HERE Project List for Fall 2019

3D Finite Element (FE) Simulations of Valve Interstitial Cell Microenvironment
Dr. Chung-Hao Lee
School of Aerospace and Mechanical Engineering (AME)

The metabolism and mechanobiology of valve interstitial cells (VICs) regulate the remodeling processes associated with collagen biosynthesis and tissue microstructural changes. Alterations in the microenvironment of VICs in response to external stimuli are essential for better understanding of disease progression mechanisms as well as for individual-optimized surgical treatment for cardiovascular diseases. Therefore, the main objective of this project is to construct high-fidelity 3D finite element (FE) models for VIC microenvironment and perform FE simulations to investigate (i) how cell down- or up-regulations will alter the overall structure and mechanical properties of the heart valve tissues, and (ii) how cellular geometry and mechanics will affect tissues’ biomechanical behaviors. Undergraduate students participating in this project will gain hands-on experience on FE model development as well as FE simulations in ABAQUS software, and will contribute to the generation of simulated VIC biomechanical data integrated with a multiscale tissue modeling framework. Students in all areas with basic background in engineering mechanics and entry-level programming skills are strongly encouraged to apply for this project.

3D Printed Middle Ear Prostheses and Tympanic Membrane Grafts – Design and Function Testing
Dr. Rong Gan
School of Aerospace and Mechanical Engineering (AME)

Surgical reconstruction of the middle ear with eardrum or tympanic membrane (TM) grafts and ossicular prostheses is a critical component in hearing restoration following surgical treatment of chronic middle ear disease. In this project, different types of middle ear prostheses and TM grafts will be designed first as the CAD models. The 3D multi-material printing system (Object350, Stratasys) will be used to produce the prostheses and TM grafts, followed by mechanical tests on these grafts and prostheses. Finally, the prostheses or TM grafts will be implanted in animal ears (e.g. chinchilla) for function tests through non-survive study. Research undergraduates will work with graduate students closely in our biomedical engineering lab located at Stephenson Research Technology Center (SRTC) with all design and experimental facilities.

A Prototype of a Mobile Cloud Database System Using Android Phones and Cloud Computing
Dr. Le Gruenwald
School of Computer Science (CS)

Innovated mobile technologies offer interesting opportunities in many domains, such as health care, transportation, and commerce. They enable distant monitoring and permit consideration of parameters such as patient and physician mobility. This makes it possible to develop applications, such as mobile health services for telemedicine and assisted ambient living (particularly in rural
areas) and mobile traffic services. Nevertheless, the amount of data to be generated and queried is very large and diverse, collected from multiple sources. The combination of big data and mobility leads to a major challenge: how to efficiently process queries from a myriad of mobile devices on a large amount of data, especially when the data are to be stored in a novel data management system supplied by several cloud providers with possibly different pricing models? This challenge is not addressed in the existing work on cloud query processing. To fill this gap, the Database Research group in the School of Computer Science (OUDB) together with the Database Research team at the University of Rennes in France have developed a novel mobile cloud data management prototype using Android phones and cloud computing. This prototype employs semantic caching and novel query processing algorithms that take mobile users’ mobility, disconnection, energy limitation, and cloud provider’s pricing models into consideration in order to improve query response time, while reducing the amount of money that must be paid to the cloud service providers. Working on the Honors Engineering Research Experience (HERE) project, the student will work with the OUDB team and the University of Rennes Database Research team to extend the prototype to implement more complex queries for mobile cloud database applications, demonstrate their executions, and evaluate their performance.

A Software Prototype to Detect and Explain Outliers for Big Data Stream Applications Using GPUs
Dr. Le Gruenwald
School of Computer Science (CS)

In many monitoring applications, such as sensor networks, web-click stream analysis and power usage monitoring, data are in the form of streams. A data stream is an infinite sequence of data points with explicit or implicit timestamps and has many special characteristics including transiency, a notion of time, a notion of infinity, uncertainty, dynamic distribution, and multi-dimensionality. For applications involving multiple related streams, additional characteristics exist, such as asynchronous data arrival, dynamic relationships among streams, and schema heterogeneity of data from different streams. Although data streams are different from regular (non-stream) data in many respects, they are not free of outliers. An outlier is a data point which has a significantly different value compared to other data points in the same dataset. In practice, outliers are inevitable in any data acquisition process as they can be introduced into a dataset because of numerous reasons, such as malicious activity or instrument error. Thus, outlier detection is an important part in the data engineering and analysis process. Instead of making outlier detection as a black box, for outlier detection to be beneficial, explanations about the properties and causes of the outliers discovered need to be provided.

Because of the special characteristics of data streams and the intrinsic difficulty of detecting outliers, outlier detection and explanation in data streams is a very computationally challenging problem. One way to tackle it is by using Graphics Processing Units (GPUs), which are parallel co-processors that can be leveraged for general purpose programming, and that can achieve up to an order of magnitude of higher instruction throughput than comparable multicore CPUs. Despite the performance benefits, popularity and affordability of GPUs, there exists little research on data stream outlier detection focusing on such hardware. To fill this gap, the OU Database group (OUDB) in the School of Computer Science together with the Database Research team at the
University of Minnesota Duluth are developing novel algorithms for detecting and explaining outliers in multiple data streams using GPUs.

