Session I: Speakers

“Low Photon Count Phase Retrieval Using Deep Learning”
Kwabena Arthur
Machine learning has proven to be a great tool in solving inverse problems. We demonstrate its capability in the phase retrieval problem, successfully reconstructing features even in low-photon count conditions.

“Partial Replanning for Decentralized Dynamic Task Allocation”
Noam Buckman
We present a decentralized allocation algorithm for allocating new tasks that appear online during the solving of the task allocation problem. Our algorithm extends the Consensus-Based Bundle Algorithm (CBBA), a decentralized task allocation algorithm, allowing for the fast allocation of new tasks without a full reallocation of existing tasks. CBBA with Partial Replanning (CBBA-PR) enables the team to trade-off between convergence time and increased coordination by resetting a portion of their previous allocation at every round of bidding on tasks. By resetting the last tasks allocated by each agent, we are able to ensure the convergence of the team to a conflict-free solution.

“Convex Engineering”
Edward Burnell
A demonstration of convex-optimization-based tools for collaborative design exploration, focusing on the creation of shared trust and nuanced understandings of risk.

“Sensitivity of statistics in chaotic systems”
Nisha Chandramoorthy
In a chaotic system like a turbulent fluid flow around an airplane wing, the derivatives of state functions such as lift and drag with respect to design or control inputs (for example, the geometry of the airfoil or the freestream Mach number) grow exponentially with time. Yet, the infinite-time average of a state function, equal to its average according to the steady-state distribution over state-space, has a bounded derivative to these input parameters. Computing this statistical response to infinitesimal changes in parameters is an important technical challenge addressing which enables uncertainty quantification, mesh adaptation, parameter estimation and other gradient-based multidisciplinary design optimization techniques under chaos. We present a novel approach, the perturbation space-split sensitivity (S3) algorithm, that is provably convergent to the sensitivity of statistics and computationally efficient. The S3 algorithm is demonstrated on classical low-dimensional examples and extended to high-dimensional numerical fluid flow simulations.

“A Hybrid Material Point and Discrete Element Method for Granular Media Modeling”
Maytee Chantharayukhonthorn
Phenomenon involving granular media bridge vast length scales, and simulating this propagation of physics from the micro to the macro is difficult. Two paradigms for modeling granular media exist: discrete element methods (DEM), wherein all of the grains and their interactions are simulated (accurate but slow) and continuum methods, where the granular bulk is assumed to be a continuum (faster but tends to be less accurate). We present a hybrid method that utilizes both DEM and continuum methods, leveraging the speed of continuum methods with the accuracy of DEM where appropriate in a single simulation.
Session I: Speakers

“The Effect of Attenuation from Multiple Forward Scattering on Ecosystem Scale Sensing of Fish Shoals”

Daniel Duane

Accounting for attenuation from forward multiple scattering is important for accurate ocean sensing in regions with high-density scatterers, such as fish shoals or bubble clouds. The effect of attenuation on wide-area imaging of vast herring, cod and capelin shoals is presented and shown to be consistent with an analytical model derived from first principles for acoustic propagation through inhomogeneities in an ocean waveguide. We find that the optimal sensing frequency for detecting dense fish shoals is above the resonance peak of the fish swimbladders, where backscattered returns are significant and attenuation is minimal. In addition, examples are given of scattering strength estimations after significant attenuation.

