Graduate Research Exposition 2016

Portland Art Museum
March 1st

4  Chemical, Biological, and Environmental Engineering
14  Civil and Construction Engineering
38  Electrical Engineering and Computer Science
70  Mechanical, Industrial, and Manufacturing Engineering
94  Nuclear Science and Engineering
Evidence that Ladybird Beetle Adhesion Fluid Adapts to Changing Surface Chemistry

James Elliott Fowler, Elena V. Gorb, Johannes Franz, Tobias Weidner, Stanislav Gorb and Joe E. Baio

Unlike most man made adhesives, insects are capable of repeatedly sticking and unsticking from a wide range of surfaces. The attachment and detachment of their feet is vital to their ability to survive. Insect adhesion is often based on a combination of surface contact of microscopic foot hairs and a secreted fluid. The ladybird beetle (Coccinella septempunctata, Coleoptera, Coccinellidae), is a well-studied example of this type of adhesion. However, no study of the molecular interactions of this insects’ fluid at the contact interface of different surfaces exists. This adhesive mechanism adapts to many surfaces in nature; therefore, the goal of this investigation is to probe beetle footprints on two substrates with different polarities, deuterated, polar poly(methyl methacrylate) and deuterated, non-polar polystyrene. Traction force experiments show no significant difference between forces required to remove the beetle’s foot from either substrate. SFG spectra indicate both polymer interfaces promote order of hydrocarbon containing molecules, with the d-PMMA substrate generating greater order than the d-PS. Only the d-PMMA spectra indicate order of lipids and free fatty acids. We conclude that beetle footprints, consisting of hydrocarbons, fatty acids and lipids, form a well-ordered layer at polar interfaces. Conversely, these molecules exhibit less hydrocarbon order and complete lack of lipid or free fatty acid order on non-polar surfaces. The beetles stick equally as well on both surface chemistries. However, surface chemistry induces clear differences in fluid molecular ordering. Therefore, we conclude that the beetle adhesion fluid makes a dynamic adaptation as it senses different surface environments.

Probing the Biophysical Interactions of Anti-Microbial Peptide WLBU2 and Cell Membranes

Thaddeus W. Golbek, Hao Lu, Johannes Franz, J. Elliott Fowler, Karl Schilke, Tobias Weidner and Joe E. Baio

WLBU2 is an engineered cationic amphiphilic antibiotic peptide that targets Gram-positive and Gram-negative bacteria, and envelops endotoxin while avoiding other cell types. The exact mechanism of how WLBU2 targets, binds, and disrupts bacterial cell membranes is still
not completely understood. Thus, the overall goal of this investigation is to determine the structural basis for recognition and interactions between WLBU2 and cell membranes. It is believed that WLBU2 binds parallel to the surface of the membrane in an $\alpha$-helical confirmation and, at a critical membrane concentration, may disrupt the membrane. We tested possible disruption mechanisms by using surface and interface specific spectroscopy tools to probe the biophysical interactions between WLBU2 and both zwitterionic and negatively charged lipid monolayers. SFG spectroscopy demonstrates binding of WLBU2 induces increased lipid monolayer order until, at a certain interfacial concentration; the peptide induces disorder within the lipid monolayer. Differences in observed surface pressure at the lipid–air interface suggest that WLBU2 selectively binds to negatively charged membranes via electrostatic interactions. NEXAFS tilt angle calculations for the peptide bound to both negatively charged and zwitterionic lipid monolayers are $71^\circ \pm 2^\circ$ and $70^\circ \pm 1^\circ$, respectively. NEXAFS and SFG together suggest that WLBU2 binds to the surface of the lipid bilayer in a predominately $\beta$-sheet conformation for zwitterionic membranes and in a $\alpha$-helical conformation for negatively charged membranes. Differences in folding demonstrate WLBU2 selectivity toward negatively charged membranes (i.e. bacteria) inserting individually by either the barrel-stave or toroidal model, and inactivity toward zwitterionic membranes (i.e. other cell types).

3 Paper-based Home Biosensor for Detecting Phenylalanine from a Sample of Whole Blood

Robert Robinson and Elain Fu

Biosensors are important tools for measuring concentrations of analytes found in biological fluids. Paper-based microfluidic devices can offer many benefits to the field of biosensor development. These devices are inexpensive, disposable, and require little to no user training. Small volumes of fluid can be used in these devices, which decreases reagent costs and the need for venipuncture blood samples. In addition, capillary flow in paper removes the need for pumping equipment. The topic of this poster presentation is a novel paper-based, biosensing device that can be used for therapeutic, home monitoring by people with the genetic disorder Phenylketonuria (PKU). People with PKU are required to maintain a strict, low phenylalanine (Phe) diet to avoid irreversible, adverse health effects. Maintaining appropriate levels of Phe can be especially challenging for young children, adolescents and pregnant women. Much like a glucose test kit helps monitor blood glucose levels by people with diabetes, a home test kit that detects the amount of Phe in a finger prick of blood could aid a person with PKU in maintaining appropriate levels of Phe and adherence to diet therapy. This presentation will describe the development of a paper-based home test kit that can detect clinically relevant levels of Phe from a finger prick of blood. Specific design choices were investigated, including reaction compatibility in various substrates and the plasma transfer capability of a plasma separation membrane into those substrates. Finally, the performance of the test was evaluated using mock samples of Phe spiked into whole blood.
Functional PEO–PBD–PEO Triblock Copolymer Synthesis and Application for Bio-processing

Bonan Yu and Karl Schilke

Poly (ethylene oxide)-co-Polybutadiene-co-Poly (ethylene oxide) (PEO–PBD–PEO) triblock copolymer has the ability to prevent the absorption of protein on the surface which coated by the triblock copolymer. Polybutadiene contains backbone double bonds (1, 4 addition) and side chain double bond (1, 2 addition). By gamma radiation in water, the radicals generate on the polybutadienes, thus use for immobilize on the surface of the material. The abundant Poly (ethylene oxide) (PEO) chains are used as nonfouling process (protein repelling). Some of proteins and enzymes have the ability to capture the endotoxin or to lyse bacteria. The non-fouling surface with functional proteins can be used to clean the endotoxin in plasma to avoid other protein absorption on the device surface. Chemical method to synthesis or functionalized the triblock copolymer is for modification its ability to react and to immobilize useful proteins or enzyme on the surface for the bio-process. Those chemical modification method should devoted to precise in changing functional group without or minor affect other group.

Chemical Engineering

Chemical Modulation and Microwave-assisted Synthesis of MOF–74(Ni)

Gustavo Albuquerque, Majid Ahmadi and Gregory S. Herman

Metal–organic frameworks (MOFs) are very attractive scientifically and technologically due to the flexibility in modifying their properties by changing metal coordination species and organic linkers. MOFs can have three dimensional long-range order, high surface area, large internal free volume space, and tunable adsorption properties. MOFs are multifunctional and may be used for a wide range of applications including: gas storage, separation, catalysis, and more recently pharmaceutical. However, the lack of feasible and scalable synthesis methods still limits their use at industrial scales. In this study the synthesis of MOF–74(Ni) was performed using a continuous flow microwave-assisted reactor. This reactor provides the advantages of both microwave induced volumetric heating to allow uniform and well controlled nucleation, while high yields with short reaction times are also obtained. Tuning the microwave nucleation temperatures, combined with the application of chemical modulators, allows significant control over the nucleation processes which modifies the crystallinity of the final product. We have found that chemical modulators significantly reduce the particle size distribution, increase the effective particle size, and enhance the adsorption properties of the MOFs. Characterization of the MOFs was performed using powder X-ray diffraction, scanning electron microscopy, transmission electron microscopy, BET isotherms, and UV–Vis spectroscopy to evaluate effects of microwave temperature and chemical modulator concentrations on MOF–74(Ni) properties.
Electrohydrodynamic Jet Printing of CuInS2 Quantum Dots for Quantum Dot Enhanced Displays

Yagenetfere Alemu, Xiaosong Du, Josh Motley, Gustavo Albuquerque, Majid Ahmadi and Gregory S. Herman

Quantum dots (QD) are finding applications in a wide range of electronic devices including solid-state lighting, photovoltaics, transistors, and displays. QD enabled displays are currently available, where the QD are being used to increase the efficiency and color quality. Even higher efficiencies and improved materials utilization may be possible by directly printing QD at the pixel by pixel level. In this study we are investigating the direct printing of QD using electrohydrodynamic jet (e-jet) printing. Our focus is on printing non-toxic, cadmium-free QD and characterizing their optical properties. E-jet printing of QD allows much higher special resolution than standard inkjet approaches. Printing is performed through micro capillary nozzle by applying a bias voltage for ejection of drops. Some of the advantages of e-jet printing over other patterning methods are maskless patterning, high thickness control, and programmable printing of features. QD loading, film thickness, bias voltage, and stage speed are varied to investigate emission and absorption spectra of printed features. A limited number of previous studies have shown that QD can be e-jet printed. In continuation to those studies, we have demonstrated e-jet printing of non-toxic CuInS2/polymer functional features as small as 50 µm with good registration using a 30 µm nozzle. Optical characterization of spin coated film of different QD/polymer matrix is performed using UV/Vis and photoluminescence spectroscopy. It is observed that absorption and emission of the film increases as QD loading and thickness increases. Furthermore, optoelectrical characterization of e-jet printed patterns will be investigated.

Development of a Microscale-Based Chemical Conversion Process Using Solar Thermal Energy

Elham Bagherisereshki, Nick AuYeung, Alex Yokochi, Goran Jovanovic and Liney Arnadottir

Given its abundance and accessibility, exploiting solar energy is a powerful approach to reduce dependency on fossil fuels for energy generation. Thermochemical reactions using concentrated solar power at high temperature are attractive and thermodynamically favorable for solar fuel generation due to potentially high solar-to-fuel energy conversion efficiency. The major goal of the proposed project is to develop the technology necessary for the commercialization of the direct use of solar thermal energy in chemical processing. The critical component in this project is the microscale solar thermochemical reactor, which will be modeled, designed, built and tested using a solar simulator developed by Oregon State University at the Microproduct Breakthrough Institute (MBI). Built with high temperature resistant ceramics, the reactor is expected to reach 1350°C in operation. Given rapid mass and heat transfer along with high surface area to volume ratio, the microchannel reactor will have significant size and weight advantages over previously built solar thermochemical reactors. This will lead to faster response to transient heat flux while minimizing heat loss to the surroundings. The precise control
of the reactor in relation to the solar simulator and of all operating conditions allows us to evaluate the performance and analyze the solar thermochemical process under steady-state operating conditions and under a variable heat flux condition. We are using nonstoichiometric perovskite oxides (Sr_{x} La_{(1-x)} Mn_{y} Al_{(1-y)} O_{(3-\delta)}) as a reactive material in two-step, solar thermochemical water or carbon dioxide splitting cycle. The lab-prepared reactive material will be characterized to investigate chemical composition, surface area and morphology using appropriate techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), etc. The chemical processing test-loop is designed to be capable of reaching and maintaining operating temperature of 1350°C while precisely monitoring and controlling the flow rates of multiple reactants entering the microchannel device.

8 Changes in Algal Sludge Characteristics with Suspension Concentration

Uranbileg Daalkhaijav and Travis Walker

Nutrient contamination from farmlands and waste streams can cause toxic blooms in the surrounding lakes and rivers, but algae also has the potential for improving the energy field as a cheap source of biodiesel. Rheology is the study of how different materials, including biological materials, react to stress and strain. During the biodiesel production process, the raw effluent from the photobioreactors or algal raceways are taken and successively concentrated to a level adequate for chemical or mechanical extraction of the algal lipids. Our results from liquid culture of Cyclotella diatoms reveal that each concentration of the algal sludge changes its rheological response. The frequency sweep of the sludge show gel-like behavior dominated by the elastic modulus, while each doubling of the concentration resulted in an order of magnitude increase in modulus. The algal sludge behaves as a shear-thinning fluid with the viscosity increasing in magnitude with each doubling of concentration. A small yield stress is associated with the algal sludge, which also increased by an order of magnitude with each successive doubling of concentration. These findings highlight the fact that, when processing the algal sludge, we must take into account the increasing interaction between the diatoms resulting in non-Newtonian behavior.

9 Characterization of Inorganic Resists Using Temperature Programmed and Electron Stimulated Desorption

Ryan Frederick and Gregory S. Herman

Inorganic resists are of interest for nanomanufacturing due the potential for high resolution, low line width roughness, and high sensitivity. The combination of high absorption coefficient elements and radiation sensitive ligands can improve inorganic resist sensitivity while still allowing high contrast. A baseline inorganic resist that we are studying is Hf(OH)_{4-2x-2y}(O_{2})_{x}(SO_{4})_{y} \cdot qH_{2}O (HafSOx), which has both high absorption coefficient elements (Hf) and radiation sensitive ligands (peroxides). In this presentation we discuss the characterization of HafSOx
dehydration using temperature programmed desorption (TPD) and the interaction of low energy electrons with HafSOx using electron stimulated desorption (ESD). Both TPD and ESD allow us to characterize the key desorption species through thermal and radiative processes that occur while patterning. ESD results indicate that the peroxo species are very radiation sensitive, even for low energy electrons that approximate the energies of secondary electrons from EUV exposures. The primary desorption products from HafSOx are O$_2$ and H$_2$O, and the time evolution suggest much faster kinetics for O$_2$ desorption. These data provide insight into the radiation-induced changes responsible for the solubility transition upon exposure and patternability during development, and the role of secondary electrons in these processes.

**Inkjet-printed Copper(I) Iodide-based p-Type Thin-Film Transistors**

Jenna Y. Gorecki, Chang-Ho Choi, Zhen Fang, Marshall Allen, Liang-Yu Lin, Kaylee Rae Eyerly, Sarah Kim, Cindy Truong and Chih-Hung Chang

Solution-based p-type thin-film transistors (TFTs) were successfully fabricated with various copper(I) iodide-based semiconductors, CuI and CuBrI, as channel layers. Copper(I) halide films were printed while varying the temperature of the substrates from room temperature (RT) to 60°C. As-printed copper(I) halide films were used as p-type active channel layers for TFTs. SU-8 encapsulation was applied in order to increase the device performances by preventing moisture from reacting with the copper(I) halides films. CuI TFTs as well as CuBrI TFTs were successfully fabricated using two kinds of substrates with different gate materials, Mo/Glass and silicon, which elucidated reproducibility. Solution-processed CuI and CuBrI films were characterized to study optical, electrical, and morphological properties. Furthermore, device performances of printed copper(I) iodide-based p-type TFTs were also investigated. CuI TFTs with SU-8 encapsulation exhibited outstanding p-type transistor behaviors with field-effect mobility as high as 4.36 cm$^2$/V s and Ion/Ioff ratios of $10^{3.24}$ on the silicon substrates. Also, CuBrI TFTs resulted in successful p-type transistor behaviors with field-effect mobility as high as 2.6 cm$^2$/V s and Ion/Ioff ratios of $10^{3.3}$ on the glass substrates.

**Hindered Translator and Hindered Rotor Models for Calculating the Entropy of Adsorbed Species Using Density Functional Theory**

Lynza Halberstadt, Charles T. Campbell and Liney Arnadottir

Catalytic reactions on surfaces are finding new uses such as in the electrocatalysis of fuel cells or the synthesis of renewable fuels. The need for a fast and accurate way to predict equilibrium constants and rate constants for surface reactions has therefore become important. Here a model for predicting partition functions and the entropy of adsorbed species is presented. It is customary to use the harmonic oscillator approximation to calculate all modes of motion in the partition function, and similarly in this model all but three of the modes do. Hindered translator and hindered rotor modes however are used for three modes of motion parallel to
the surface, two for translations parallel to the surface and one for rotations about the axis perpendicular to the surface. At the limit of low temperature, or high energy barrier, this model is the same as the harmonic oscillator approximation while at the limit of high temperature, or low energy barrier, this model becomes identical to the 2D ideal gas model for translations and the 1D free rotor model for rotations. It is mainly in the region where the ratio of the energy barrier to the temperature is of the order 1 to 1000 that the hindered translator and hindered rotor models become important. Here density functional theory was used to simulate the translations and rotations of four adsorbates on the surface: methanol, propane, ethane, and methane. The adsorbate entropies of these species were then determined and found to agree well with experimental results.

12 Calculations of H$_2$O and OH Interactions with Iron and Iron Oxide Surfaces

Qin Pang, Hossein DorMohammadi, O. Burkan Isgor and Líney Árnadóttir

Water and OH interactions with iron and iron oxides are critical initial steps of iron corrosion. Here we use density functional theory (spin-polarized GGA-PBE) to study H$_2$O and OH adsorption on $\alpha$-Fe$_2$O$_3$ (0001) (1×1) and Fe (100) (3×3) surfaces. On the Fe (100) surface we studied different adsorption sites with different H$_2$O orientations and found that the H$_2$O is most stable on top sites. The H$_2$O is also stable on bridge sites but significantly less stable on hollow sites. The Fe-terminated $\alpha$-Fe$_2$O$_3$ (0001) surface has multiple adsorption sites but the most stable configuration is top site just like on the Fe (100) surface. H$_2$O and OH are found to be more stable on the Fe (100) than on the $\alpha$-Fe$_2$O$_3$ (0001) surface. OH is generally more stable on both surfaces than H$_2$O. The most stable site for OH is bridge site of Fe (100), which is slightly more stable than top site of Fe (100). OH is significantly less stable on the $\alpha$-Fe$_2$O$_3$ (0001) surface, on which the most stable site is top site.

13 Modeling Alignment Dynamics of Magnetic Microdisks in Rotating Magnetic Field

Mingyang Tan, Han Song, Pallavi Dhagat, Albrecht Jander and Travis W. Walker

Composites, consisting of particles embedded in a matrix, have potential in a variety of applications, including magneto-optics, biological tissue scaffolds, drug-delivery vehicles, microwave absorption, inductors, and antennae. Composites with aligned particles can have enhanced magnetic, mechanical, optical, and thermal properties over traditional composites. Particles with anisotropic geometry can be aligned with several methods. In this study, disk-shaped magnetic particles are aligned by a rotating magnetic field. Under a rotating magnetic field, the high-susceptibility plane of the magnetic disks can be aligned into the plane of the rotating field, where a planar anisotropy is achieved. The dynamics of the alignment of dispersed magnetic microdisks (5 micron in diameter and 150 nm in thickness) in Newtonian fluids (silicon oil) are studied by real time microscopy and explained by a theoretical model that we have developed. We study the dependence of alignment time on fluid viscosity, magnetic field strength, and rotating frequency by varying fluid viscosities (215cp and 550cp),
field strength (1mT to 4mT) and rotating frequency (0.2Hz to 100Hz). The theoretical model is developed based on Stokes flow of single oblate ellipsoidal particle in a rotating magnetic field. We provide a complete analytic solution to predict the alignment dynamics that covers the entire frequency range (0 to infinity) of the field. The analytic solution agrees with the experiment results. By using an asymptotic expansion, a simplified solution is achieved when frequency becomes large. This solution also provides a direction to optimize the alignment process for industrial applications.

