Oklahoma State University
Mechanical and Aerospace Engineering

6th Annual OSU MAE
Graduate Research Symposium

Where: Student Union

When: March 01, 2024
08:30 AM to 5:00 PM
(Come and go event)

- [ ] **Graduate student talks**
- [ ] **Graduate student posters**
- [ ] **Undergraduate student posters**

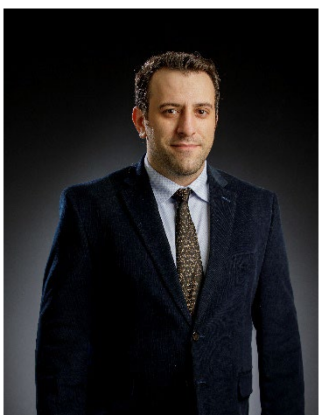
Symposium Schedule

ORGANIZERS
MAE Graduate Activities Committee

Dr. Arvind Santhanakrishnan
(Chair)

Dr. Rushikesh Kamalapurkar

Dr. Christian Bach



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Dr. Atanu Halder

Dr. James Manimala

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(President)

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(Vice-President)

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OKLAHOMA STATE UNIVERSITY

School of Mechanical and Aerospace Engineering

6th ANNUAL MAE GRADUATE RESEARCH SYMPOSIUM

Friday, March 01, 2024

OSU Student Union

https://ceat.okstate.edu/mae/research/gsc/symposium/

Event Schedule

07:30 - 08:00	Attendee Check-in & Breakfast
08:00 - 08:05	Welcome Remarks by MAE Department Head, Prof. Sandip Harimkar
08:05 - 08:10	Opening Remarks by Chair of MAE Graduate Activities Committee (GAC), Prof. Arvind Santhanakrishnan
08:10 - 08:15	MAE Graduate Student Council Representative
08:15 – 09:00	**Undergraduate Student Posters** *Room 265 – Ballroom*

Austin Rouser, *An Experimental Evaluation of Upper Leading-Edge Surface Roughness Effects on Propeller Performance*

Kate Spillman, *Mitigation of Infrasound Noise on Stratospheric Solar Powered Balloons*

Sam Glenn, *Wing Shape Has Minimal Impact on the Aerodynamic Performance of Hovering Tiny Insects.*

Dawson Manning, *Evaluation of Self-Aspirated Flow Controls to Suppress Boundary Layer Separation for Low Reynolds Number Operations*

Caroline King, *Motion Analysis of Pregnant Women for Musculoskeletal Modeling*

Gavin Sockey, *Realistic Wind Field Prediction in Various Urban Morphologies for Application to Small Unmanned Aerial Systems Using Deep Learning*

	Adam Leicht, *Design, Manufacturing, and Experiments of Additive Manufactured Stiffened Thin-walled Plates*
	James Schiermeyer III, *In-Silico Prediction of Tension-Type Chronic Headaches*
	Trey Dorrell, *Investigating the Performance Effects of Aluminum Powder Additives in 3D-Printed Hybrid Rocket Motors*
09:00 – 10:30	**Graduate Student Talks: Session 1** *Room: 297 - Suite 1600*
09:00 - 09:15	**Liyaqat Ali Kamran**, *Effect of Crystallinity on Mechanical Properties of Polyethylene Terephthalate (PET)*
09:15 - 09:30	**Garett Terry**, *Preliminary Acoustic Results from a Turbulent Jet to Examine the Effect of Latent Heat*
09:30 - 09:45	**Noel Rajive**, *Effects of Varying Aspect Ratio on the Hydrodynamics of Copepod Escape Maneuvers*
09:45 - 10:00	**Md Saiful Islam**, *Pairwise Interactions, Feedback Rule Changes, and Deliberative Observation/Decision Periods Support Flying Insect Group Coordination*
10:00 - 10:15	**Bunty Tomar**, *Microstructure Evolution in Steel/Copper Graded Deposition Prepared Using Wire Arc Additive Manufacturing.*
09:00 – 10:30	**Graduate Student Talks: Session 2** *Room: 280 – Sequoyah Room*
09:00 - 09:15	**Pouria Moghimi**, *Thermal Energy Storage Tank in Residential Buildings; Buried or Above-ground?*
09:15 - 09:30	**Md Raqibul Hasan Prince**, *Discrete Material Optimization of Manufacturable Composite Laminated Structures*
09:30 - 09:45	**Soham Bhakta**, *Design and Evaluation of A Compact Axial Compressor Test Rig For Heating And Air Conditioning Applications*
09:45 - 10:00	**Muzaffar Qureshi**, *Scalar Field Mapping with Online High-Intensity Region Avoidance*

10:00 - 10:15	**Adetokunbo Awonusi**, *Whole-Colony Flexibility and Orientation Of Sheet-Like Sea Fans Assists In Particle Capture*
10:15 - 10:30	**Ishriak Ahmed,** *In Orbit Orbital Debris Capture: Fundamental Acceptance Limits and Mechanical Experiment Design*
13:00 – 14:30	**Graduate Student Talks: Session 3** *Room: 297 – Suite 1600*
13:00 - 13:15	**Mitchell Ford**, *Increasing Number of Propulsors in a Metachronal Rowing System Augments Body Speed but Lowers Mechanical Efficiency.*
13:15 - 13:30	**Ashraf Kassem**, *Reconstructing Equations of Motion of Atmospheric Entry Vehicle and Aerodynamic Parameters Estimation Using System Dynamics Discovery Model*
13:30 - 13:45	**David Kelley**, *Achieving a Desired Wing Lift Distribution through use of a Multibody Dynamic System*
13:45 - 14:00	**Muhammad Abir Mahdi**, *Material Properties Prediction of Lattice Structures using Machine Learning & Homogenization Approach*
14:00 - 14:15	**Tochukwu Ogri**, *An Adaptive Optimal Control Approach to Monocular Depth Observability Maximization*
13:00 – 14:30	**Graduate Student Talks: Session 4** *Room: 280 – Sequoyah Room*
13:00 - 13:15	**Nahid Uzzaman**, *A Novel Adaptive Kalman Filter for Systems with Dynamic Noise Covariance*
13:15 - 13:30	**Jacqueline Esimike**, *Gasper-induced Jets Promote Momentary Downward Transport of Exhaled Particles Inside Airliner Cabins*
13:30 - 13:45	**Nafis Mohammad Nayeem**, *Recursive Multi-agent Wind Structure Estimation Formulation*
13:45 - 14:00	**Erick Pepek**, *Additive Manufacturing Filament Testing Methods for Increasing Sustainability*
14:00 - 14:15	**Furkan Oz,** *Nonlinear Parameter Estimation for Blunt Body Dynamic Stability Identification*

14:15 - 14:30	**Soumik Dutta,** *Reduced Order Modeling and Image Processing Based Structural Analysis of Tow Steered Composite Laminates Considering Gaps/Overlaps*
10:30 – 12:00	**Graduate Student Posters: Session 1 & Coffee Break** *Room 265 – Ballroom* **Masoud S. Sakha**, *Event-Triggered Control with Switched Observers* **Anthony Hassett**, *Examination of the Applicability of the Method of Brooks et al. for Noise Prediction of Low Reynolds Number Propeller Airfoils* **Tasfia Kamal**, *Developing a Modular Multi-Disciplinary Modeling Framework for Electric Vertical Takeoff and Landing (eVTOL) Aircraft* **Md Nazmus Sakib**, *Modeling Thermally Induced Reversible Actuation in 4D-Printed Liquid Crystal Elastomers* **Sanzida Hossain**, *Cooperative Driving Between Human-Driven and Autonomous Vehicles: Incorporating Stochastic Human Driving States* **Mehdi Yadipour**, *Optic flow embodiments of Cucker-Smale flocking in three dimensions.* **Obichukwu Iheonu**, *Optimal Bone Architectures Under Lunar and Martian Gravity* **Tawhidur Rahman**, *Mechanism of Melt Primary Breakup in Still Air for Powder Production* **Shafi Al Salman Romeo**, *Data Fusion Model Incorporating Physics for Assessing Uncertainty in Dynamic Stability of Atmospheric Entry Vehicles* **Petra Kis**, *Effect of Blood Flow Occlusion on Changes in Torque Complexity During Intermittent Maximal-Effort Contractions* **James Cheh**, *A New Class of Tensile Structure: Nets with Crosslinks*
12:00 – 13:00	**Lunch** (*room 265 – Ballroom*)
14:30 – 16:00	**Graduate Student Posters: Session 2 & Coffee Break** *Room 265 – Ballroom*

Zachary Wattenbarger, *Leading Edge Convection Heat Transfer for an Airfoil at Low Reynolds Number*

Nabia Fardin, *Design of a Cycloidal Rotor Based eVTOL Aircraft*

Anuj Maheshwari, *Structural Composites from Post-consumer PP Carpet and Recycled PP Resin*

Shahbaz P. Qadri Syed, *Approximate Constrained Stochastic Optimal Control via Parameterized Input Inference*