“Vibration-Enhanced Cleaning of Fouled Membranes in Desalination”

Zi Hao Foo

To artificially augment the dwindling water supplies triggered by the onset of climate change and population growth, membrane processes like reverse osmosis (RO) have steadily grown to produce over 59% of the desalination output at high energy efficiencies. Despite that, the long-term effectiveness of membrane processes is greatly limited due to deposition of foulants on the membrane surface, prompting the use of harsh chemicals for its subsequent removal. Given the undesirable repercussions of chemical cleaning, including the active layer damage and system downtime, there is growing interest in developing chemical-free cleaning methods through the employment of vibrations and foulant layer swelling. Thus, the present study aimed to develop a nascent physical membrane cleaning technique, by inducing transverse vibrations of the membrane to allow for in-situ foulant removal, using alginate as the model organic foulant. Initial vibration experiments demonstrated that membrane vibrations led to a decrease in the interfacial energy, with the greatest reduction registered during resonance at the natural frequency, enabling easier removal. Membrane vibrations in a flat-sheet cross-flow RO configuration led to consistent flux recoveries of over 30 percent per cycle.
Session I: Speakers

Powering Desalination with Recycled Aluminum

Peter Godart
Natural disasters like hurricanes and earthquakes can leave hundreds of thousands of people without access to clean water or electricity for weeks. Highly energy-dense scrap aluminum from damaged houses and vehicles is typically abundant, however, and instead of throwing it away, we have developed a process which harnesses this energy to provide potable water and electricity. Our research utilizes a simple surface treatment to enable aluminum to react exothermically with water to produce hydrogen. We have developed a new device that passively uses these reaction products to drive a batch reverse osmosis desalination system. Once desalination is complete, the hydrogen is re-used to provide electricity via a fuel cell.

"Extra Robotic Legs for Augmenting Human Payload and Positioning Capabilities"

Daniel Gonzalez
The Extra Robotic Legs (XRL) system is worn by the operator and consists of two articulated robotic legs that move with the operator to bear a heavy payload and will ultimately walk, climb stairs, crouch down, and crawl with the operator while eliminating all external loads on the operator. The design was driven by a need to increase the effectiveness of hazardous material emergency response personnel who are encumbered by their personal protective equipment (PPE).

"Coastal Forecasting for a Sustainable Fisheries Management System in India"

Abhinav Gupta
Developing physical and biogeochemical forecasting products and technologies for sustainable coastal fisheries management in India. Our modeling systems will provide deterministic and probabilistic predictions of Potential Fishing Zone (PFZ) fields to the fishermen, informing them about ocean regions where sustainable and efficient fishing operations could be carried out. Also, our forecasts have diverse local commercial and societal applications involving not only fisheries but also coastal zone management, pollution mitigation, monitoring, ocean engineering, tourism, shipping, financial hedging, and re-insurance.

"Placental pericytes contribute to dysfunction and inflammation in a 3D model of placental microvasculature through VEGF-Ang-Tie2 signaling"

Kristina Haase
Placental pathologies, such as pre-eclampsia, critically affect microvessel morphology and function leading to maternal-fetal morbidity and mortality. Here, using an in vitro microfluidic platform we recapitulate placental microvessel growth and remodelling. In our 3D platform, we show that placental pericytes play an FGF and VEGF-A dependent role in microvessel formation, whereby they contribute to reduced lumen diameter and connectivity, and limit perfusability.

"Enhancing Interfacial Thermal Transport In Wide Bandgap Power Electronics"

Kiarash Gordiz
Realizing the next generation of power-electronics is mostly dependent on overcoming the large thermal resistance values between wide-band gap semiconductor materials present in the system. In this project, we explore different strategies to achieve this goal.
“Dry sampling of heavy metal cations for improved water quality monitoring”

Emily Hanhauser

Analysis of water quality for chemical, physical, and microbial contaminants is integral to identifying safe water sources, addressing sources of contamination, and increasing awareness of water issues. Field test kits have limitations for monitoring for heavy metals, and long-distance transport of large-volume water samples to centralized labs for analysis using high-throughput spectroscopic methods is difficult. This project seeks to demonstrate an alternate paradigm by creating a dry sampling device that quickly and reliably adsorbs contaminants from a water sample, and preserves the contaminants in a compact dry state suitable for transport and easy recovery of contaminants for analysis at a centralized laboratory.