Direct Growth of Ordered and Highly Conductive Metal–Organic Framework Thin Films on an Oxide Surface

Yujing Zhang, Ki-Joong Kim and Chih-Hung Chang

Assembly of metal–organic framework (MOF) thin-films with well-ordered growth directions enables many practical applications and is likely part of the future of functional nanomaterials. High quality MOF thin films with preferred growth in the (111) direction on an oxidized silicon surface were obtained in the absence of not only gold substrate but also organic-based self-assembled monolayers. Electrically conducting MOF thin films were realized by introducing the redox-active molecule, 7,7,8,8-tetracyanoquinodimethane, into highly oriented MOF thin films, producing a conductivity of ~10 S m⁻¹, an over seven orders of magnitude increase in current compared to that of the unfiltered MOF at room temperature. These results provide an important insight that highly oriented MOF thin films play a significant role in the adsorption of guest molecules into the MOF pores for designing electrically conductive MOF thin films.

Environmental Engineering

Evaluating Biochar as a Sustainable Alternative for Heavy Metals Remediation in Stormwater

Sarah Burch and Jeffrey A. Nason

Heavy metals, such as copper, zinc, and cadmium, are ubiquitous in stormwater and potentially toxic to aquatic organisms at low concentrations. Removal of heavy metals contamination by conventional treatment is expensive and does not always reduce metals concentrations low enough to ensure safety of all aquatic species. This research seeks to evaluate the effectiveness of biochar as a low-cost, sustainable solution for the remediation of heavy metals in stormwater. Biochar is created as a byproduct during the conversion of biomass to bioenergy by pyrolysis and has potential to advance sustainability in metals remediation based on the added benefits it offers of bioenergy and heat production, soil enrichment, and carbon dioxide sequestration. These added benefits, in combination with the results of this research,
focusing on improving water quality, seek to improve the three pillars of sustainability: society, economy, and environment. Different biomass feedstocks of naturally available materials (Douglas fir chips and hazelnut shells) were pyrolyzed at varying temperatures to determine the effects of feedstock and production conditions on biochar characterization and metals removal. Adsorption experiments were conducted in batch reactors and constant flow fixed-bed column filtration experiments. Preliminary batch and fixed-bed column results indicate that biochar exhibits superior performance in copper removal compared to granular activated carbon (GAC), the current prevailing adsorbent. Adsorption results will be used in conjunction with biochar characterization and modeling techniques to elucidate the mechanisms for metals removal by biochar, which will be used to inform engineering design and optimize biochar production conditions to advance sustainability.

**Development of Gold-Labeled Titanium Dioxide Nanoparticles for Tracking Behavior in Complex Environmental Matrices**

**Alyssa Deline and Jeffrey A. Nason**

Titanium dioxide nanoparticles (TiO2 NPs) have great potential for use in consumer, industrial, and environmental applications. It is imperative that the environmental effects of these materials are well understood as use increases, but researchers face the challenge of distinguishing engineered NPs from high concentrations of naturally occurring titanium. To better facilitate detection and quantification of TiO2 NPs in complex systems, TiO2 NPs labeled with a gold core were developed. Gold core particles were prepared using a seeded-growth synthesis. The core particles were coated with TiO2 by hydrolyzing titanium isopropoxide on the particle surfaces. The core/shell structure was confirmed using transmission electron microscopy. Particles were hydrothermally treated to alter the crystal structure of the TiO2 shell. The properties and behavior of the core/shell particles were compared with those of unlabeled TiO2 NPs with the goal of minimizing differences by modifying synthetic methods. Ongoing work is designed to demonstrate the utility of the labeled particles in experiments simulating drinking water treatment. Preliminary results will be discussed.

**Copper Speciation in Wastewater-impacted Surface Waters**

**Ariel Mosbrucker and Jeffrey A. Nason**

Improved information regarding the toxicity of metals, including copper, to aquatic organisms has led to want of knowledge regarding dissolved metal speciation. The Biotic Ligand Model (BLM) adequately describes the binding of copper with dissolved organic matter (DOM) derived from natural sources, but the model’s ability to describe this process for DOM derived from anthropogenic sources is unclear. This research examines the speciation of copper and the stability of copper-DOM complexes in natural water, effluent from a wastewater treatment plant (WWTP), and water downstream from a WWTP to evaluate the applicability of the BLM.
to wastewater-impacted surface waters. Free ionic copper concentrations are determined via cupric ion-selective electrode, with binding constants and ligand concentrations determined via FITEQL. Results are then compared to BLM predictions. Preliminary data suggests that wastewater derived DOM may bind copper more strongly than naturally derived DOM, which has important implications for regulatory determinations.

**Assessing the Influence of Surface Coatings on the Fate of Engineered Nanomaterials within Aquatic Environments**

Mark Surette, Aubrey Dondick and Jeffrey A. Nason

Research suggests that the environmental fate of engineered nanomaterials (ENMs) within natural aquatic environments is strongly tied to their interactions and potential to aggregate with other ENMs (homoaggregation) and natural colloids (heteroaggregation). By affecting the environmental fate of ENMs, these dynamic and complex interactions can in turn influence the potential risk posed by ENMs to human health and the environment. The mechanisms governing these interactions are poorly understood and surface coatings that are typically applied to ENMs can alter those interactions. The focus of this research is to assess the role that common ENM surface coatings have upon ENM stability (i.e., the ability to resist aggregation) under complex, environmentally relevant conditions. Aggregation of ENMs coated with citrate (CIT), various functionalized forms of polyethylene glycol (PEG), and branched polyethylenimine (bPEI) were assessed in a range of environmentally relevant mediums; e.g., pH 6–10 with varying ionic strengths and ion valency. Furthermore, interaction of the surface coating with natural organic matter (NOM) are investigated. Initial findings suggest that the surface coating can play a significant role in ENM stability across a wide range of aquatic chemistries. For example, results show that bPEI can stabilize ENMs in high ionic strength solutions. However, in the presence of NOM, bPEI-coated ENMs were found to aggregate at conditions typical of natural waters.

**Transformation of Carbon Tetrachloride by Tetrachloroethene and Trichloroethene Respiring Anaerobic Mixed Cultures**

Kyle Vickstrom, Mohammad Azizian and Lewis Semprini

Carbon tetrachloride (CT) is a toxic and recalcitrant groundwater contaminant with the potential to form a broad range of transformation products including carbon dioxide (CO$_2$), chloroform (CF), dichloromethane (DCM), and carbon disulfide (CS$_2$). Results will be presented from batch experiments with the Evanite (EV), Victoria Strain (VS) and Point Mugu (PM) anaerobic mixed cultures, which are capable of fully dechlorinating tetrachloroethene (PCE) and trichloroethene (TCE). The cultures are grown in continuous flow chemostat systems, and have not been previously acclimated to CT. For the batch CT transformation tests, cells and supernatant were harvested from the chemostats and spiked with 0.86, 2.6, or 8.6 µM CT and an excess of formate (EV and VS) or lactate (PM). CT transformation was complete with 30-
40% of the mass accounted for with the remainder unknown. CT transformation is pseudo-first order and likely co-metabolic, and multiple additions of CT to the same reactors showed reduced transformation rates. Batch reactors were then established with cells and supernatant poisoned with 50 mM sodium azide (NaN3) to test the relative contributions of biotic and abiotic transformation. CT was fully transformed by poisoned reactors at comparable or faster first order rates, suggesting a limited importance of live cells to the transformation of CT. In order to quantify the transformation pathways completely, experiments utilizing GC-MS with $^{13}$CT will be conducted with the dechlorinating cultures. Furthermore, experiments will be conducted that explore the potential of different electron donors in order to increase the overall fraction of $^{13}$CT mineralized to $^{13}$CO2. The results clearly demonstrate that transformation can be promoted by anaerobic cultures not previously acclimated to CT.

School of Civil and Construction Engineering

Coastal/Ocean

1. **BARSED: A Large-scale Sandbar Sediment Transport Experiment at the O.H. Hinsdale Wave Research Laboratory**

Dylan Anderson and Dan Cox

Surf zone sandbars are migratory features that significantly affect wave dissipation and thus directly impact the hazards present along coastlines throughout the world. Observations of sediment transport and the hydrodynamic conditions forcing sandbar migration have been limited to date by the available technology, equipment, and laboratory facilities. We utilize the Large Wave Flume at OSU’s O.H. Hinsdale Wave Research Laboratory to simulate real-world wave conditions in a controlled environment where small-scale processes can be individually monitored. The experiment uses conventional current meters and wave gauges to monitor hydrodynamics, combined with two novel instruments (Conductivity Concentration Profilers and a Pore-Pressure Transducer Array) buried within the sediment bed to observe the forces driving transport at the crest of a sandbar. The majority of the profile was constructed of concrete such that the sediment response for the same cross-shore profile could be observed under a wide range of wave conditions. Bed shear stresses dominated transport under longer period waves with large orbital velocities, while horizontal pressure gradients induce sediment motion as shorter period steep wave fronts cross the sandbar. Vertical pressure gradients dilate the bed just prior to the arrival of the wave front, reducing sediment bed compaction such that greater
sand volumes can be moved. Strong downward directed pressure gradients are coincident with onshore fluid velocities, forcing transport to move in a concentrated stream close to the bed, a form of transport previously described as “sheet flow.” These observations are leading to a more holistic understanding of wave-sediment interactions within the surf-zone.

2 Hitting the Peaks: Hindcasting Extreme Wave Conditions

Ashley Ellenson, H. Tuba Özkan-Haller, Merrick Haller, Jim Thomson and Adam Brown

This project focuses on accurately hindcasting extreme wave conditions (wave heights greater than six meters) along the Oregon coast. The application of this work is within the marine renewable energy technology field. Quantification of the most violent sea-states via environmental parameters (peak period and significant wave height) will set design criteria and thus mitigate vulnerability for wave energy converters. Wave Watch III (WW3) is utilized for performing the hindcast. The predictions are validated by currently deployed National Oceanic and Atmospheric Association buoys as well as University of Washington’s Applied Physics Laboratory’s tracer buoys. Validation includes comparison of bulk parameters through error metrics and a more detailed energy spectra evolution analysis. Approaches to improve the hindcast include utilizing a different physics package for wave growth and dissipation and wind and bathymetric input data of higher resolution and greater quality. Findings include identification of specific environmental conditions which result in greatest model error for extreme events, and the most effective methods to improve performance.

3 Unusually Large Runup Events

Gabriel García-Medina, H. Tuba Özkan-Haller, Rob Holman and Peter Ruggiero

Understanding the primary hydrodynamic processes that cause extreme runup events is important for the prediction of dune erosion and coastal flooding. Large runups may be caused by a superposition of physical and environmental conditions, bore-bore capture, infragravity-short wave interaction, and/or swash-backwash interaction. To investigate the conditions leading to these events we combine optical remote sensing observations (Argus) and state-of-the-art phase resolving numerical modeling (primarily NHWAVE). We evaluate runup time series derived from across-shore transects of pixel intensities in two very different beaches: Agate (Oregon, USA) and Duck (North Carolina, USA). The former is a dissipative beach where the runup is dominated by infragravity energy, whereas the latter is a reflective beach where the runup is dominated by short surface gravity waves. Phase resolving numerical models are implemented to explore an expanded parameter set and identify the mechanisms that control these large runups. Model results are in good qualitative agreement with observations. We perform a series of controlled numerical simulations to isolate physical parameters that lead to large runups. We evaluate the relative contribution of the dominating physics to extreme and unexpected runup events.
Real-Time Wave-by-Wave Forecasting for Wave Energy Applications

Alexandra Simpson and Merrick C. Haller

A method for wave-by-wave forecasting is under investigation for the application to Wave Energy Converter (WEC) control systems. It has been shown in numerous studies that a controls system can dramatically improve WEC power production by tuning the device’s oscillations to the incoming wave field. A requirement of an efficient controls system is a deterministic surface elevation forecast on the order of several wave periods. The current study aims to demonstrate a method for providing deterministic forecasts by coupling an X-band marine radar with a predictive wave model. Using the radar as a remote sensing technique, the wave field in a 3-km-range footprint is imaged through wave-modulation of surface roughness. The intensity modulations recorded in the radar image time series can be used to determine the radial (radar look direction) component of water surface slope using a newly developed model. The figure below shows radial slopes calculated at the radar site in Newport, Oregon. From the radial slopes, a best-fit model hindcast is determined which is used as the input condition for a wave-by-wave forecasting model. The chosen wave model is the linear Mild Slope Equation with the capability of adaptation to capture wave nonlinearities. The method is being tested with synthetic data, and comparisons with field data are imminent.

Construction Engineering Management

Evaluation of Radar Speed Sign for Mobile Maintenance Operations

Ali Jafarnejad and John A. Gambatese

Roadway maintenance projects often require working during nighttime hours in close proximity to ongoing traffic and may reduce traffic flow to a single lane while work is undertaken. In many cases the work is of short duration and a mobile operation. The Oregon Department of Transportation has conducted several research studies to identify best practices for traffic control during maintenance work. Radar speed signs (RSSs) are a traffic control device that has shown promise for positively affecting driver behavior and reducing speeds. RSSs use radar technology to measure the speed of oncoming vehicles and display the vehicle speed and accompanying messages to the drivers. This research study evaluated the impact of truck-mounted RSSs on vehicle speeds in maintenance work zones and identified best practices for their use as part of mobile and stationary maintenance work operations. The research study includes four case studies on multi-lane maintenance projects in Oregon. On each case study, the researchers conducted two periods of testing: one with the RSS display turned on and one without the RSS display turned on, and recorded vehicle speeds. The research findings indicate that vehicle speeds are typically lower and there is less variation...
in speeds between adjacent vehicles with the RSS turned on. Based on the findings, the researchers recommend use of truck-mounted radar speed signs during mobile maintenance operations on high-speed roadways.

6 Integration of Lifecycle Safety into the LEED Rating System

Ali Karakhan

The U.S. Green Building Council’s (USGBC) Leadership in Energy and Environmental Design (LEED) rating system developed in 1993 is a nationally accepted benchmark for the design, construction, and operation of high performance green buildings. Since its inception, the LEED implementation has been increasingly expanding in the construction industry to promote sustainable buildings. Green design elements and construction practices have been criticized for incorporating only the environmental and economic aspects of sustainability, and disregarding the significance of social welfare. Those with this viewpoint contend that this trend represents a discrepancy from the holistic view of sustainable development. A LEED credit-by-credit review was conducted to evaluate the potential positive or negative impact of green design elements and construction practices on health and safety of construction and maintenance workers in the construction industry. The result shows that a large portion of LEED credits is neutral toward worker safety and health. However, 12 credits are found to have negative impact on the safety of construction and maintenance personnel. Only 4 credits enhance occupational health and safety (OHS) positively. Four credits have mixed impact – both positive and negative potential impact on OHS. However, a paradigm shift has recently been noticed in the formation of the LEED credits. The USGBC has started to pay more attention to imperative factors of sustainability, such as lifecycle safety and social equity, through the release of at least four pilot credits. This change in focus represents a shift toward a more holistic vision of sustainability that incorporates not only ecological and financial considerations, but also human factors into high performance buildings.

7 Evaluating Strength and Durability Characteristics of Construction Concrete Joints

Shreyas Panduranga Setty and David Trejo

Most mass concrete construction contain horizontal construction joints. Many State Highway Agencies (SHAs) require contractors to cure these construction joints (aka cold joints) for several days prior to placing the next section. The water used to cure these construction joints must be collected and treated. In addition, the construction joint surface must be prepared by air-water cutting, high-pressure water jetting, or wet sandblasting prior to placing the next concrete lift. These requirements are implemented to ensure sufficient strength across the cold joint and to ensure that the joint resist degradation. Significant amounts of money are spent in curing, treating the curing water, and preparing and cleaning these cold joints. However, limited research has been performed to assess the influence of cold joint preparation on strength and durability.
An experimental study was implemented to provide information on the bond strength of concrete-to-concrete construction joints. Forty-five slant shear specimens were designed, constructed, and tested. Three curing conditions (no cure, water cure, and agent cure) and three surface preparations (struck-off, intentionally roughened, and sand-blasted) were assessed. The results from this research should provide SHAs and contractors with guidance on what construction methods are essential for durable construction joints.

Specifications and Contractor Risks: Chloride-Induced Corrosion in Concrete Structures

Mahmoud Shakouri and David Trejo

Several committees in the American Concrete Institute (ACI) address the durability issues associated with chlorides in concrete structures. Chlorides can penetrate into the hardened concrete from the local environment, e.g., seawater, de-icing salts or can be introduced into fresh concrete during construction. When sufficient chlorides reach the surface of reinforcing steel, corrosion can be initiated which leads to other durability issues. To reduce the risk of corrosion, ACI committees have limited the maximum amount of allowable admixed chlorides ($C_A$) that can be included in new reinforced concrete structures. However, the published $C_A$ values by ACI committees are not in accord with each other and despite extensive research, specifying a unanimous $C_A$ for concrete has been faced with several challenges caused by the lack of a standard definition for corrosion activation resulting from chlorides; a standardized test method for determining the amount of chlorides that result in corrosion activation known as critical chloride threshold ($C_T$); and a systematic approach to specifying allowable chloride limits. As a result, there is a wide scatter in $C_T$ values in the literature and little consensus on $C_A$ limits in ACI documents which have created confusion and uncertainty among the users of such documents. This poster is an attempt to fill this gap by proposing systematic approach to quantify $C_A$ limits. The objectives are to (i) perform meta-analysis to identify a probability distribution for $C_T$, (ii) develop a probabilistic model for measuring the service life of concrete structures exposed to chlorides, and (iii) propose a standardized protocol for predicting $C_A$ limits that is based on the risk-aversion level of the owner and defined as the function of structure type, exposure conditions and constituent materials.

Engineering Education

Teaching Evaluation and Assessment Practices in Engineering Departments

Keisha Villanueva

Teaching evaluation is a critical aspect of higher education, and potentially the improvement of teaching practices. There is a substantial knowledge base on best teaching evaluation
practices, yet, it is generally reported that engineering departments have minimal programs and practices for evaluating teaching. Research has shown that it is important for departments and schools to have a well-designed, and properly implemented evaluation system for faculty teaching. The purpose of this research is to identify current practices to evaluate teaching in engineering departments across the country to understand and assess the current state of practice with qualitative interviews. In addition, an in-depth literature review of best practices will be completed with the goal of summarizing best practices from the literature review and interviews. This research uses an exploratory sequential mixed-method design. Twenty faculty members participated in a semi-structured interview that lasted around 40 minutes. Most participants were department chairs from different engineering departments and schools. The qualitative interview results were analyzed and interpreted to determine which existing teaching evaluation practices are described by participants to be effective. The review and analysis of literature and in-depth research allow for the identification of best evaluation teaching practices. The result of this study shows that about quarter of engineering departments implement a comprehensive teacher evaluation system, which includes student teaching of evaluation, peer evaluation, observation of lectures, and review of classroom materials. These departments find their evaluating practices to be effective. There are departments that rely only to one source and do minimal programs for evaluating teaching. As a result, more than three quarters of the participants express interest in identifying a better way to evaluate teaching. Although there is substantial interest in improving teaching evaluation practices, generally current practices are still much different from identified best practices. The teaching evaluation system in engineering departments can improve if instructors become aware and identify best practices to evaluate and assess teaching.