In this project, the student will work with the OUDB team and the University of Minnesota Duluth Database Research team to help build and test a software prototype to discover and explain outliers in data streams using Nvidia GPUs and CUDA. The student will learn how to exploit the parallel computing capabilities of GPUs to tackle real-life Big Data problems for Data Science and Analytics applications.

Biomechanical Testing for Soft Biological Tissues  
Dr. Chung-Hao Lee  
School of Aerospace and Mechanical Engineering (AME)

Mechanical properties of soft biological tissues are important and necessary information for development of predictive computational models for many biological systems. This project aims at understanding the mechanical properties of native tissue materials, which consists of three key ingredients: (i) acquisition of biomechanical data for soft biological tissues, (ii) statistical analyses of the acquired data for subject-averaged biomechanical characteristics, and (iii) formulation of constitutive models that best describe the overall mechanical behaviors of tissues. Undergraduate students who participate in this project will have an opportunity to work on tissue experiments using commercial biaxial mechanical testing device, learn about fundamental statistical analysis techniques, and to gain experience on systematic fitting of the mechanical data for constitutive model parameter estimations. Students in all engineering disciplines are welcome to apply for this project.

Cascade fan speed control to achieve stable and energy efficient fan operations in an air handling unit  
Dr. Li Song  
School of Aerospace and Mechanical Engineering (AME)

With the increasing application of occupancy sensors in commercial buildings, the information generated by occupancy sensors can be used to not only reduce the electricity loads from lighting and controllable plug loads, but also improve HVAC system efficiencies through common practices, e.g., dynamic resets of outdoor air (OA) intake and minimum supply airflow set points. However, these actions greatly elevate the dynamics of air handling unit (AHU), which may introduce unstable supply fan operations. For the supply fan speed control, two control processes are included: the primary process controls the supply airflow rate to maintain the duct static pressure; the secondary process controls the fan speed to maintain the supply airflow rate. Therefore, cascade control is a perfect solution to improve the fan operation for AHUs. This project is designed to experimentally test effectiveness of implementing a cascade fan control to stabilize the fan operations. A student in AE, ME or ECE who is interested in implementing PID controller design is preferred.
Develop new clinical tools to detect early ear infection
Dr. Chenkai Dai
School of Aerospace & Mechanical Engineering (AME)/Biomedical Engineering (SBME)

Otitis media (OM) is the most commonly diagnosed infectious disease in young children. The early diagnosis is critical for treatment and recovery but is difficult due to accuracy limitations of current clinical tools. Our long-term goal is to develop new clinical tools by investigating the feasibility of early detection of infection/inflammation with novel laser scanning/OCT plus new algorithms derived by enhanced machine learning of data from simulation measurements in 3D printed ear and animal otitis model. In this project, we are going to measure the TM motion within the animal model and 3D printed ear with simulation of OM. The data collected from simulation in 3D printed ear will be used for machine learning to enhance the algorithm of TM motion prediction. The data obtained from animal model will be used to validate the algorithms and FE modeling. Undergraduate students who participate in this project will have an opportunity to learn about 3D printing, FE modeling, machine learning, novel laser scanning and OCT measurements. Students in all engineering disciplines are welcome to apply for this project.

Developing clinical tools and medical devices to diagnosis and treat ear disorders
Dr. Chenkai Dai
School of Aerospace & Mechanical Engineering (AME)/Biomedical Engineering (SBME)

Hearing/balancing injury have been known as the consequence of expose to blast overpressure (BOP) or repeated loud noise in military and civilian population while hearing/balancing function loss was ignored due to its chronic progress. However, complaints of hearing loss and dizziness are increasing in the population and the mechanism of hearing/balancing function loss due to BOP/loud noise remains partially unclear. We created a chinchilla model to test a hypothesis: 1. The BOP can travel through air and fluid-filled inner ear and cause acute impact on hearing/balancing function. 2. The acute impact of BOP/noise on hearing/balancing function could become chronic due to the slow, yet progressive change in the auditory/vestibular system. To test above hypothesis, we will develop a video-oculography (VOG) plus smart motion system to measure the Vestibuloocular reflex (VOR) in chinchillas exposed to low/mild intensity BOP over time to characterize the balancing function change after blast. We will also develop new tools to evaluate hearing function. The goal of this project is to provide solid preliminary data for future prevention, medical treatments and protection devices design. Undergraduate students who participate in this project will have an opportunity to learn about blast setup, animal ear surgeries, VOR measurements with video-oculography and smart motion system, statistical analysis and computational simulation. Students in all engineering disciplines are welcome to apply for this project.
Developing New Ultrasound Imaging System for Proton Therapy Guidance  
Dr. Shawn Xiang  
School of Electrical and Computer Engineering (ECE)  

In Oklahoma, one in two men and one in three women will develop cancer during their lifetime. The state has the seventh highest cancer mortality rate in the nation. We are working with the Stephenson Cancer Center to develop new image guided proton therapy. The undergraduate students will help to build an ultrasound transducer array in the lab, and test the device in the clinic. Training in electronics, LABVIEW based system control, and Matlab based image reconstruction will be provided by graduate students and postdocs. Publications are expected from the experiments. Students who plan to get PhD or PhD/MD are highly encourage to apply.