“Features of Free Motion Persist in Constrained Actions”

James Hermus

Human physical interaction with complex dynamic objects is superior to contemporary robots despite markedly inferior resources (neuro-mechanics). Nonetheless, neuroscience research has primarily focused on the examination of elementary behaviors under strict experimental control (unconstrained motion). Physical interaction with a kinematic constraint (crank) provides an intermediate stage between unconstrained motion and physical interaction with complex dynamic objects. Thus, in this study human subjects turned a planer crank. When we 'subtracted' the limb dynamics, patterns observed in unconstrained motion emerged.

“Human-inspired balance model to account for foot-beam interaction mechanics”

Meghan Huber

The locomotion and balance capabilities of bipedal robots have greatly improved in recent years. However, while maintaining balance on difficult terrain is easy for humans, it still poses a significant challenge for robots. In this study, we examined how humans maintain mediolateral balance when standing on a narrow beam with bare feet and wearing rigid soles. Our results show that foot-beam interaction dynamics critically influence balancing behavior. Importantly, this suggests that differences in human balancing behavior across different support surfaces may not solely result from changes in their neural control strategy. They may also result from changes in foot-ground interaction. Thus, the altered foot-ground interaction dynamics must be considered to accurately capture changes in the human controller across different support surfaces. A simplified model of foot-beam interaction was added to a double inverted pendulum model for human balancing. This extended model could replicate the change in human behavior across different foot contact conditions (bare feet vs. rigid feet). A better understanding of how humans coordinate whole-body behavior across a range of conditions will inform the development of balance controllers for bipedal robots.
Session I: Speakers

“PlotSEAS: Interactive Maps for Ocean Visualization”
Chinmay Kulkarni

Comprehensive modeling and forecasting systems for ocean dynamics necessitate robust and efficient visualization techniques. In this work, we present a novel ocean visualization product: PlotSEAS.

PlotSEAS serves as the front end for the MIT-MSEAS ocean modeling system, which provides predictive capabilities for ocean physics, biology, acoustics, hazards management, optimal path planning in a probabilistic manner. PlotSEAS is an interactive and intuitive tool. It grants a high degree of user control allowing easier study over multiple spatio-temporal scales, which helps in deciding the future course of action.

A wide range of applications of PlotSEAS are demonstrated, ranging from scientific research, to search and rescue operations, to shipping and coastal management.

“Nanoporous Flexographic Printing”
Dhanushkodi Mariappan

There is a growing industrial need for manufacturing technologies that can print devices with high resolution (< 10 microns) and high throughput. The feature sizes that can be printed with technologies including inkjet printing, gravure, screen, and flexography (relief printing) are limited to tens of microns. Conventional flexography is limited in resolution due to the instabilities associated with ink loading and transfer mechanisms. A recent invention from our research group, engineered nanoporous stamps composed of polymer coated carbon nanotube (CNT) forests, are highly porous (>90%) and can retain the ink within their volume rather than on their surface only and can transfer highly uniform ink layers under mechanical contact. Using this method, we have demonstrated direct printing of features with micron-scale lateral dimensions (<10 microns), line edge roughness (<1 micron) and highly uniform thickness in the sub-100nm range.

“Characterizing Resource Demand and Sensitivity in Biological Synthetic Circuits”
Cameron McBride

Resource sharing and retroactivity are some of the major problems to building increasingly large synthetic circuits, therefore limiting the scalability of synthetic biology applications to the real world. In this work we propose the concept of the resource sensor, which, with characterization of a synthetic circuit module in isolation, enables the prediction of the output of this module when measured with other modules sharing resources. Using this additional information to describe a synthetic circuit, we are able to recover the modular composition of genetic circuits.
“Development of low cost water filters using plant xylem”
Krithika Ramchander
I am working on the development of water filters using plant xylem. Xylem, which is the tissue responsible for transporting water and nutrients in plants has nanoscale pores that are smaller than the size of bacterial pathogens in water. I will be presenting on how we can re-purpose this naturally occurring membrane as a water filter for household drinking water applications and achieve practically useful performance. In addition to lab studies, findings from field studies in India where filters were locally manufactured filters and tested with natural water will also be presented.

