Sibley Graduate Research Symposium

Thursday, April 28th, 2022
Upson Lounge
Mechanical and Aerospace Engineering Department
Cornell University Ithaca, NY

Welcome!

Welcome to the 2022 Sibley Graduate Research Symposium! We look forward to an engaging afternoon exploring all of the research being conducted in the Mechanical and Aerospace Engineering Department at Cornell University.

In this document, you will find the presentation abstracts for our keynote address in addition to that of each student presenter. We encourage each and every attendee to take a step outside of their comfort zone at this research symposium: attend a presentation on a research topic that is outside of your realm of expertise, maybe even expand your academic network!

All in all, we truly hope that this will be an interactive and educational experience for everyone involved! Enjoy and thank you for coming from your SGRS committee members:

- *President*: Kalani Danas-Rivera
- *Corporate Liaison/Treasurer*: Sean Kim
- *Event Coordinator*: Corey Spohn

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Schedule of Events

Presenter	Start	End	Topic
Coffee hour			
	9:00	10:00	
Keynote Address			
Dr. Matt Miller and Dr. Kelly Nygren	10:00	11:00	*Collaborative research at CHESS*
Presentation Block 1			
Kalani Danas Rivera	11:00	11:20	*Spacecraft Navigation*
Hanfeng Zhai	11:20	11:40	*Biomechanics*
Jenniffer Bustillos	11:40	12:00	*Additive Manufacturing*
Akane Wakai	12:00	12:20	*Additive Manufacturing*
Adrita Dass	12:20	12:40	*Metal Additive Manufacturing*
Alap Kshirsagar	12:40	1:00	*Human Robot Interaction*
Lunch			
	1:00	2:00	
Presentation Block 2			
Rachel Oliver	2:00	2:20	*Dynamics and Controls*
Fernanda Fontenele	2:20	2:40	*Solid Mechanics*
Andrew Kang	2:40	3:00	*Microfluidics*
Amy Fang	3:00	3:20	*Robotics*
Coffee Break			
	3:20	4:00	
Presentation Block 3			
Rebecca McCabe	4:00	4:20	*Renewable Energy*
Walker Lee	4:20	4:40	*Climate Engineering*
Yan Zhang	4:40	5:00	*Dynamics and Controls*
Happy Hour			
	5:00	6:00	

Keynote Speakers


Matthew Miller, MAE Professor, CHESS Associate Director

Kelly Nygren, MAE Adjunct Professor, Lead Scientist, CHESS Structural Materials Beamline

Collaborative Research at the Cornell High Energy Synchrotron Source (CHESS)

Over the past two decades, government-funded university research has evolved from being mostly “Single Investigator” grants – research topics originated and pursued within the lab of a single faculty member – to topics and programs involving multiple investigators from multiple universities and national labs. For instance, every funding agency has a form of MURI (Multidisciplinary University Research Initiative) grant programs designed to fund investigators from several universities and even national laboratories to work on “larger”, more comprehensive topics. Our group is part of the Advanced Manufacturing and Materials research area within the Sibley School. High energy x-rays – the kind that can only be created at a facility like CHESS – play a central role in the research we conduct, which focuses primarily on structural materials (metallic alloys). In this talk we explore some of the challenges and opportunities of team research by describing how our group “works” – mostly within the context of the projects we are working on, the proposals we have written and the students we advise.

Presentation Abstracts

Kalani Danas Rivera

Spacecraft Navigation
Mason Peck

The Application of Saturn's Rings to Spacecraft Optical Navigation

This work explores the feasibility of using images of Saturn's ring system as a navigation beacon for spacecraft. The perspective geometry of Saturn's rings provides closed-form expressions for estimating a spacecraft's relative position as well as its analytical covariance. Numerical simulations detail the performance and sensitivity of the position estimates. An Extended Kalman Filter fuses the relative position estimates with spacecraft dynamics for more accurate relative position and velocity estimates. An Enceladus sample collection mission serves as a case study where the proposed method seems viable. Autonomous navigation may reduce the cost of such a mission to the point where several small spacecraft can achieve the science objectives.

Hanfeng Zhai

Biomechanics
Jingjie Yeo

An automated Bayesian optimization workflow for antimicrobial nanosurfaces

Biofilms pose a huge problem for engineers in diverse fields, such as marine science, bioenergy, and biomedicine, where effective biofilm control is a long term goal. The adhesion and surface mechanics of biofilms play crucial roles in generating and removing biofilm. Designing customized nano-surfaces with different surface topologies can alter the adhesive properties to remove biofilms more easily and greatly improve long-term biofilm control. To rapidly design such topologies, we employ discrete element simulations and Bayesian optimization to automate the design process and generate different active surfaces for effective biofilm removal. Our framework successfully generated ideal nano-surfaces for biofilm removal through applied shear and vibration. For shearing, a slim pillar-like topology is generated from the optimization. For vibration, thick trapezoidal cones are found to be optimal. Our results provide insights for various engineering fields that require surface-mediated biofilm control. Our framework can also be applied to more general materials design.