Development of an Ontology for Representing Uncertainties in Engineering Design  
Dr. Zhenjun Ming (Postdoctoral Research Associate, AME), Dr. Janet K. Allen (ISE), Dr. Farrokh Mistree (AME)  

In engineering design, designers usually confront a variety of uncertainties. Classifying and carefully managing these uncertainties are critical for the achievement of robust designs that are relatively insensitive to uncertainties. In design literature, researchers have proposed different uncertainty classification schemes from different perspectives. Examples include a) uncertainty in noise factors, uncertainty in control factors, uncertainty in modeling methods; b) natural uncertainty, model uncertainty, data uncertainty; c) reducible uncertainty, irreducible uncertainty. There is a lack of a unified model to represent the concept of uncertainty. Ontology, referred to as the study of being and what there is, is usually used to define the common understanding of a domain. In this project, HERE scholars will work with Dr. Zhenjun Ming to develop an ontology for formally representation of uncertainties in engineering design. The ontology will be used as a template for managing uncertainties in a Cloud-Based Platform for Decision Support in the Design of Engineering Systems (CB-PDSIDES). HERE scholars with some knowledge of design optimization, information modeling, and willingness to read and learn, and plan to take no more than 15 credits (including this course) are encouraged to apply.

Effective aerobic zinc retention from contaminated waters  
Dr. Robert W. Nairn  
School of Civil Engineering and Environmental Science (CEES)  

The OU Center for Restoration of Ecosystems and Watersheds (CREW) has generated a substantial, long-term dataset on water quality improvement performance of passive treatment systems for metals retention. Through promotion of a variety of naturally occurring oxidative and reductive processes, these ecologically engineering ecosystems retain elevated concentrations of ecotoxic metals. Although zinc retention via bacterial sulfate reduction in anaerobic vertical flow bioreactors has been documented, recent research indicates the potential for effective zinc removal via aerobic processes, if elevated iron is present. This project will include a field microcosm experiment in which mixed-metal contaminated artesian-flowing mine waters will be collected and incubated under various aeration scenarios. The short-term experiment will include temporal
collection of samples, laboratory analyses via microwave-assisted hot acid digestion and inductively coupled plasma-optical emission spectroscopy and initial treatment system design.

**Experimental study for the development of a Smart Home Thermal Comfort System**  
**Dr. Li Song**  
**School of Aerospace and Mechanical Engineering (AME)**

The research aims to develop and validate an affordable smart home comfort SYSTEM that can utilize thermostat data, along with other key information, to make homes both comfortable for the resident and more energy efficient. A home thermal model that can capture the heat transfers from multiple heat gains and predict the HVAC thermal energy output is particularly important for the SYSTEM development. Specifically, this project is designed to collect operational data in a test home located in Norman, OK to validate and improve the accuracy of a previously developed home thermal model. A student with basic skills of Excel/MatLab is preferred.

**Heart Valve and Brain Aneurysm 3D Geometry Reconstruction**  
**Dr. Chung-Hao Lee**  
**School of Aerospace and Mechanical Engineering (AME)**

Analysis of biological systems can be benefit by 3D geometric reconstructions of those systems from patient imaging data, which allow for subsequent computational frameworks to predict mechanical alterations to those biological structures. Specifically, aneurysms in the brain and the heart valves can be digitally reconstructed, which is an important first step towards developing innovative therapeutics. Hence, the execution of this project is two-fold: (i) acquiring micro-CT image data at the OU Advanced Medical Imaging Facility, and (ii) performing reconstruction of the 3D geometry of the brain aneurysms and heart valves and (iii) developing finite element meshes of the constructed geometries. Undergraduate students involving in this project will have an opportunity to gain experience on image segmentation via commercial software Amira as well as finite element mesh generation using software Hypermesh. Students from all engineering disciplines are welcome to apply for this project.

**How do microparticles move in a porous material, like an oil hydrocarbon reservoir?**  
**Dr. Dimitrios V. Papavassiliou**  
**School of Chemical, Biological and Materials Engineering (CBME)**

A lot of oil remains in the ground after an oil reservoir is produced. In the State of Oklahoma, most of the oil is still in the ground, even after we have been an oil and gas producing State for almost 150 years now. One way to get the remaining oil out is to use micro- and nano-particles that can move through the soil and can reach the sites where oil is trapped. Then these particles can release some chemical to make the trapped oil move. We want to investigate how this particle movement may occur in a fundamental manner, using model porous media made of small spheres packed together like a packed tower. We use software to do this, and we want to conduct numerical experiments to simulate the transport of particles in a computationally generated porous material.
We want to understand exactly how different particle types move, and where exactly they go in the porous medium, so we track individual trajectories of thousands different particles. From the particle trajectories, we can learn the details of the effects of flow on transport, and we can develop models to describe the process. A student who has had intermediate Fluid Dynamics classes and an interest in computing would be the better fit for this project. Skills to be developed include programming, working with virtual reality and super-computers, presenting research results and thinking critically about open-ended problems.