Geomatics

10 Remote Bridge Inspections using Unmanned Aircraft Systems (UAS)

Matthew N. Gillins, Daniel T. Gillins and Christopher Parrish

Highway workers and road users across the U.S. and around the world face safety hazards associated with bridges. ASCE estimates that over 10% of the nation’s bridges are rated as structurally deficient, with an average age of 42 years. In an effort to reduce the risks associated with bridges, the Federal Highway Administration (FHWA) requires a visual inspection and inventory of all federal-aided highway system bridges every two years. These mandatory inspections can be costly and dangerous, especially when inspectors need to stand in platform trucks, bucket trucks, or under-bridge inspection vehicles in order to access and view necessary bridge elements. Furthermore, some inspections require extensive climbing, temporary scaffolding and ladders, and/or rescue boats. Interest in the use of Unmanned Aircraft System (UAS) technology for visual inspection and inventory of bridges is growing, due to potential safety and efficiency gains. UASs can carry high resolution digital cameras and/or other sensors and are capable of flying a pre-programmed flight path. During flights, the
operators can view live video feed from the camera sensor on a monitor. In addition, digital imagery collected during flights can be mosaicked, georeferenced, and used to generate 3D point clouds for quantitative spatial analysis. This poster presents the methodology and results of inspections of a bridge in Oregon using a multicopter UAS. Because multicopters can be flown close to objects, are easy to maneuver, and can hover in place, high-resolution remote sensing data can be collected from advantageous viewing angles. These images are similar to what can be seen visually by an inspector at arm’s length from the bridge. Results indicate that today’s UAS technology has great potential for performing remote and safe visual inspections of bridges.

11 Application of High-resolution Aerial Imagery Collected from UAS Platforms for Earthquake Damage Mapping

Farid Javadnejad, Matthew N. Gillins and Daniel T. Gillins

Recent advances in computer vision, batteries, robotic, navigation and sensor technologies have made small Unmanned Aircraft Systems (sUAS) feasible platforms for neighborhood-scale remote sensing. This study is an example application of high resolution UAS-based photogrammetry for mapping earthquake damage. The area of interest is the historic village of Bungamati, Nepal, that was severely damaged during the magnitude 7.8 Gorkha earthquake in 2015. The area was surveyed using a sUAS carrying a consumer-grade digital camera for collecting close-up, high resolution aerial images. The images were processed using the Structure-from-Motion (SfM) technique to produce 3D point cloud and an ortho-rectified image for the study area. SfM is a computer vision technique that is capable of three-dimensional reconstruction of a scene from a series of overlapping images that are taken from arbitrary locations at multiple angles. In order to geo-reference these products to a global coordinate system, a GNSS survey was conducted on a series of Ground Control Points (GCPs) established in the study area. Structural failures of Bungamati buildings were identified via visual exploration of the 3D and planimetric data and then were mapped with GIS tools. The results of this study show the feasibility of UAS-based photogrammetry for high resolution imagery and earthquake damage mapping.

12 Comparison of Terrestrial Lidar and Structure from Motion Techniques for Assessment of Unstable Rock Slopes in Alaska

Matt S. O’Banion, Mahsa Allahyari and Michael J. Olsen

Terrestrial lidar scanning (TLS) has been proven as a valuable technique for assessment and monitoring of unstable slopes. Comprehensive TLS surveys of slopes and cliffs commonly require numerous discreet instrument setups, which can be time consuming. Even with numerous setups, sometimes portions of a slope or cliff are simply not visible from areas accessible to the scanner and valuable information is lost. The use of unmanned aerial vehicles...
(UAVs) to gather overlapping aerial imagery can be used to generate 3D point clouds similar to that generated by TLS by way of Structure from Motion (SfM) processing techniques. Acquisition of cliff geometry using a UAV can allow for superior accessibility when compared to TLS methods. To evaluate the capabilities of SfM, Numerous unstable rock slopes were surveyed along the Glenn Highway in Alaska using both TLS and SfM techniques. The datasets were acquired simultaneously and captured the same control network. Simultaneous 3D visualization of the TLS and SfM datasets in an immersive virtual reality system allowed for detailed visual inspection of any significant discrepancies between the datasets. Quantitative assessment of the data included, differencing of point cloud derived 3D surface models, comparison of point clouds to cliff surface control points, and a histogram comparison of surface morphological properties including slope, surface roughness, and a slope hazard classification. Results indicate that SfM derived point clouds have potential as a viable option for unstable rock slope characterization. However, with respect to monitoring of unstable rock slopes, the inconsistency of SfM techniques raises concerns regarding reliable comparisons of data from different epochs.

Seafloor Habitat Mapping using EAARL-B Bathymetric Lidar

Nicholas Wilson and Christopher E. Parrish

In addition to spatial coordinates of seafloor surfaces, full waveform capabilities of bathymetric lidar systems enable seafloor reflectance to be mapped and used in applications such as habitat classification and resource management. The EAARL-B, a new topographic-bathymetric system developed by the USGS, differs from many conventional bathymetric lidar systems in a number of ways, including: a) it uses a smaller field of view, and b) it does not maintain a nominally-fixed incidence angle on the water surface, but rather scans back and forth, passing nearly through nadir. The unique design and performance characteristics of the EAARL-B enable the system to be used in supporting a wide range of topographic-bathymetric lidar applications, but generation of seafloor reflectance products from the data is challenging. This study aims to develop and test algorithms and procedures for producing seafloor relative reflectance from the EAARL-B. The procedures are being developed and tested in two project sites, which differ markedly from one another, in terms of water clarity, depth range, and seafloor characteristics. The first project site is located within the Barnegat Bay estuary in New Jersey, and utilizes EAARL-B data collected just days before and after Hurricane Sandy made landfall. The second project site is in the vicinity of Buck Island, Saint Croix, in the U.S. Virgin Islands.
Geotechnical

14 Theoretical Considerations for Foundation Design in Unsaturated Soils

J.D. Baker and T.M. Evans

Conventional foundation design historically has considered only completely dry soils or completely saturated soils. This approach suggests that a dry state exists above the groundwater table and a saturated state below. While this assumption is good for the saturated state, it fails to describe the partially saturated state that exists above the groundwater table, which is especially predominant in fine-grained soils.

More recently, researchers have characterized many of the stress states that exist in unsaturated soils. Saturation and suction stress profiles can now be described above the groundwater table with only a few additional soil properties. Changes in these profiles is also a function of surface flux (infiltration and precipitation).

This work incorporates unsaturated soil mechanics into the design of shallow foundation. Careful consideration is made to the general failure mechanisms that are present in shallow and deep foundations. Generally there is an increase in bearing strength due to the suction stresses present along the failure surface. Variation in unit weight can also make a considerable change in the performance of the foundation. Another consideration detrimental to the bearing strength of a foundation is that suction stresses, if high enough, may result in the loss of particle contact. This is the manifestation of surface cracks, which result in no additional strength. These considerations have all been made within one framework.

15 GIS-based Analysis of Shallow Landslides on Forested Slopes

D. Hess, B. Leshchinsky and M. Bunn

Landslides are a natural hazard that has major societal, economic and environmental impacts on an international scale. In particular, shallow landsliding presents a persistent obstacle, especially in mountainous, marginally stable regions with weak, yet critical root reinforcement. This challenge is compounded as the size and location of a potential slide is often unknown. This study presents a limit equilibrium model to characterize the spatial distribution of the factor of safety based on a three-dimensional sliding block analysis. Application of a grid-based approach for calculating stability enables the model to incorporate soil properties, water table elevation, root strength, and seismic forces for each pixel of a digital elevation model (DEM). Input DEM resolution is also considered, especially for converging on landslide size. Findings include lower factors of safety for convex surfaces due to reduced boundary forces, particularly under seismic loading; a convergence upon critical landslide size; and a quantification of the effects of root reinforcement under static and seismic conditions.
Small Scale Blast Induced Liquefaction Testing

Kengo Kato, Ben H. Mason and Scott A. Ashford

Blast induced liquefaction testing has been recognized as a useful in-situ soil liquefaction testing and a soil compaction technique since blast techniques has been employed over fifty years in geotechnical engineering fields. However, predicting pore water pressure is still difficult because the mechanism is not fully understood. The objectives of this research is to model the small size blast testing and to reveal the effect of confining stress and relative density on pore water pressure response and corresponding soil deformations under blast load propagations.

In order to model explosives and soils in small scale size, the soil element that mimics an in-situ soil condition under propagation of blast loads was set up using the transparent cylinder and the small charge of primers with loose–dense saturated sand. 209 and M209 primers were used as a small charge explosive and were placed on the bottom of the cylinder. The high frequency piezometers and accelerometers were placed inside of the specimen. All procedures to ignite primers were followed to SAAMI recommendations.

The results showed that increasing of relative density and confining stress decreased the peak and residual pore water pressure. This clearly indicates that both factor is critical on the contract–dilatant behavior of sands under blast load propagations.

Evaluation of Torsional Capacity of Drilled Shaft Foundations Using Finite Difference Method

Qiang Li and Armin W. Stuedlein

Drilled shaft foundations offer an excellent alternative for transferring the superstructure loads on mast arm traffic sign and signal poles to the supporting soil and/or rock stratigraphy below the ground surface. The design of these drilled shafts must provide sufficient capacity to resist the maximum anticipated loads, including lateral and torsional loads, both of which are critical for traffic sign and signal pole foundations. Despite the prevalent usage of drilled shafts to resist the anticipated loads, the understanding of the actual torsional resistance provided by drilled shafts is not well established, there is no accepted national standard for the sizing of drilled shafts to resist design torsional loads, and there is no validated model that exists that satisfactorily captures torsional resistance including soil–structure interaction. To evaluate the torsional resistance and rotation response of drilled shafts embedded in multi-layered soils, a program is developed to solve the finite difference equations describing the behavior of a drilled shaft subjected to torsional loads. This allows iterative solution of the soil reaction based on the relative movement between the soil and the foundation at the depth of interest, accounting for internal twist. The drilled shaft is treated as an elastic bar supported by discrete nonlinear torsional springs along the shaft and at the shaft tip. Based on the torsional load transfer data from several scale model and centrifuge torsional loading tests in literature and a full-scale loading test conducted at the Oregon State University, some simplified relationships between unit torsional soil resistance and rotation, known as \( \tau - \theta \) curves, are implemented in the program. Users can select from a hyperbolic model for plastic, fine-grained soils, and
the hyperbolic model, power-law model, and hardening-softening model for cohesionless soil. User-defined $\tau-\theta$ curves can also be input at specific depths. The finite difference model program is validated by comparing the calculated torque-rotation response with existing torsional loading tests data.

18 Anchoring of Marine Hydrokinetic Energy Devices: Three Dimensional Simulations of Interface Shear

Nan Zhang and Matthew Evans

Marine hydrokinetic (MHK) energy devices rely upon seafloor anchors and compliant mooring systems to maintain their station, but without retarding the motion being converted to electricity. The capacity of these anchors is a significant design parameter for the entire MHK system. Numerous factors will influence the pullout capacity of an anchor, including anchor type and seabed properties – and particularly, how those two components interact to manifest as interface friction. This interface friction is difficult to measure in-situ and thus, robust numerical models are necessary for system simulation and design. Offshore anchors interact intimately with the sediments around them. Anchor self-weight and soil-anchor interface shear forces provide holding capacity for the MHK device. The current work uses discrete element method (DEM) simulations to model soil-anchor interface shear when the anchor is subjected to a constant axial load. The effects of anchor friction and surface roughness are considered. Anchor surface roughness and asperity angle are defined as functions of mean grain size, consistent with prior definitions of counterface roughness from the literature. Fabric evolution at the sediment-anchor interface are investigated and the micromechanics of strain softening discussed.

Materials

19 HMAC Layer Adhesion Through Tack Coat

David James Covey, Erdem Coleri, and Aiman Mustafa Mahmoud

Tack coats are the asphaltic emulsions applied between pavement lifts to provide adequate bond between the two surfaces. The adhesive bond between the two layers helps the pavement system to behave as a monolithic structure and improves the structural integrity. The absence, inadequacy or failure of this bond result in a significant reduction in the shear strength resistance of the pavement structure and make the system more vulnerable to many distress types, such as cracking, rutting, and potholes. Tracking, the pick-up of bituminous material by construction vehicle tires, reduces the amount of tack coat in certain areas and creates a non-uniform tack coat distribution between the two construction lifts. This non-uniform tack coat distribution creates localized failures around the low tack coat locations and reduces the overall structural integrity of the pavement structure. In addition, tack coat type, residual application
rate, temperature, and existing surface condition (cracked, milled, new, old, or grooved) are the other factors that affect the tack coat performance. By considering all these factors, a quality-control and quality-assurance process need to be developed to maximize tack coat performance during the pavement design life. The output of this research study will be a low cost in-situ tack coat testing apparatus, a quantitative process for tack coat performance evaluation, a model to determine tack coat set times (to avoid tracking), and a test apparatus to evaluate the long term tack coat performance of ODOT pavement sections. The process will include step-by-step procedures that can be implemented by ODOT when deciding tack coat type and residual application rates for pavements with different textures.

Measuring the Electrical Properties of Concrete for Improved Specification and Infrastructure Service Life

A Coyle, R Spragg and J Weiss

The number of people wanting to use electrical tests to determine the transport properties of concrete has increased with advancements in the portability of hand-held testing devices. Electrical measurements are an attractive test method to quantify transport properties of cement-based materials since they can be performed rapidly. There is a high potential for using these tests in quality control or mixture qualification. However, electrical measurements can be significantly influenced by curing and storage conditions as well as temperature. This study uses a general equation developed by the authors with improved understanding of the role of testing temperature. The authors propose that rather than using resistivity itself, a normalized formation factor can be used to describe the microstructure that allows for the determination of a true transport property that can be used for service life prediction. The work is currently being developed as a part of a national project aimed at improving specifications by rewarding or penalizing contractors for the quality of the product provided as measured in the calculated change in service life and its associated costs.

Practical Monitoring of Reinforced Concrete Bridge Decks

Silas Shields, David Rodríguez, Jason H. Ideker and O. Burkan Isgor

Performing reinforced concrete bridge deck inspections is an important yet difficult task for the Oregon Department of Transportation (ODOT). Corrosion of the reinforcing steel is the leading cause of deterioration in reinforced concrete bridge decks, therefore, early detection is important for remediation and increasing the service life of these structures. The current methods for monitoring corrosion-induced deterioration involve visual inspections as well as laboratory tests, such as coring used to analyze chloride profiles. This time consuming process is less than ideal. The goal of this research project is to use quick and non-destructive surface resistivity tests to
create a model that relates these measurements to the rate of chloride ingress. This model could be used to predict whether or not corrosion is an impending issue in a given reinforced concrete bridge deck. The experimental method for this project consists of taking surface resistivity measurements of reinforced concrete slabs after they have been ponded with a magnesium chloride de-icing solution, containing a corrosion inhibitor. This solution is used by ODOT as a deicer. Certain slabs and cylinders are also undergoing freeze/thaw cycling to observe its effect on surface resistivity in congruence with exposure to chlorides. Many factors such as internal and ambient temperature and relative humidity affect surface resistivity measurements so this data is also collected to be used in the model. To compare the surface resistivity to the rate of chloride ingress, cores are being taken from the slabs. The method of titration is then used to obtain a chloride depth profile. As expected, the surface resistivity of the concrete slabs initially increased while the concrete cured and lost moisture due to the hydration process. Once ponding of the chloride solution started, however, there began to be a decrease in surface resistivity. The corresponding slabs that were ponded with tap water remained constant. This decrease in surface resistivity is believed to be caused by the increase of free chlorides present in the slabs after being saturated with the de-icing solution. These results show that surface resistivity measurements are a potential indicator of chloride ingress and, therefore, corrosion. The effect of freeze/thaw cycling on surface resistivity is currently inconclusive. However, chloride profile data thus far has shown that freeze/thaw attack has led to higher permeability in the OPC mixtures. Deterioration due to corrosion and freeze/thaw attack is also evident on the high w/cm ratio concrete slab. The HPC mixture that is going through freeze/thaw cycling has not experienced these deleterious effects. Freeze/thaw cycling will continue until the slabs have undergone a full 300 cycles. Final results will then be analyzed and interpreted.

The Influence of Construction Practices and Test Methods on Chloride Detection in Concrete

Vaddey Naga Pavan and David Trejo

The risk involved with the corrosion of steel reinforcement embedded in concrete increases with increasing chloride content of concrete. To lower this risk, existing specifications limit the amount of chlorides in the fresh concrete. Chloride concentrations in fresh concrete are based on standard tests provided by the American Society for Testing and Materials (ASTM) and the American Concrete Institute (ACI). Although significant research has been conducted to estimate the influence of concrete mixture constituents and proportions on time to corrosion, little research has been done to assess the influence of construction characteristics on the time to corrosion. In this research construction characteristic are defined as characteristics that can be controlled by the contractor. This research investigates how cement content, nominal maximum aggregate size aggregate (NMSA), fine to coarse aggregate ratio, and degree of consolidation influence chloride transport and time to corrosion. In addition, the influence of these construction characteristics on chloride binding was assessed. Concrete specimens containing different admixed chloride levels (0.05 and 0.25% by cement weight) were cast and subjected to two curing periods: 28 & 84 days. Standard test methods for acid-soluble (ASTM C1152), water-soluble (ASTM C1218) and soxhlet extraction (ACI 222.1) are being performed to assess the influence of construction characteristics on chloride transport and time to corrosion of reinforced concrete structures.
Efficient Nonlinear Time History Analysis of California Bridges

Karryn E. Johnsohn and Michael H. Scott

When designing bridges for the seismicity in California, the California Department of Transportation (Caltrans) performs nonlinear time history analysis of bridge models using CSI Bridge. For some bridge designs, CSI Bridge produces acceptable and expected results, but for other bridges the results are unfeasible. This research aims to determine why CSI Bridge produces erroneous results for some bridge designs and offer recommendations to Caltrans for modeling these bridges using OpenSees to provide a more accurate nonlinear time history analysis. To achieve this, Caltrans provided four ordinary standard bridge designs and their CSI Bridge models. OpenSees models of the four OSBs were then created using various nonlinear element formulations including concentrated and distributed plasticity models. These models will be utilized to determine appropriate OpenSees modeling recommendations and will allow Caltrans to understand more accurately the seismic response of their bridges.

