MECHEALLIANCE

MechE-X project cohort program

September 14, 2020

Draft Project Topics. Please recommend your own.

The MechE Alliance industry-connected experiential project cohort - a coordinated group of UROP-like projects with powerful enhancements.

This collaborative program is designed to create a small cohort of students whose individual or small team projects are guided by academic and professional mentors and connected with industry interests. The student cohort will have group support with common learning and support activities. The project format is based on MIT's Undergraduate Research Opportunities Program (UROP); a long established program supporting MIT undergraduate students to engage in research with MIT faculty.

The cohort model is a potent construct with a strong and positive academic heritage. Cohorts promote project completion and amplify students' engagement through identity building. Students share and learn from each other, leading to overall better project outcomes. Cohorts will help to invigorate remote undergraduate engineering projects in a unique and powerful way that is especially important during these stressful times of a pandemic crisis.

Linking the projects and students with industry for mentoring and learning opportunities further empowers students' learning and experience by providing real-world challenges and advice. Through these activities, relationship between students, MIT advisors and company mentors are built and enhanced.

We encourage sharing the project openly: Create or use your personal GitHub repository to share your solution publicly. Submit your solution under an open source BSD-3 or MIT license.

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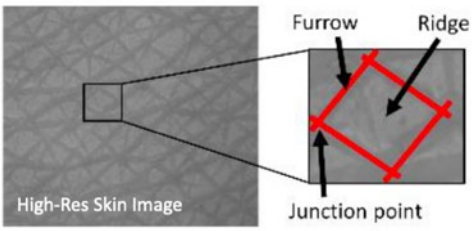
Projects

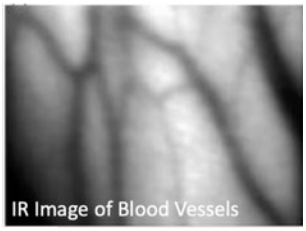
The projects will reflect the full breadth of MechE research with a particular affinity for the use of **simulation, modelling, and data analytics and machine learning** applied to Mechanical Engineering in design, machines, analysis, and systems (e.g. internet of things, additive manufacturing, bio-devices, infrastructure and the environment) and on ways of thinking (critical, creative, analytical, personal, interpersonal, systems, humanistic, computational, etc.). A project combining some simple first order modelling and coupled with real data analysis provides a nice scope.

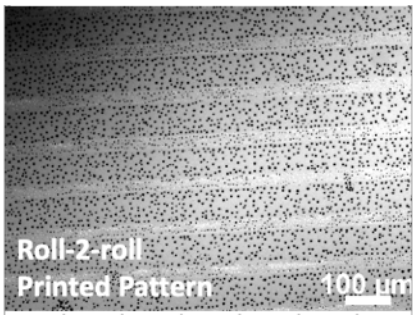
Draft Project Topic Descriptions

Deformable materials analysis – dermatology or manufacturing inspection

Summary: Deformable surfaces (naturally or artificially coated or patterned) must be inspected and sequentially compared and characterized for applications in manufacturing and in dermatology. Image properties can be used for quality control, feedback control and health assessment of machines or of people.







Multiple difficulties arise in large-area and high-resolution image measurement of deformable surfaces. This project will address a key issue in deformation measurement: the registration and matching of deformed patterns including those with noise, occlusions, and artifacts. The emphasis will be on accurate and robust registration and constellation matching algorithms. The registration algorithm will use deviation metrics to estimate global translation, rotation and scaling; the matching algorithm will use a constellation reference grid to characterize local deformed point patterns.

Learning: Image processing, optimization.

Impact: This project is of broad interest to the flexible electronics manufacturing industry and to dermatology.