**How to Make a Brain in a Billion Easy Steps**  
**Dr. Dean Hougen**  
**School of Computer Science (CS)**

Member of the Robotics, Evolution, Adaptation, and Learning Laboratory (REAL Lab) conduct fundamental artificial intelligence research aimed at developing machines that can think in sophisticated ways. We focus primarily on six topics that may at first seem incongruous but that are deeply interwoven: Learning, nurturing, evolution, speciation, mutualism, and risk. These concepts come to us from biology, cognitive science, psychology, child development, sociology, education, and economics, among other disciplines. We pursue these topics individually and in combination, theoretically (mathematically) and experimentally. Research assignments will be based on particular interests and skills but are likely to include many of the following: Determining research questions; formulating hypotheses; conducting mathematical proofs; designing experiments; writing and modifying simulation software; porting software from simulation to real robots; conducting experiments; collecting, organizing, and analyzing data; and collaboratively writing up results for publication.

**Image Processing for OCT Middle Ear Images**  
**Dr. Qinggong Tang**  
**Stephenson School of Biomedical Engineering (SBME)**

Optical coherence tomography (OCT) is an established biomedical imaging technology for subsurface imaging of tissues with high resolution (<10 µm) and 1-2 mm penetration depth, which is comparable to the size of standard pinch biopsy and histology. OCT can be used to noninvasively and quantitatively determine tympanic membrane (TM) thickness and the presence and thickness of any middle-ear biofilm located behind the TM.

In this project, the student will help to process the images from OCT and develop automated algorithms to differentiate normal, acute, and chronic otitis media (OM) infections in pediatric subjects based on measurements from OCT.
In-Vitro Flow Loop Design and Validation for Replicating Blood Flow in Cardiovascular System
Dr. Chung-Hao Lee
School of Aerospace and Mechanical Engineering (AME)

This project aims to replicate blood flow properties in the cardiovascular system(s) using a closed loop flow system. Such a system will allow our lab to investigate the flow patterns that emerge upon the introduction of a variety of geometries/shapes to better inform treatment efforts. With guidance from other student researchers, students involved in this project will likely spend time performing some or all of the following tasks: (1) researching the flow characteristics, (2) performing calculations to scale this flow to more manageable dimensions, (3) selecting and validating pumps and sensors for use in the flow system, and (4) assembling all components into a functional testing apparatus. Students from all engineering disciplines who are interested are welcome to apply for this project.

Innovative Control Algorithms and Implementation for Quadcopter Drones
Dr. Wei Sun
School of Aerospace and Mechanical Engineering (AME)

This project aims to design control algorithms under constraints such as external obstacles or power/energy constraints and implement them on a real-world aerial robotics application, namely, a quadcopter system. This project will involve: (i) incorporate control/state constraints to currently available algorithms so that they can handle various types of constraints, (ii) implement the new algorithm on a simulated quadcopter system, (iii) test the algorithm on real quadcopters and (iv) gain experience in using state-of-the-art software and hardware for robotics systems. Students in aerospace, mechanical, electrical, computer engineering, and computer science are welcome to apply. Prior exposure to Matlab, Python, C++ will be helpful and experience in ROS is a big plus.

Interference Mitigation for Automotive Radar
Dr. Justin Metcalf
School of Electrical and Computer Engineering (ECE)

Radar systems are emerging as a key sensor for the automotive industry. The robust all-weather, day or night sensing capability offered by radar provides a reliable information source to automatic driver assistance systems and will be a vital input to future autonomous driving solutions. However, the proliferation of the number of radar sensors on automotive vehicles combined with the number of new models adopting those sensors is leading to a “crowding” of the spectrum allocated to automotive radar. In other words, with many radars using the same spectrum there is an increasing chance of radars interfering with each other. This project will investigate the impact and the mitigation of interference for automotive radars. The student will learn the fundamental technology underlying automotive radar and develop software to control a provided automotive radar. The project will culminate in the demonstration of two automotive radars interfering with each other, and manipulation of the radar management software to mitigate the interference. Time allowing, the student will begin to derive optimal resource management strategies to determine
capacity levels for the number of radars a particular roadway can accommodate without unacceptable degradation in sensor performance. Comfort or willingness to learn Matlab and/or Python will be required. Understanding of Fourier Transforms is strongly desired, but not required for a motivated student. Students interested in radar or autonomous vehicles are encouraged to apply.

Janus Nanoparticles Targeted for Membrane Applications
Dr. Sepideh Razavi
School of Chemical, Biological and Materials Engineering (CBME)

Separation and purification processes, such as distillation, consume a substantial amount of energy and contribute to environmental pollution. For instance, CO2 removal accounts for a large fraction of costs in oil and gas processing. Membrane technology offers a promising alternative to traditional thermal separation methods. Membrane-based separations require an amount of energy which is two order of magnitude lower than traditional processes. Despite their potential, use of membranes is limited by the intrinsic trade-off between permeability and selectivity. Highly permeable membranes often exhibit poor selectivity, and vice-versa, such that the performance of gas separation membrane materials remains constrained to below an upper limit. In this project, using rational criteria, we are developing a new membrane material tailored to CO2 removal from natural gas and CO2 sequestration from process effluents. These membranes will contain Janus nanoparticles, a particle with a dual characteristic that is composed of both polymer and silver compartments. The presence of Janus nanoparticles in the composite will enhance the membrane permeability (i.e., membrane productivity) by disrupting the polymer chain packing, that is, by creating additional pathways for penetrant transport. In addition, the presence of silver in the particle will boost the CO2 sorption in the membrane. The student will synthesize the nanoparticles, fabricate the membranes, and carry out transport measurements on the membranes. Students with some knowledge in chemical synthesis who are willing to learn and contribute ideas are encouraged to apply.