Ujjval Patel, *Power Line Detection Using ToF Sensor Data: A MAP Estimation Approach*

Carson Kelly, *Pneumatic Launching of High-Performance Fixed Wing Unmanned Airframes*

Sterling Pittman, *Exo-Prosthetics to Improve The Gait Of Below-Knee Amputees*

Rohit Kameshwara Sampath Sai Vuppala, *Machine Learning based Reduced Order Models for wind field prediction in urban spaces for Unmanned Aerial Systems*

Caleb Besmer, *Effect of Varied Burn Rate Catalyst Sensitivity on APCP Solid Rocket Motor Performance*

Soroosh Farsiani, *Development of Robotic Arm Platform for Fused Deposition Modeling of Polymer Composites*

Undergraduate Students Posters

Austin Rouser

Advisor: Dr. Kurt Rouser

An Experimental Evaluation of Upper Leading-Edge Surface Roughness Effects on Propeller Performance

Room 265: Ballroom, 08:15 – 09:00

Abstract: This poster presents an experimental evaluation of upper leading-edge surface roughness effects on propeller performance. The propellers used in this study have a 16-in diameter and a 10-in pitch. Four propellers were 3D printed with dome shaped roughness in a staggard pattern. Each of the propellers have different roughness area coverage, varying chordwise and spanwise extent. Tests with these propellers were performed in a low subsonic wind tunnel, measuring thrust, torque, air speed, and rotational speed. Air speeds varied from 20-ft/s to 50-ft/s and rotational speed varied from 3000-RPM to 6000-RPM. These conditions all fall into the low Reynolds number regime, which can be vulnerable to boundary layer separation. The results indicate that in some conditions the surface roughness had a positive influence on propeller performance, which may indicate that the roughness passively energized the flow over the upper surface. Conclusions from this study inform unmanned aircraft operators of potential effects on performance at low flight speed in adverse weather, prompting propeller selection and design changes.

Kate Spillman

Co-author: Taylor Swaim

Advisor: Dr. Brian Elbing

Mitigation of Infrasound Noise on Stratospheric Solar Powered Balloons

Room 265: Ballroom, 08:15 – 09:00

Abstract: Infrasound, low frequency pressure waves (< 20 Hz), can travel thousands of kilometers which allows for the remote sensing of earthquakes, a known source of infrasound. They can be monitored through solar powered balloons, termed heliotropes, that float in the lower stratosphere. The balloon carries two sensors and floats along the path of the local winds. The sensors must be separated by some distance to accurately resolve the direction of any incoming signal. The added separation between them increases the relative speed on the lower sensor, generating excess wind noise. Identifying a method of wind noise reduction for balloons on Earth can translate to recording quakes via balloon-based infrasound sensors on the interior of Venus. Although it has extreme surface conditions, Venus has a much less severe middle atmosphere where balloons could be deployed. Four windscreens were developed and tested in an open field. The SunFoam filter composed of two different materials had the highest noise reduction (~ 11.5 dB) at higher wind speeds. Another ground-based test was performed to determine if multiple inlets influence the filter's reduction. Both filtered configurations had the same noise reductions (~ 15 dB) showing that the filter is already averaging the incoming signal.

Sam Glenn

Co-author: Mitchell Ford

Advisor: Dr. Arvind Santhankrishnan

Wing Shape Has Minimal Impact on the Aerodynamic Performance of Hovering Tiny Insects.

Room 265: Ballroom, 08:15 – 09:00

Abstract: The bristled wings of tiny flying insects such as thrips and fairyflies show remarkable diversity in shape, ranging from short, teardrop-shaped to long, slender profiles. We measured several shape variables in 28 species of fairyflies and 13 species of thrips using published forewing images. Principal component analysis revealed that the ratio of leading edge (LE) area to trailing edge (TE) area (denoted LE/TE) was an important shape parameter, where each area was defined as the portion of wing surface covered from an edge to a fixed line connecting wing root to wing tip. To examine the effects of LE/TE on the aerodynamics of tiny insect flight, we conducted force and flow field measurements on 4 dynamically scaled bristled wing models with LE/TE ranging from 0.25 to 2 using a flapping robot. Varying LE/TE had marginal effect on cycle-averaged lift and drag coefficients. Particle image velocimetry measurements were used to characterize the circulation of the LE vortex (LEV) and TE vortex (TEV) due to their established roles in force production. LE/TE models of 0.25 and 2 showed minimal difference in LEV and TEV circulation. These findings show that bristled wings of tiny insects can provide consistent aerodynamic performance despite broad variations in wing shape.

Dawson Manning

Advisor: Dr. Kurt Rouser

Evaluation of Self-Aspirated Flow Controls to Suppress Boundary Layer Separation for Low Reynolds Number Operations

Room 265: Ballroom, 08:15 – 09:00

Abstract: This research presents experimental results for two propellers with varying flow controls to suppress boundary layer separation. The two propellers were first modeled using computer aided design software, starting with a scanned 16-inch by 10-inch APC propeller. Two novel propeller designs were created, each with integrated flow controls consisting of a singular rectangular jet acting as a self-aspirating flow control. One set of jets were cut at 20 degrees and the other at 40 degrees measured from the surface of the propeller. To test the performance of the jet geometry of each propeller, data was captured for Reynolds numbers ranging from 30,000 to 60,000 at 20, 30, 40 and 50 ft/s bulk flow velocities. The coefficient of thrust and propeller efficiency at varying advance ratios is then compared to the baseline unmodified propeller to assess propeller performance.

Caroline King

Co-author: Dr. Jerome Hausselle

Advisor: Dr. Aurelie Azoug

Motion Analysis of Pregnant Women for Musculoskeletal Modeling

Room 265: Ballroom, 08:15 – 09:00

Abstract: The goal of this study is to collect data on the movement of pregnant women to assist in musculoskeletal modeling. Throughout pregnancy, the body experiences changes that affect how a person walks. These changes can increase the likelihood that a person will fall while pregnant. To explore these risk factors and possibly mitigate the risk of falling during pregnancy, models can be built. However, there is no musculoskeletal model of the pregnant woman to predict motion. A skeletal model has been built, but it remains focused on changes in mass and inertia. Our goal is to build a musculoskeletal model of pregnancy considering changes in muscle paths and activation patterns. This study aims to collect data from women of various BMIs since a large percentage of women in the United States are overweight and this could change how a person walks during pregnancy. Data collection consists of 3D scans of the body as well as motion capture while the person is standing and walking. Once these measurements are collected, a musculoskeletal model can be validated to increase the understanding of how a body moves during pregnancy.

Gavin Sockey

Co-author: Rohit Vuppala

Advisor: Dr. Kursat Kara

Realistic Wind Field Prediction in Various Urban Morphologies for Application To Small Unmanned Aerial Systems Using Deep Learning

Room 265: Ballroom, 08:15 – 09:00

Abstract: Unmanned Aircraft Systems (UAS) ' safety in densely populated urban environments is a significant concern, primarily due to the challenging atmospheric conditions and turbulent wind flow produced around architectural structures. To effectively integrate UAS into existing aerial infrastructure, enhancing the predictability of these flow conditions and developing robust wind-aware navigation systems is imperative. In this study, we investigate the impact of building geometries on the atmospheric flow field within a simplified urban layout. The configurations we consider are arrays of buildings at various spacings. A Large-Eddy Simulation (LES) is employed to probe the unsteady turbulent flow structures introduced by buildings under neutral atmospheric boundary layer flow conditions. These acquired insights inform the development of a deep learning model for precise flow field prediction. Integrating LES-derived data with advanced machine learning algorithms augment wind-aware navigation systems for UAS, demonstrating an initial stride towards safely accommodating UAS within our urban aerial landscapes. This research represents an integral advancement in ensuring UAS safety and operational reliability, potentially catalyzing broader applications of UAS in dense environments.

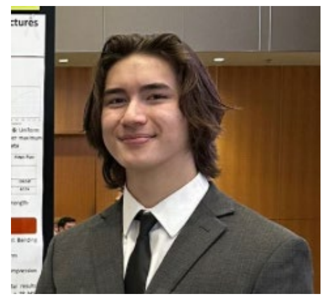
Adam Leicht

Co-author: Mohammad Mahdi, Kathleen McNamara, and Dr. Hadi Noori

Advisor: Dr. Wei Zhao

Design, Manufacturing, and Experiments of Additive Manufactured Stiffened Thin-walled Plates.

Room 265: Ballroom, 08:15 – 09:00



Abstract: This paper presents the design, manufacturing, and testing for a thin-walled lightweight plate stiffened with nonuniform shape stiffeners for a higher compression buckling load study. The nonuniform stiffeners are found to tailor the buckling mode shapes to increase the buckling load of designs compared to those with stiffeners of uniform height. A Stereolithography (SLA) 3D printer is employed for fabricating such stiffened plates with nonuniform shape stiffeners. The three-point bending test is first conducted on a rectangular test specimen to determine the bending properties of the material used in the plate's manufacturing. The measured material properties are then used to design the stiffened plate through a buckling load maximization study. Optimization studies for the stiffened plate with different boundary conditions are conducted. The boundary conditions were considered simple support for all edges of the plate.