Testing and Novel Modeling Approach for Cross Laminated Timber Panels Subjected to Out-of-plane Loading

Vahid Mahdavifar, Andre Barbosa, Arijit Sinha, Rakesh Gupta and Lech Muszyński

Cross Laminated Timber (CLT) is widely used in Europe both in modular and tall building construction. CLT is now being produced in the United States to form wall and floor components. CLT employs layers of dimensional lumber glued in orthogonal layers and consisting in 2-by-4 or 2-by-6 of Douglas-Fir or pine. CLT is commonly manufactured in 3, 5, and 7 layers. CLT is being planned for manufacturing in the US, with the first installation planned for a mixed-use building in Portland. In slabs and out-of-plane wall deformations, the rolling shear modulus of deformation and rolling shear strength are known to control the performance of CLT panels in out-of-plane loading. The shear analogy is the most common used technique for modeling CLT panels in out-of-plane loading. Limitations exist in the shear analogy since it cannot be used to predict the capacity of the panels nor is it useful for modeling complex panel geometries or complex loading scenarios, mainly due to the complex interaction between the orthogonal layers of the CLT panel and the contribution of the rolling shear to prediction of failure load and deformation. This poster presents recent developments of CLT, including results of a series of long-span and short-span bending tests performed to characterize the out-of-plane behavior of the CLT panels. In addition, a multilayer coupled shell modeling approach is proposed to capture the stiffness and failure loads of the CLT panels, both in short- and long-span bending. The modeling approach is validated using the experimental data and a parametric sensitivity study is used to inform the most influential parameters and their effect on the response measures of interest.
Quantifying the Environmental Utility of Wood Substitution in Commercial Construction

Kristina Milaj, Arijit Sinha and Thomas H. Miller

Wood is the primary building material in single-family residential construction, however, it lacks significant application in mid-rise and commercial buildings. Therefore, the objective of this research was to evaluate and identify the environmental utility (avoided emissions) of using wood in place of other building materials in the commercial construction and renovation sector in Oregon. The study used comparative cradle-to-gate, life-cycle analysis, with the help of the Athena Impact Estimator for Buildings software, for six case studies that represent different building functionalities, material systems, and construction techniques, to evaluate the global warming potential and impacts on fossil fuel consumption when structural materials are progressively substituted with wood. The results showed that the average reduction in global warming potential due to wood substitution was 30% across the six case studies. In addition, this research compared the environmental savings between direct substitution (using the Athena software) and the actual engineering redesign of the building, with wood as a material of choice, for one of the case studies. These findings could help enhance the perception of wood as a green building material, in commercial construction, encouraging architects, engineers, and building owners to use wood for structural application, which would, in return, increase markets for Oregon wood products.

Wireless Sensors for Bridge Monitoring

Kelli Slaven and Daniel Borello

The Pacific Northwest is at risk for significant seismic and tsunami events, which are capable of severely damaging lifeline transportation infrastructure, particularly bridges. Structural health monitoring systems can be used to evaluate the condition of bridges throughout the area, and to quickly determine the state of lifeline bridges after a disaster. The cost and labor involved with typical wired monitoring systems make widespread use challenging. This research focuses on developing a low-cost wireless sensor network with increased ease of installation that will make widespread deployment realistic. This will increase community resilience by allowing first responders to assess the condition of transportation routes and respond more effectively. After a natural disaster, a real-time overview of the transportation network will be available by collecting and presenting the data from wireless sensors.

Bridge models will be developed using OpenSees software to determine critical parameters and ideal sensor placement. The sensors will be placed at points along the bridge to best represent the overall behavior and condition of the structure. Strain gauges or accelerometers will be used to assess local member demands at critical points. Significant changes in readings will be evidence of damage to the structure.

Teams of senior students in the Electrical and Computer Engineering department are helping to develop the wireless sensor nodes and software using low cost platforms that will be adapted
for use in structural health monitoring. With the low power consumption of available platforms, a combination of battery and solar power will allow for multiple year deployments.

27 Behavior of Cross-laminated Timber Diaphragm Panel-to-panel connections with Self-tapping Screws

Kyle Sullivan, Thomas Miller and Rakesh Gupta

The goal of this project is to contribute to the development of design methods for cross-laminated timber (CLT) diaphragms (floors and roofs) as critical elements of the seismic load-resisting system for buildings. The long, 8’ connection joints of this study are close to full-scale, and are of great interest to practicing engineers and academics working on the structural development of CLT in the United States. The objectives of this study are to examine the following: 1) Determine strengths/stiffnesses of common self-tapping screwed connections with fastener spacings that will be used in practice, and 2) find the ductility/energy dissipation of the connections to more accurately model structural performance characteristics in seismic design. ASTM E455 will be the standard used for the static loading of the diaphragms while ASTM E2126-11 and the CUREE testing protocol will be used for cyclic loading. Looking at how CLT floor diaphragm connections transfer lateral loads will lead to design provisions in the National Design Specification for Wood Construction and the International Building Code that will help structural engineers to confidently use CLT in designing lateral-force-resisting systems. This information is important because the structural strengths and stiffnesses of CLT will enable it to be a choice structural system for taller wooden buildings. These buildings, made with renewable materials, will then be much more competitive with construction from materials which are more energy intensive to produce.

28 Large-Scale Laboratory Tests and Numerical Simulation of Tsunami Forces on a Bridge Deck

Tao Xiang and Solomon Yim

The fluid impact forces on a bridge deck in horizontal and vertical directions due to solitary waves are investigated through large-scale laboratory experiments and numerical simulations. The experiment is conducted in a 2D wave basin using a 1:5 scaled reinforced concrete bridge deck model tested under shallow water waves of two water depths. The experiment measured fluid impact forces and pressures on the bridge deck model. An analysis of the experiment data reveals two types of fluid forces: a high frequency impulsive slamming force and a lower frequency quasi-static force. By applying an Empirical Mode Decomposition (EMD) technique, these two types of the forces can be separated from the original time histories. The results have important design implications for bridge engineers. Numerical simulations are performed under the same wave conditions as in the laboratory experiments. Additionally, different bridge elevations are simulated to determine the influence of bridge deck elevation on the magnitude of the tsunami fluid forces.
Characterization of Dynamic Properties of Inundated Buildings Subject to Tsunami and Storm Surge Excitation

Zhongliang Xie and Daniel Borello

Tsunami and storm surge are natural hazards of concern along coastal regions. Buildings are commonly inundated during these events and further subject to dynamic excitation such as wave loading or seismic aftershocks. However, limited research has been conducted on the dynamic properties of inundated buildings. This paper presents the experimental results of a 2-story flexible steel structure subject to tsunami and storm surge loading conducted at the Hinsdale Wave Laboratory at Oregon State University in the Large Flume. The structure was subjected to solitary wave loading and periodic wave loading with different wave heights and inundation heights. This paper studies the resulting wave loading and the response of the structure including acceleration and displacement. The influence of inundation on the dynamic properties of buildings are then presented.

Transportation

Developing Horizontal Curve Database and Curve Safety Performance Functions for Oregon Public Highways

Harith Abdulsattar and Haizhong Wang

Road safety is a serious problem in the world. According to the World Health Organization (WHO), 1.2 million people are killed in road traffic crashes each year, and up to 50 million are injured. Because of this, the importance of crash modeling to discover the contributing factors of crash injury severity has increased significantly. In 2008, more than 27 percent of fatal crashes worldwide occurred at horizontal curves; the vast majority (over 80 percent) of these were roadway departures. Roadway departure crashes consistently account for more than half of the fatal crashes in the United States (51% in 2011, FHWA). In Oregon, roadway departure crashes account for 66% of all highway fatalities, the majority of which happen on rural highways. Due to the predominance of horizontal curves on 2 lane rural roads, a higher percentage of fatal curve-related crashes occur on these roads. Traffic safety studies use Safety Performance Functions (SPFs) to analyze the safety performance of roads and their relation to different road characteristics. Safety SPFs predicts crash frequency rates for roadway segments as a function of exposure and roadway characteristics.

This project provides a complete database of horizontal curve database for the entire state of Oregon and non-state public highways. Engineers and planners can use this data base to design low-cost countermeasures to mitigate curve-related crashes to reduce the roadway
departure crashes on Oregon highways. In addition, this project develops curve SPF that provides an alternative prediction tool to evaluate curve safety by connecting crash rates on curves with curve attributes. As a result, low-cost countermeasures and treatments can be made to mitigate high-risk curves to meet Oregon’s goal of eliminating deaths and severe injuries on the transportation system.

Exploring the Viability of European Union Multimodal Freight Movement Collaboration: Hub Location and Network Design Problems

Jason Anderson, Sal Hernandez, Jiri Tylich, José Osiris Vidaña Bencomo and Helena Novakova

New collaborative technologies have been developed in recent years and they offer potential solutions and opportunities for collaboration among all modes of transportation. Multimodal transportation is the shipment of goods in a single transportation unit. The main factor for the creation of efficient multimodal transportation network is an appropriate location of multimodal facilities and effective routing through existing transportation networks with focus on minimizing the operational costs. Hence, this research seeks to understand and develop collaboration models for both rail and highway modes of transportation, referred to as rail/road collaboration, thereby filling a key gap in the current collaborative logistics literature. From an operations research perspective, two models were developed. First, a static multimodal freight collaborative hub location problem (MFCHLP) was addressed to gain insights on effects of multiple commodities on collaborative intermodal transshipment facility locations from a planning perspective. Second, a collaborative freight multimodal network design problem (SMMCCP) was addressed to gain insights on the effects of multiple commodities on multimodal collaborative routing over a fixed network. The aforementioned models provide an analytical foundation for exploring the rail/road carrier collaboration paradigm.

Development and Implementation of Physical Models for Transportation Geotechnics

Kamilah Buker, Rachel Adams, David Hurwitz and Ben Mason

In many undergraduate engineering programs, students do not synthesize content learned from multiple courses until the capstone senior design experience. Within civil engineering, transportation (e.g., geometric alignment, asphalt design procedures) and geotechnical concepts (e.g., shear strength of soils, soil compaction) often seem like disparate topics to students. However, these topics both contain concepts vital to understanding transportation geotechnics. In addition, few undergraduate programs teach students about the effects of extreme loading cases (e.g., earthquakes, tsunamis, storm waves) on infrastructure response, although this is a critically important consideration for civil engineers entering the workforce in areas prone to natural hazards such as the Pacific Northwest. Providing students more opportunities to synthesize disparate civil engineering concentrations will result in an
academic experience that is more authentically situated in engineering practice. Desktop learning modules could be implemented to improve student learning outcomes. Prototype of the physical models have been designed to show a single response aspect of structures subject to earthquake loading. The response spectrum device could be used to explain the response of buildings, bridges, and even soil deposits during earthquakes. The use of these visual demonstration models will undoubtedly provide tools for students to more easily grasp these new concepts and understand how they relate to the various sub-disciplines within transportation geotechnics.

33 Hardware-in-the-Loop Simulation for Optimal Implementation of Red Light Extension

Masoud Ghodrat Abadi, David Hurwitz, Pat Marnell and Shaun Quayle

Advances in signal controller software and hardware are introducing many new features and functions to the signal engineer’s proverbial toolbox. Hardware-in-the-loop simulation (HILS) using VISSIM offers a unique tool to test different configurations of timing parameters, detections strategies, and intersection geometries in a safe and cost effective manner. One advanced feature that is increasingly available in many controller software packages is red clearance extension. This feature operates by detecting potential red-light-running vehicles and dynamically increasing the duration of the all-red clearance interval to reduce the probability of a crash. This paper aims to determine the optimal placement of point detectors when using a red clearance extension feature. This research used HILS with Northwest Signal’s Voyage software running on a 2070 signal controller. This hardware/software configuration is common at state, county, and city maintained signalized intersections in Oregon. Simulation of several scenarios modeled in VISSIM confirms that while downstream detection (ODOT’s existing Red Light Extension (RLE) system) provide higher accuracy in triggering of the extensions, RLE are placed more efficiently in smart upstream speed conditional detection systems. The results could provide guidance on which locations red clearance extension should be implemented at, and what detection placement and timing parameter configurations can increase the benefit/cost ratios of implementation.

34 Determinants of Vehicle Miles Traveled (VMT) in Oregon

Yue Ke, B. Starr McMullen and Haizhong Wang

Road user charges (RUCs) in the form of per mile charges, such as the one proposed by Oregon Senate Bill 810, have been suggested as an alternative to fuel taxes that could keep up with the costs of maintaining and expanding public road systems. The success of a RUC in providing for the long term stability of highway finance depends on how drivers respond to changes in the tax structure and other determinants of driving behavior. Thus, of interest in assessing both the potential financial and geographic impacts of a RUC includes the changes this policy would create in the cost of driving as well as how the impacts might differ from place to place.
as a result of other factors that might differ between locations. This paper uses econometric techniques to examine the determinants of VMT using data from the Oregon Household Activities Survey. We examine the impact of factors such as urban density, household income, fuel cost, transit mileage, household location, and additional household characteristics on VMT.

We find that increasingly disaggregated scales beyond urban/rural definitions are necessary to understand the role location plays in VMT demand. Demand for VMT at the statewide level is positively and significantly impacted by household income. Fuel price, transit use, and population density are found to be statistically significant and negatively related to household VMT. At regional and city levels however, some variables lose significance. The impacts of public transit and walking/biking facilities on VMT differ between metropolitan areas. Contrary to previous national studies, we find that Oregon households owning these types of vehicles drive less, perhaps as a result of different attitudes towards the environment. Overall, these results suggest that studies that evaluate projected impacts of a policy change, such as the implementation of a RUC, should more carefully consider differences in the impact between locations.

Transportation Network Vulnerability Assessment: Study on Tsunami Evacuation, an Agent-based Modeling Approach

Alireza Mostafizi, Haizhong Wang, Shangjia Dong and Dan Cox

The most probable natural hazard threatening coastal communities – especially in the Pacific Northwest – is a massive earthquake followed by a tsunami. Evacuation scenarios aimed at reducing the number of fatalities require perfectly functioning infrastructure, particularly the transportation network. However, infrastructure required for the tsunami evacuation and for the recovery of affected areas will be severely damaged by the seismic event.

This research presents an agent-based modeling approach to assess the transportation network’s vulnerability under disruptions (e.g., bridge failures and road closures) due to a near-field tsunami caused by a Cascadia Subduction Zone earthquake on Coastal Oregon. The criticality of each link in the network is iteratively evaluated by connecting the impacts of link failures to the resultant mortality rate of the evacuation scenario. After assessing all the links, this research introduces a method to identify the most critical links within a network, and uses the city of Seaside, OR, one of the most vulnerable cities on the Oregon coast, as a case study. Further, assessment is conducted on the identified critical links to formulate the optimal link retrofitting plan for minimizing the mortality rates, considering the limited resources. Finally, Monte-Carlo simulations were used to demonstrate how various failure probabilities of the identified critical links can cause mortality rate to fluctuate. Results indicate that the critical links are not necessarily the bridges in the network. Therefore, the identification of such links requires a systematic assessment of the entire transportation network.
Assessing Externalities and Risk Factors for Pedestrian and Bicycle Crashes

Elizabeth Rios

There are many states, cities, and countries view that any traffic death and serious injuries is a tragedy and is unacceptable when there are tools and capability that can be utilized to prevent them. To achieve this concept one must identify targets areas for improvement and employs countermeasures, through the process of the “4 E’s” (education, enforcement, engineering, and emergency medical services), as well as, a combination of strategies from different focus areas. My research it to develop a tool allowing Oregon Department of Transportation to improve, identification and prioritization of high risk areas for bicyclists to treat existing road infrastructure. By developing this tool, funding will be able to reach the areas of most need not the areas that are able to submit the best applications. The overall goal of this research is to create an environment that everyone can use without any harm coming to them or anyone they know.

Impact of Vehicle Automation on Travel Behavior

Merih Wahid and Dr. Haizhong Wang

The advent of autonomous vehicles will cause a major change in society by changing the various aspects of transportation ranging from travel behavior, safety, emission and parking. With car manufacturers already setting the foundation work and testing self-driving cars it is a matter of when rather than if. In fact The United State congress approved a bill entitled “Fixing America’s Surface Transportation Act” or the “FAST Act” (H.R. 22) which sees emerging technologies as part and parcel of the future solution with a funding nearing $ 61 billion annually.

As a concept automation as a concept can be traced back to 1939 World Fair when Normal Bel Geddes designed a Pavilion sponsored by General Motors named Futurama (also called Highways and Horizons), a "futuristic" urban model. However it is only the recent progress in communication technologies that has increased the capability of vehicles to collect and exchange information with the surrounding environment with aim of supporting the driver in the execution of maneuvers and to communicate with other road users or infrastructure.

Automation will alter the travel behavior in multitude ways: an immediate effect is that in-vehicle time becomes less of a disutility but rather productive time. From safety point of view, human error which is often recognized as the main contributing factor in road accidents claimed around 32,675 fatalities in US roadways (National Center for Statistics and Analysis 2015). It is of paramount importance therefor to assess in advance the potential changes that will take place in travel behavior and to enhance the readiness of policy makers and stakeholders.
Water Resources

A One-dimensional Numerical Model for Predicting Pressure and Velocity Oscillations of a Compressed Air-pocket in a Vertical Shaft

YunJi Choi, Arturo S. Leon and Sourabh V. Apte

The presence of pressurized air pockets in stormwater and combined sewer systems have been argued to produce sewer geysers, which are oscillating jet of a mixture of air-water through vertical shafts. A 1D numerical model was developed for predicting pressure and velocity oscillations of a compressed air-pocket in a vertical shaft. The vertical shaft was closed at the bottom and open to ambient pressure at the top. Initially, the lower section of the vertical shaft was filled with compressed air and the upper section with water. The interaction between the pressurized air pocket and the water column in the vertical shaft exhibited an oscillatory motion of the water column that decayed over time. A rigid water column approach was used. The model accounted for quasi-steady friction loss using the Darcy-Weisbach equation. The model estimated and parameterized the proportion of air expansion that was due to the falling volume of water around the external perimeter of the pressurized air pocket. The expansion and compression of the pressurized air pocket were assumed to follow the ideal gas law. The performance of the developed 1D numerical model was compared with that of a commercial 3D CFD model. Overall, a good agreement between both models was obtained for pressure and velocity oscillations.

A Laboratory Study on Geysers with CO\textsuperscript{2} Dissolved in Water. Implications on the Design of Stormwater and Combined Sewer Systems

Ibrahem S. Elayeb and Arturo S. Leon

A geyser in stormwater and combined sewer systems is characterized by an explosive jetting of a mixture of gas and water through drop shafts. The oscillating jet of gas-liquid mixtures may reach a height of the order of a few to tens of meters above ground level. Previous hypotheses suggested that geysers are propelled by air-water interaction when a pressurized pocket arrives at a vertical shaft. It is stated that the air pocket convey energy to the standing water within the vertical shaft. Even though this explanation seems plausible, it has not been proven neither numerically nor experimentally. For instance, for a geyser to rise a height of 20 meters, the velocity of the gas-liquid mixture at the manhole exit would need to be about 19.8 m/s. Using actual geyser formulations, it is not clear how such a large velocity would be attained in an actual dropshaft. A very recent study performed by the second author of the present paper suggests that geysers in stormwater and combined sewer systems are propelled by exsolution of dissolved gases such as ammonia, sulfur dioxide, chlorine, hydrogen sulfide, carbon dioxide.
and methane that are present in these systems. For testing this hypothesis we carried out extensive laboratory measurements with CO$_2$ gas dissolved in water. It is worth mentioning that this gas was used due to safety considerations. In actual stormwater and combined sewer systems, it is believed that the geyser is propelled by the exsolution of a mixture of dissolved gases with large solubility coefficient such as ammonia, sulfur dioxide, chlorine, among others. The implications of these experiments in the design of stormwater and combined sewer systems are discussed in the paper.