Local Drug Delivery to the Inner Ear through the Round Window Membrane
Dr. Rong Gan
School of Aerospace and Mechanical Engineering (AME)

The delivery of regenerative medicine to the inner ear for the treatment of hearing loss most relies on local pathways because of the blood-perilymph barrier that isolates the inner ear from the blood. Round window membrane (RWM) composed of three layers is the only soft tissue barrier between the middle ear and inner ear, which serves as a critical pathway for local drug delivery to the inner ear or cochlea. The pharmacokinetics of the membrane with vast types of drugs, however, remains unclear. This project aims at the development of an experimental setup to determine the RWM permeability to various drugs categorized by the molecular weight and structure. It is an in-vitro study on RWM samples from different species or animal models. Research undergraduates will work with graduate students closely in our biomedical engineering lab located at Stephenson Research Technology Center (SRTC) with all experimental facilities.
Machine Learning for Radar Detection
Dr. Justin Metcalf
School of Electrical and Computer Engineering (ECE)

A key challenge for radar systems is the detection of small or distant targets. It is difficult to determine if low signal values detected by the radar are the result of a reflected echo from a small target or just a random fluctuation caused by internal thermal noise. Typical radar detectors analyze a single output to determine whether the signal value is large enough to have come from a target (and therefore declare a detection). An advanced method for detection of small targets is the so-called “track-before detect” technique, where sequential potential detections are matched to a position/velocity profile to integrate the target signal over a longer observation period. However, such techniques quickly become computationally prohibitive due to the large number of potential data points and position/velocity profiles that must be tested. A key capability of machine learning algorithms is the ability to learn complex patterns. Therefore, we will investigate whether machine learning techniques can be used to replace analytical track-before-detect algorithms. The student will simulate a large training and testing dataset using provided standard models, and then apply current machine learning techniques to determine whether they can extract the target patterns from the data. Students interested in radar, machine learning, or statistics are encouraged to apply. Comfort or willingness to learn Matlab and/or Python will be required.

Magnetic Colloidal Particles and their Tunable Assembly
Dr. Sepideh Razavi
School of Chemical, Biological and Materials Engineering (CBME)

The process of assembly in a system of building blocks gives rise to ordered structures as a result of specific local interactions among the components. In nature, assembly manifests itself in form of complex biological architectures such as viral capsids. Inspired by the plethora of naturally occurring assemblies, scientists are employing the assembly principles to design materials with a tailored set of properties using synthetic building blocks. In this project, we will use polymeric nanoparticles as the building block for assembly and coat their surface with magnetic nano-layers in order to obtain anisotropic nanoparticles. We will study the self-assembly of these particles followed by the use of magnetic fields in driving the assembly via induced dipole interactions. Our findings will guide us in engineering structures that are reconfigurable and possess tunable functional properties. In this project, the student will design an experimental setup suitable to a system of micron-sized colloidal particles that are coated with a thin layer of magnetic materials. Next, the student will expose these particles to magnetic fields and measure their response and assembly behavior. Students with some knowledge in the design of experimental setups who are also familiar with electromagnetism and are willing to learn and contribute ideas are encouraged to apply.
Managing Emergent Properties of a Complex System
Lin Guo (Doctoral Candidate, ISE), Dr. Janet K. Allen (ISE), Dr. Farrokh Mistree (AME)

In a complex system, there are organized complexity and disorganized complexity. Disorganized complexity is known as emergent properties, which can be interpreted as "the whole is greater than the sum of its parts." For example, in a business organization, interactions between departments may affect the behavior of the organization, and the challenge is that such affects cannot be captured perfectly all the time for operation adjustment. Given this challenge, our goal in this project is to frame the complex-system-realization problem in an adaptive way, explore the solution space and make real-time adjustment to manage the emergent properties while boosting the potential of the system in a holistic view.

In this project, the HERE scholar will be assisting PhD candidate Lin Guo in extending the Formulation-Exploration framework and apply it to a test problem on business organization management. A journal article coauthored by the HERE scholar is possible. A HERE scholar with knowledge and passion in operations research, statistics, management science and psychology, experience with Python, and willingness to read and to learn are desired. Time and dedication are required. The HERE scholar working with us should take no more than 15 credit-hours including this course in Fall 2019.

Modelling Robustness for Coupled Decision Problems Encountered in Design of a Gearbox
Gehendra Sharma (MS, AME), Dr. Janet K. Allen (ISE), Dr. Farrokh Mistree (AME)

Decision Support Problems (DSPs) are used to model design decisions involving multiple trade-offs. In practice, such design decisions are also coupled, i.e., selection and compromise decisions have to be made concurrently accounting for the influence they exert on one another. Selection involves making choice among a number of alternatives considering several attributes while compromise involves synthesizing design variables against multiple conflicting requirements. In context of designing a gearbox, the decision about gearbox geometry must come from the requirements such as torque and speed, low weight, constraint on size, noise and vibration reduction, etc., which leads to a compromise decision. We also have numerous material alternatives available for selection. These two decisions have to be made concurrently by considering the influence of one decision over the other. Further, it is imperative that the design decisions are robust against the expected variability in design variables, material properties and manufacturing process. In this project, the HERE scholar will work with Gehendra Sharma (MS student) to further our effort to develop decision support that aids:
- Modelling of coupled decision problems encountered in design of a gearbox
- Incorporating robustness into the model
- Exploring design decisions against multiple conflicting goals (more than 3 goals)