James Schiermeyer III

Co-author: Nathan T. L. Ong

Advisor: Dr. Jerome Hausselle

In-Silico Prediction of Tension-Type Chronic Headaches

Room 265: Ballroom, 08:15 – 09:00

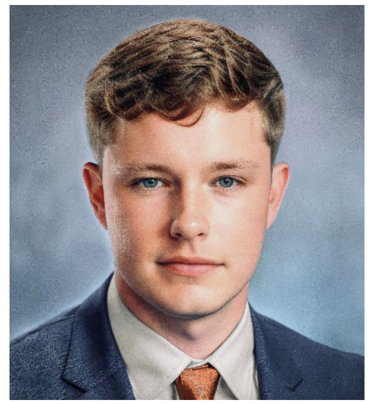
Abstract: Chronic headaches lead to sleep disorders, fatigue, depression, and drug addiction. The most common form is tension headaches, which are caused by neck muscle imbalances. Despite affecting more than a third of the population, the etiology of these headaches remains elusive. Therefore, our project focuses on determining head postures that lead to muscle imbalances. We hypothesize that specific head postures trigger excessive muscle fatigue, leading to overcompensation of the surrounding neck muscles. We have adapted a musculoskeletal model of the head-neck system and performed static simulations to estimate which neck muscles are activated during nine common head postures. Our results highlighted increase in muscle forces up to 200% when compared to the reference position (head straight). These preliminary results support our hypothesis that some postures lead to muscle fatigue. Our current work focuses on implementing a muscle fatigue model to estimate compensatory muscle activities, and on validating this model by measuring muscle activities on human subjects holding different postures. Ultimately, our findings will provide a deeper understanding of the mechanisms triggering tension headaches, which will drive the development of novel diagnostic tools and treatment options.

Trey Dorrell

Advisor: Dr. Kurt Rouser

Investigating the Performance Effects of Aluminum Powder Additives in 3D-Printed Hybrid Rocket Motors

Room 265: Ballroom, 08:15 – 09:00



Abstract: The development of efficient and safe propulsion systems is a key challenge in aerospace. Solid and liquid rockets, though powerful, pose safety risks in manufacturing and transport. Hybrid rocket motors, safer but less efficient, could benefit from enhanced performance. This research explores the impact of adding aluminum powder to 3D-printed Acrylonitrile Butadiene Styrene (ABS) hybrid rocket motors. ABS pellets are mixed with 5% aluminum powder by weight, extruded into 1.75mm filaments, and used to 3D-print fuel grains. The motors' performance, assessed on a hybrid rocket test stand with Nitrous Oxide as oxidizer, is compared against control motors without aluminum. Preliminary results show increased thrust with aluminum concentration. This study aims to prove aluminum powder's effectiveness in improving hybrid motors' performance, potentially equating them with solid and liquid rockets in efficiency. The success of this additive could revolutionize hybrid rocket motor efficiency, contributing to safer, more reliable propulsion systems in rockets, missiles, and unmanned aircraft.

Graduate Student Talks: Session 1

Liyaqat Ali Kamran

Co-author: Dr. Hadi Noori

Advisor: Dr. Frank Blum

Effect of Crystallinity on Mechanical Properties of Polyethylene Terephthalate (PET)

Room 297: Suite 1600, 09:00 – 09:15

Abstract: Polyethylene terephthalate (PET) is one of the widely used polymers in the food packaging industry due to its unique mechanical and thermal properties together with relatively low production cost. PET is one of the common thermoplastic polymers of the polyester family made by the polycondensation of terephthalic acid and ethylene glycol. The semicrystalline nature of PET primarily contributes to its desirable physical and chemical properties. In this study, PET blocks were made by compression molding. Varying crystallinity in the molded samples was achieved by annealing and quenching at different temperatures during the molding process. The crystallinity values were calculated from temperature-modulated differential scanning calorimetry (TMDSC) data. A trend in the crystallinity of PET with respect to the quenching was observed. Three-point flexural bend test (according to ASTM D790) was performed to determine the effect of different crystallinity levels on the flexural strength and modulus of the molded samples. The three-point flexural data indicated a relationship between the flexural strength and modulus of the samples and PET crystallinity.

Key Words: PET, compression molding, crystallinity, three-point bend test.

Garrett Terry

Co-authors: Dr. Aaron Alexander, Douglas Fox, Real KC

Advisor: Dr. Brian Elbing

Preliminary Acoustic Results from a Turbulent Jet to Examine the Effect of Latent Heat

Room 297: Suite 1600, 09:15 – 09:30

Abstract: Infrasound is sound that is below the human threshold of hearing. It has been observed that tornadoes can produce an infrasound signature that is related to characteristics about the tornado and its formation. Detecting this infrasound signature from tornadoes could be an alternative method for tornado detection, especially in areas with more hilly terrain where line-of-sight methods are not as effective. However, in order to use this method of detection, the fluid mechanisms in tornadoes responsible for producing this signature must be determined. It has been proposed that a thermodynamic effect associated with condensing of water in the air within the tornado is amplifying the infrasound. An experimental method to recreate this effect within a turbulent jet has been developed. The jet was created in an environment with either dry or saturated air as well as with or without cooling of the jet. Preliminary findings from the experimental facility indicated that the amplification phenomenon could have been present. This presentation will present those preliminary results in addition to updated findings with a lower noise floor.

Noel Rajive

Co-author: Mitchell Ford

Advisor: Dr. Arvind Santhanakrishnan

Effects of Varying Aspect Ratio on the Hydrodynamics of Copepod Escape Maneuvers

Room 297: Suite 1600, 09:30 – 09:45

Abstract: Copepods are small planktonic crustaceans (0.5-3 mm long) and include some of the most maneuverable animals, capable of accelerations greater than 20 g while escaping from predators at speeds of 100s of times their body length per second. These high escape speeds are achieved using a hybrid-metachronal rowing technique in which multiple swimming legs—arranged in a row along the longitudinal axis of the body—are stroked sequentially during a thrust-generating power stroke and recover simultaneously during a drag-generating recovery stroke. Among copepods, there is a great deal of morphological variation of the bodies and swimming legs. We examined published images of the swimming legs of copepods and other crustaceans to quantify the aspect ratios (ARs) of the swimming legs, defined as the ratio of length to average width. Using a robotic paddling model which was fitted with flat-plate paddles of varying AR in the biological range ($1 \le AR \le 4$), we conducted three-dimensional particle tracking velocimetry measurements to examine the effect of varying aspect ratio on tip vortex characteristics and propulsive forces. We found that decreasing AR resulted in increased tip vortex circulation. This suggests that lowering AR can augment thrust production for rapid escape maneuvers.

Md Saiful Islam

Advisor: Dr. Imraan Faruque

Pairwise Interactions, Feedback Rule Changes, and Deliberative Observation/Decision Periods Support Flying Insect Group Coordination

Room 297: Suite 1600, 09:45 – 10:00

Abstract: Systematic descriptions of the underlying interaction rules that insects use to support swarm flight have a great potential for the scientific community. This study analyzes 1,000 recordings of flying honeybees in groups approaching a moving stimulus involving pairwise interactions. The experimental setup consists of 3D position reconstructions via several high-speed cameras. Neighborhoods are identified using three different methods (cross-correlation, distance threshold, and average distance threshold), which indicates that pairwise interactions dominate. Our analysis finds that each follower demonstrates a three-stage process involving a feedback rule change, linked by an observation/decision phase. Following the decision phase, the velocity tracking of the follower is consistent with a closed-loop feedback proportional-integral-derivative (PID) controller regulating velocity tracking error. Across the insect population studied, the proportional gain remained largely constant, the derivative gain was negligible, and the integral gain varied by individual. Collectively, these findings underscore the existence of an alternative swarm model, highlighting individual decision-making capabilities, feedback rule changes, and PID interaction rules contained within aerial groups.

Bunty Tomar

Co-authors: S. Shiva

Advisor: Dr. Pranjal Nautiyal

Microstructure Evolution in Steel/Copper Graded Deposition Prepared Using Wire Arc Additive Manufacturing.

Room 297: Suite 1600, 10:00 – 10:15

Abstract: Components combining Cu and steel show great usage in many industries since they combine high corrosion resistance, ductility, thermal conductivity, and wear resistance to excellent mechanical properties. Joining steel and copper is challenging due to the mismatch in their thermos-mechanical properties. Fabrication of steel and copper bimetallic material through cold metal transfer-based wire arc additive manufacturing (CMT-WAAM) is a novel exploration. In this experiment, a graded structure was obtained successfully by depositing copper layers on the AISI 316L stainless steel. The iron-rich phases were present in the deposit up to the interface of second and third copper layer, and the iron distribution in the copper matrix was comparably more uniform after the first copper layer. The iron phase is deposited in globular and dendritic morphologies. Supersaturated copper phase precipitates were traced inside the globular iron, but no such precipitation was evident in iron dendrites. No metastable or intermetallic phases were detected by XRD analysis. Hardness measurement results were in good agreement with the grain size and phase precipitation within the copper layers.