Of interest:

https://www.ornl.gov/group/rtrm

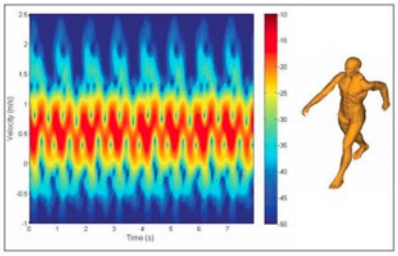
https://www.3m.com/3M/en_US/paper-and-print-us/

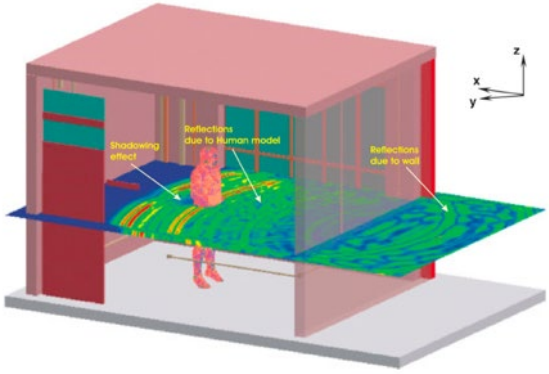
https://www.sciencedirect.com/science/article/abs/pii/S2352431620300225

Link to position posting:

https://urop.mit.edu/content/deformable-materials-analysis-%E2%80%93-dermatology-or-manufacturing-inspection

Radar in the home





Summary: In this project, students will simulate the interaction of people and radar signals in building and home environments.

They will analyze experimental data in order to extract information about a respiration rate, heart rate, and motion.

Learning: Radar modelling, machine learning, data processing.

Impact: In home and ambient monitoring of health and wellness.

Of interest:

https://altairuniversity.com/wp-content/uploads/2016/03/ExampleGuide.pdf

Link to position posting:

https://urop.mit.edu/content/radar-home

Tires and tire treads

Summary: Tire aging and wear is an inevitable part of current automotive transportation. As tires are moving toward higher mileage and longer durability it is very important to keep their performance within safe limits. Wet traction is one of the critical to safety performance parameters and is dependent on tire to road contact that is mitigated by a water layer. Removal of excess water is critical for improved wet traction. Current technology uses a variety of patterns that allow maintenance of a sufficient tire footprint for traction at safe vehicle speeds. As a tire wears, patterns degrade, and thus water evacuation is reduced. Investigating general design principles, constraints and limitations that would consider reduction of tread volume would be of general interest to tire industry, as well to other industries dealing with changing patterns and contact liquid distribution (lubrication, paint, etc.).

In this project, a student will analyze (combining simple first order modelling with experimental data analysis) the water evacuation from tires as a function of the properties of tire tread pattern and tire wear to characterize the performance properties of different designs and constraints.

Learning: Fluid flow modelling and simulation, machine learning and data analytics techniques.

Impact: This is of broad interest to the tire manufacturing industry.

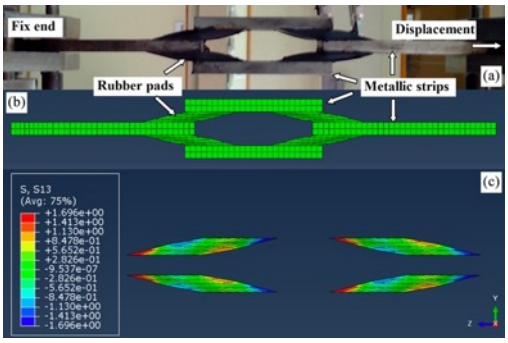
Of interest:

https://www.bridgestonetire.com/tread-and-trend/tire-talk/tire-tread-patterns

Link to position posting:

https://urop.mit.edu/content/tires-and-tire-treads

Tires and multi-materials fabrication – materials analysis



Summary: This project will investigate the general physico/chemical interaction of complex rubber materials' stickiness to metal surfaces. Molding of rubber articles is a complex (often high temperature and pressure) process that involves various simultaneous chemical reactions paired with physical changes in viscosity, ingredient distribution and ingredient diffusion. There are applications where stickiness to the metal surface is detrimental to the final product (i.e. sticking to molds) and where it is desired (i.e. complex material assemblies). Investigation of material design parameters, constraints and limitations would allow for advanced manufacturing technologies and more optimal processes.