**Robust Optimization of Reservoir Operation Considering Uncertainty of Inflows and Flexible Decision Variables**

Parnian Hosseini, Duan Chen, Arturo S. Leon and Nathan Gibson

This study presents a robust optimization framework for the operation of a single reservoir. Robust optimization considers the effects of uncertainty in the process of finding optimal solutions. The main source of uncertainty considered in this study is due to inflows. Uncertainties of outflows can be correlated to the uncertainties of inflows via the dynamics of the reservoir system. Because other sources of uncertainty can also influence the reservoir operation, instead of deterministic decision variables, the reservoir operator may prefer flexible decision variables, which ensure that no constraints are violated as long as the reservoir operation is within the range of these decision variables.

A multi-objective evolutionary algorithm is used for maximizing hydropower generation and minimizing variation in forebay elevation of the Grand Coulee reservoir, which is located in the Columbia River (U.S. Pacific North West). The results of this study are compared against a deterministic optimization framework and the advantages of this robust optimization approach are presented.

**Towards a Hydrodynamic and Water Quality Model of the Lower Klamath River**

Amir Javaheri, Meghna Babbar-Sebens and Julie D. Alexander

The myxozoan parasite Ceratomyxa shasta is responsible for high mortality in juvenile salmon in the lower Klamath River below the Iron Gate Dam. Water temperature is another important factor that affects the mortality rates of salmons especially Coho salmon juveniles. Prediction of the flow discharge, velocity and water temperature can determine the areas with higher risk of mortality. Such a model is expected to assist decision makers in identifying management actions that could decrease disease effects in salmonids. Numerical methods are effective tools to predict the behavior of complex aquatic systems such as rivers. A three-dimensional hydrodynamic model of Klamath River was developed to estimate the flow discharge and velocity. A Lagrangian particle transport and CE_QUAL_ICM water quality model were
integrated into the hydrodynamic model to track the parasite spores dispersion along the river and predict the water temperature. The accuracy of model is reliant on different model parameters and variables that need to be calibrated to reproduce changing aquatic conditions accurately. Different observations such as the spatial and temporal abundance of the parasites, atmospheric data, water surface elevation, water temperature and flow discharge from USGS stations were used to set the model’s boundary conditions and calibrate the model.

### Water Temperature Modeling for Marys River Watershed

Mamoon Mustafa and Meghna Babbar-Sebens

Increases in water temperatures in rivers have increased the risk of aquatic life survivability. More oxygen is consumed when water temperature increases, thereby, leading to hypoxia and fish kills. Soil and Water Assessment Tool (SWAT) is a watershed model that has been developed to assess effect of watershed processes on flow rates, and water quality (e.g., sediment load, phosphorous level, nitrates level and water temperature). The original SWAT model uses a linear approach developed by Stefan and Prud’homme to estimate stream water temperature in which the empirical equation uses only air temperature to calculate the water temperature and it does not account stream flow, groundwater inflow and snowmelt for estimating stream temperature calculation. In order to obtain accurate stream temperatures from this empirical equation the weather stations should be located near the streams. This is inefficient because it is not always possible to get the weather stations near the streams due to monitoring costs and logistical hurdles. The current empirical equation also does not consider any process parameters related to soil, ground and land practices that are critical for water temperature estimations. Ficklin, et al. recently developed a new stream temperature model in which meteorological and hydrological parameters were combined to calculate the stream temperature. The new model uses air temperature, stream flow, lateral flow, snowmelt, groundwater flow and surface runoff for water temperature calculations. The newly developed model uses three components for the stream temperature calculation; within a sub-basin (temperature and flow rate), up-stream of sub-basin (temperature and incoming flow), and air-water temperature transfer. The model developed by Ficklin, et al. will be tested for the Marys River watershed located in Oregon, west of the Willamette River. The output from the model will be compared to observed stream temperatures for different locations within the watershed to assess the model efficiency, and the developed model will then be calibrated using the available observations. This presentation will provide our results and findings of the effect of multiple model assumptions on the estimation of river water temperature.
Statistical dependency parsing of natural language sentences is an important processing step for many downstream text analysis applications. Traditional parsing methods, which are cubic in sentence length, are too slow for many applications requiring parsing large quantities of text. Incremental transition-based parsers solve this problem by considering a sentence left-to-right, building up the parse tree as they go by making predictions for local actions, which also more closely models how humans understand sentences when listening or reading.

Linear models make decisions based on a parser state representation using very sparse “one-hot” features to represent the parser state. This requires potentially imprecise hand engineering, and the extraction of such features is a significant component of parsing time. Recent neural network approaches have alleviated this problem by representing discrete state features (words, parts of speech, arc labels) in a low-dimensional continuous space and learning their combination automatically.

We extend this line of work by using memory-based recurrent networks to model each word in the sentence using its context in both directions. An extremely simple form of parser state representation can then be used: the recurrent output for the sentence positions of the head words of the top two trees on the stack, and the next word on the buffer. Using this very simple feature representation, and without random restarts or expensive hyperparameter tuning, we are able to equal the state of the art on greedy linear-time parsing (93.21% on Penn Treebank).

Genes are expressed in cell-type specific patterns, and gene expression is largely what distinguishes one cell-type or tissue from another. The evaluation of high dimensional
expression values is therefore an important task in computation biology. The ability to distinguish cell-types from gene expression could be valuable for medical analysis and diagnosis of certain diseases. Cancer diagnosis and treatment is an intricate task which needs biological and medical expertise and after decades of research there is uncertainty of clinical diagnosis and medical assessment of cancerous tumors. Using machine learning techniques is effective for classification purposes as well as finding patterns in such complex high level data. Finding common patterns within a group of samples from a specific cancer type, could lead to novel tumor-specific markers and eventually appropriate treatments. Here, we present a novel approach for deeply extracting functional features from high dimensional cancer expression data using Stacked AutoEncoder (SAE). We evaluate the performance of the extracted features by applying different supervised classification models to verify the usefulness of the extracted representations. In addition, highly interactive features of original data are extracted by analyzing the SAE connectivity matrix and further are evaluated by the classification algorithms. Highly accurate results from our experiments on ovarian and prostate cancer confirm that our method is a powerful approach to extract generative and effective feature space for cancer classification as well as finding sets of cancer biomarkers that deserve further studies.

3 Learning Letter-to-Phoneme Conversion with Violation-Fixing Perceptron

Dezhong Deng

Letter-to-phoneme conversion is a task of finding the phonemic representation of a word given its written form, which is of importance being central to the technology of text-to-speech (TTS) synthesis and highly useful for some aspects of speech recognition. However, previous work on this task shows that handling various features is a challenging problem due to the limitations of the models, with training on large-scale datasets is also required.

In this way, we propose a novel learning framework by adopting violation-fixing perceptron model to this problem. Violation-fixing perceptron allows inexact inference while training, with no impact on the performance, which leads to a better efficiency and shows its scalability to the big data. Moreover, the perceptron models enable us to apply a rich set of features, including most of the features used in the previous approaches. We implement and evaluate our approach on several letter-to-phoneme datasets. Experimental results indicate that our approach is competitive to the state-of-the-art system, with significantly reduced training times.


Andrew Emmott, Shubhomoy Das, Thomas Dietterich, Alan Fern and Weng-Keen Wong

Research in anomaly detection suffers from a lack of realistic and publicly-available data sets. Because of this, most published experiments in anomaly detection validate their algorithms with application-specific case studies or benchmark datasets of the researchers’ construction.
Inconsistent approaches to algorithm evaluation have made it difficult to compare different methods or to measure progress in the field. It also limits our ability to understand the factors that determine the performance of anomaly detection algorithms. This article summarizes approaches to benchmarking anomaly detection algorithms across the literature, identifying areas where experimental design might have an impact on results. We criticize the literature for publishing incremental improvements to algorithms which are only validated by benchmarks of the experimenters design. We then identify and validate four important problem dimensions that appear in real-world applications: (a) point difficulty, (b) relative frequency of anomalies, (c) clusteredness of anomalies, and (d) relevance of features. This article then proposes a methodology for controlling and measuring these dimensions when constructing benchmarks. This methodology is used to generate thousands of benchmark datasets to which we apply a representative set of anomaly detection algorithms. The evaluation of these results verifies the importance of these dimensions and shows that anomaly detection accuracy is determined more by variation in the four dimensions than by the choice of algorithm, suggesting that real-world applications might be better served by trying to address these problem dimensions.

5 Training Deep Networks for Visual Object Tracking via Imitation
Trevor Fiez, Sinisa Todorovic and Alan Fern

This paper addresses the problem of training deep convolutional neural networks (DCNNs) for tracking objects in video under significant occlusion and pose variations. In recent years, DCNNs have led to significant advances for the problem of object detection, however, they have received much less attention for object tracking. In this paper, we propose a novel approach for training DCNNs for object tracking, based on the framework of imitation learning. The approach provides a principled way of incrementally increasing the amount of training data for a DCNN in a way that aims to cause the DCNN to imitate ground-truth training trajectories. Experimental results on a series of challenging tracking datasets show that the proposed algorithm performs well against state-of-the-art methods.

6 Event Detection with Forward-Backward Recurrent Neural Networks
Reza Ghaeini, Xiaoli Fern, Liang Huang and Prasad Tadepalli

In this project we study the problem of automatically extracting anthologized events from natural texts. Traditional event extraction methods rely heavily on rich features that require significant manual tweaking and engineering. Recent studies show that deep learning could automatically extract meaningful features from raw data. In this work, we study the event detection task using a deep learning method, namely, forward-backward recurrent neural networks (FBRNNs). The proposed method is flexible and can detect single word mentions or phrasal mentions of events. To the best of our knowledge, this is the first attempt in using RNNs for event detection. Specifically, our study empirically explores the effect of network
architectures, different types of recurrent nodes, and different ways to rearrange the natural text when applying RNN in order to better capture both the syntactic structure and the semantics of natural texts.

7 Active Imitation Learning of Hierarchical Policies

Mandana Hamidi

In this paper, we study the problem of imitation learning of hierarchical policies from demonstrations. The main difficulty in learning hierarchical policies by imitation is that the high level intention structure of the policy, which is often critical for understanding the demonstration, is unobserved. We formulate this problem as active learning of Probabilistic State-Dependent Grammars (PSDGs) from demonstrations. Given a set of expert demonstrations, our approach learns a hierarchical policy by actively selecting demonstrations and using queries to explicate their intentional structure at selected points. Our contributions include a new algorithm for imitation learning of hierarchical policies and principled heuristics for the selection of demonstrations and queries. We developed a novel two-level active learning framework, where the top level selects a trajectory and the lower level actively queries the teacher about the intention structure at selected points along the trajectory. Moreover, we developed a new information-theoretically justified heuristic, cost-normalized information, for selecting trajectories, and employed Bayesian active learning for the lower-level query selection. Experimental results on five benchmark problems indicate that our approach compares better to a number of baselines in learning hierarchical policies in a query-efficient manner.

8 DeepLinc: Featureless RNA Coding Prediction with Deep Learning

Steven T. Hill, Rachael Kuintzle, Erich Merrill III, and David Hendrix

Differentiating protein coding transcripts (mRNAs) from long noncoding transcripts (lincRNAs) is a recent area of interest in bioinformatics. LincRNAs have been shown to play an important role in gene regulation, however they are hard to distinguish from classical mRNAs due to their poly-A tail and the presence of open reading frames. Traditionally, lincRNA identification is done by manually selecting features to consider during classification. This leads to bias and poor performance on lincRNAs that are unusual. In the past year, natural language processing has made large strides by using deep neural networks and recurrent neural networks. Natural language and RNA have much in common; for example, both are represented by a sequence of characters. Here we present a coding prediction tool, DeepLinc, which uses recurrent neural networks with gated recurrent units (GRUs) for non-biased classification of lincRNAs and mRNAs. Neural nets bypass the bias introduced by manual feature selection. This is the first reported use of recurrent neural networks for DNA or RNA analysis. DeepLinc achieved state-of-the-art in accuracy and several other tasks. The remaining tasks performed at a near state-of-the-art level. It also distinguished unusual lincRNAs from mRNAs, previously difficult due to bias. Furthermore, DeepLinc allows for identification of novel sequence features that may be biologically important for distinguishing lincRNAs from mRNAs in the cell.
Progressive Abstract Tree Search for Large-scale Online Planning with Applications to Smart Electrical Grids

Jesse Hostetler, Alan Fern and Thomas Dietterich

Planning problems such as those arising in smart electrical grid control are characterized by large state and action spaces and a high degree of uncertainty. Uncertainty may arise from stochastic effects of actions, stochastic exogenous events, or uncertainty about the environment state, all of which complicate decision making. Deliberation time is also limited. Localized faults in an electrical grid can trigger a cascading failure if corrective action comes too slowly. We propose the framework of progressive abstract tree search (PATS) to address these planning problems. PATS works by solving a sequence of abstract planning problems, each of which is a refinement of the previous problem in the sequence, using Monte Carlo tree search as the solver. The sequence begins with a coarse abstraction, which induces a small abstract problem that can be solved quickly. The optimal policy for each abstract problem induces a valid policy in the un-abstracted problem, and each refinement increases a lower bound on the value of the corresponding induced policy. The algorithm can halt at any time and output the policy for the most-refined problem solved so far. We express abstraction refinements as operations on an abstraction diagram, which allows us to unify several existing forms of state and action abstraction and extend them to the non-stationary case. We also discuss how PATS can be applied to the problem of fault recovery in electrical grids by leveraging industry-standard power grid simulators.

A Framework for Classification of Brain Tumors from Histopathological Images

Thi Kim Phung Lai

Automated histopathological image analysis has recently become a significant research problem in the diagnosis, classification and stratification of primary brain tumors. Due to the diversity of histology features suitable for each problem as well as presence of rich geometrical structure of histopathology images, feature extraction is a challenging task. In this paper, we propose a feature discovery framework involving a human in the loop. First, we actively train classifiers over image patches to identify the presence of documented medical indicators of cancer (e.g., white matter tracks or nuclei density). We represent images of tumor tissue as bags of patches characterized by the trained reliable features. Then, using a supervised topics model approach, we tackle the problem of classification of two types of brain cancer, namely, Astrocytoma and Oligodendroglioma. Preliminary numerical evaluation results indicate the merit in the proposed approach.
Identification of Hummingbird Species through Analyzing the Sound of Wingbeats

Xingyi Li, Xiaoli Z. Fern and Raviv Raich

In this project, we aim to build a system for automatically identifying hummingbird species based on the recorded sound of their wingbeats. Our inputs are audio recordings of wingbeats activities from 15 different humming bird species. The wingbeats of hummingbirds have a much lower frequency range than traditionally analyzed bird songs, making existing bioacoustics tools for bird song analysis unsuitable. Empirically observing the sound of bird wingbeats reveals a clear harmonic structure. Our approach is based on the belief that the harmonic structure, its frequencies and energy contain useful information for differentiating different hummingbird species. We automatically identify the presence of harmonics in the low frequency range to detect wingbeats and then extract features from the detected harmonics to represent the wingbeats. In our preliminary study, a nearest neighbor classifier was able to achieve 90% accuracy on recordings containing three hummingbird species with the longest, medium, and shortest wing length.

Integrating Classification and Decision-Making

Liping Liu

In many applications, the user of a learning system often need to first make predictions on a known test set and then select positive examples under some constraints. Such problem are often solved by a two-step process: prediction and decision-making. However, this method ignores uncertainties in predictions, and such uncertainties often leads to suboptimal solutions. In this work, we proposed integrate classification and decision-making in one optimization problem. Our method optimizes the goal directly instead of solving the indirect goal of the general prediction problem. In another view, we use selection constraints to reduce the hypothesis space to reduce the structural risk. Experiment results show that our method outperforms the traditional method in several benchmark datasets.

Dependency-Based Convolutional Neural Networks for Sentence Embedding

Mingbo Ma, Liang Huang, Bing Xiang and Bowen Zhou

In sentence modeling and classification, convolutional neural network approaches have recently achieved state-of-the-art results, but all such efforts process word vectors sequentially and neglect long-distance dependencies. To combine deep learning with linguistic structures, we propose a dependency-based convolution approach, which convolves on making use of tree-based n-grams rather than surface ones, thus utilizing non-local interactions between words. Our model improves sequential baselines on all four sentiment and question classification tasks, and achieves the highest published accuracy on TREC.
14 A Signaling Game Approach to Database Querying and Interaction

Ben McCamish, Vinod Ramaswamy, Arash Termehchy and Behrouz Touri

Often users have difficulty in communicating their information needs, making it challenging to database querying and exploration interfaces to interpret these needs properly. This work proposes a novel framework that effectively represents and interprets the information needs in database querying and exploration. We consider querying as an interaction that takes place between the user and the database, overtime creating a mutual language properly representing the user’s needs. This interaction is modeled as a signaling game. We discuss some equilibrium, strategies, and the convergence of this game. We also propose a reinforcement learning technique and analyze its effect on the interaction. We prove that this signaling game model improves the effectiveness of answering queries over time, stochastically speaking, and converges almost surely. Regardless of the reward chosen by the database, the learning rule is robust.

15 Facilitating Testing and Debugging of Markov Decision Processes with Interactive Visualization

Sean McGregor, Hailey Buckingham, Thomas G. Dietterich, Rachel Houtman, Claire Montgomery and Ronald Metoyer

Researchers in AI and Operations Research employ the framework of Markov Decision Processes (MDPs) to formalize problems of sequential decision making under uncertainty. A common approach is to implement a simulator of the stochastic dynamics of the MDP and a Monte Carlo optimization algorithm that invokes this simulator to solve the MDP. The resulting software system is often realized by integrating several systems and functions that are collectively subject to failures of specification, implementation, integration, and optimization. We present these failures as queries for a computational steering visual analytic system (MDPvis). MDPvis addresses three visualization research gaps. First, the data acquisition gap is addressed through a general simulator-visualization interface. Second, the data analysis gap is addressed through a generalized MDP information visualization. Finally, the cognition gap is addressed by exposing model components to the user. MDPvis generalizes a visualization for wildfire management. We use that problem to illustrate MDPVIS.

16 Designing Intelligent Agents for Hearthstone

Erich Merrill III, Steven T Hill and Alan Fern

Hearthstone is a turn-based adversarial collectable card game in which players use the diverse cards in their deck to attempt to bring their opponent’s life to zero. This type of game presents many difficulties for artificial intelligence (AI) systems. Difficulties include hidden information about the opponent’s hand and deck, uncertainty regarding the upcoming cards to be drawn,
and complex resource systems. Here we apply Monte-carlo tree search (MCTS), UCT, and a random agent base policy to the Hearthstone domain using a prebuilt simulator, MetaStone. The UCT agent was evaluated using six different decks, each with different play-styles. The UCT agent and a rule-based agent played in a round-robin – the UCT agent had a win rate of over 75% in every matchup, and reached a win rate of over 90% in some matchups. Surprisingly, the agent was able to correctly play decks that required counterintuitive strategies, such as “Handlock”, which is played optimally by intentionally taking damage. The agent was also evaluated against a handful of human opponents of varying skill level, and had a win rate of over 50% in each matchup other than against a top-500 player.