Pouria Moghimi

Co-author: Dr. Jeffrey Spitler

Advisor: Dr. Christian Bach

Thermal Energy Storage Tank in Residential Buildings; Buried or Above-ground?

Room 280: Sequoyah Room, 09:00 – 09:15

Abstract: Heating Ventilation and Air Conditioning (HVAC) represents the largest share of residential buildings' final energy consumption. Integration of renewable energies and energy efficiency can reduce their indirect GHG emissions. Renewables have an intermittent nature, and their electricity production profile does not match the heating or cooling loads of the building. Storage of thermal energy can facilitate renewable electricity use by providing a way to mitigate renewable's intermittent nature. In our research group, we aim to investigate the techno-economics of integrating a Thermal Energy Storage (TES) tank in a single-family house. A secondary loop system model is developed with all required components, including the TES. Different scenarios with TES and without TES will be studied in a system level to investigate the advantages and disadvantages of each scenario at different climatic conditions in the U.S. Our focus at the current stage is on comparisons between a buried-in-the-ground tank and an above-ground tank for the TES component in terms of their efficiency and costs.

Md Raqibul Hasan Prince

Advisor: Dr. Wei Zhao

Discrete Material Optimization of Manufacturable Composite Laminated Structures

Room 280: Sequoyah Room, 09:15 – 09:30

Abstract: Due to the non-convex nature of composite laminate stiffness with respect to the fiber path orientation, a local optimal solution is often obtained when using a gradient-based optimization for such structural designs. Additionally, the fiber path orientation and layer thickness for composite laminates are often constrained by manufacturing constraints and economic requirements. This makes the optimization of the laminate design a discrete problem. In this study, we propose a novel approach using binary variables to optimize the design. Instead of using separate binary sets for each design variable, we treat the combination of fiber orientation and layer thickness as a single binary variable. To accelerate the binary variable design optimization considering quadratic constraints, we also linearize these quadratic constraints by introducing a new set of binary variables to express the multiplication of two binary variables. For comparison purposes, a genetic algorithm (GA) is also employed for this study. In addition, we also consider relaxing the binary variable to a continuous variable using the discrete material optimization for this problem for another comparison study. Weight minimization of the laminate plate results obtained using various methods are compared and discussed.

Soham Bhakta

Advisor: Dr. Kurt Rouser

Design And Evaluation of a Compact Axial Compressor Test Rig For Heating And Air Conditioning Applications

Room 280: Sequoyah Room, 09:30 – 09:45

Abstract: This paper presents the design and evaluation of a compact axial compressor test setup that can accommodate up to a 200-kW powertrain. The primary motivation of this study is to determine the feasibility of an axial compressor, that is typically used in gas turbine engines but uncommon for heating, ventilation, and air conditioning (HVAC) applications. The compressor requires high power (up to 172-kW) and rotational speeds up to 95,000 RPM (Revolution Per Minutes) to operate at its desired test conditions. The pressure ratio of the compressor is 8.5, and discharge air temperature is 1070 R (322 C). The option for power supply was explored to test a given compressor were using electric motors. Cascadia Motion iM-225 motor was selected, which requires a gear box to produce the desired compressor shaft rotational speed. The motor will run on a battery pack supplying roughly 350 volts to the motor. The compressor casing is secured using bolts on a test table, the compressor shaft is connected using a coupler to the motor. Temperature and pressure data will be measured directly using temperature and pressure probes at the the inlet and outlet of compressor to evaluate overall efficiency. Observation from this study will aid future compressor design and testing for such scenarios.

Muzaffar Qureshi

Advisor: Dr. Rushikesh Kamalapurkar

Scalar Field Mapping with Online High-Intensity Region Avoidance

Room 280: Sequoyah Room, 09:45 – 10:00

Abstract: This research is motivated by a scenario where a group of UAVs is assigned to map a radar field, with the imperative of maintaining a safe distance from unknown radar sources to evade detection. The location of the radar sources is unknown a priori, so the UAVs rely on radar intensity measurements to gauge safety, where intensity above a given threshold represents a high probability of detection. The methodology employed involves creating a map of the unknown scalar field using Gaussian Process (GP) regression, while simultaneously developing a high-intensity region map, updated in real-time based on data gathered by the UAVs. The novelty of the work lies in the integration of a multi-agent GP learning model with an online high-intensity region avoidance algorithm using the Hough transform (HT). The developed HT-based algorithm uses the scalar field predictions from the GP model to create a high-intensity map that guides the UAVs away from these areas. The convergence analysis shows boundedness of error between the actual scalar field and the learned scalar field while restricting the agents to take measurements inside high intensity regions. Simulation indicates effective learning of a test-field that has multiple high-intensity regions with moderate computational cost.

Adetokunbo Awonusi

Co-authors: Jacqueline Esimike, Mitchell Ford

Advisor: Dr. Arvind Santhanakrishnan

Whole-Colony Flexibility and Orientation of Sheet-Like Sea Fans Assists In Particle Capture

Room 280: Sequoyah Room, 10:00 – 10:15

Abstract: Reticulate sea fans consist of intricate colonies of polyps that form planar, sheet-like structures oriented across the ambient current in shallow marine environments plagued with wave surges. Feeding, excretion, and exchange by polyps rely on the underlying fluid-structure interaction. While recirculating flow behind polyps has been shown to enhance particle capture, the importance of fan orientation and whole-colony flexibility to capture is unclear. We conducted particle image velocimetry (PIV) measurements on a rigid (thickness: 3 mm) and multiple flexible physical models (thickness: 0.8-4 mm) of a reticulate sea fan in continuous background flow (2-12 cm/s). The rigid model was rotated about its base to vary streamwise orientation from 90° (vertical) to 60° relative to the horizontal, while the flexible models were allowed to bend freely in the background flow. Velocity fields from PIV were input to an agent-based model to examine transport of fictitious, massless particles. Particle capture rate was calculated as number of particles "stuck" to the fan surface divided by initial number of particles. Particle capture was diminished for the most flexible models that bent the farthest downstream, while the influence of orientation on capture was minimal in faster flows.

Ishriak Ahmed

Advisor: Dr. Imraan Faruque

In Orbit Orbital Debris Capture: Fundamental Acceptance Limits and Mechanical Experiment Design

Room 280: Sequoyah Room, 10:15 – 10:30

Abstract: Orbital debris presents a persistently growing threat to active satellite systems. This study explores the design of a passive orbital debris collector using aerogel to protect individual orbits. The research includes modeling the orbital debris environment, utilizing the LEO as a representative example. Aerogel-based capture configurations were examined, considering material characteristics, and conducting simulations to identify key performance specifications. A scaled experimental design based on energy and momentum conservation to test the performance of the collector in laboratory conditions is described representing the performance in orbit.

Graduate Student Talks: Session 3

Mitchell Ford

Advisor: Dr. Arvind Santhanakrishnan

Increasing Number of Propulsors in a Metachronal Rowing System Augments Body Speed but Lowers Mechanical Efficiency

Room: 297 – Suite 1600, 13:00 – 13:15 PM

Abstract: Numerous aquatic organisms ranging from microns to tens of centimeters in body length use metachronal rowing for locomotion, where thrust is generated via sequential, rhythmic oscillations of multiple propulsors (legs, appendages, cilia) starting from the rear to the front. This range of body sizes corresponds to 7 orders of magnitude of Reynolds number (Re) variation, from strongly viscous flows at Re~0.01 to inertially dominated flows at Re~10,000. Dimensionless swimming and propulsor speeds of biological swimmers show linear correlation across this entire range of Re. Interestingly, the number and coordination of propulsors differ across organisms and developmental stages. We use a bio-inspired metachronal rowing robot to examine how changing the number of flat-plate-paddles affects the swimming speed, pressure force distribution on the paddles and the dynamics of the paddle-tip vortices. Increasing the number of paddles results in an increase in swimming speed but decreases in per-paddle swimming speed and circulation in the thrust-generating paddle-tip vortices. We suggest that using a larger number of paddles can be used to augment swimming speed and agility, but at the cost of lower efficiency due to destructive interactions between the pressure fields of adjacent paddles.