In this project the student will analyze adhesion properties (combining simple first order modelling with experimental data analysis).

Learning: Surface modelling and simulation, peel and shear simulation, machine learning and data analytics techniques.

Impact: This project is of broad interest to the tire manufacturing industry, to multilateral fabrication in medical devices, and broadly to joining adhesives.

Of interest:

- https://www.bridgestoneamericas.com/en/corporate-social-responsibility/safety/tires-101/tire-construction
- https://www.ustires.org/whats-tire-0
- https://www.scientificamerican.com/article/what-exactly-is-the-physi/
- https://www.lord.com/products-and-solutions/adhesives/rubber-bonding/adhesion-science-rubber-metal-bonding

Link to position posting:

https://urop.mit.edu/content/tires-and-multi-materials-fabrication-%E2%80%93-materials-analysis

Design of the Interior of the Car of the Future

Summary: What goes into the interior of the car of the future? Is it more like a living room or like the cars of today? What functionality will the passenger demand? What sensors are required? What will passengers do while travelling? How does the car 'sense' the occupants? How much power is required? Data connectivity? How does this vary for inter or intra city applications?

You will develop conceptual designs, analyze those design assuming that car is for local commuting, or for long distance leisure, or other. You may choose to optimize for power distance, comfort, or combination.

Learnings: Product design, design analysis.

Impact: This project is of broad interest to the automotive industry.

Link to position posting:

https://urop.mit.edu/content/design-interior-car-future

Coffee roasting

Summary: Coffee roasting is the process of transforming green coffee beans into the flavorful coffee beans we all know and love. By roasting coffee beans at an elevated temperature, chemical and physical changes take place to induce the taste and smell of a traditional cup of coffee. While unroasted beans still contain comparable amounts of acid, sugar, oil, and caffeine as found in roasted beans, they will ultimately lack the flavor. Therefore, roasting is a necessary step and it is very common to find commercial-scale coffee roasters around the world. However, it is important that these companies remain consistent in their roasting process so that each batch is of equal quality.

Project data captures the overall roasting process of coffee beans. It is comprised of over 70 variables such as time of day, various temperatures, inlet air pressures, fuel flow rates, etc. The data also includes 63 separate roasting processes each spanning several minutes of operation. We hypothesize that accurately maintaining the true roasting temperature will result in better yields and more consistent coffee bean quality. Secondly, we explore the relationship between the temperature of the coffee beans after cooling and the subsequently measured features.

Learning: Machine learning and data analytics, data visualization, process modelling.

Impact: This project is of interest to volume roaster and other types of batch processing manufacturing.

Of interest:

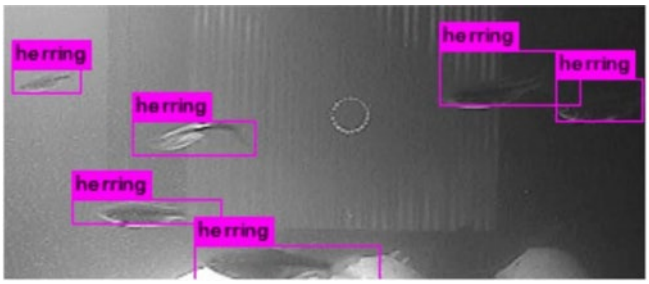
https://www.ncausa.org/About-Coffee/Coffee-Roasts-Guide
https://www.baristainstitute.com/blog/sampo-latvakangas/may-2017/coffee-roasting-basics-developing-flavour-roasting