“TeachBot Education System for Workforce Development”
Nicholas Selby
The shortage of skilled workers who can use robots and advanced equipment is a crucial issue hampering the growth of manufacturing industries. We present a new type of workforce training system using a collaborative robot and online learning system for expanding the user base of robots. TeachBot is a robotic instructor that delivers a series of lectures from an online learning site and a demonstration machine that can perform spatial movements and physically interact with learners.

“Development of a system model for low-cost, solar-powered drip irrigation systems in the MENA region”
Carolyn Sheline
Drip irrigation has the potential to conserve water and increase crop yields. However, existing drip irrigation systems often require high pumping power, making them financially inaccessible to smallholder farmers. Integrating a holistic system model with a cost-optimization scheme can enable the design and implementation of low-cost, solar-powered drip irrigation systems, ultimately making this technology more cost-effective. This presentation illustrates the algorithms comprising an integrated model of solar-powered drip irrigation systems, and it introduces a preliminary optimization scheme for the power system, which uses the system hydraulics and pump curve to select an optimal solar array and energy storage configuration that minimizes capital cost. The results show that the model successfully encapsulates the entire system and therefore offers a greater level of flexibility than commercially available software, which tends to have broader applications and focuses on larger systems.

“Improving Hurricane Prediction”
Sydney Sroka
Some simulation results from my research trying to understand how sea spray evaporation contributes to both sustaining a hurricane and our ability to predict its characteristics.
Session I: Speakers

“3D plate-lattices: An Emerging Class of Low-Density Metamaterial Exhibiting Optimal Isotropic Stiffness”
Thomas Tancogne-Dejean
Mechanical metamaterials with high isotropic stiffness and strength are developed by assembling plate along the close-packed planes of cubic crystal. Analytical and numerical simulations reveal that the proposed lattices reach the upper bound of stiffness for isotropic porous solids and are up to three times stiffer than conventional truss-lattices. Furthermore, an almost plastically isotropic composition is found with near optimal strength. The proposed designs are manufactured through two-photon lithography and compress uniaxially to partially validate the stiffness scaling.

“Modeling Capillary Flow and Thin Film Evaporation in Micropillar Wicks”
Geoffrey Vaartstra
Porous wicks are of great interest in thermal management because they are capable of passively supplying liquid for thin film evaporation. While dryout heat flux has been well characterized for many wick configurations, key design information is missing as many previous models cannot determine the distribution of evaporator surface temperature. Here, we present a comprehensive modeling framework for thin film evaporation in micropillar wicks that can predict dryout heat flux and local heat transfer coefficient (HTC). The capillary pumping mechanism raises a significant modeling challenge as the liquid/vapor interface shape is a function of the local liquid pressure. Our numerical approach captures the effect of varying interface curvature across the micropillar evaporator to determine the spatial distributions of temperature and heat flux.

“Charge controller with decoupled and self-compensating configurations for operating piezoelectric actuators in a wide bandwidth”
Chen Yang
In this presentation, I will show a novel technique that could achieve highly precise motion control of piezo-actuators. Different from traditional methods, the implemented scheme is sensorless, model-free and most importantly, low-cost, thus particularly suitable for industrial applications.

“Magnetically Levitated Linear Stage for In-Vacuum Transportation Tasks”
Lei Zhou
We are developed a magnetically levitated linear stage, targeting at the in-vacuum reticle transportation in EUV photo-lithography machines. The stage's linear motion is driven by linear hysteresis motors, which uses permanent-magnet-free secondary in the moving stage. The magnetic suspension is achieved using a novel linear slice bearingless motor design, where the stage's levitation in 3 DOFs, including vertical, pitch, and roll are passive. The prototype has successfully levitated the stage, and demonstrated 1000mm/s^2 acceleration.
“Simultaneous Contact, Gait and Motion Planning”

Bernardo Aceituno

In this letter, we propose a mixed-integer convex formulation to plan simultaneously contact locations, gait transitions, and motion, in a computationally efficient fashion. We experimentally validated our approach on the HyQ robot by traversing different challenging terrains, where nonconvexity and flat terrain assumptions might lead to suboptimal or unstable plans.