Ashraf Kassem

Co-Authors: Furkan Oz, Shafi Al Salman Romeo, Dr. Omer San

Advisor: Dr. Kursat Kara

Reconstructing Equations of Motion of Atmospheric Entry Vehicle and Aerodynamic Parameters Estimation Using System Dynamics Discovery Model

Room: 297 – Suite 1600, 13:15 – 13:30

Abstract: A blunt body entering through the atmosphere is subjected to strong forces and moments, which can lead to strong oscillations in the trajectory. It is important to identify and analyze the dynamic motion for a safe entry and descent. However, this challenging event includes complex interactions of the vehicle with wake flow, compression wave, and shear layer. To that end, a simplified model is derived and used in literature to identify the dynamic stability of the vehicle. However, the simplified model is a first-order approach where the relation of the trajectory with the pitch-damping and pitching rate derivatives is neglected. In the present study, a theoretical approach is developed to incorporate the relation of the high-order. Additionally, a system dynamics discovery model based on a Bayesian method is used to estimate the dynamical derivatives. Initially, the approach will be verified through an inverse problem, and then it will be applied to actual CFD results.

David Kelley

Advisor: Dr. Kurt Rouser

Achieving a Desired Wing Lift Distribution through use of a Multibody Dynamic System

Room: 297 – Suite 1600, 13:30 – 13:45

Abstract: This study presents a wing that is significantly affected by a dynamic system which modifies the span wise lift distribution to match a desired outcome. This system addresses the inefficiency in wing design regarding suboptimal lift distributions. For a wing, an elliptical lift distribution produces the minimum induced drag which corresponds to overall higher fuel economy. In practice, this distribution is difficult to achieve due to manufacturing capabilities. The system presented is a wing that is divided into a multibody system with each element having a position, velocity, and acceleration that will passively adjust the lift distribution based on various flight conditions. The steady state results of this system will have a corresponding lift distribution, which can be customized to achieve an elliptical lift distribution. The system consists of equations of motion which employ vortex lattice method (VLM) for computing the aerodynamic forces. To obtain the desired lift distribution, the model iterated on the length of the moment arms which correlate to aerodynamic force contribution for lift and drag. The results demonstrate that, with a continuous desired lift distribution and enough system elements, the intended distribution can be successfully achieved.

Mohammed Abir Mahdi

Advisor: Dr. Wei Zhao

Material Properties Prediction of Lattice Structures using Machine Learning & Homogenization Approach

Room: 297 – Suite 1600, 13:45 – 14:00

Abstract: Homogenization is commonly used when designing lattice structures to simplify the modeling of complex geometric structures using simple solid elements through the use of Representative Volume Element(RVE). Although asymptotic homogenization(AH) approach has been widely employed in lattice structure design, it requires fine meshes when analyzing complex lattice geometries for computing material properties by finite element methods. Thus, it increases modeling complexity by including model preprocessing and generates a large order stiffness matrix, resulting in a computationally expensive analysis. Therefore, the current study focused on developing a rapid material properties prediction approach for the lattice structures in terms of different shapes during design optimization studies. By using this approach, any image of a random-shaped RVE can be converted into a binary matrix, which is then utilized instead of a finite element mesh for calculate the effective material properties by AH. A Convolutional Neural Network model is also developed using image processing results for square lattice RVEs. The developed model showed an error rate of 1.60% Mean Absolute Error and 0.08% Mean Squared Error during training, which resulted in accurate and rapid material properties prediction.

Tochukwu Ogri

Co-Authors: Muzaffar Qureshi, Zachary Bell, Kristy Waters

Advisor: Dr. Rushikesh Kamalapurkar

An Adaptive Optimal Control Approach to Monocular Depth Observability Maximization

Room: 297 – Suite 1600, 14:00 – 14:15

Abstract: Recent years have seen a surge in the development of drone technology and micro air vehicle systems, valued for their ability to tackle complex tasks like surveillance and weather monitoring. Operating in GPS-denied areas, these systems rely on local sensing data, like camera images and inertial measurement units. In the absence of state-feedback information from a positioning system, the performance of most controllers deteriorates, and the robotic system may fail to achieve the desired objective. Consequently, the positions of objects in the surrounding environment relative to the robot must be determined from sensor data to inform the estimation of the robot's position. This paper presents an integral concurrent learning (ICL)-based observer for a monocular camera to accurately estimate the Euclidean distance to features on a stationary object, under the restriction that state information is unavailable. Using distance estimates, an optimal control problem is solved, which aims to regulate the camera to a goal location while maximizing feature observability. Feature observability maximization is achieved using a novel cost function that yields controllers with theoretical stability guarantees, and the effectiveness of the proposed approach is verified in simulation.

Graduate Student Talks: Session 4

Nahid Uzzaman

Advisor: Dr. He Bai

A Novel Adaptive Kalman Filter for Systems with Dynamic Noise Covariance

Room: 280 – Sequoyah Room, 13:00 – 13:15

Abstract: This study addresses the challenge of state estimation within a dynamic system characterized by latent, state-dependent dynamic process, and measurement noise covariance matrices. Conventional Kalman filters (KF) encounter limitations when confronted with state-dependent noise covariances. In response, we propose a novel solution wherein we model the covariance matrices through the application of the Wishart process. We introduce a variational Bayesian adaptive Kalman filter (VB-AKF) that amalgamates variational Bayesian inference for the Wishart process with the Kalman filter. This innovative approach facilitates precise estimation of system states, accounting for both state-dependent dynamic processes and measurement noise covariances. Through simulations, we demonstrate the superior performance the developed VB-AKF.

Jacqueline Esimike

Advisor: Dr. Arvind Santhanakrishnan

Gasper-induced Jets Promote Momentary Downward Transport of Exhaled Particles Inside Airliner Cabins.

Room: 280 – Sequoyah Room, 13:15 – 13:30

Abstract: Though purified air is introduced roughly every three minutes in airliner cabins, infectious aerosols can be dispersed from rapid events such as a sneeze that lasts under half a second. Air recirculation regions are formed in the cabin as purified air moves downward and against upward air motion from human heat dissipation. We sought to determine whether the jets induced by gaspers (overhead vents) can reduce intracabin particulate dispersion during coughing, sneezing, and talking. A custom respiratory flow simulator attached to a human dummy was used to generate exhalation flows. Particle image velocimetry (PIV) measurements were conducted in the cabin of a McDonnell Douglas MD-80 airliner. The dummy attached to the simulator was placed in the middle seat of the middle row of three consecutive front-to-back rows. Non-exhaling dummies were placed in the other eight seats. Gasper jets increased vertical momentum flux and decreased horizontal momentum flux of exhaled flows. Downward momentum transfer was greatest for coughing and lowest for talking. Using agent-based modeling driven by PIV data, gasper-induced jets were observed to significantly enhance downward particle transport. The use of gaspers can promote airborne transport of contaminants to exhaust vents near the floor.

Nafis Mohammad Nayeem

Advisor: Dr. Imraan Faruque

Recursive Multi-agent Wind Structure Estimation Formulation

Room: 280 – Sequoyah Room, 13:30 – 13:45

Abstract: UAS-borne wind sensing creates the potential for improved flow structure mapping and estimation with improved resolution. Multi-agent (MA) sensor fusion algorithms may be used to improve estimates through coordinated estimation. This work develops an information-driven gradient-based optimization framework across a MA graph theoretic structure to estimate parameters of an established vortical structure. An undirected graph-theoretic construction with a high degree of connectivity is used to develop a MA sensor fusion approach based on gradient optimization. The fusion formulation dynamically incorporates instantaneous information weighting and an information-driven variable forgetting factor. The formulation is then manipulated to achieve a concise recursive expression in a discrete-time frame. Convergence and high-time asymptotic properties are shown to depend on an exogenous innovation vector and on an element-wise multiplication, which requires adaptation of existing Perron-Frobenius theory to analyze stability. Simulations are conducted for four aerial vehicles with initial conditions distributed quadrant-wise about an example vortical structure, a tornado. The estimation error is quantified across the simulation to compare against theoretical convergence expectations.

Eric Pepek

Advisor: Dr. Jay Hanan

Additive Manufacturing Filament Testing Methods for Increasing Sustainability

Room: 280 – Sequoyah Room, 13:45 – 14:00

Abstract: 3-D Printing filaments are an exciting frontier of materials research from not only a sustainability perspective but also for greater material diversity in manufacturing. A pain point in filament research is quantifying the performance loss from filament to 3D printed part. Wasted prints are a concern in the industry, such that recycling of printed parts is of interest. Furthermore, even properly printed structures often have a short useful life and would benefit from ease of recyclability. Developing a recyclable 3-D printing filament requires reliable filament testing methods. Both measuring and improving print performance and as well as fundamental material properties are of interest. A few solutions exist to measure mechanical and thermal metrics, but they are currently expensive or time consuming which is counter to the rapidly evolving 3D printing industry. Tensile testers can commonly be found in most engineering labs, ideally that equipment could be utilized in tandem with an apparatus to accurately measure the strength of a given filament. However, in order to properly measure properties, test methods must be convenient and reliable. Here we review a set of recently developed grips for testing 3-D printing filaments. Issues related to compliance, repeatability.