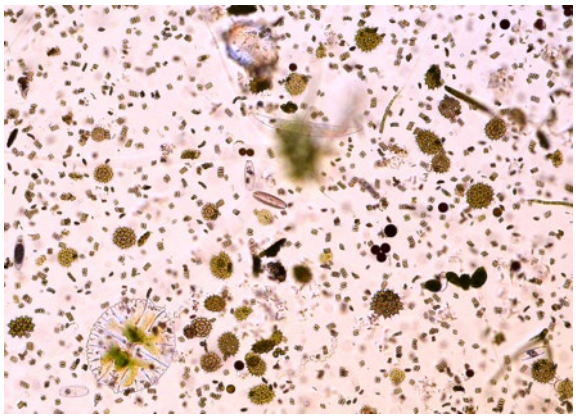
Link to position posting:

https://urop.mit.edu/content/coffee-roasting

Image recognition under water - enhance fisheries management and/or water quality assessments

Summary: Marine fisheries populations have a large impact on the U.S. economy – from commercial fishing to coastal communities. Overfishing, barriers to migration, and other forms of human activity may impact spawning patterns of these species. Therefore, it is necessary to monitor these populations to maintain sustainable resources, healthy oceans, and marine life. Federal and state agencies deploy camera equipment to monitor fisheries populations. Employees then manually count the number of specimens in the gathered videos and images. Not only is this an inefficient use of resources and employee time, but it can also lead to inaccurate results due to human error.





A closely related problem, of interest to some of the industry mentors, is optical bacteria recognition, tracking, and counting.

Through the application of deep learning-based image recognition, identification of target species in video and image data can be automated. Current state-of-the-art image recognition relies on Convolutional Neural Networks (CNNs) to achieve learning and recognition. CNNs loosely represent biological neural networks: each neuron, or layer, accomplishes a specific task, such as edge detection.

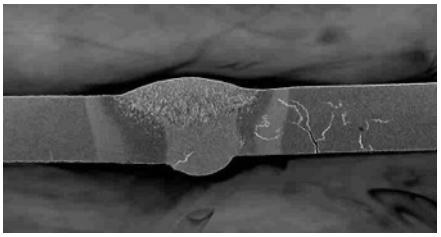
Learning: Machine learning and data analytics, image visualization, process modelling.

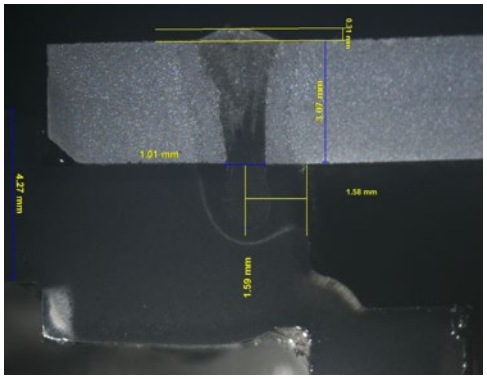
Impact: This project is of interest to fisheries and other animal monitoring applications and water monitoring applications. Such algorithms can be adopted to enhance the capabilities of Fisheries Management in monitoring fisheries populations or adopted to aid in water quality measurement.

Link to position posting:

https://urop.mit.edu/content/image-recognition-under-water-enhance-fisheries-management-andor-water-quality-assessments

Automating metallographic image analysis





Summary: Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics.

A large database of weld images (weld cross-sections) from an industry partner will be used to help to explore and create machine vision and machine learning algorithm which automatically measure features like weld penetration, width, defects, etc. The focus will be on learned feature recognition, segmentation, and dimensioning and results in models of images with reference points, feature dimensions, and contours.

Impact: This project is of interest to many manufacturers and applied to defect detection in welding, incoming material inspection, and in-line measurement. The approaches can be applied to other fields, for example, in medical radiography measuring the size of objects of interest (e.g. cancerous growth, etc.).

Link to position posting:

https://urop.mit.edu/content/automating-metallographic-image-analysis

Design a very low earth orbit (VLEO) constellation

Summary: There are currently several commercial satellite communication firms in varying stages of deploying and operating large constellation of small satellites in low and medium earth orbits (LEO and MEO). You will design a very low earth orbit (VLEO) constellation that is able to communication with three of these LEO/ MEO satellites through their user link (designed to communicate with a user on earth).