A Novel Approach for Bird Species Recognition Based on Spectrogram Analysis

Tam Nguyen

Extracting and recognizing bird species from audio recorded in forests have been becoming interesting issues in bioacoustics recently. The analysis of spectrograms generated from audio data to separate the bird syllables from background is definitely challenging in machine learning because of the high influence of natural environmental conditions such as noise, wind, vehicles, rain etc. Moreover, the separate and simultaneous appearance of species is a matter of concern as well. State of the art approaches have attempted to isolate the background from bird syllables but none of them have achieved a reasonable result. In this research, we introduce a novel approach to segment and classify bird species from the spectrograms. A window with step of one pixel in the time direction is slid through each frequency which is expected for bird signal to appear to extract features and neighbor relationship among pixels before applying the PCA to reduce the dimensions of data. Random forest learns the model of data with each frequency to segment out species areas before using MIML to classify them. The experiences showed the promising results for our novel approach. The future work is to build a model of the data distribution for each frequency to classify species directly.

Learning Scripts as Hidden Markov Models

J. Walker Orr, Prasad Tadepalli, Janardhan Rao Doppa, Xiaoli Fern and Thomas G. Dietterich

Scripts have been proposed to model the stereotypical event sequences found in narratives. They can be applied to make a variety of inferences including filling gaps in the narratives and resolving ambiguous references. This paper proposes the first formal framework for scripts based on Hidden Markov Models (HMMs). Our framework supports robust inference and learning algorithms, which are lacking in previous clustering models. We develop an algorithm for structure and parameter learning based on Expectation Maximization and evaluate it on a number of natural datasets. The results show that our algorithm is superior to several informed baselines for predicting missing events in partial observation sequences.
Learning novel relations from relational databases is an important problem with many applications in database systems and machine learning. Relational learning algorithms leverage the properties of the database schema to find the definition of the target relation in terms of the existing relations in the database. Nevertheless, the same data set may be represented under different schemas for various reasons, such as efficiency, data quality, and usability. Unfortunately, many current relational learning algorithms tend to vary quite substantially over the choice of schema, both in terms of learning accuracy and efficiency, which complicates their off-the-shelf application. In this paper, we introduce and formalize the property of schema independence of relational learning algorithms, and study both the theoretical and empirical dependence of existing algorithms on the common class of vertical (de)composition schema transformations. We prove that current relational learning algorithms are generally not schema independent. We further modify two existing algorithms, Golem and ProGolem, and prove that their modified versions are schema independent.

Anomaly detection is a popular approach in security and data cleaning for identifying unusual/rare data points. In many applications, an anomaly detection system presents the most anomalous data instance to a human analyst, who then must determine whether the instance is truly of interest (e.g., a threat in a security setting). Unfortunately, most anomaly detectors provide no explanation about why an instance was considered anomalous, leaving the analyst with no guidance about where to begin the investigation. To address this issue, we study the problems of computing and evaluating sequential feature explanations (SFEs) for anomaly detectors. An SFE of an anomaly is a sequence of features, which are presented to the analyst one at a time (in order) until the information contained in the highlighted features is enough for the analyst to make a confident judgement about the anomaly. Since analyst effort is related to the amount of information that they consider in an investigation, an explanation’s quality is related to the number of features that must be revealed to attain confidence. In this paper, we first formulate the problem of optimizing SFEs for a particular density-based anomaly detector. We then present both greedy algorithms and an optimal algorithm, based on branch-and-bound search, for optimizing SFEs. Finally, we provide a large scale quantitative evaluation of these algorithms using a proposed novel framework for evaluating explanations. The results show that our algorithms are quite effective and that our best greedy algorithm is competitive with optimal solutions.
Yet Another Piecewise Constant Model on Geo-Spatial Prediction

Ga Wu and Ben Brook

In pursuit of smart city, large amounts of data has been collected, cleaned and sorted for later convenience of making analysis or predictions. We can easily notice that some of those urban data are bounded by geo-location features such as house price, temperature and even soil moisture. Effectively making use of the data with geo-location features are still an open question, since lots of geo-spatial questions waiting to answer has piecewise property. For example, the house prices between two neighbor communities may has huge difference. General supervised learning approaches can be naively applied on those prediction problems, but they more or less has disadvantage on making reasonable prediction. Even for robust model like KNN, when generalization, it can easily loss its piecewise property. Regression Tree is, on another hand, able to maintain this particular property of data. However, the piecewise constraints in its hypothesis space are all convex set, which limit the model flexibility. In this project, we are introducing a novel piecewise constant model, which does not have convex set limitation and also won’t loss the piecewise property when generalization. The basic of this model is to use minimum spanning tree to merge Voronoi diagram cells and look for best merging step that minimize generalized error. Experiment result, so far, shows, this novel model is more stable and often obtain better minimum squared error than GP, KNN and Regression Tree on problems with piecewise property.

Cross-Species Transcriptome Investigation of Human and Canine Bladder Cancer

Tanjin Xu, Stephen A. Ramsey, Cheri Goodall, Jun He and Shay Bracha

Canine transitional cell carcinoma (TCC), which occurs spontaneously in dogs, is similar to invasive human bladder cancer at an anatomic level. We hypothesized that genes that are differentially expressed in human urothelial carcinoma vs. normal bladder tissue are more likely to be differentially expressed in canine TCC vs. normal bladder than would be expected by chance, and that for the majority of genes that are differentially expressed in bladder cancer vs. normal bladder in both species, their directions of differential expression (i.e., higher in cancer or lower in cancer vs. normal) would be consistent across species. We further conjectured the somatic mutation load of canine genes in bladder cancer is correlated with the genes’ frequency of mutations in human urothelial carcinoma. We tested these hypotheses by first acquiring global measurements of gene expression from RNA-seq in canine TCC (N = 8) and normal bladder (N = 3), 50× exome sequencing data from canine TCC and matched blood samples, and RNA-seq data from the TCGA project data portal. We found that orthologous genes that are differentially expressed both human and canine bladder cancer vs. normal are strongly likely to have consistent directions of differential expression across (O.R. = 31.5). We further found that somatic mutation load of canine genes in TCC correlates with somatic mutation frequency in human urothelial carcinoma. When RNA-seq data from both species are transformed to Gene Ontology summary expression levels using GSVA, human and canine bladder cancer samples show similar patterns of differential expression vs. normal bladder.
Joint Probabilistic Model for Outlier Detection and Data Cleaning in Weather Stations

Tadesse Zemicheal and Tom Dietterich

In meteorological application remote sensor play an important role in recording data at fine temporal resolution. However, the readings of such sensors are not often correct and usually data cleaning operation is required to clean the anomalous data manually before announced to the public. In this work, we have tried to detect anomalous readings of a correlated sensors from network of weather station to detect abnormal readings. We have used a combination of statistical anomaly detection algorithms with pairwise joint probability distribution of correlated sensors to identify the anomalous readings. The accuracy result measured by AUC shows, the proposed method achieves good result in finding most common type of anomalies in the data. The model is planned to be deployed as sensor diagnosis for weather station in Africa weather stations, Oklahoma and other related networked weather stations.

Neural Sentence Entailment Recognition with Structured Attention

Kai Zhao and Liang Huang

Automatically recognizing sentence entailment relations between a pair of sentences has been dominated by approaches using bag-of-words and rigid logic inferences, all of which are based on sparse features, making these approaches brittle in generalizing to unseen sentences. Recent advances in neural learning reveal another promising attempt to solve this problem. Instead of discrete features and logics, continuous representation of the sentence is more robust to unseen features in the sentence entailment task without loss of accuracy. In particular, introducing the attention model to sentence entailment recognition specifies the word-by-word correspondences between the two sentences that lead to entailment or contradiction, which makes the entailment relation recognition more reliable. However, conventional neural attention models for entailment recognition problem treat sentences as sequences, ignoring the fact that sentences are formed bottom-up with a syntactic tree structure, which inherently associates with the semantic meaning. Thus, using the tree structure of the sentences will be beneficial in inducing the entailment relations between parts of the two sentences, and the further improve the sentence-level entailment relation classification. Here we propose a structured attention model that force the attention follow the tree structured compositions, which helps determine entailment between parts of the sentences. Furthermore, we use this entailment information on subtrees to predicate the entailment relations on the parent node of the subtrees with composition. This can be viewed as a soft version of the logic inference over neural models, and will make the entailment relation recognized easier to interpret.
Graphics and Visualization

25 Covering Space Construction and Visualization

Sanaz Golbabaei

The solution to the Branched Covering Space (BCS) construction and visualization can benefit many applications in computer graphics and mathematics. The theory of covering space is used in many research areas in computer science such as vector and tensor field topological simplification, parametrization, and remeshing. However, understanding Covering and Branched Covering Spaces is difficult because of the complicated mathematical concepts; hence, having a tool for construction and visualization of BCS will be beneficial for researchers in these areas.

The BCS construction can also be used to create self-intersecting surfaces which are difficult and also time consuming to produce.

In this paper, we will discuss the generation of branched covering space and we will introduce our visualization schemes.

26 Escher Patterns on Surfaces

Prashant Kumar

This paper introduces an interactive way to draw Escher patterns on arbitrary surfaces. Our approach works through using a smooth fourth or sixth order rotational symmetry field over the surface as an input. This field is used to parameterize the surface. The parameterization then helps in drawing Escher patterns based on their wallpaper groups which are compatible to the 4-RoSy or 6-RoSy field. A 4-RoSy based parametrization supports the p4, p4m and p4g symmetry groups and while 6-RoSy based parameterization supports the p6 and p6m symmetry groups.

27 Visual Analysis of Attorney Portfolio Diversity

Surendar Nambirajan, Ronald Metoyer and Sachin Pandya

Attorney behavior is of interest to law researchers who often view lawyers as managers of case portfolios. They are interested in the makeup of these portfolios and how they evolve over time. Portfolio models of attorney behavior lead to different predictions than models in which attorneys act based only on the return of a particular. For example, in a portfolio model, attorneys may take or settle any particular case for a low or even negative net return if doing so advances an overall strategy for managing a portfolio’s estimated risks and rewards, adjusting the concentration of cases by type within a portfolio, or developing a reputation for expertise or tenaciousness that may attract clients and favorably affect negotiations with opposing counsel.
in other or future cases. We have designed an interactive visualization tool for analyzing attorney litigation portfolios using a diversity index as the primary metric for comparison of portfolios. We employ Munzner’s nested model to guide our visualization design process. Our design is centered around exploration of portfolios based on a diversity ordering. Identification of generalist and specialist attorneys is the most important part of the process and thus we design around an exploratory step that allows users to sort attorneys/portfolios by diversity.

28 Multi-Style Pen-and-Ink Sketching of Images

Botong Qu, Todd Kesterson and Eugene Zhang

Hatching, stippling and scumbling are three basic techniques being used to create pen-and-ink fine arts by the artists. In this article, we present an interactive multi-style pen-and-ink rendering system which allow the user design and combine all these different styles in one rendered result based on a given input image. Instead of adapting traditional hatching method, we also present a computer-generated N-family hatching method, which is using multiple layers of hatching instead of only one or two to produce a tone continuous rendering image, we also introduce a pattern-designed scumbling algorithm, which draw spiral curves based on the input pattern to create a scumbling painting.

In our system, users can use tensor field design to create a desirable orientation field and use spatial and tonal segmentation to separate the image into different regions. With a universal density control plot users are able to easily control and design the rendering style parameters for each region. Multi-style rendering can be used to meet some special design purposes, such as edit the content, adjust the tone and emphasize objects. And it utilizes the strength of each pen-and-ink scheme to overcome the shortages of one scheme sketching. With the flexibility provided by the controls over most style parameters, our multi-style pen-and-ink system allow everyone efficiently, liberally and economically to produce desirable esthetic hand drawn style rendering results.

29 3D Symmetric Tensor Field Visualization using A-Patches

Ritesh Sharma, Jonathan Palacios and Eugene Zhang

3D symmetric tensor fields have a wide range of applications in solid and fluid mechanics. In order to analyze topological feature of 3D symmetric Tensor field, visualization is one of the main tool in Computer graphics. In our work, we have first identified different surfaces based on eigenvalue manifold and then extracted them for visualization using different techniques practiced by Computer Graphics Community. These surfaces and degenerate curves are topological features of 3D Symmetric Tensor Field. Extracting these surfaces using well known Marching Tetrahedra method can lead to the loss of geometric and topological details, which can also lead to false physical interpretation. To robustly extract these surfaces, we develop a polynomial description of these surfaces which enabled us to borrow techniques from algebraic surface extraction known as A-Patches, a topic well-researched by the computer-
aided design (CAD) community as well as the algebraic geometry community. In addition, we adapt this surface extraction technique to improve the speed of finding degenerate curves. We found these new surface and degenerate curve visualization to be useful for domain application in solid and fluid mechanics. We also provide real life examples to show the usefulness of these topological features.

Networking and Computer Systems

30 Approaching Optimal Hop Count for Multiple Ring-based Network-on-Chips

Fawaz Alazemi, Lihong Chen and Bella Bose

As the number of cores in chip multiprocessors (CMPs) continues to escalate from hundreds to over a thousand, it is critical to design network-on-chips (NoCs) that connect all the cores efficiently. A major issue in conventional NoC designs is that on-chip routers usually incur very high cost of hardware. Recently, a novel approach based on the use of isolated multiple rings (IMR) is proposed that shows the promise of removing routers completely and, at the same time, improving network throughput. However, this approach faces serious scalability challenge as existing works are unable to find the ring sets that achieve acceptable network latency for larger networks. In this work, we tackle this important challenge by proposing a highly efficient algorithm to generate a satisfying set of rings. Using the N x N mesh topology as an example, the proposed algorithm runs in polynomial time and generates ring set that achieves near optimal network latency for general N. For 32x32 mesh topology capable of supporting kilo-core CMPs, the proposed algorithm reduces the average hop count by 2.5X, from 63.92 hops in the state-of-the-art to 24.81 hops. This value approaches the theoretical minimal of 21.33 hops. Furthermore, the algorithm is able to finish for the 32x32 case in less than a second on our testing computer while the best existing work takes several hours. These results highlight the effectiveness and efficiency of the proposed algorithm.

31 Removing Packet Injection Bottleneck for On-chip Networks in GPUs

Yunfan Li and Lihong Chen

Graphic processing units (GPUs) with thousands of processing cores on a chip have now become critical to various graphic applications as well as general-purpose high-performance computing (HPC) systems. To enable the growing number of concurrently running threads in GPUs, it is imperative to design on-chip networks (a.k.a. NoCs) that can support a large amount of on-chip communication cost-effectively. In this work, we identify a bottleneck in GPU NoCs that significantly limits the rate at which data reply packets can be injected from the memory back to the on-chip networks. This bottleneck happens as the reply packets containing the...
fetched data from memory are typically much longer than data request packets to memory (~5X in size), thus causing severe congestion at the injection points of reply networks. To combat this issue, we propose a novel approach called Priority-based Asymmetric Crossbar Speedup (PACS) that selectively increases the input speedup of crossbar from certain injection ports to output ports, allowing the injected packets to be quickly transferred out of the “hot-spot” regions to free up injection queues. Moreover, the priority of packets will gradually decrease as packets are transferred further into the network, thus enabling acceleration during injection while ensuring fairness once the packets are injected. Evaluation results using cycle-accurate simulator show significant improvement in network latency and overall execution time with minimal increase in hardware cost. This work increases the fundamental understanding of the design of on-chip networks in GPUs.

32 Proactive Multi-Path TCP for Seamless Handoff in Heterogeneous Wireless Access Networks

Hassan Sinky, Bechir Hamdaoui and Mohsen Guizani

Multi-Path TCP (MPTCP) is a new evolution of TCP that enables a single MPTCP connection to use multiple TCP subflows transparently to applications. Each subflow runs independently allowing the connection to be maintained if endpoints change; essential in a dynamic network. Differentiating between congestion delay and delay due to handoffs is an important distinction overlooked by transport layer protocols. Protocol modifications are needed to alleviate handoff induced issues in a growing mobile culture. In this article, findings are presented on transport layer handoff issues in currently deployed networks. MPTCP as a potential solution to addressing handoff- and mobility-related service continuity issues is discussed. Finally, a handoff-aware cross-layer assisted MPTCP (CLA-MPTCP) congestion control algorithm is designed and evaluated.

Programming Languages

33 Toward Human-Computer Symbiosis: Developing a Domain-Specific Language for Mixed-Initiative Execution

Keeley Abbott

Mixed-initiative execution is becoming increasingly important for solving problems that neither humans nor machines could easily solve alone. When should the human or computer be responsible for managing the control flow though? How do we optimize these processes to utilize both machine and human computation to the best of their respective abilities?
The objective of my research is to understand the intersection between human computation and machine computation, and use that knowledge to improve models for mixed-initiative programming and execution to optimize the use of both actor and machine skill sets in a way that benefits the goals of both. As a part of achieving my objective, I am attempting to shift the way we think about mixed-initiative execution toward a continuum of control, where both human actor and machine “negotiate” management of the control flow in programs rather than being assigned explicit roles.

One potential application of the insights and results of our studies — along with a mixed-initiative execution domain-specific language — is in existing mixed-initiative programs such as interactive proof tools like Coq. This work supports end-user programmers by providing explicit advice as well as familiar language features to help guide them along a desired path while simultaneously providing mechanisms to support deviation from the prescribed path as well as mechanisms for recovery if or when the user selected deviation fails. In the specific case of interactive proof tools, this would take the form of providing tactic choices to the user while working toward proof goals.

### The Choice Calculus as a Versioning Representation

**Deepthi Satish Kumar and Spencer Hubbard**

For a software project under version control, the version control system (VCS) allows developers to apply reverse patches to undo changes that introduce bugs. However, this can lead to merge conflicts that must be resolved manually. We tried to revert commits using git commands and only 19.5% of reverts were successful. Also, analysis of responses from a user survey conducted by Git wiki shows that 8% of participants did not like operations like revert, merge which causes conflicts. In this paper, we explore using Choice Edit Model to represent version history that allows developers to apply reverse patches without having to manually resolve conflicts. Our tool which implements CEM, reverted 89.7% of commits without any manual conflict resolution.

### Software Engineering & Human-Computer Interactions

### A Syntax-Directed Keyboard Extension for Writing Source Code on Touchscreen Devices

**Islam Almusaly, Ronald Metoyer and Carlos Jensen**

As touchscreen mobile devices grow in popularity, it is inevitable that software developers will eventually want to write code on them. However, writing code on a soft (or virtual) keyboard is cumbersome due to the device size and lack of tactile feedback.
We present a soft syntax-directed keyboard extension to the QWERTY keyboard for Java program input on touchscreen devices and evaluate this keyboard with Java programmers.

Our results indicate that a programmer using the keyboard extension can input a Java program with fewer errors and using fewer keystrokes per character than when using a standard soft keyboard alone. In addition, programmers maintain an overall typing speed in words per minute that is equivalent to that on the standard soft keyboard alone. The keyboard extension was shown to be mentally, physically, and temporally less demanding than the standard soft keyboard alone when inputting a Java program.