Furkan Oz

Advisor: Dr. Kursat Kara

Nonlinear Parameter Estimation for Blunt Body Dynamic Stability Identification

Room: 280 – Sequoyah Room, 14:00 – 14:15

Abstract: Atmospheric entry vehicles tend to oscillate during deceleration due to the blunt body characteristics. If the amplitude of these oscillations exceeds a specific safe limit, it may jeopardize the parachute deployment phase of the mission. Hence, identifying dynamic stability coefficients is pivotal in entry, descent, and landing applications. Although several methods are available to determine stability characteristics from experimental and numerical data, the critical deficiencies still need to be addressed. In this study, we propose a nonlinear parameter estimation framework that utilizes a neural network (NN) and Markov Chain Monte Carlo (MCMC) algorithm to predict the stability coefficients and identify the uncertainties in the predictions. Given the sensitivity of Markov chains to the initial chain location, the NN is utilized to generate an initial sample for the first chain that will be used in the MCMC method. The data required by the framework is obtained from computational fluid dynamics (CFD) simulations with US3D to estimate the static and dynamic stability coefficients. The estimated coefficients are used in the trajectory reconstruction. The results show excellent agreement between trajectories coming from NPE estimations and CFD.

Soumik Dutta

Advisor: Dr. Wei Zhao

Reduced Order Modeling and Image Processing Based Structural Analysis of Tow Steered Composite Laminates Considering Gaps/Overlaps

Room: 280 – Sequoyah Room, 14:15 PM – 14:30 PM

Abstract: Variable angle tow (VAT) laminated structures improve the structural performance by tailoring the in-plane stiffness and redistributing the inplane stress distribution under external loads. Recent developments in the automated fiber placement (AFP) machinery have made it possible to fabricate such composite structures with spatially varying angle fiber ply path laminates. Nevertheless, these laminates frequently exhibit manufacturing defects when stacking the curved prepreg tapes during the AFP process where the gaps and overlaps defects are often generated. The present research focuses on understanding the effect of these manufacturing defects on the VAT laminates structural performance. To model the defects in the finite element model, first, each fiber prepreg tape for each lamina is treated as an image. A high-resolution binary image is used to identify each lamina's overlaps and gaps. Afterward, each pixel is modeled as a finite element, which in the end leads to an extremely dense mesh. Each pixel stores defect information that is used in the stiffness matrix calculation. However, the high-resolution image created a very dense mesh, which took a long time to compute. Therefore, reduced-order modeling is considered for an efficient structural analysis.

Graduate Student Posters: Session 1

Masoud S. Sakha

Advisor: Dr. Rushikesh Kamalapurkar

Event-Triggered Control with Switched Observers

Room 265: Ballroom, 10:30 – 12:00

Abstract: Event-triggered control is a strategy for adjusting control actions based on specific events or conditions. Since direct access to complete state measurements for generating control signals is often lacking, a mathematical algorithm called observer is employed to estimate the internal states of the dynamical system. While traditional approaches rely on a single observer, many applications require the utilization of several observers with various measurement data, each with differing levels of reliability or accessibility. Hence, it is essential to establish a framework that enables a smooth transition between observers. This work involves the development of event-triggered control for a linear time-invariant (LTI) system with an unknown disturbance, employing two observers. Two events are specified. The controller generates control signals based on state estimates obtained from the first observer which uses accessible but high-error data. This process persists until the predefined estimation error bound is exceeded (first event). Subsequently, the second observer, utilizing accurate data, takes over until a satisfactory level of state estimation accuracy is achieved (second event). In the end, Lyapunov analysis guarantees the stability of the closed-loop control system.

Anthony Hassett

Co-Authors: Dr. Richard Gaeta

Advisor: Dr. Andrew Arena

Examination of the Applicability of the Method of Brooks et al. for Noise Prediction of Low Reynolds Number Propeller Airfoils

Room 265: Ballroom, 10:30 – 12:00

Abstract: Examination of the methods of Brooks et al. is undertaken for the case of moderately cambered airfoils, specifically the APC 11 x 4.7 SF, the OSU quiet 3 blade, and the OSU quiet 5 blade, to determine its applicability to propeller self-noise prediction at low Reynolds numbers (Re = 3.05E+04, 7.11E+04, and 1.12E+05). The study is done using Reynolds Averaged Navier Stokes (RANS) Computational Fluid Dynamics to develop trailing edge boundary layer profiles for comparison with the expected results via the semi-empirical predictions from Brooks et al. The results demonstrate poor agreement for the boundary layer thickness over the range of examined Reynolds Numbers indicating inconsistency with the Brooks et al. boundary layer model. Validation is taken against the Brooks et al. experimental NACA 0012 boundary layer data used in development of their prediction method. Comparison to the wind tunnel data gives an error ranging from 31% to 48% under-prediction over the cases for zero lift but demonstrate correct scaling behavior of the boundary layer thickness with Reynolds number for 99% velocity, displacement, and momentum thicknesses. Comparison with Garcia-Sagrado and Hynes is also taken confirming initial findings of RANS under-prediction of the boundary layer thickness.

Tasfia Kamal

Co-Authors: Samin Yaser Ahmed

Advisor: Dr. Atanu Halder

Developing a Modular Multi-Disciplinary Modeling Framework for Electric Vertical Takeoff and Landing (eVTOL) Aircraft

Room 265: Ballroom, 10:30 – 12:00

Abstract: The objective of this project is to develop a multi-disciplinary modeling framework for eVTOL aircraft. A key feature of this framework is its innovative modular architecture, enabling the integration of various component models tailored to specific aircraft configurations. So far we have incorporated several models of key components and integrated it with the flight dynamics of the vehicle an aircraft such as the battery, drive train, and aerodynamic components. However, one major challenge here is that there exist about 800 eVTOL configurations that use different types of fuselage shapes which is difficult to generalize. To tackle this problem we are approximating them as a combination of canonical shapes. For instance, a quad-rotor fuselage can be approximated as an ellipsoid with 4 cylindrical arms. In the first step forces and moments around these canonical shapes are obtained and later those are combined together according to the shapes of a specific fuselage. So far CFD models have been developed of different types of ellipsoid. We have developed a wing model that can capture the effects of Reynolds number, vortices, etc. Our models have been validated using experimental data through our collaborators. We are also developing a rotor test stand to validate the model.

Md Nazmus Sakib

Co-Authors: Dr. James E. Smay

Advisor: Dr. Aurelie Azoug

Modeling Thermally Induced Reversible Actuation in 4D-Printed Liquid Crystal Elastomers

Room 265: Ballroom, 10:30 – 12:00

Abstract: Liquid crystal elastomers (LCEs), renowned for their large, anisotropic, and reversible shape change in response to thermal stimuli, hold great potential for applications in artificial muscles and soft robotics. Their stimulus-response is attributed to lightly cross-linked polymer networks with an oriented liquid crystal direction. Recently, the use of 4D printing in LCE fabrication has introduced novel possibilities for concurrently controlling the alignment of mesogens and the 3D geometry, providing increased prospects and practicality in designing LCE objects with desired characteristics. However, modeling the thermally induced deformation of LCEs is challenging due to the intricate properties arising from the interplay between mesogen alignment changing with temperature and polymer network deformation. In this study, we conducted Finite Element Analysis incorporating anisotropic thermal deformation to simulate mesogen reorientation in the microstructure, predicting the folding of an LCE hinge. Future work involves printing complex oriented LCE specimens with Direct Ink Writing (DIW) and validating the model by comparing experimental actuation measurements with the model's predictions.

Sanzida Hossain

Co-Authors: Jiaxing Lu, Dr. Weihua Sheng

Advisor: Dr. He Bai

Cooperative Driving Between Human-Driven and Autonomous Vehicles: Incorporating Stochastic Human Driving States

Room 265: Ballroom, 10:30 – 12:00

Abstract: Because human drivers have a multitude of stochastic behavioral components that influence their driving styles, modeling a human-driven vehicle is a challenging task. We create a cooperative driving framework that takes into account several characteristics of human behavior, such as a driver's attentiveness and tendency to obey instructions. We examine the integration of human-driven and autonomous (AV) vehicle coordination in a connected setting to demonstrate the framework. To handle the stochasticity in human driving behavior, we suggest a stochastic model predictive controller (sMPC). To address the stochasticity in human driving behavior, we offer a stochastic model predictive controller (sMPC), which we use to construct coordinated merging actions to optimize the AV input while influencing human driving behavior through advising commands. Results from simulations and human-in-the-loop (HITL) experiments demonstrate that our framework can optimize AV inputs based on human driving behavior recognition and accommodate for different human driver behaviors.

Mehdi Yadipour

Advisor: Dr. Imraan A. Faruque

Optic flow embodiments of Cucker-Smale flocking in three dimensions

Room 265: Ballroom, 10:30 – 12:00

Abstract: This study addresses the need for theoretic constructions enabling fast, lightweight algorithms that provide vision-guided swarming on maneuverable air vehicles having limited computational tools and no explicit communication network or position measurement. We show that flocking algorithms dependent on position and velocity can be implemented by agents that cannot measure positions and (relative) velocities of their neighbors but use optic flow sensors as observed in bees and other insects. The study begins by developing a framework for sensing optic flow in a multi-agent, a group of quadrotors in this study, environment. It then integrates an idealized inter-agent velocity and distance structure describing distributed feedback under perfect information with optic flow perception to create an analogous visually-guided feedback path.