You will define the orbital parameters for a 100-satellite VLEO constellation (e.g. altitude, inclination, phase spacing, etc.), as well as steerable "inter-constellation" communication payload parameters (e.g. min and max angular velocity, field of regard, range requirements, etc.). Open source technology research will be conducted to understand the limitations present in even the state of the art technology.

Which combinations of altitude / inclination should be targeted, and which should be avoided, in order to achieve the best overall connectivity? The student will create evidence that the VLEO constellation design provides "continuous coverage" for the three commercial constellations under consideration and determine "rules of thumb" or best practices for multi-shell links.

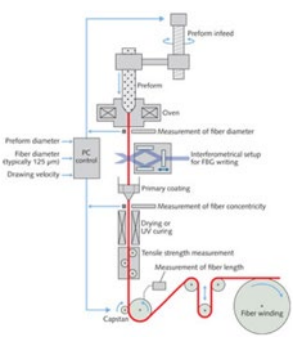
Learning: Orbital dynamics, data analysis, data visualization, optimization (optional).

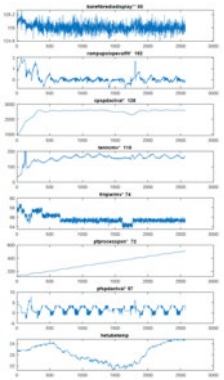
Impact: This project is of interest to public and private space organizations.

Link to position Posting: https://urop.mit.edu/content/design-very-low-earth-orbit-vleo-constellation

Machine learning applied to optical fiber production control systems

Summary: The goal of the project is to develop a data driven model of the fiber draw manufacturing process and to simulate new fiber draw control strategies. You will be supplied with production data from multiple draw towers and specification(s) of the drawing process.





You will develop a full simulation of the fiber draw process taking into account and modeling the control system as currently implemented. You won't develop models from complete first principles; feedback loop structures will serve as constraints on the data analysis learning algorithms. You will learn an aggregate model of the full system.

You will develop a realistic virtual model of the full controllers and system as implemented – to use as a simulation tool. Then, in simulation, you will modify the controllers in order to predict how a new control setting or system will perform. The simulation will serve as a design and decision tool to guide experiments and deployment on real draw towers.

Learning: Machine learning and data analytics, regression and autoregression, data visualization, process modelling, hybrid modelling.

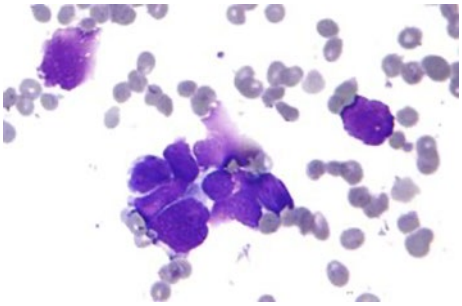
Impact: This project is of interest to fiber draw processing and other continuous production systems.

Link to position posting:

https://urop.mit.edu/content/machine-learning-applied-optical-fiber-production-control-systems

Medical data classifiers

Summary: There are many thousands of applications of the pattern classification problem. One example that comes from medicine is to create a classifier that will allow you to classify a benign or malignant tumor based on characteristics of the tumor cell nuclei.



Features are computed from a digitized image of a fine needle aspirate (FNA) of a breast mass. They describe characteristics of the cell nuclei present in the image. Features have been computed for each cell nucleus. You will explore features and classifiers for medical image data interpretation.

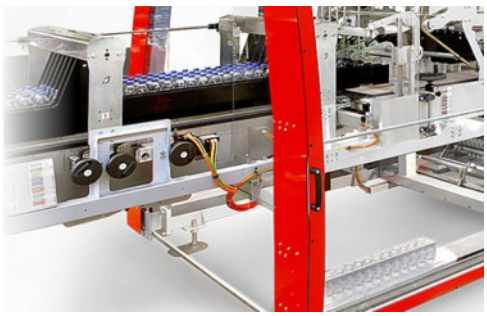
Learning: Machine learning and data analytics, data visualization.