Jenniffer Bustillos

Additive Manufacturing
Atieh Moridi

Not all defects are bad defects: A paradoxical approach to achieve higher performing microstructures in additive manufacturing

Additive manufacturing (AM) has opened up a number of opportunities to design complex geometries with tailored microstructure and properties. This capability is of significant interest to AM Titanium alloys, where directional thermal gradients, high cooling rates and stochastic powder-laser interactions result in parts with anisotropic properties, high strength but poor ductility. Recently, by harnessing the inherent AM defects and using a standardized thermomechanical process, the authors have designed a Ti alloy with duplex microstructure that overcomes the aforementioned shortcomings. The designed microstructure, consisting of defect-free globular α-grains and hierarchical α-laths, exhibits an excellent combination of strength (UTS=1.0±3×10-2 GPa) and ductility (εf=20±1%). In this work, we uncover the deformation mechanisms and defect evolution of the engineered Ti-6Al-4V duplex microstructure. Post-mortem evaluation of the tensile surface via electron backscattered diffraction reveals the deformation sequence to begin with the early saturation of work hardening capability in α-laths, followed by the transfer of strains to neighboring defect-free globular α-grains. Plastic strains partaken by the globular α-grains prompt crystal rotations to “softer” crystallographic orientations (basal, and prismatic) and generate a fine network of dislocation cells. These findings suggest the ability to prevent brittle-like fracture of AM Ti alloys by engineering microstructures with desirable morphologies and grain orientations.

Akane Wakai

Additive Manufacturing
Atieh Moridi

The effect of solidification pathway on grain boundary fractality

Austenitic stainless steels 304L (SS304) and 316L (SS316) were additive manufactured under the same processing conditions to reveal two distinct solidification microstructures. The chemical composition, and more specifically the ratio of ferrite-stabilizing constituents to austenite-stabilizing constituents, determines the solidification pathway (ferrite-to-austenite solidification mode for SS304 and direct transformation into austenite for SS316). Despite the same solidification conditions for both materials, the resulting grain morphology for SS304 is singular – a large amount of misorientation results in formation of substructure boundaries within the grains; there is a wide range of grain size spanning nearly two orders of magnitude; and the grain boundaries are rough and convoluted, resembling a fractal object. Operando X-ray diffraction studies at Cornell High Energy Synchrotron Source substantiate the solidification pathway of the materials. The findings from the study open up a new avenue for grain boundary engineering using additive manufacturing.

Adrita Dass

Metal Additive Manufacturing
Atieh Moridi

Operando synchrotron x-ray diffraction during metal additive manufacturing to de-convolute the complex nature of the solidification process

The dynamic solidification behavior during metal additive manufacturing (AM) directly influences final microstructures, defects, and hence mechanical properties of the part. Many efforts towards understanding solidification behavior are based on numerical and computational approaches. Some studies focus on the experimental determination of solidification parameters using operando monitoring including pyrometry or IR imaging, which fail to provide sub-surface information. More recently, synchrotron x-ray imaging studies during operando AM also gives critical insights into the dynamics of the process at the sub-surface level, albeit without any thermal information.Here we demonstrate a novel approach using operando synchrotron x-ray diffraction to analyze theoperando solidification process by tracking the evolution of the mushy zone during a single line scan of Inconel 625. The experiments were carried out using a custom-made AM setup designed and built in the Lab for Advanced Materials and Manufacturing (LAMM). This setup was integrated at the Cornell High Energy Synchrotron Source (CHESS) -FAST beamline. We employed a specialized fast detector with very high acquisition frequency (~ 1 kHz) called the MM-PAD to collect real-time data. Focusing on only the transient zone during solidification, i.e. mushy zone, we see can discern very specific solidification related phenomena including crystallite formation, grain rotation and growth, grain fragmentation, and formation of secondary metastable phases, which ultimately governs the solidification pathway and final microstructure. Also, unique features such as angular velocity of grains in the melt pool, jagged nature lines in the azimuthal domain, and x-ray peak shoulders are further investigated. Finally, we verify our x-ray analyses with post-processing techniques such as Electron Dispersive Spectroscopy and Electron Back Scattered Diffraction. Our work is the first reported attempt to use synchrotron x-ray diffraction to explain the fundamentals of the grain-related mechanisms during operando metal AM.