Caleb Amy

Intermittent renewable energy sources can reliably supply the entire electricity grid if low cost energy storage is available. However, there is no clear technology that can deliver the low cost at long durations (hours to days) needed. Thus, a new concept that could meet the low cost required is presented with initial experiments and techno-economic modeling that considers the trade off between cost and efficiency. This concept is a form of thermal energy grid storage (TEGS), where excess electricity is stored as extremely high temperature thermal energy in a low cost, liquid medium. Then, multi-junction photovoltaics are used to convert back to electricity on demand.

“Room-Temperature Quantum Error Correction with Nitrogen-Vacancy Centers”

Mo Chen

In pursuit of near-term quantum devices that either demonstrate a ‘quantum supremacy’ or perform a meaningful algorithm, quantum error correction (QEC) is required. Arguably, fault-tolerance (FT) is not mandatory at this stage. Therefore, instead of traditional FT QEC, we focus on hardware-efficient QEC that demands less redundancy and imposes less overhead penalty. The system of interest is a room-temperature solid-state quantum register consisting of qubits and one ancilla, respectively given by the nuclear spins and the electronic spin associated with the NV center in diamond.

We first studied the decoherence process of the nuclear spins to better characterize the system. The errors on the nuclear spins turn out to be caused by the same source and are thus strongly correlated. We can then proceed to design custom QEC codes for this system, and develop experimental tools for realizing hardware-efficient QEC.

“Challenging the 40 year-old theory of Reynolds-number-independent flows”

Lup Wai Chew

Flows around buildings are governed by Reynolds number, \( Re = UH/ν \), where \( U \) is a reference wind speed, \( H \) the building height, and \( ν \) the kinematic viscosity. It is impossible to match the \( Re \) of models in wind tunnels (\( \sim 10^4 \)) to the \( Re \) of full-scale buildings (\( \sim 10^6 \)). This mismatch of \( Re \) is circumvented by satisfying the \( Re \) independence criterion, where a flow is assumed to be \( Re \) invariant above a critical \( Re \). The critical \( Re = 10,000 \) was derived from flow across a cube about 40 years ago. Since then, this critical \( Re = 10,000 \) has been adopted and (incorrectly) generalized to other flows. Two examples of common mistakes are illustrated: flows across narrow urban street canyons and flows with heated exterior building walls. This study reminds us that an old theory or assumption does not guarantee its validity. Challenging an old theory might lead us to discover something new!
“Planning Beyond the Sensing Horizon Using a Learned Context”

**Michael Everett**

Last-mile delivery systems commonly propose the use of autonomous robotic vehicles to increase scalability and efficiency. The economic inefficiency of collecting accurate prior maps for navigation motivates the use of planning algorithms that operate in unmapped environments. However, these algorithms typically waste time exploring regions that are unlikely to contain the delivery destination. Context is key information about structured environments that could guide exploration toward the unknown goal location, but the abstract idea is difficult to quantify for use in a planning algorithm. Therefore, this work proposes a novel formulation of utilizing context for planning as an image-to-image translation problem, which is shown to extract terrain context from semantic gridmaps, into a metric that an exploration-based planner can use.