Obichukwu Iheonu

Advisor: Dr. Jerome Hausselle

Optimal Bone Architectures Under Lunar and Martian Gravity

Room 265: Ballroom, 10:30 – 12:00

Abstract: As humanity is embarking on its next journey, the colonization of the Moon and Mars, understanding the long-term effects of gravity on bone strength is critical to develop efficient countermeasures for a healthy extra-terrestrial life and a safe return to Earth. A decrease in gravity allows for efficient asymmetrical modes of locomotion that exhibit different variability of the kinematics and kinetics variables when compared to walking on Earth. In turn, these variables affect bone microarchitectures and thus their strength. We performed musculoskeletal simulations of a subject walking at various speeds under terran, lunar, and martian gravity levels. For each gravity level and speed, ten optimal walking patterns were determined, characterized by low metabolic costs. Asymmetry was quantified by computing the average Normalized Symmetry Index for the hip, knee, and ankle angles, whereas variability was quantified by computing the coefficient of variation for each joint angle. Results confirmed our hypothesis that, under hypogravity, it is possible to adopt asymmetrical gaits without increasing the metabolic cost, and that gravity affects joint angle variabilities. Our current work focuses on predicting optimal bone architectures using the forces computed from these simulations.

Tawhidur Rahman

Advisor: Dr. Khaled Sallam

Mechanism of Melt Primary Breakup in Still Air for Powder Production

Room 265: Ballroom, 10:30 – 12:00

Abstract: An experimental investigation of the primary breakup mechanism of melt is conducted motivated by its significant impact on the characteristics of power production. In the process of producing metal powders, the molten metal is atomized using different technologies including pressurized gas, either in the crossflow or co-flow directions, water jet atomization, plasma torches, and centrifugal atomization. The primary breakup of the molten metal jet is initiated by the appearance of surface disturbances, which gradually grow and eventually cause the jet to break into droplets. Previous studies, focused on numerical modeling the primary breakup of liquid melt and influence of solidification rate of molten droplets, are lacking a unified theory for the primary breakup of liquid melt that could be validated experimentally. In the present study, high pressure and high temperature chamber is used to inject jets in still air. The working fluids include both Newtonian liquids and melts. Back light photography is used measure the wavelength of the jet surface instabilities, the breakup length of the intact core, the distance to the onset of breakup, and the droplet sizes at onset of breakup. The results will be correlated and interpreted using phenomenological analysis.

Shafi Al Salman Romeo

Co- Authors: Furkan Oz, Ashraf Kassem, Dr. Omer San

Advisor: Dr. Kursat Kara

Data Fusion Model Incorporating Physics for Assessing Uncertainty in Dynamic Stability of Atmospheric Entry Vehicles

Room 265: Ballroom, 10:30 – 12:00

Abstract: Atmospheric entry vehicles often experience dynamic instability, characterized by angle of attack oscillations during descent, particularly at mid to low-supersonic velocities. Addressing this challenge is crucial during the design phase to prevent mission failure. This study explores a comprehensive approach for reconstructing ballistic range experimental data by integrating sparse observations with free-flight computational fluid dynamics (CFD) data. While data-driven models based solely on sparse ballistic range testing and CFD data exhibit accuracy in reconstructing flight trajectories, dynamic stability coefficient uncertainty poses challenges. To overcome this, the proposed method employs physics-based Bayesian optimization through Gaussian processes to seamlessly fuse ballistic range and CFD datasets. An innovative approach is introduced to refine predictions and quantify uncertainties in dynamic stability, utilizing a Bayesian physics-informed neural network (B-PINN) interfacing with the system's equation of motion. This collaborative framework's outcomes, termed Physics-Informed Data Fusion, optimize and direct the B-PINN through Physics-Based Bayesian Optimization, providing a robust understanding of atmospheric entry vehicles' trajectory and aerodynamic coefficients.

Petra Kis

Co- Authors: Kylie Sears, Colin Kipper, Tony Montgomery Jr., Taylor Dinyer-McNeely

Advisor: Dr. Shane Hammer

Effect of Blood Flow Occlusion on Changes in Torque Complexity During Intermittent Maximal-Effort Contractions

Room 265: Ballroom, 10:30 – 12:00

Abstract: Torque complexity reflects the modulation of motor output to active skeletal muscle. The development of neuromuscular fatigue results in a loss of torque complexity. Blood flow occlusion expedites neuromuscular fatigue development during intermittent maximal effort contractions (IMECs); however, the impact of occlusion on muscle torque complexity is unknown. Our hypothesis is that blood flow occlusion exacerbates the loss of torque complexity during IMECs. Sixteen participants performed IMECs (forearm flexion) for five minutes under control conditions (CON) and with complete limb blood flow occlusion (OCC) followed by immediate reperfusion (REP). Torque variability was characterized by the coefficient of variation and torque complexity was characterized by fuzzy entropy (FEn) and detrended fluctuation analysis. The main result is that FEn was significantly lower at End-OCC compared to CON, and returned to similar values by the end of the trial after REP. The fall in FEn corroborates our hypothesis and reflects an exacerbated loss in torque complexity with limb blood flow occlusion. Considering the return of complexity during REP, these data suggest oxygen availability acutely impacts motor unit control during IMECs.

James Cheh

Advisor: Dr. Wei Zhao

A New Class of Tensile Structure: Nets with Crosslinks

Room 265: Ballroom, 10:30 – 12:00

Abstract: Humanity has long appreciated the strength, efficient use of material, and ease of set up that nets provide for tasks such as catching fish and loading cargo onto ships. In being adapted for use as architectural structures, however, nets' ease of set up was sacrificed to achieve permanence and stiffness. We present herein an investigation into crosslinks as a novel method for producing structural nets without that sacrifice. We assembled a net out of off-the-shelf components and tested it under conditions of five different patterns of crosslinks and four different support geometries. When weights were suspended from the net, we found that nets with crosslinks exhibit up to 8x greater stiffness and simpler, less nonlinear behavior than nets without crosslinks. Notably, we also found that the set up procedure for nets with crosslinks was the same as for nets without crosslinks. We propose that nets with crosslinks act as a hybrid that combines the advantages of the nets that ordinary people routinely use with those of the monumental nets that have been used in structures such as stadium roofs. Nets with crosslinks therefore show great promise for terrestrial and space applications that lie between those extremes.

Graduate Student Posters: Session II

Zachary Wattenbarger

Advisor: Dr. Alessa Avery

Leading Edge Convection Heat Transfer for an Airfoil at Low Reynolds Number

Room 265: Ballroom, 14:30 – 16:00

Abstract: This paper presents data and analysis for convection heat transfer on an airfoil at low Reynolds number. Convection heat transfer for larger scale aircraft is well documented but is less so for smaller, slower aircraft. With the increasing emergence of unmanned aircraft, it is crucial to have a robust understanding of the low Reynolds number heat transfer that takes place at this level, especially given that early studies have found that existing icing models show little agreement with experiments. This paper sets out to tabulate low Reynolds number heat transfer by acquiring Nusselt numbers for various initial conditions. In phase one a prototype sensor is developed and shown to collect reliable data in a small wind tunnel. A copper bar was inserted into a 3D printed ClarkY airfoil. A foil element heater and thermocouple were fixed to the copper and were used to set a constant temperature. After data processing, the percentage time on from the test yields a Nusselt number for that condition. Early testing shows the expected trend that increasing air speeds increases the required time on, indicating increase in Nusselt number and greater convection heat transfer.

Nabia Fardin

Advisor: Dr. Atanu Halder

Design of a Cycloidal Rotor Based eVTOL Aircraft

Room 265: Ballroom, 14:30 – 16:00

Abstract: The objective of this project is to design a 2000 lbs. eVTOL manned aircraft propelled by distributed cycloidal rotors. A cycloidal rotor is a novel propulsion system that provides full 3600 thrust vectoring which can be utilized for both vertical flight (i.e., take-off and landing) and cruise flight. This eliminates the need for separate propellers as observed in typical lift plus cruise eVTOL configurations. In the first step, I shall utilize in-house cycloidal rotor analysis tools and other existing aircraft sizing methodologies to conduct preliminary performance evaluation (endurance, range, cruise speed, etc.) and sizing of the cycloidal rotors for efficient thrust production. In the next step, I would perform high fidelity CFD-CSD studies to conduct a detailed analysis of the coupling between aerodynamic/inertial forces and the elastic bending/twist deflections of the blade on a large cycloidal rotor. Additionally, I would perform a multi-disciplinary optimization study to improve performance of the entire platform. The cycloidal rotor configuration and the blade geometry will be updated based on this detailed aeroelastic analysis. Finally, I will design other components of the aircraft using traditional methodologies.