We look forward to the HERE scholar be a co-author on a paper that eventuates from this work. A HERE scholar, who will be taking no more than 15 units in Fall 2019, with some knowledge about the design of machine elements, interest in mathematics and programming and a willingness to learn and contribute is highly encouraged to apply.
Novel glassy polymers containing configurational free volume  
Dr. Michele Galizia  
School of Chemical, Biological and Materials Engineering (CBME)

Sustainable energy and chemicals supply is critical for mankind’s survival. Energy-efficient membrane technologies have raised significant attention in the last three decades, as they can successfully compete with traditional thermal separation processes, such as distillation. Development of competitive membrane systems relies, however, on a solid molecular-level understanding of transport mechanism in the membrane material, which is the main focus of this project. Glassy polymers exhibiting (ultra)microporosity have recently shown great promise in overcoming the limitations of conventional membrane materials. Among these high-performing microporous polymers, triptycene-based polymers are of particular interest, largely due to their unique molecular structures involving “configurational free volume” defined by the shape of triptycene units. Triptycenes are 3-dimensional functional groups made of 3 aromatic rings in a paddlewheel-like configuration.

However, most of the literature on triptycene-based polymer membranes focuses primarily on their separation performance, with limited or no fundamental understanding of small molecule transport mechanism in these innovative materials. Such fundamental knowledge is essential to take advantage of the exceptional performance (high permeability and selectivity, combined with resistance to physical aging and plasticization) exhibited by these materials. In this project, we will fill this gap in the literature, in collaboration with the University of Notre Dame. Students that are willing to work in an interdisciplinary, collaborative environment are encouraged to apply. The undergraduate student involved in the project will be co-author of peer-reviewed publications in international journals.

Numerical Investigation of Capacity Degradation of Lithium-Ion Batteries for Dynamic Storage Applications  
Dr. Jie Cai  
School of Aerospace and Mechanical Engineering (AME)

Electrochemical batteries are increasingly used for dynamic storage applications in power systems. Examples include the recent mega-watt battery installation projects on the west and east coasts for power grid frequency regulation. In these dynamic applications, batteries are charged/discharged aggressively with high power throughput, which could lead to fast aging of the batteries and increase the overall operation cost. In this project, students will simulate control algorithms and use previously developed battery degradation models to quantify the aging rates for a few dynamic storage applications, including but not limited to frequency regulation. All simulations will be carried out in MATLAB and prior experiences are preferred.
Optical Methods for Microstructural Analysis of Heart Valve Tissue  
Dr. Chung-Hao Lee  
School of Aerospace and Mechanical Engineering (AME)

Characterizing the complex microstructure of biological tissues is essential to create valid structural models and to inform tissue engineering efforts. In heart valves, a complex network of semi-aligned collagen fibers leads to anisotropic, or directionally-dependent, mechanical properties. This project utilizes the polarization-specific refractive response of collagen fibers to characterize the preferred fiber direction and degree of orientation throughout the region of the heart valve. We are working to integrate this system with our biaxial mechanical tester in order to observe changes in collagen alignment and orientation when load is applied to the tissue. Undergraduate students who participate in this project will learn about novel optical methods for microstructural analysis, image processing and analysis methods, and methods for mechanical analysis of anisotropic materials. Prospective students should have an interest in tissue biomechanics, optics or optical engineering, and microstructural analysis. Students in all engineering disciplines are welcome to apply for this project, especially students in mechanical, biomedical, and electrical engineering.

Optimal Controller Design for Variable-Speed Vapor-Compression Cycles  
Dr. Jie Cai  
School of Aerospace and Mechanical Engineering (AME)

Vapor-compression cycles are predominantly used in modern air-conditioning, refrigeration and heat pump systems. Conventional refrigeration systems cycle on and off the compressor to maintain a desired temperature setpoint. Significant efficiency loss occurs in the cyclic operation and variable-speed heat pumping equipment emerges in recent years with much improved efficiency and control accuracy. However, optimal control of such systems is challenging with nonlinear and dynamic couplings between the various components in a vapor-compression cycle. In this project, students will be engaged in industry sponsored projects to develop optimized control algorithms for variable-speed refrigeration equipment. Basic optimization and numerical skills are preferred in this effort.

Organic solvent nanofiltration: a new separation technology to change the world  
Dr. Michele Galizia  
School of Chemical, Biological and Materials Engineering (CBME)

The vast majority of industrial organic synthesis occurs in solution. Downstream processes, such as solute concentration and solvent recovery, play a crucial role in the chemical industry and pose problems that are as relevant as the synthesis process itself. Separation and purification technologies often rely on distillation. In the US, we have over 40,000 distillation columns that consume 50% of the energy required by the American chemical industry, and account for 6% of the total US energy use. Novel, energy-efficient technologies based on polymer membranes are emerging as a viable alternative to thermal processes. Despite organic solvent nanofiltration (OSN) could revolutionize the chemical, petrochemical, food and pharmaceutical industry, its
development is still in its infancy for two reasons: i) the lack of fundamental knowledge of elemental transport phenomena in OSN membranes, and ii) the instability of traditional polymer materials in chemically challenging environments. While the latter issue has been partially solved, the former was not addressed at all. In this project, we propose a fundamental investigation of small molecule transport in OSN membranes. These studies will help to design next generation membrane materials, in collaboration with the Georgia Institute of Technology and the University of Notre Dame. Students that are willing to work in an interdisciplinary, collaborative environment are encouraged to apply. The undergraduate student involved in the project will be co-author of peer-reviewed publications in international journals.