“A Permanent Magnetic Dipole Reaction Sphere for Spacecraft Attitude Control”

**Tyler Hamer**

The attitude control system (ACS) of small spacecraft contains a minimum of three reaction wheels to rotate the spacecraft in 3 degrees of freedom (DoF), but typically contains additional reaction wheels for both redundancy and improved pointing accuracy. Each wheel rotates the spacecraft about its axis by imparting an equal-and-opposite torque when the spacecraft accelerates the wheel. Since space, weight, and power (SWaP) are a premium on a spacecraft, reaction spheres, which impart an equal-and-opposite torque about an arbitrary axis when the spacecraft accelerates the sphere about that axis, can reduce the ACS down to a single device. Induction spheres are difficult to model and suffer from high eddy current losses. Permanent magnet and hysteresis-sphere can be simpler to model, but often have rotors constructed from multiple magnets which presents fabrication, strength, and balance issues. To have a simple model and a single magnet rotor, a spherical permanent magnetic dipole rotor actuated by a stator of 12 surrounding coils with translation feedback from 12 optical sensors and rotation feedback from 12 Hall effect sensors has been modeled, constructed, and levitated.
“Untethered Soft Machines and Robots by Printing Ferromagnetic Domains in Soft Materials”
Yoonho Kim
Soft materials capable of switching between complex 3D shapes in response to external stimuli have potential uses in areas such as robotics, electronics, and biomedicine. We introduce our recent development of a technique for creating soft materials that undergo rapid, reversible transformations via magnetic actuation based on 3D printing of an elastomer composite containing ferromagnetic microparticles. We also present a theoretical model that allows us to quantitatively predict the behavior of our printed magnetic shape shifters. We further demonstrate diverse functions derived from such complex shape changes, including reconfigurable soft electronics, a mechanical metamaterial that jumps and a soft robot that crawls, rolls, catches fast-moving objects.

“Synthesis and Electrochemical Characterization of Carbon Nanotube Forests on Metal Foils for Battery Electrodes”
Bethany Lettierie
Lithium-ion batteries are used in devices of all sizes from laptops and smartphones to robots to electric vehicles (EVs). However, for decades practical battery designs have been limited by the geometric constraints of planar electrodes. This flat electrode design limits the thickness of the active material layer, which in turn results in a tradeoff between energy and power density. The goal of our study is to develop the scalable manufacturing of battery electrodes with three-dimensional (3D) microstructured active materials by combining interdigitated microstructures with a conformal solid electrolyte in order to simultaneously achieve high energy density and power density.

“Imaging through glass diffusers using densely connected convolutional networks”
Shuai Li
We propose for the first time, to our knowledge, a convolutional neural network architecture called “IDiffNet” for the problem of imaging through diffuse media and demonstrate that IDiffNet has superior generalization capability through extensive tests with well-calibrated diffusers. We also introduce the negative Pearson correlation coefficient (NPCC) loss function for neural net training and show that the NPCC is more appropriate for spatially sparse objects and strong scattering conditions. Our results show that the convolutional architecture is robust to the choice of prior, as demonstrated by the use of multiple training and testing object databases, and capable of achieving higher space–bandwidth product reconstructions than previously reported.

“The role of damping in shaping flow-induced vibration of flexible cylinders”
Leixin Ma
At present, there are no dimensionless damping parameters that are able to quantify the global VIV (vortex-induced vibration) response of flexible cylinders on a spectrum of lightly to heavily damped systems. This presentation addresses how structural, hydrodynamic and radiation damping regulate the VIV of the entire structure. Global behavior may vary from full-length standing waves to traveling waves on an infinite cylinder. Data from experiments and numerical simulations are presented to support the conclusions.
“Acoustic far-field subwavelength imaging”

Chu Ma

In this poster we present the design and experimental realization of an acoustic far-field sub-wavelength imaging system based on a transmitting/receiving pair for wave vector filtering and conversion. Far-field imaging and edge detection of sub-wavelength objects are experimentally demonstrated. The proposed system brings new possibilities for far-field sub-wavelength wave manipulation and may find applications in medical imaging, nondestructive testing, and acoustic communication.