The benefits are:
- 34.9 % reduction in Keystrokes Per Character (KSPC)
- Similar Word Per Minute (WPM) after 10 minute practice
- 37.4 % reduction in Total Error Rate (TER)
- Less mental, physical, and temporal demand

36 Longitudinal Statistical Modeling of Collaboration Graphs of Forked Open Source Software Development (FOSS) Projects

Amirhosein Azarbakht

Software development community splits are referred to as forking. Forking in FOSS development, either as a non-friendly split or a friendly divide, affects the community. Such effects have been studied, shedding light on how forking happens. However, most research on forking is post-hoc.

We focus on the seldom-studied run-up to forking events. We statistically model the longitudinal social collaboration graphs of software developers to study the evolution of social dynamics of FOSS communities. Our goal is to identify measures for influence and its shifts, unhealthy group dynamics (e.g. a simmering conflict), and early indicators of major events in the lifespan of a community.

We use an actor-oriented approach to statistically model the changes a community goes through in the run-up to a fork. The model represents tie formation, breakage, and maintenance. It uses several snapshots of the network as observed data to estimate the influence of several statistical effects on formation of the observed networks. As exact calculation is not trivial, we simulate the changes and estimate the model using a Markov Chain Monte Carlo approach.

When a well-fitting model is found, we test our hypothesis about model parameters, the contributing effects using t-tests and Multivariate Analysis of Variance between Multiple Groups, which enables us to make meaningful statements about whether the network dynamics depends on particular parameters/effects.
This approach may help predict formation of unhealthy dynamics, which gives communities a heads-up when they can still take action to ensure the sustainability of the project.

37 TDDViz: Using Software Changes to Understand Conformance to Test Driven Development

Michael Hilton

A bad software development process leads to wasted effort and inferior products. In order to improve a software process, it must be first understood. Our unique approach in this paper uses code and test changes to understand conformance to a process. As a case study, we use code and test changes to understand conformance to the Test Driven Development (TDD) process.

We designed and implemented TDDViz, a tool that supports developers in better understanding how they conform to TDD. TDDViz supports this understanding by providing novel visualizations of developers’ TDD process. We analyze these visualizations using the Cognitive Dimensions framework to discuss findings and design adjustments. To enable TDDViz’s visualizations, we developed a novel automatic inferencer that identifies the phases that make up the TDD process solely based on code and test changes.

We evaluate TDDViz using two complementary methods: a controlled experiment with 35 participants to evaluate the visualization, and a case study with 2601 TDD Sessions to evaluate the inference algorithm. The controlled experiment shows that, in comparison to existing visualizations, participants performed significantly better when using TDDViz to answer questions about code. In addition, the case study shows that the inferencing algorithm in TDDViz infers TDD phases with an accuracy of 87%.

38 Where Do Experts Look While Doing 3D Image Segmentation

Anahita Sanandaji, Cindy Grimm and Ruth West

3D image segmentation is a fundamental process in many scientific and medical applications. Automatic algorithms do exist, but there are many use cases where these algorithms fail. The gold standard is still manual segmentation or review. Unfortunately, even for an expert this is laborious, time consuming, and prone to errors. Existing 3D segmentation tools do not currently take into account human mental models and low-level perception tasks. Our goal is to improve the quality and efficiency of manual segmentation and review by analyzing how experts perform segmentation. As a preliminary step we conducted a field study with 8 experts capturing video and eye track data. We developed a novel coding scheme to analyze this data and verified that it successfully covers and quantifies the low-level actions, tasks and behaviors of experts during 3D image segmentation.
Electrical & Computer Engineering
Analog/Mixed-Signal

39 Single-photon Detector Array in Silicon Integrated Circuit Substrate for Radiation Detection

Spencer Leuenberger

The goal of this project is to develop and demonstrate a low-cost, single-chip radiation sensor for detection and dosimetry of ionizing radiation. Radiation detectors are often bulky, power hungry, or single use. This prevents low-cost, continuous monitoring, which is especially valuable for medical, industrial, and security applications. Our proposed solution will enable ubiquitous radiation sensing through integration with smart devices like phones or tablets. It consists of integrated single-photon detectors in a standard CMOS process, combined with post-fabricated scintillator materials to produce monolithic radiation sensors. The detector will be implemented as a single-photon avalanche diode (SPAD), which is a photodiode reverse biased beyond its breakdown to operate in “Geiger-Mode”. This has a binary output which enables easy counting. A 4mm² test chip has been designed in a 0.18µm standard CMOS process, consisting of 14 structural variants of SPADs with active device diameters ranging from 5µm to 100µm. They cover a wide range of diode junction and guard-ring structures and will be tested with off-chip circuits to characterize and evaluate their performance. In parallel, behavioral models of SPAD devices will be used to quantify energy and power consumption in radiation detection applications. Based on both experimental and simulation results, the best performing detector and circuit architectures will be integrated to produce a low-power, low-dark-count radiation sensor chip. A monolithic scintillator will be deposited on the chip surface to convert X-ray photons to near-visible light. The final packaged sensor platform will be tested and characterized as a self-contained, single-chip radiation dosimeter.

40 Efficient Design of Thermal Noise Limited Ring Amplifiers

Soumya Bose, Hyunkyu Ouh, Shaan Sengupta and Matthew L. Johnston

Amplifiers are key components of many high performance analog-to-digital converters (ADC). In particular, residue amplifiers in Pipeline ADCs enable the fabrication of robust medium-high resolution ADCs. However, these amplifiers are power hungry and increasingly hard to design in sub-micron technilogies. Recently Ring Amplifiers have emerged as a scalable amplification technique built on a three-stage uncompensated amplifier. The noise performance of a Ring Amplifiers has remained a unclarified due to its changing gain-bandwidth product during amplification. This work is a Pipeline ADC with Ring Amplifiers designed in 180 nanometer. It is purposely not limited by sampling noise in order to investigate the interdependence of the deadzone and noise performance of Ring Amplifiers. The measured ADC performance achieves 69 dB signal-to-noise-distortion ratio at 20 MHz sampling.
Decoding Hand Trajectories from Electrocorticographic Recording of Surface Local Field Potentials Using Nonlinear Models

Henrique Dantas and V John Mathews

Kalman filters have been used to decode neural signals and estimate hand kinematics in many studies. However, most prior work assumes a linear system model, an assumption that is almost certainly violated by neural systems. This paper presents a new approach to continuously estimating hand position and velocity from neural signals acquired via microelectrocorticographic (ECoG) grids placed over the arm and hand representations in the motor cortex. Experimental results show that a Kalman filter with a polynomial generative model relating the hand kinematics signals to the neural signals improves the mean-square tracking performance in the hand movements over traditional approaches employing a linear system model. In addition, the approach of this paper estimates the delay between the neural signals and the hand movement separately for each channel. This non-uniform delay estimation, performed using particle swarm optimization, substantially improves the decoding performance. Finally, this paper also presents a systematic method based on mutual information between the neural channels and the hand movements to identify the channels and the polynomial components of the generative model that contribute the most to the decoding process. These additions improved the correlation coefficient from 0.72 to 0.93.

Exploring the Mechanism of Adversarial Examples in Deep Learning

Xin Li and Fuxin Li

Deep neural network is the state of the art of recent machine learning technology. However, recently, Goodfellow et al discovered that, instead of non-linearity or overfitting, due to the linear nature of neural network, small but intentionally worst-case perturbations can be introduced to original image and, hence, cause misclassification. The mission of our work is to discover the difference introduced by the perturbation that can cause this misclassification at very deep level by analyzing and compare the properties of images before and after introducing the perturbation respectively. Currently, perturbations that cause the misclassification has been generated for images, and we use visualization method, deconvolution method and principal component analysis of features on different layers to reveal the peculiarity of the perturbed images and reveal the mechanism of the perturbation.
Dictionary Learning of Bird Vocalizations with Applications to Bioacoustics Monitoring

Zeyu You

In recent years, digital signal processing and machine learning techniques have been widely applied to the task of wildlife monitoring. Dictionary learning of spectrograms consists of detecting their fundamental spectra-temporal patterns and their associated activation signals. We propose an efficient convolutive dictionary learning approach for analyzing repetitive bioacoustics patterns from a collection of audio recordings. Our method is inspired by the convolutive non-negative matrix factorization (CNMF) model. The proposed approach relies on random projection for reduced computational complexity. As a consequence, the non-negativity requirement on the dictionary words is relaxed. Moreover, the proposed approach is well-suited for a collection of discontinuous spectrograms. We evaluate our approach on synthetic examples and on two real datasets consisting of multiple birds audio recordings. Results show that the learned dictionary is formed by the most relevant patterns in each dataset. Additionally, we apply the approach for spectrogram denoising in the presence of rain noise artifacts.

Communications and Signal Processing

The Required Number of RF Chains for a Hybrid Beamforming Design in Massive MIMO Systems

Mohammed Alarfaj

Massive multiple-input multiple-output (MIMO) systems have been shown to improve cellular service features through the use of a larger number of antenna arrays at each end of a wireless communication network. The wide bandwidth of mmWave can provide the desired gigabit per second data rates in cellular systems. However, the issue of high pathloss and signal attenuation in mmWave systems must be overcome. The small wavelength of mmWave frequencies is an advantage that can offer high beamforming gain to combat pathloss in a large number of antenna elements. Beamforming techniques such as precoding can improve the performance of mmWave cellular system. The type of beamforming that is used in traditional MIMO systems is the digital beamforming at the baseband. This beamforming technology is not practical for a large-scale MIMO system because the number of expensive and power consuming radio frequency chains (RF) will be large since we need RF chin for each antenna element. In the other hand, the hybrid digital and analog beamforming is a good solution to reduce the number of RF chains for massive MIMO systems. In this work, we discuss energy-saving technologies and methods in wireless networks, which are more reliable and able to maintain more users while keeping higher rates of data. We study the minimum number of
RF chains needed for a high performance MIMO system using a hybrid structure. RF chains management and antenna selection techniques that can result in significant power saving in MIMO system are highlighted.

### WiFo: A Hybrid WiFi and Free-Space Optical Communication System

**Yu-Jung Chu**

The popularity of wireless internet access and the huge development of handy devices, such as smart phones and tablets, enable people to get information instantaneously in recent years. And so WiFi becomes indispensable and important to people’s daily life nowadays. However, with the rapid growth in wireless communication usage, the better transmission quality is urgent needed, and then how to provide sufficient bandwidth for these mobile devices is becoming a critical problem. Fortunately, a complementary approach to increasing wireless capacity with minimal changes to the existing wireless technologies is guaranteed by recent remarkable advances in Free-Space Optical (FSO) technology, which does not interfere with RF transmission. We proposed a novel communication system, WiFo (WiFi Free-Space Optical), based on FSO and well integrated with existing WiFi networks. Specifically, WiFo resolved both capacity and mobility issues that the present WiFi and FSO technologies are facing. We will explain about the architecture of WiFo and mobility protocol in details and predict a potential transmission rate at 100Mbps.

### Distributed State Estimation of Electric Power System

**Jia Guo**

The modern electric power network is expected to be “smart.” It should be capable to deliver affordable electric power within the limits of transmission networks, greater security, more efficiency and self-healing. Hence, it is important to ensure the accuracy of measurements. State estimation (SE) algorithms have been researched for several decades at the transmission level. With an increasing interest in distribution level measurements, distributed state estimation (DSE) is one hot topic of the smart grid. Unlike the traditional SE at the transmission level, DSE lacks knowledge of real-time measurements. DSE algorithms are investigated based on different measurements. Due to the nonlinearity and large number of state variables of distribution power grid, the method of multi-are state estimation (MASE) is more suitable for the distribution state estimation with large amount of bus branches. Weighted least square (WLS), extended Kalman filter (EKF) and unscented Kalman filter are popular estimation methods currently. Also, a new type of Kalman filter called cubature Kalman filter (CKF) shows more advantage properties than others. Our research interested is applying the CKF into the MASE algorithm to make the DSE both accurate and efficiency.
Sparse Bad Data Identification for Power System with Multiple Measurement Vectors

Sharmin Kibria

Power system processes a massive collection of sensor data to make inferences about system operations and environments. Some portion of sensor data might be corrupted by bad data—originated from cyber attacks, sensor failure or calibration errors that may result in poor inferences, leading to poor decision making in system operations. Exploiting a sparse nature of bad data in power system measurements, feasibility of bad data identification and robust state estimation is studied. Under the practical assumption that potential locations of bad data stay the same during multiple measurement periods, bad data identification based on multiple measurement vectors is proposed. Our feasibility analysis shows that the maximum number of identifiable bad data can double compared to the identification based on a single measurement vector, if bad data values are diverse across different measurement periods. A convex optimization framework is proposed to identify bad data locations and calculate an accurate state estimate. The proposed state estimator is tested using IEEE 14-bus network and shown to outperform benchmark techniques based on a single measurement vector.

Cross-layer Security Mechanism for Wireless Communication Network

Yousef Qassim, Mario Magaña and Attila Yavuz

In all communication systems, the issues of authentication, confidentiality, and privacy are handled at the upper layers of the protocol stack using variation of private-key and public-key cryptosystems. Recently, various results emerged from the field of information theory, signal processing, and cryptography propose that there is much security can be gained by taking into considerations the imperfection of the physical layer when designing a secure system. When noise and fading are usually treated as impairments in wireless communications, information-theoretic results suggest that they can be used to hide messages from a potential eavesdropper or to authenticate devices without requiring an additional secret key. The security solutions at the physical layer can complement the traditional communications security mechanisms, or work as a standalone solution for system with strict energy requirements like the one found in sensor networks.

Secrecy codes are practical but limiting since they require information about the wiretap channel which is not practical assumption in reality. Also, they impose strict conditions on the main channel and do not adapt to varying channel conditions. Additionally, it is usually hard to prove strong or perfect secrecy for such codes.

Therefore, we propose a cross-layer security mechanism that uses a combination of practical code and traditional cryptographic techniques to provide best effort security. The cross-layer security mechanism will help to reduce the power consumption and the computational cost required in standard cryptographic systems.
Lamb Waves Mode Decomposition Using the Cross-Wigner-Ville Distribution

Ahmad Zoubi and V John Mathews

Guided Lamb waves have been widely studied for characterizing damage in structures. Lamb waves are characterized by their multimodal and dispersive propagation, which often complicate analysis. As a result, separating the mode components arriving at each acoustic emission sensor is a critical part of many guided wave Structural Health Monitoring (SHM) systems. This poster considers an active SHM system in which the monitored structure is excited with a linear chirp signal using piezoelectric actuators. The measured signals are analyzed to decompose the individual Lamb wave modes. The method employs the cross-Wigner-Ville Distribution (xWVD) between the excitation signal and the received sensor signal and assumes that overlapped modes in the time domain may be separable in the time-frequency domain to reconstruct the modes separately. The mode decomposition method uses a ridge extraction algorithm to identify the location of the individual modes in the time-frequency distribution and separate them using a rectangular window. Once the individual modes are separated in the time-frequency domain, the inverse xWVD is used to reconstruct the modes in the time domain. The method’s effectiveness to separate and reconstruct the first two fundamental Lamb wave modes (zeroth symmetric and zeroth anti-symmetric) is demonstrated in the poster through numerical simulations and experimental results on an aluminum plate.

Energy Systems

Robust Application of Multiple Power Sources and Systems Tool (RAMPS2-PF)

Ridwan Azam and Eduardo Cotilla-Sanchez

The integration of renewable sources has become one of the most important energy challenges worldwide. With ever-evolving grid and energy policies, one of the major issues experienced by power system operators today is maintaining reliability and efficiency of the assets on the grid. Current successful and robust power generation systems that have a significant penetration level of renewable energy sources, despite not having been optimized a priori, can be used to inform the advancement of modern power systems to accommodate the increasing demand for electricity. This research explores how an accurate and state-of-the-art computational model can be employed as part of an overarching power system’s optimization scheme that looks to inform the decision-making process for next-generation power supply systems. When fully developed, the Robust Application of Multiple Power Sources & Systems – Power Flow tool (RAMPS2-PF) will allow the user to define targets for a grid region to meet various limits (e.g., CO2 limits, water-use limits, etc.) and/or to make changes to the grid region’s configuration.
RAMP2-PF will determine the optimal power flow for an arbitrary equivalent system to study, approximating assets that have little influence for the questions asked by the user, while minimizing the cost of the targets and changes input by the user.

51 Investigating the Impact of Wave Energy Converters on Power System

Brandon Johnson and Eduardo Cotilla-Sanchez

Ocean wave energy is a developing industry with potential to be a big contributor to meeting the growing energy demand. There are several utility-scale projects that plan to establish a grid connection with hopes for more projects to follow. This progression dictates the need for comprehensive grid reliability studies that incorporate wave energy to ensure that reliability standards are met. This research leverages a system well-being analysis approach using a sequential Monte Carlo simulation to capture the inter-annual variability associated with sea conditions as well as protection information about the elements in a power system (i.e. generators and transmission lines).

The proposed method was applied to a modified version of the IEEE Reliability Test System 1996 (RTS-96) incorporating data for five years of sea conditions that were gathered from a buoy off the coast of Oregon and provided by the National Data Buoy Center (NDBC). Preliminary results suggest that initial levels of penetration for wave energy have little impact to the reliability of the power system.

52 Learning Scheme for Micro-grid Islanding and Reconnection

Carter Lassetter, Eduardo Cotilla-Sanchez and Jinsub Kim

The future electrical power systems tend toward smarter and greener technology. Micro-grids go hand in hand with the building of this smarter grid, helping to integrate renewable resources as well as aiding in the mitigation of cascading blackouts. The main benefit of micro-grids may also be their biggest detriment: A micro-grid may operate in an islanded or interconnection mode; the ability to optimally and safely reconnect a micro-grid is not well understood. With recent advances in power system engineering, the ability to compute adequately accurate models of the electrical grid in near real time is becoming more feasible. Phasor Measurement Units, or PMUs, are actively being installed throughout the electrical grid. The high-resolution measurements that PMUs capture will allow for better state estimation practices to be formulated. With several PMU data streams, machine learning techniques can be utilized on the plethora of data created to determine safe reconnections of micro-grids dynamically. Utilizing machine learning techniques for micro-grids to predict the state of a reconnect will also give way to future applications of artificial intelligence on the grid. A micro-grid armed with this powerful prediction method could dynamically learn from its own predictions for future operation.
Electrical Parameter Aggregation of Wave Energy Farms

Adam Mate and Eduardo Cotilla-Sanchez

Wave energy could play a significant role in the U.S. renewable energy portfolio and be a substantial source of the nation’s total energy need due to high power density and good forecastability. It is anticipated that – similarly to offshore wind farms – wave energy converters (WECs) will be implemented in a farm layout – that may consist of hundreds of WECs – in order to improve economic feasibility and power quality.

With development and spread of WECs and farms, the penetration level of wave energy in the power grid is expected to increase and seriously impact the operation and control of the system. Thus the need for adequate wave farm models enabling system operators to carry out dynamic simulations in order to investigate the effect of these farms on the stability and reliability of the grid under varying operating conditions.

A detailed model of each individual WEC in the farm would be complex and computationally intensive for large-scale simulation. This research investigates the aggregation of electrical parameters for an arbitrary wave farm into a reduced, equivalent generator model. These models could be included in power system simulation software in order to represent the behavior of wave farms, evaluate their impact in grid reliability, and improve the planning and exploitation of electrical networks with large penetration of renewable resources.