Alap Kshirsagar

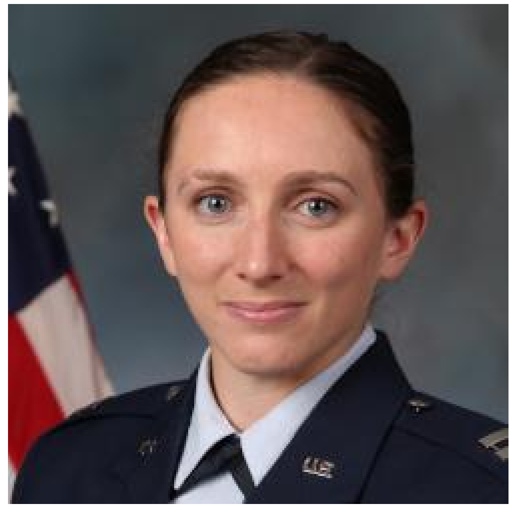
Human Robot Interaction
Guy Hoffman

Robot Controllers, Gaze Behaviors and Human Datasets for Object Handovers

This work investigates the collaborative task of object handovers between a human and a robot, a central aspect of human-robot collaboration. Our research contributes along three directions: first, designing robot controllers for previously unexplored human-robot handover scenarios; second, investigating gaze behaviors of a receiver in human-to-human and human-to-robot handovers; and third, investigating human behavior in bimanual and multiple sequential human-to-human handovers. Our contributions could help enable robots perform the complex but essential tasks of handing over objects to and receiving objects from humans.

Rachel Oliver

Dynamics and Controls
Dmitry Savransky



Event-based Sensor Satellite Track Identification

Larger satellite constellations and orbital debris are exponentially increasing the complexity of tracking objects in space. Augmentation of current Space Domain Awareness (SDA) processes with event-based sensors is one possible way to improve identification and tracking of resident space objects (RSOs). Event-based sensors only record data when the change in photocurrent reaches a threshold for each independent pixel. These sensors produce a timestamped list of pixel locations with a positive or negative polarity of the photocurrent change instead of a traditional frame. This sensing arrangement has high temporal sensitivity and dynamic range that is well suited to capture RSOs quickly passing through the field of view. Additionally, these sensors, with the right settings, generate orders of magnitude smaller files than traditional cameras. Integrating the list of events into a traditional frame diminishes the disaggregated data’s computational and storage benefits. With this usage constraint in mind and a database of on-sky collections, I collect spatial and temporal characteristics of an event-based camera by clustering the data and assigning labels for the type of detection. Then I demonstrate inference of satellite tracks from noise events and stars in the field of view using these characteristics without traditional frames.

Fernanda Fontenele

Solid Mechanics
Nikolaos Bouklas

Instabilities in soft composite materials

Soft fiber-reinforced composites, such as biological tissues, and more specifically tendon, follow a different paradigm from engineered composites. Instead of combining a ductile matrix with stiff and brittle fibers, collagen fibers in tendons exhibit significant ductility which allows for increased toughness, extensibility and resilience to cyclic loading. In this talk, we aim to discuss the mechanical response of soft composites with fiber plasticity under cyclic load. Specifically, the emergence of kinking instabilities in soft and biological composites is investigated, a phenomenon that has significant biomechanical implications, such as the prognosis of diseases like tendinopathy. In this context, we will discuss key elements to build a predictive model for the mechanical behavior of soft fiber-reinforced composite materials with a complex hierarchical structure, which could in turn help shed light on the damage cascade during cyclic loading in these materials, and inspire the design of the next generation of soft materials.

Andrew Kang

Microfluidics
Brian Kirby

Extracting mural and volumetric growth patterns of platelet aggregates on engineered surfaces by use of an entity tracking algorithm

Thrombosis is a major safety concern in blood-contacting implanted devices and occurs under pathologically high shear rates and in the presence of a thrombogenic or artificial surface. Although microfluidic devices have emerged as excellent avenues to model and study thrombus formation and stability, metrics are reported using bulk averages, which can obscure the dynamic evolution of thrombi microstates. To clarify these dynamics, we have developed a standalone tracking algorithm that utilizes spatiotemporal image connectivity and minimal centroid distance mappings to uniquely index all appearing thrombi in fluorescence time-lapse videos. We applied our algorithm to videos of thrombosis on pathologically high shear flow across a collagen-functionalized substrate and physiological shear flow across the surface of a roughened titanium alloy (Ti6Al4V). When comparing ensemble-averaged measurements to bulk-averaged metrics, we unveiled thromboembolic events on Ti6Al4V surfaces that inflated mean aggregate areas. Additionally, we provided biophysical interpretation of tracked thrombus eccentricity, fluorescence intensity, and aggregate area that relate back to the primary thrombosis mechanism at play. This work advocates for supplementation of surface macrostate metrics with characteristic thrombus microstate growth patterns in order to better predict critical thrombosis events.