“Mechanistic description of biofilm formation”

Rachel Mok

We use a custom mechanistic individual cell-based code employing GPUs to identify the underlying physical mechanisms governing the spatiotemporal dynamics of Vibrio cholerae biofilm formation. In our model, we have incorporated viscous drag, bacteria-surface interactions, and bacteria-bacteria interactions, which are uniquely realized through an effective cell-cell interaction potential. Comparisons with single-cell experimental data show that the model is successful in capturing and predicting the emergent global architecture and local nematic order of these biofilms.

“Droplet Optics!”

Sara Nagelberg

Multi-phase emulsion droplets display a variety of interesting optical properties, including lensing, morphology dependent emission, and structural color. This makes them an appealing system for sensing, imaging, display technologies, and fundamental optics investigations.

“Additively manufactured vanes with modified geometries for measurements of yield-stress fluids”

Crystal Owens

Materials that exhibit a yield stress, such as toothpaste, hair gel, and many industrial materials, experience slip on standard measurements of the fluid rheology. For these, the vane is an alternative geometry, designed to trap a plug of material between extended vanes, shearing a slip-free, approximately round cylinder. We use 3D printing to design and test vanes and cups with more elaborate shapes, to see the effect of a more homogeneous shear profile on measurements, and compare different models for converting between machine values (torque, rotation rate) and material values (stress, strain rate).

“Stable States of Confine Fluids in the Near-Freefall Environment”

Aaron Persad

How a fluid behaves in a closed container when exposed to the near-freefall environment of space is of central importance to the design of rocket fuel tanks, engines, and life support systems. The stable states of water confined to cylindrical containers have been predicted using classical thermodynamics. Here, we use Citizen Science to experimentally test the predictions aboard a reduced gravity aircraft as a precursor to performing experiments aboard the International Space Station.
“Mechanical Component Optimization Design, and Testing of a Fully Passive Prosthetic Knee Mechanism”

Nina Petelina

With over 30 million people worldwide in need of assistive devices, there is a great need for low-cost, high performance prosthetic technologies in the developing world. A majority of the hydraulic dampers used in prosthetic knee designs are highly specialized, expensive, require regular maintenance, and are incompatible for use with low-cost, single-axis prosthetic knees popular in developing countries. In this study, optimal damping coefficients were computed based on a theoretical analysis of gait, specifically during the transition from the stance to swing phase of human walking when a large damping torque is needed at the knee. A novel rotary hydraulic damper prototype was designed using high-viscosity silicone oil and a concentric meshing of fins for shearing the oil. The prototype was validated experimentally to provide the desired damping torque profile. For preliminary, user-centric validation of the prototype, a gait study on one above-knee amputee in India was conducted with four different damping magnitudes. Feedback from the subject validated the optimal damping torque magnitude predicted for minimizing gait deviations and for enabling able-bodied knee kinematics. The new rotary hydraulic damper design is novel, passive, and compatible with low-cost, single-axis knee prostheses.

“Demonstration of Passive Acoustic Detection and Tracking of Unmanned Underwater Vehicles”

Kristen Railey

In terms of national security, the advancement of unmanned underwater vehicle (UUV) technology has transformed UUVs from tools for intelligence, surveillance, and reconnaissance to autonomous platforms that can perform complex tasks like tracking submarines, jamming, and smart mining. Today, they play a major role in asymmetric warfare, as UUVs have attributes that are desirable for less established navies. They are covert, easy to deploy, low-cost, and low-risk to personnel. The concern of protecting against UUVs of malicious intent is that existing infrastructure on ships, harbors, and submarines falls short in detecting, tracking, and preventing the vehicles from causing harm. Addressing this gap in technology, this thesis work demonstrates and quantifies passively detecting and tracking UUVs in realistic environments strictly from the vehicle’s self-generated noise.