Impact: This project is of interest to expert medical systems.

Link to position posting:

https://urop.mit.edu/content/medical-data-classifiers

Condition monitoring



Summary: You are supplied with data from 519 production runs from a packaging line. This dataset consists of the IoT machine data which (presumably) contain information about a degrading component (blade) recorded over a duration of 12 months.

The blade cannot be inspected visually during operation due to the blade being enclosed in a metal housing and its fast rotation speed. Monitoring the cutting blade's degradation will increase the machines reliability and reduce unexpected downtime caused by failed cuts. If the "wear" can be predicted accurately, a remaining useful life prediction can be made in order to determine maintenance windows, i.e. predictive maintenance.

Your objectives are to: 1) Identify and extract features in the data. 2) Using extracted features, construct several models predicting degradation of the blade. 3) Optimize and/or evaluate predictive ability of models for different design decisions.

Learning: Machine learning and data analytics, predictive maintenance.

Impact: This project is of interest to many manufacturers.

Link to position posting:

https://urop.mit.edu/content/condition-monitoring

Condition Monitoring of Offshore Structures

Summary: Deepwater offshore structures are at a water depth > 400 ft and these are usually at remote locations (Figure: Floating Production Storage and Offloading (FPSO) Facility in 1000m Water Depth). These structures are excited by complex forces and information about the condition of the

asset, to evaluate multi-disciplinary failure mechanism(s), during operation is challenging and sometimes not possible.

It is important to assess the safety and reliability of these structures to prevent incidents such as the Deepwater Horizon in Gulf of Mexico and Piper Alpha in explosion in North Sea.

The objective of this work will be to determine how we can close the gap on the information we have on the condition of assets by using sensors and enable a data driven approach towards structural integrity management.

Learning: Machine learning and data analytics, condition monitoring and wear prediction.

Impact: This project is of interest to offshore air industry, oil and gas industry, municipalities in support of bridges.

Link to position posting:

https://urop.mit.edu/content/condition-monitoring-offshore-structures

Rotor-flying manipulation simulation - using MATLAB and Simulink

Summary: Rotor-flying manipulators are Unmanned Aerial Vehicles (UAVs) equipped with a lightweight manipulator and have the potential to transform major industries thanks to their unconstrained 3D motion; making them ideal for deployment in cluttered environments. Rotor-flying manipulation is a natural evolution of mobile manipulation and a popular research area in robotics that attracts the interest of many companies and public institutions. Its applications range from aerial transportation in construction, manipulations in hazardous places, inspections and installations on sites with a difficult access, search and rescue, and more.

Autonomous aerial manipulation is a challenging problem because of the coupled dynamics between the two systems.

The project objectives are to: Develop an autonomous aerial manipulation simulation including a UAV equipped with a multi-DoF manipulator to pick an object and place it into a goal location. Pose estimation and perception of the environment will be developed using a visual system. Global motion planning with obstacle avoidance will allow the system to reach the target location to approach and pick an object and eventually place it into a goal location.

Learning: System and dynamics modelling, simulation.

Impact: The project is of broad interest to diverse companies, including those in delivery of medical and consumer goods.

Of interest:

https://www.mathworks.com/matlabcentral/fileexchange/68788-robotics-system-toolbox-uav-library

https://www.mathworks.com/help/robotics/examples/pick-and-place-workflow-using-stateflow.html

Link to position posting:

https://urop.mit.edu/content/rotor-flying-manipulation-simulation-using-matlab-and-simulink

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We encourage sharing the project openly: Create or use your personal GitHub repository to share your solution publicly. Submit your solution under an open source BSD-3 or MIT license.