Recovery and reuse of spent acid generated from hydrogen sulfide stripping
Dr. Robert W. Nairn
School of Civil Engineering and Environmental Science (CEES)

Granular activated carbon (GAC) has been demonstrated to be an effective control for elevated gaseous hydrogen sulfide concentrations. At a field-scale sulfate-reducing bioreactor operated by the OU Center for Restoration of Ecosystems and Watersheds (CREW), a 180-kg GAC tower receiving approximately 30 ft³/minute of humid, sulfide-rich air addresses sulfide concentrations up to several hundred ppm. The system operates wholly off-the-grid using solar power. However, although still performing as designed in terms of air quality improvement, the system produces sulfuric acid. This project will characterize the acid produced and explore potential reuse options, including the treatment of recovered iron oxide residuals to generate wastewater treatment flocculants. Other possibilities to be explored include the production of fertilizers, if the materials do not exceed Resource Conservation and Recovery Act (RCRA) criteria, and other industrial applications. The project will examine the potential for resource recovery from passive treatment systems addressing substantial environmental liabilities.

Starting a Knowledge-Based Method Selector for Managing Non-Convex Engineering Design Problems
Lin Guo (Doctoral Candidate, ISE), Dr. Janet K. Allen (ISE), Dr. Farrokh Mistree (AME)

In decision support problems, nonconvexity has been a tough issue for years. There are methods, algorithms and tools in different concept categories for managing non-convex problems, such as approximating the non-convex equations with specific linear algorithms, partitioning the problem to convex sub-problems, transforming the problem to another design space by identifying a different group of decision variables, etc. Each method has pros and cons and may work well for a genre of problems. A knowledge-based method selector is needed. We expect such selector to share knowledge on the properties of typical non-convexity methods and assist the decision makers to select appropriate methods under various design situations and requirements. Our goal in this project is to build the framework of the knowledge-based method selector and give user-interface to share their knowledge and further improve the selector. The outcome of this project is a cool module on a beautiful open-resource platform and a journal article.
In this project, the HERE scholar will be assisting PhD candidate Lin Guo in literature reviewing, knowledge categorizing and coding the architecture of the module. A review paper on non-convexity management coauthored by the HERE scholar is possible. A HERE scholar with knowledge and passion in operations research, experience with Python, and willingness to read, summarize and write are desired. Time and dedication are required. The HERE scholar working with us should take no more than 15 credit-hours including this course in Fall 2019.

**Synthesis and Characterization of Polymeric Materials for Biomedical Applications**  
**Dr. Chung-Hao Lee**  
**School of Aerospace and Mechanical Engineering (AME)**

Shape memory polymers (SMPs) are unique materials capable of returning from large deformations to a single “programmed” shape when they are given a thermal trigger. They have a wide variety of potential uses, and our lab is interested in exploring their potential use in the field of implantable medical devices. The main objective of this project is to investigate a variety of synthesis and manufacturing methods for the production of shape memory polymers. This project will involve: (1) synthesis of polymers with various chemical compositions, (2) modifying synthesis procedures to produce unique SMP shapes and structures (ex: foams, solid beams, filaments and resins for 3D printing, etc.), and (3) exploring the use of additive components to allow for triggering mechanisms other than heat (e.g., light, electric current, chemical, etc.) Students from all engineering disciplines who are interested are welcome to apply for this project.

**Synthetic Aperture Radar Mapping with Automotive Radar**  
**Dr. Justin Metcalf**  
**School of Electrical and Computer Engineering (ECE)**

The explosion in interest in automotive radars has led to low-cost, lightweight, high-resolution radars being commercially available. These radars are of a suitable size and weight for mounting on small unmanned aerial systems, such as drones. The student will learn to program and record data from an automotive radar and mount it on a drone for experimentation. The student will then take part in flight tests to obtain flight data from the drone mounted radar and learn to process the data to obtain a high-resolution radar “image”. Time permitting, the student will develop new processing algorithms to take advantage of the unique capabilities of the automotive radar and produce innovative new radar imaging techniques. Comfort or willingness to learn Matlab and/or Python will be required. Understanding of Fourier Transforms is strongly desired, but not required for a motivated student. Students interested in radar or autonomous vehicles are encouraged to apply.
Using Network Partitioning to Design a Green Supply Chain with Low Cost of Greenhouse Gas Emissions
Reza Alizadeh (Doctoral Candidate, ISE), Dr. Janet K. Allen (ISE), Dr. Farrokh Mistree (AME)