“Design of a 2 Degree of Freedom Ankle-Foot Prosthesis for Rock Climbing”

Emily Rogers

This research presents the design and evaluation of a bionic prosthetic ankle optimized to enhance rock climbing ability in persons with trans-tibial amputation. The bionic rock climbing prosthesis helps restore biologic performance of the ankle by allowing the user to volitionally control position of the foot about two degrees of freedom with input from EMG surface electrodes worn on the residual limb. The system is designed to provide sufficient torque to move the foot in free space, while supporting full body mass in a static position. This allows for precise free space control of the foot position, while the non-back drivable linear actuators lock the ankle position of the device when loaded with body mass.
Session II: Speakers

“Energy Consumption in a Batch Reverse-Osmosis Prototype”
Carson Tucker
Through models, the batch reverse osmosis (RO) process has been shown to consume less energy than continuous RO. By building a batch RO prototype, the energy consumption of a batch RO system can be experimentally determined. The results are used to validate a batch RO model and show how energy usage is distributed in the batch RO process. This provides insight on how to select feed salinity, flux, and recovery ratio when trying to reduce the energy consumption of batch RO.

“A Day in the Life of a Nanoscale Plumber”
Jerry Wang
Nanoscale pipes are physically small, but they can sure cause some big physics problems. In this work, we will describe a few of the many remarkable phenomena that this nanoscale plumber makes house calls for every day – unusually slow leaks, unusually fast leaks, and also some leaks that seem perfectly normal (but are actually the most unusual of all). Along the way, we will discuss some of our recent innovations in nanoscale plumbing, which have the potential to make a huge engineering splash. It is quite possible you will walk away with the realization, as Einstein realized late in his career, “if I could do it all again, I’d be a plumber!”

“Methodology to Quantify Risk of Failure for Dynamic Robots”
Albert Wang
When performing dynamic tasks near the boundary of safety, humans possess an innate sense of self-risk that safely guides the execution of extraordinary dynamic maneuvers. We are developing methods to give robots a similar sense, thus providing an aspect of physical intelligence and self-awareness to machines.

“Kinetics and economics of thermo-electro-chemical processes for sustainable energy conversion and chemical production systems”
XiaoYu Wu
The remarkable expansion of intermittent renewables requires a six-fold increase in the global energy storage capacity from 2016 to 2030. Meanwhile, world chemical sales will double to $7.3 trillion in 2030. Since bulk chemical production and refining consume enormous amount of energy (>15% of total US energy consumption in 2017), converting excess energy into value-added chemicals can reduce the need for storage. Sustainable and adaptable energy conversion and chemical production systems based on thermo-electro-chemical processes can serve this purpose. Eventually, these flexible systems can be integrated into smart grids to maximize their efficiency.

“Scanless volumetric imaging by selective access multifoci multiphoton microscopy”
Yi Xue
We demonstrate a new parallelized approach to address such questions, increasing the signal-to-noise ratio by an order of magnitude compared to previous approaches. This selective access multifocal multiphoton microscopy uses a spatial light modulator, to generate multifocal excitation in 3D, and a Gaussian-Laguerre phase plate, to simultaneously detect fluorescence from these spots throughout the volume. We test the performance of this system by simultaneously recording Ca2+ dynamics from cultured neurons at 120 locations distributed throughout a three dimensional volume. This is the first demonstration of 3D imaging in a "single shot" and permits synchronized monitoring of signal propagation across multiple different dendrites.
“Non-Contact Laser Ultrasound”

Xiang (Shawn) Zhang

We have developed a magnetically levitated linear stage, targeting at the in-vacuum reticle transportation in EUV photo-lithography machines. The stage's linear motion is driven by linear hysteresis motors, which use permanent-magnet-free secondary in the moving stage. The magnetic suspension is achieved using a novel linear slice bearingless motor design, where the stage's levitation in 3 DOFs, including vertical, pitch, and roll are passive. The prototype has successfully levitated the stage, and demonstrated 1000mm/s^2 acceleration.