Amy Fang

Robotics
Hadas Kress-Gazit

Automated Task Updates of Temporal Logic Specifications for Heterogeneous Robots

Given a heterogeneous group of robots executing a complex task represented in Linear Temporal Logic and a new set of tasks for the group, we define the task update problem and propose a framework for automatically updating individual robot tasks given their respective existing tasks and capabilities. Our heuristic, token-based, conflict resolution task allocation algorithm generates a near-optimal assignment for the new task. We demonstrate the scalability of our approach through simulations of multi-robot tasks.

Rebecca McCabe

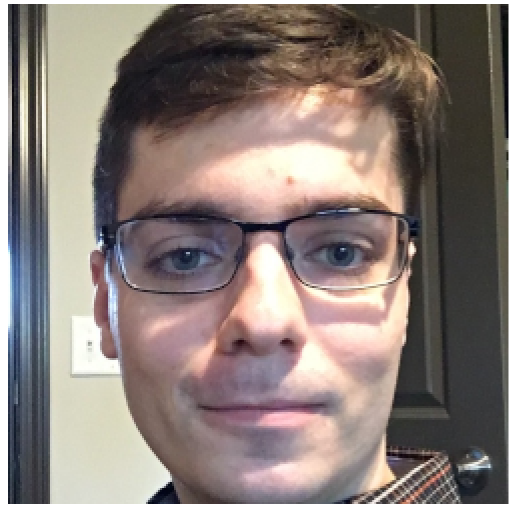
Renewable energy
Maha Haji

Multidisciplinary optimization to reduce cost and power variation of a wave energy converter

Wave energy converters (WECs) can advance the global energy transition by producing clean power for utility grids and offshore technologies. This paper provides a multidisciplinary, dual objective optimization of the Reference Model 3 (RM3), a two-body point absorber WEC design benchmark. The simulation model employs linear hydrodynamics with force saturation and probabilistic regular waves. The RM3 geometry, controller parameters, and structural material are optimized using sequential quadratic programming to minimize the levelized cost of energy (LCOE) and the coefficient of variation of power. The minimum-LCOE design produces a power variation of 195% and an LCOE of $0.08/kWh, a seven-fold cost reduction and 23% lower variation from the RM3 baseline of $0.54/kWh and 255% variation. Parameter sensitivities show that LCOE depends more strongly on site and economic than geometric or material parameters, while power variation is largely insensitive to all parameters. A Pareto tradeoff between cost and power variation reveals different optimal designs depending on which objective is prioritized, suggesting application-specific design heuristics. Three final designs are recommended: a minimum-LCOE design for cost-sensitive operations like utility power, a minimum-variation design for cost-insensitive installations like small offshore systems, and a balanced design for intermediate applications. Power probability distributions are shown for each.

Walker Lee

Climate Engineering
Douglas MacMartin



A Geoengineered Arctic: High-Latitude Stratospheric Aerosol Injection to Preserve Sea Ice

Stratospheric aerosol injection (SAI) has been shown in climate models to reduce some effects of global warming in the Arctic, including the loss of sea ice, permafrost thaw, and reduction of Greenland Ice Sheet (GrIS) mass. SAI at high latitudes could preferentially preserve these aspects of the Arctic with smaller effects at lower latitudes. In this study, we design “Arctic-focused” SAI strategies, which inject at 60°N latitude each spring with injection rates adjusted to either maintain September Arctic sea ice at ~2030 levels (“Arctic Low”) or restore them to ~2010 levels (“Arctic High”), and simulate them using the Community Earth System Model (CESM). Both simulations restore and maintain September Arctic sea ice to within 10% of their respective targets, and they also reduce carbon loss from thawing permafrost and increase GrIS surface mass balance by reducing runoff. However, the effects of Arctic-focused SAI in our simulations are not limited to the Arctic; furthermore, they do not simply revert the Arctic or global climate to that of an earlier pre-warmed period, but rather bring about novel climate states, including altered temperature gradients and changes to seasonal cycles.

Yan Zhang

Dynamics and Controls
Douglas MacMartin

Evaluating the Design Space for Climate Engineering

Excessive amount of greenhouse gases (GHGs) being released to the atmosphere are causing climate change. With the current projection based on measurements and simulations, reducing emissions of CO2 and other greenhouse gases (GHG) may not be enough by itself to avoid significant risks associated with climate change. As a supplement to emission reduction, Stratospheric aerosol injection (SAI) has the potential to cool the planet and reduce some of the risks associated with climate change. There are an infinite number of ways to inject aerosols in the stratosphere, which lead to differences in regional surface climate responses. To evaluate the trade-offs between different design strategies and find an optimal design strategy, we need to have a good understanding of the design space. This research evaluates the design space by using a sample set of different design strategies and quantifies the number of meaningfully independent degrees of freedom of the SAI design space.