Anuj Maheshwari

Advisor: Dr. Frank Blum

Structural Composites from Post-consumer PP Carpet and Recycled PP Resin

Room 265: Ballroom, 14:30 – 16:00

Abstract: This research was focused on making composites from whole post-consumer PP carpets and recycled PP resin via compression molding. Various processing parameters and compositions were analyzed. Flexural strength, modulus, creep behavior, and microscopic images were used to study the quality of the composites. The composites exhibited useful mechanical properties, suggesting they have potential for structural applications. Transforming discarded materials into useful materials can add value to potential feedstocks that would otherwise be considered waste and end up in landfills.

Shahbaz P Qadri Syed

Advisor: Dr. He Bai

Approximate Constrained Stochastic Optimal Control via Parameterized Input Inference

Room 265: Ballroom, 14:30 – 16:00

Abstract: Approximate methods to solve stochastic optimal control (SOC) problems have received significant interest from researchers in the past decade. Probabilistic inference approaches to stochastic optimal control have been developed to solve nonlinear quadratic Gaussian (non-LQG) problems. In this work, we propose an Expectation-Maximization (EM) based inference procedure to solve structured SOC problems. We perform the EM updates on the non-zero subsets of the parameters which preserves the structure of the controller over the iterations of the EM algorithm. In addition, we employ a barrier function approach to encode constraints in the inference-based SOC formulation. We demonstrate the effectiveness of the algorithm on a nonlinear quadcopter model, a nine-zone linear thermal system, and four-unicycle formation control. We also perform a comparative study on the effect of the choice of smoothing algorithms on the computational performance of the proposed approach for structured control applications.

Ujjval Patel

Advisor: Dr. Imraan Faruque

Power Line Detection Using ToF Sensor Data: A MAP Estimation Approach

Room 265: Ballroom, 14:30 – 16:00

Abstract: This paper presents work to extract power lines from Time of Flight (ToF) sensor data. A three-step approach incorporates point cloud separation, maximum a posteriori (MAP) estimation, and linear structure identification. Individual data points in the point cloud are portioned into distinct geometric components (linear, planar, volumetric) using principal component analysis (PCA). Subsequently, power lines are identified based on their linear structure. The point cloud is classified into individual span using MAP estimation and Gaussian clustering.A central theme is developing a MAP estimation algorithm which calculates joint posterior probability and optimizes segmentation label configuration. This algorithm includes a data term, based on normal and principal direction vectors, and a smoothness term to enforce label consistency among neighboring points. Experimental validation involves data from a performance-optimized commercial near-field ToF sensor, focusing on powerline segmentation efficacy. Preliminary results demonstrate successful point cloud-based segmentation, categorizing powerline clouds as linear structures. This research has significant implications for offering solutions for power line extraction in complex environments.

Carson Kelly

Advisor: Dr. Imraan Faruque

Pneumatic Launching of High-Performance Fixed Wing Unmanned Airframes

Room 265: Ballroom, 14:30 – 16:00

Abstract: Recent drone advancements underline the potential for aerial" swarming." A major challenge in field performance testing for fixed wing swarming UAVs is the ability to simultaneously prescribe the multiple agent's initial flight conditions. To address this challenge, this project developed a pneumatic launch system to release agents at or near the required flight speeds via aircraft launch tube integration and propulsion via compressed nitrogen gas. This presentation reports on the comparison between a coupled nonlinear pneumatic simulation [Griffith and Faruque, Submitted for publication] and experimental test results with simulated launch projectiles of 2.5in diameter with a high speed camera tracking system [Islam and Faruque, 2022] to digitize the projectile's position. Results are quantified for aircraft ranging from 6.7lbs to 40lbs and pressures ranging from 60psi to 180psi. Results from a single launch tube configuration indicate that the launcher can achieve aircraft launch velocities within 10% of simulator predictions from 17mph to 90mph. This comparison of velocity helps to validate the pneumatic simulation model via real world data. The results indicate expansion to a multi-tube launch system is feasible and design considerations guiding this expansion are discussed.

Sterling Pittman

Advisor: Dr. Jerome Hausselle

Exo-Prosthetics to Improve the Gait of Below-Knee Amputees

Room 265: Ballroom, 14:30 – 16:00

Abstract: About 150,000 lower limb amputations are performed annually in the US. Diabetes is one of the most common reasons, as well as explosion-related injuries for military personnel. Regardless of the cause, an amputation is a life-changing event that may lead to a severe loss of independence. Common issues are the higher metabolic cost required to walk with a prosthetic coupled with long-term joint issues related to side-to-side asymmetry. Our main goal is to develop a novel exo-prosthetics that minimizes energy expenditure and maximizes symmetry during walking. To quantify the muscle forces at play, we implemented a musculoskeletal model that mimics the characteristics of a below-knee amputee. This new model had eight degrees of freedom and consisted of six joints and fifteen muscles. Our results highlighted a 40% increase of the peak hip joint moment on the prosthetic side. These findings corroborate the need to supply additional moment to the hip joint to minimize muscle fatigue and enable a more energy-efficient walking pattern comparable to a non-amputee. The current work focuses on designing and validating biomimetic exo-prosthetics, combining a soft exoskeleton with traditional prosthetics to enhance hip joint biomechanics and restore walking gait symmetry.

Rohit Kameshwara Sampath Sai Vuppala

Advisor: Dr. Kursat Kara

Machine Learning based Reduced Order Models for wind field prediction in urban spaces for Unmanned Aerial Systems

Room 265: Ballroom, 14:30 – 16:00

Abstract: In recent years, Unmanned Aerial Systems (UAS) have penetrated the domain of civilian applications for various mission profiles. The ongoing urban expansion and ever-increasing interest in unmanned aerial vehicles have created the need for UAS in urban applications. Urban areas are usually characterized by heterogeneous landscapes primarily consisting of buildings with different shapes and sizes, leading to complex wind patterns in the urban canopy. Unlike UAS applications elsewhere, their applications in urban spaces are characterized by their significant size and weight restrictions due to the dense nature urban ecosystem. Unmanned Aircraft Systems have rapidly evolved to tackle these limitations but remain susceptible to external factors like gusts in urban wind fields. While numerical simulation models like Large Eddy Simulations (LES) accurately depict the unsteady wind in urban spaces, they are computationally expensive. Therefore, they are not feasible for real-time prediction. In comparison, Reduced Order Models (ROMs) are computationally less expensive. With the advent of machine learning (ML), robust ML-based Reduced Order Models (ML-ROMs) could be generated completely non-intrusively using the data or with some knowledge about the underlying physics.

Caleb Besmer

Advisor: Dr. Kurt Rouser

Effect of Varied Burn Rate Catalyst Sensitivity on APCP Solid Rocket Motor Performance

Room 265: Ballroom, 14:30 – 16:00

Abstract: This paper presents an experimental assessment of varying burn rate catalyst weight percentages in ammonium perchlorate caste propellant (APCP) and its effect on solid rocket motor performance. A common issue with rocket-assisted take-off (RATO) is having consistent rocket performance and mitigating chamber pressure and thermal failures during the duration of the burn. Typically, burn rate catalysts are nano-metallic powders primarily used to modify how quickly the propellant thermally decomposes. 54-mm solid rocket motors were made at varying catalyst weight percentages; 0.05%, 0.1%, 0.15%, and 0.2%. Preliminary testing determined copper chromite to be the most consistent burn rate catalyst with lower average pressure. Average thrust and burn time will be determined with a Futek load cell, and pressure will be monitored through a Futek pressure sensor; both utilizing SENSIT software for data acquisition. Prioritizing consistent performance and reducing chamber pressure failures, 0.05% was chosen as the best amount of catalyst in the APCP composition. A series of testing with this chosen weight percentage was conducted for 54 and 76-mm sized motors. Nozzle throat was varied to have a range of chamber pressures associated with different burn rates.

Soroosh Farsiani

Advisor: Dr. Wei Zhao

Development of Robotic Arm Platform for Fused Deposition Modeling of Polymer Composites

Room 265: Ballroom, 14:30 – 16:00

Abstract: We have developed a robotic arm-based platform for fused deposition modeling (FDM) of polymer composites, which offers more freedom for 3D printing polymer composites than the conventional gantry-based method. An FDM printhead is assembled on a robot arm with 6 degrees of freedom, so layers of extruded material made of thermoplastic-based composites can be deposited on the print bed to construct a three-dimensional structure of a product. Our custom printhead, equipped with a PID controller, allows for adjusting the extrusion nozzle temperature and filament feeding rate. The controlling parameters extend to print bed temperature, robot head speed, and CAD model slicing. We successfully printed test coupons for three-point bending tests for future studies on optimizing process parameters, such as robot arm speed, nozzle temperature, and feeding rate, to customize the mechanical properties and surface roughness of printed products. The developed robotic arm-based platform for FDM-based additive manufacturing extends the research capabilities in composites manufacturing by leveraging the manufacturing freedom offered by combining 3D printing and robot-assisted manufacturing of complex design geometries.

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