer limbs, so each individual limb had to produce more force over the course of a stride and likely tired faster as a result. This research has potential applications in the design of existing cockroach-inspired search and rescue robots.

Vade Shah, Steven Zadourian, Charles Yang, Zilan Zhang, & Grace Gu. *Data-driven approach to the prediction of mechanical properties in carbon fiber reinforced composites.*
Research Area: Mechanical Engineering; Materials prediction
Abstract: For decades, fiber-reinforced composite materials have been integral to the aerospace, automotive, and military industries due to their lightweight properties. Fiber-reinforced composite manufacturing process involves the curing of the matrix material, which is typically a resin, polymer, or ceramic. The curing process is dependent on several factors, including humidity, temperature, and

cycle time, altogether referred to as the curing environment. Curing environments are known to have a significant impact on the mechanical properties, such as modulus and strength, of the final product. While many studies have focused on predicting the mechanical properties of composites, the curing environment is usually not considered. In this work, a data-driven method is applied to various uni-directional carbon fiber laminates to investigate the effects of curing environments on mechanical properties such as longitudinal/transversal strength and modulus. We have conducted statistical and exploratory data analyses to identify trends, using data from the National Center for Advanced Materials Performance (NCAMP). Results show that high curing temperatures can yield stronger composites, and that the variability in material property values may be resistant to temperature for some resins but not all. Additionally, using machine learning techniques, we develop and compare regressive models considering varying curing environments to predict the strength and modulus of these materials in both longitudinal and transverse directions. This work establishes a statistical framework to analyze complex empirical data for both inference and insight for optimal designs.

X Sun, Hayden Taylor, Rafael Prieto, Maria Molina, Jacob Brito, Jack Walli, Nicole Luk: Bear Air
Research Areas: COVID-19; Air Ventilation; Mechanical Engineering
Abstract: The Covid-19 outbreak has shown that facilities around the world were seriously underprepared for the airborne spread of the virus. The need for effective and accessible systems for lowering aerosol concentrations in indoor spaces becomes strong. Our research aims to examine if a combination of a moderate filtration efficiency and a high recirculation rate can be an effective solution. Based on this hypothesis, we are designing a mobile air purifying system using a low-cost, high flow-rate air blower and commodity filters. We are currently in cooperation with the Elder Care Alliance to further the application of our device and research to the broader community.

Erica Whiting. *CO Diurnal Cycles Amidst COVID-19*
Research Areas: Environmental Engineering; Earth and Planetary Sciences; Air Quality, Carbon Monoxide, in situ, Diurnal Cycle, COVID-19
Abstract*:* This summer, I compared changes in column and in situ carbon monoxide (CO) measurements with changes in traffic data in the Los Angeles Basin to examine how the COVID-19 pandemic has affected air quality in the region. I hypothesized that changes in human behavior as a result of local and state Shelter-in-Place orders would cause a decrease in CO emissions throughout the LA Basin as there were significantly fewer cars on the road. Both the diurnal CO cycle from in situ data and the diurnal traffic pattern showed this decrease, but not in the same way. The most visible changes in the traffic data and carbon monoxide diurnal cycles occurred in the first 30 days following the stay-at-home order. Traffic data showed a reduction by half while maintaining the same overall shape, while air quality data showed a more time dependent reduction. Weekend versus weekday data highlighted the difference between the changes in traffic and air quality data. While traffic decreased by a similar magnitude on both weekdays and weekends, the air quality diurnal cycle showed changes only on weekdays. This leads me to ask, why does the CO diurnal cycle vary so much on weekends versus weekdays while the traffic diurnal cycle does not? To answer this, my next steps include coupling with STILT model outputs to better understand the sources of the air surrounding the in situ instrument as well as how to weight the traffic data accordingly.

Trevor Wu, Dr. Saleh Albeaik & Prof. Alexandre Bayen. *DeepTruck: Using Deep Reinforcement Learning to Model Truck Dynamics and Controls.*
Research Area: Transportation Engineering, Machine Learning
Abstract: Accurate cruise controllers and adaptive cruise controllers can be considered the first step towards autonomous trucks. To create an accurate controller, we need an accurate model of truck dynamics. We used a Recurrent Neural Network to learn the dynamics of a truck from a large amount of

raw data generated from an advanced physics-based simulation. This presented many challenges such as data collection strategy specifications. Accurate models derived from data require datasets that span the operational state space of the truck. By generating more data from specific behaviors such as braking, and tuning hyperparameters, we were eventually successful in creating a reasonable model. After the model had reached an acceptable performance level, we used Deep Reinforcement Learning to train a controller for the truck model we produced. We had to design a loss function which allows the model truck to converge as close to the set speed as possible without making dangerous maneuvers or oscillating. These constraints lead to a trade-off introducing a speed offset.