Network partitioning or community detection is rapidly becoming the trend for representing and analyzing problems across all of the domains from natural science to engineering and management. There is also a growing need for integrating environmentally and socially sound choices into different areas of research and practice. In this project, the HERE scholar will assist PhD candidate Reza Alizadeh in modeling a green supply chain, which is an environmentally friendly, economical and socially acceptable supply chain using network partitioning. The density, size, and location of stores in a retailer’s network influences both the retailer’s and the consumers’ costs. With stores few and far between, consumers must travel a long distance to shop, whereas shopping trips are shorter with a dense network of stores. Longer distance means higher emission. The layout of the retail supply chain is of interest to retailers who have greenhouse gas emission reduction targets and urban planners concerned with sprawl. The question that the HERE scholar and the PhD candidate will address is “Are small local shops (small partitions) preferred over large retailers (bigger partitions)?” To find the answer of this question, we need to model the network, build network partitioning method and find the appropriate size of each partition. Here scholar will learn how to do research and enjoy from doing it; how to think critically and critically evaluate the literature and identify the gaps; how to implement network partitioning method; and how to model a real network. A conference or journal article co-authored by the HERE scholar is a possibility. HERE scholars with some knowledge of operation research and network science, experience with R or Python, willingness to read and learn, and plan to take no more than 15 credits (including this course) are encouraged to apply.

Using Wideband FMCW Radar for Pre-Avalanche Detection
Dr. Jay McDaniel
School of Electrical and Computer Engineering (ECE)

Avalanches are a major concern for many outdoor enthusiasts including climbers and backcountry skiers. Although many efforts have been put forth to mitigate risks, the unpredictability of avalanches still results in several deaths annually. Highlighting the dangerous unpredictability of avalanches, a group of well-trained individuals were recently partaking in an advanced avalanche course offered by the Colorado Silverton Avalanche School when an avalanche was triggered, resulting in a fatality. This event exemplifies the dangers associated with avalanches and the need for newer technologies to aid in pre-avalanche detection.

In some avalanche prone areas, radar technology is currently being used to monitor the movement of an avalanche through means of a Doppler shift in the radar’s frequency content. This method is ideal for triggering warnings for railroads and underpasses but can only detect an avalanche that has already begun. Therefore, this research project will produce a paper study on the potential of a frequency-modulated continuous wave (FMCW) radar to detect dangerous conditions where an avalanche is likely to initiate. Specifically, this project will investigate and characterize the conditions that lead to avalanches, such as mountain slope angles and snow stack-up characteristics.
that yield a high probability of avalanche initiation. Armed with an understanding of these conditions, a paper design will be conducted to determine requirements for an FMCW radar capable of creating echograms of sufficient quality to detect and localize areas of high avalanche probability.

**Visual scanning pattern analysis through machine learning**  
**Dr. Ziho Kang**  
**School of Industrial and Systems Engineering (ISE)**

Eye tracking will become ubiquitous in our every day lives. If we could better analyze and predict eye tracking characteristics, especially visual scanning patterns, we would be able to design better interfaces to reduce human errors and increase human performance. This research investigates ways to analyze visual scanning patterns through machine learning approaches. State-of-the-art eye tracker is used. Students who already have a bit of experience in machine learning methodologies are encouraged to apply.

**What happens to large molecules, like proteins, when they travel through medical devices?**  
**Dr. Dimitrios V. Papavassiliou**  
**School of Chemical, Biological and Materials Engineering (CBME)**

When blood moves through medical devices (like blood pumps during open heart surgery, or through prosthetic heart valves), the blood cells undergo changes because of mechanical stresses acting on them. In addition, proteins that circulate with the blood can change their molecular configuration when forces that are not physiological act upon them. Such changes can result in disease and in serious health complications after a heart valve implantation. We use molecular level simulations to understand the changes that protein molecules undergo when they get to flow through medical devices. The two extreme conditions are shear flows (where shear stresses are exerted on the molecules) and elongational flows (where normal forces act on the proteins). We want to see what are the conditions that lead to significant changes in the protein configuration, what are the conditions that might lead to cleavage (the breakage of bonds in the protein) and to develop guidelines for the design of medical devices. We use simulations with high end computers (locally, at the OU Supercomputing Center for Education and Research, as well as across the country) to simulate molecular interactions and to generate the flow conditions for purely shear and purely elongational flows. A student who has had intermediate Physical Chemistry and Fluid Dynamics classes and an interest in computing would be the better fit for this project. Skills to be developed include programming, working with high end computers, presenting research results and thinking critically about open-ended problems.
Wideband Biomedical Phantom Construction
Dr. Justin Metcalf
School of Electrical and Computer Engineering (ECE)

Most common high-resolution biomedical imaging technologies use some form of X-ray radiation, such as computed tomography (CT) scans or X-ray mammography. However, X-ray radiation is ionizing, limiting physician flexibility in ordering tests. Biomedical radar has recently been shown to be a feasible alternative to X-ray sensing modalities in some applications, particularly in the detection of breast cancer. OU is in the process of building a new form of biomedical radar that will provide increased sensitivity, dynamic range, and resolution. The increased resolution is due to the use of a wider range of frequencies – including much higher frequencies than typical biomedical radars. The biomedical radar group lacks high fidelity phantoms – or electromagnetically representative test articles – that may be used to verify and validate the biomedical radar performance. The student under this project will start with available designs in the literature, including molding, casting, and 3-D printing techniques, to construct, characterize, and test biological phantoms – including for the human breast and maxillary sinuses. The student will assess the electromagnetic properties of the artificial tissues over the desired frequency range of the OU biomedical radar. The test equipment and fabrication laboratory at the Advanced Radar Research Center will be used to construct and test the phantoms. Students interesting in radar, biomedical engineering, or electromagnetics are encouraged to apply.