A Real-Time Load Composition Scheme for Advanced Microgrid Protection

Benjamin McCamish, Janhavi Kulkarni, Ziwei Ke, Scott Harpool, Chen Huo, Ted Brekken, Eduardo Cotilla-Sanchez, Juilia Zhang, Annette von Jouanne and Alex Yokochi

As the power grid technology is continuously developed, it is becoming more vital to have consistent and accurate information about the status of the grid. Current SCADA technology typically provides measurements every two to five seconds. Utilizing Phasor Measurement Units (PMUs), measurements can be collect at 60Hz consistently, with the option of much higher sampling when predetermined conditions are met. This pilot project, done in conjunction with the Bonneville Power Administration (BPA), uses PMUs to observe a limited number of buses on the power grid (for example, 5 buses on a 100 bus system) to determine the estimated percentage load composition (residential, commercial, and industrial). For this estimation, Singular Value Decomposition (SVD) is used to match the observed voltage and current values to a library of solved power flows. To verify the correct operation of the model, the Oregon State University (OSU) power grid is being used as a test bed. A Graphic User Interface has been designed to improve situational awareness for grid operators. Since each of the three aspects of the load composition have their own characteristic patterns, knowing this information assists grid operators in both short-term generation planning and identifying if a potential problem is developing on the grid, as the library of solved power flows includes fault conditions. Especially in microgrids, proper usage of this information can lead to better protection schemes.
Evaluating Power Take-off (PTO) Forces through Active Instrumentation in Small-scale Wave Energy Converter (WEC) Model Testing

Asher Simmons, Pedro Lomonaco, Bret Bosma, Kelley Ruehl and Ted Brekken

Governmental agencies, such as the United States Department of Energy (USDOE), provide guidance to wave energy converter (WEC) designers in the form of a technology development methodology that is reinforced through funding agreements. However, the recommended approach undervalues the early stage of the power take-off (PTO) sub-system. Early evaluation of PTO sub-systems complicated, as the rules that enable small-scale hydrodynamic characterization do not apply to the PTO physics. Small-scale testing guidelines recommend the use of a passive damper to represent the PTO, with the full PTO characterization incorporated significantly later during the large-scale testing efforts. Developers that follow these guidelines effectively ignore the PTO system impacts on the WEC system, which can result in critical architectural choices that ultimately complicate or prevent commercial viability. However, the forces that feed into the PTO physics can be well understood at small-scales with the appropriate instrumentation. This research explores the benefits that understanding and analyzing small-scale PTO sub-system forces bring to technology. Results from experiments using multiple instruments, measurement locations, and experiment setup from a model-scale PTO are explored. The data analysis will focus on understanding how the gathered data is used to make critical WEC system architecture changes early in the design cycle. After exploring the utility of the data, a second analysis using data gathered from WEC developers will assess the cost/benefit tradeoffs associated with a methodology change. Finally, these analyses will be used to form conclusions and recommendations regarding the current paradigm.

Materials and Devices

Plasmonic Nanostructures for Biosensing Applications

Vishvas Chalishazar

We demonstrate a sensitive biosensor based on a plasmonic metal composite nanostructure. The device can be fabricated and duplicated with ease using a novel nano printing technology which allows precise transfer of metal nanostructures without complicated lithography processes. The design featured by its unique material composition and sub-wavelength structures maximizes the exposure of localized plasmonic hot spots to analyte and, therefore, enhances the refractive-index sensitivity with a plasmon resonance peak in visible range. A refractive-index-sensitivity of ~502 nm/RIU and a figure-of-merit of ~30.1 RIU-1 has been achieved. The new sensing technology will find applications in medical diagnostics and environmental monitoring.
Investigation of Ultra-thin Amorphous In-Ga-Zn-O Thin-Film Transistors

Tsung-Han Chiang, Bao Yeh and John F. Wager

The impact of decreasing channel layer thickness on radio-frequency (RF) sputtered amorphous indium gallium zinc oxide (a-IGZO) thin-film transistors (TFTs) electrical performance is investigated through the evaluation of drain current versus gate voltage (ID-VG) transfer curves. For a fixed set of process parameters, it is found that the turn-on voltage, VON (off drain current, IDOFF) increases (decreases) with decreasing a-IGZO channel layer thickness (h) for h < 11 nm. The VON-h trend is attributed to a large density (3.5×10^{12} cm^{-2}) of backside surface acceptor-like traps and an enhanced density (3×10^{18} cm^{-3}) of donor-like trap states within the upper ~11 nm from the backside surface. The precipitous decrease observed in IDOFF-h when h < 11 nm is ascribed to backside surface acceptor-like traps and the closer physical proximity of the backside surface when the channel layer is ultra-thin. Alteration of the sputtering process gas ratio of Ar/O_2 from 9/1 to 10/0 and reduction of the anneal temperature from 400 to 150ºC results in improved transistor performance for a h = 5 nm a-IGZO TFT, characterized by VON = 0 V, field-effect mobility of \( \mu_{FE} = 9 \text{ cm}^2\text{V}^{-1}\text{s}^{-1} \), subthreshold swing of S = 90 mV/dec, and drain current on-to-off ratio of IDOFF = 2.0×10^5.

Plasmonic Integrated Circuits with High Efficiency Nano-Antenna Couplers

Qian Gao, Fanghui Ren and Alan X. Wang

Plasmonic waveguides have caught researchers attention due to its highly confinement of light beyond the diffraction limit. However, the challenge is coupling the light from free space directly into a sub-wavelength waveguide. To overcome this challenge, nanocouplers are needed as a focusing component and mode converter. Recently, nanoantennas have been used as nanocouplers for their ultra compact size, easy fabrication and highly efficient conversion radiation from free space into plasmonic waveguides. The role of nanoantenna is capturing free radiation and converts into accepting waveguide modes. In this paper we demonstrate direct optical coupling from an optical fiber into plasmonic integrated circuit at 1.55 μm wavelength using plasmonic nanoantennas. The plasmonic integrated circuits consist of slot waveguides with single-chip integrated three types of ultra-compact nanoantenna couplers, which are dipole nanoantenna, Yagi–Uda nanoantenna and serially connected dipole nanoantenna. The design of radiowave nanoantenna is different than traditional antenna because at optical frequency the penetration of wave into metal is non-negligible. Our design of nanoantennas is based on fullwave 3D FDTD simulations. Far field emission patterns of designed antennas are also presented in this letter. Light at 1.55 μm is directly coupled into the plasmonic slot waveguide from an optical fiber with high numerical aperture. And the couple-out efficiencies are experimentally measured and compared. Moreover, the inverse proportional relationship between incident light spot size and couple-in efficiency is both theoretically and experimentally studied. As incident light spot size increases with constant total incident power, couple-in efficiency will decrease due to decreasing of incident power density.
Surface Plasmon Enhanced Photoluminescence of Quantum Dots based on Open-ring Nanostructure Array

Akash Kannegulla and Li-Jing Cheng

Enhanced photoluminescence (PL) of quantum dots (QD) in visible range using plasmonic nanostructures has potential to advance several photonic applications. The enhancement effect is, however, limited by the light coupling efficiency to the nanostructures. Here we demonstrate experimentally a new open-ring nanostructure (ORN) array 100 nm engraved into a 200 nm thick silver thin film to maximize light absorption and, hence, PL enhancement at a broadband spectral range. The structure is different from the traditional isolated or through-hole split-ring structures. Theoretical calculations based on FDTD method show that the absorption peak wavelength can be adjusted by their period and dimension. A broadband absorption of about 60% was measured at the peak wavelength of 550 nm. The emission spectrum of CdSe/ZnS core-shell quantum dots was chosen to match the absorption band of the ORN array to enhance its PL. The engraved silver ORN array was fabricated on a silver thin film deposited on a silicon substrate using focus ion beam (FIB) patterning. The device was characterized by using a thin layer of QD water dispersion formed between the ORN substrate and a cover glass. The experimental results show the enhanced PL for the QD with emission spectrum overlapping the absorption band of ORN substrate and quantum efficiency increases from 50% to 70%. The ORN silver substrate with high absorption over a broadband spectrum enables the PL enhancement and will benefit applications in biosensing, wavelength tunable filters, and imaging.

High Resolution Magnetic Particle Imaging

Philip Lenox, Colby Whittaker, Albrecht Jander and Pallavi Dhagat

This work seeks to develop a new imaging system for medical diagnostics and biological studies. The system utilizes magnetic particle imaging (MPI), an imaging technique which uses magnetic nanoparticle as tracers. This approach has received interest due to benefits in resolution, speed and cost compared to standard methods such as nuclear magnetic resonance imaging (MRI). To date, most MPI research has been oriented toward decreasing measurement time and increasing measurement volume for whole-body diagnostic scans, leaving the limits of high resolution (>100 µm or less) MPI, largely unexplored.

A major challenge in the field of cellular biology and medicine has been the inability to observe subdermal cellular processes without significantly disturbing the cell’s environment. Light based microscopy, a mainstay of biological and medical imaging community, is limited by the diffusion and absorption of light as it penetrates the sample. Since magnetic fields are not scattered by most biological samples, magnetic imaging does not encounter these challenges, making it highly attractive as a biological imaging technique.

In this effort, a high-resolution system suitable for transdermal imaging is being developed. The poster will present details of the design and characterization of the system, as well as the
first high-resolution MPI images. While not yet achieving subcellular imaging, the continued development of MPI scanners will enable observation of sub cellular features and processes in live tissue and advance existing knowledge of cell biology. This has applications including in understanding processes involved in cancer metastasis.

61 Controlled Laser Ablation of Titanium Clad Polyimide using 355nm Nd:YAG Laser for Glucose Sensing Applications

Kamesh S. S. Mullapudi, Robert S. Cargill, John F. Conley Jr. and W. Kenneth Ward

Advances in implantable glucose sensors has made continuous glucose monitoring (CGM) for type I diabetes patients, more accurate and affordable. However, they are known to cause patient discomfort, a problem which has been overcome in recent times through the usage of flexible substrates. The bio-compatibility of titanium and durability of polyimide has made the use of titanium-clad polyimide flexible substrates a topic of growing interest in the field of CGM. However, many processes involving these substrates still employ a wet etch to pattern sensors, resulting in hydrogen embrittlement of titanium and undercutting of high aspect-ratio traces, which compromise the integrity and lifetime of sensors. Laser direct-write patterning (LDP) as a manufacturing technique for processing flexible substrates is prevalent for copper-clad polyimide, the work horse material for the PCB industry. Physical removal of titanium using LDP can help circumvent these issues. However, poor optical absorptivity of titanium and the task of protecting the underlying thin adhesive and polyimide layers during this process presents a significant challenge. We demonstrate a process to achieve controlled laser ablation of titanium over polyimide and a reliable and repeatable way to pattern titanium clad polyimides with feature spacing as close as 30µm, using a ubiquitous 355nm Nd:YAG laser. Electrical isolation was achieved over large pattern areas and LDP fabricated sensors showed superior durability compared to their wet-etched counterparts. This novel patterning technique demonstrates enormous potential in improving reliability of sensors, reducing the cost per sensor, enabling rapid prototyping and can benefit many applications related to bio-sensing.

62 Atomic Layer Deposition of Two Dimensional MoS2 on 150 mm Substrates

A. Valdivia, D. J. Tweet and J.F. Conley, Jr.

Two-dimensional transition metal dichalcogenides (TMD) that exhibit properties distinct from their bulk forms have recently come under intense investigation as building blocks for van der Waals heterostructure electronics. One of the most promising TMDs is molybdenum disulphide (MoS2), which transitions from an indirect bandgap (1.3eV) in its bulk state to a direct band gap (1.8eV) in its single layer state making it suitable for optoelectronic and transistor applications. However, the synthesis of high quality single layer MoS2 on large substrates remains challenging. A natural technique for the synthesis of 2D materials is atomic layer deposition (ALD). ALD is a CVD technique in which reactants are introduced to the chamber sequentially
rather than simultaneously. Sequential self-limiting surface reactions allow for precise thickness control, high conformality, and scalability to large surface areas.

We demonstrate low temperature ALD of monolayer to few layer MoS2 uniformly across 150 mm diameter SiO2/Si and quartz substrates. Purge separated cycles of MoCl5 and H2S precursors were used at reactor temperatures of up to 475 °C. Raman scattering studies show clearly the in-plane (E12g) and out-of-plane (A1g) modes of MoS2. The separation of the E12g and A1g peaks is shown to be a function of the number of ALD cycles, shifting closer together with fewer layers. X-ray photoelectron spectroscopy (XPS) indicates that stoichiometry is improved by post deposition annealing in a sulfur ambient. High resolution transmission microscopy (TEM) confirmed the atomic spacing of monolayer MoS2 thin films.

Comprehensive Depletion-Mode Modeling of Oxide Thin-Film Transistors

Fan Zhou and J. F. Wager

The primary focus of this thesis is modifying the comprehensive depletion-mode model and extending its applicability to p-channel thin-film transistor (TFT) behavior and subthreshold (subpinchoff) operation. The comprehensive depletion-mode model accurately describes depletion-mode TFT behavior and establishes a set of equations, different from those obtained from square-law theory, which can be used for carrier mobility extraction.

In the modified comprehensive depletion-mode model, interface mobility (μ\text{INTERFACE}) and bulk mobility (μ\text{BULK}) are distinguished. Simulation results reveal that when square-law theory mobility extraction equations are used to assess depletion-mode TFTs, the estimated interface mobility is often overestimated. In addition, the carrier concentration of a thin channel layer can be estimated from an accurate fitting of measured depletion-mode TFT current-voltage characteristics curves using the comprehensive depletion-mode model.

Networking and Computer Systems

REPLISOM: Disciplined Tiny Memory Replication for Massive IoT Devices in LTE Edge Cloud

S. Abdelwahab and B. Hamdaoui

Augmenting the LTE evolved NodeB with cloud resources offers a low latency, resilient, and LTE-aware environment for offloading the Internet of Things (IoT) services and applications. By means of devices memory replication, the IoT applications deployed at an LTE integrated edge cloud can scale its computing and storage requirements to support different resource-intensive service offerings. Despite this potential, the massive number of IoT devices limits the
LTE edge cloud responsiveness as the LTE radio interface becomes the major bottleneck given the unscalability of its uplink access and data transfer procedures to support a large number of devices that simultaneously replicate their memory objects with the LTE edge cloud. We propose REPLISOM; an LTE-aware edge cloud architecture and an LTE-optimized memory replication protocol which relaxes the LTE bottlenecks by a delay and radio resource efficient memory replication protocol based on the Device-to-Device communication technology and the sparse recovery in the theory of compressed sampling. REPLISOM effectively schedules the memory replication occasions to resolve contentions for the radio resources as a large number of devices simultaneously transmit their memory replicas. Our analysis and numerical evaluation suggest that this system has significant potential in reducing the delay, energy consumption, and cost for cloud offloading of IoT applications given the massive number of devices with tiny memory sizes.

RF and Microwaves

A Lumped Element Circuit Model for Monolithic Transformers in Silicon-based RFICs

Dyuti Sengupta

Monolithic transformers have a wide spectrum of applications in Radio Frequency Integrated Circuit (RFIC) designs. The first pass success of circuits like Low Noise Amplifiers (LNA), Voltage Controlled Oscillators (VCO) and mixers need an accurate transformer model, effectively capturing all the pertinent loss mechanisms. Among other effects, accounting for the proximity and the substrate eddy currents is of prime importance to accurately estimate the power consumption in the transformer.

Proximity effect can be modeled by a frequency dependent mutual resistance. Previous models have implemented this using controlled voltage and current sources. Presence of these controlled elements can lead to convergence issues in circuit simulations. We present a lumped-element equivalent circuit model for on-chip monolithic transformers comprising of only ideal R, L, C elements and an ideal transformer. The novelty of the work is in the manner in which the magnetic field interactions are captured using a T-network topology with Foster-I canonical representations. As this design abstains from the use of any controlled source, it not only enhances robustness and reliability, but also resolves simulator convergence issues. Model passivity is guaranteed by the topology and positive circuit elements.

Available two-port measurement data was used to calibrate the four-port S-parameter data obtained by full-wave electromagnetic simulation using HFSS. The circuit element values were then extracted using available optimization techniques. Our modeling approach exhibits good agreement with the simulation data and measurements over a broad frequency range of 0.1 GHz – 10 GHz.
Scalable Passive Modeling: Bridging the Gap between Physical Layout and Electrical Circuitry

Lei Zheng

In radio frequency and mm-wave integrated circuits, on-chip passive circuits, such as transmission lines, inductors and transformers, are implemented through multi-layer metal wiring with various dimensions and shapes. To enable the system-level simulation for circuit designers, it is crucial to accurately map the physical dimensions and material properties to the electrical characteristics (scalable models). The challenges of scalable and compact modeling include the large number of physical parameters (i.e., geometry parameters and material properties) and making the models applicable for a broad frequency range. To address these problems, we have developed a systematic approach based on both electromagnetic and network theory to reduce the complexity of the problem and make the development of scalable and compact models feasible. We have verified our models through both rigorous electromagnetic simulation and on-wafer measurements of fabricated test chips.

School of Mechanical, Industrial and Manufacturing Engineering

Industrial Engineering

Integrated Intermodal Logistics Network Design

Mohammad Ghane-Ezabadi and Hector Vergara

In intermodal freight transportation, at least two different modes of transportation are used to move freight that is in the same transportation unit (e.g., a shipping container) from origin to destination. An important strategic planning decision related to intermodal freight transportation is the design of an intermodal logistics network. In this research, the hub location problem was integrated with the freight load routing and the transportation mode selection problems in a single mathematical model to design logistics networks that are optimal under several limitations and more applicable in practice. Two different mathematical formulations were developed for this problem; an arc based formulation and a route based formulation. The arc based formulation proved to be intractable for large size problem instances and a heuristic method that combines both a genetic algorithm and the shortest path algorithm was developed to solve the problem in reasonable times. Alternatively, composite variables were used to improve tractability given a route based formulation. A decomposition-based search algorithm in which a master problem uses optimal load
routes and transportation modes obtained by sub-problems to find optimal intermodal terminal locations was developed. Computational results show that this approach is able to obtain optimal solutions for non-trivial problem instances of up to 150 nodes in reasonable computational times. A Bender’s decomposition algorithm was implemented to solve real size instances of the IILND problem. The original Bender’s decomposition algorithm was improved using several accelerating techniques.

2 Success Factors to Overcome the Challenges Faced By Quality Directors When Implementing Lean in Healthcare

Bhuvanamalini Karaikudi Ramesh and Chinweike Eseonu

Lean thinking is not a manufacturing tactic or a cost reduction system, but a management strategy which can be widely used in all sectors including healthcare. Although lean thinking is applied by several organizations, various studies have shown that more than half of the intended actions in lean implementation are never executed or partially implemented. Various studies have documented the need for the transition of single-loop to double-loop learning behavior to successfully implement lean culture in the organization. The literature also documents that this transition can be affected by lack of communication, poor management support and lack of goal clarity across the organization. The aim of the research is to validate the challenges that are identified in the literature and to identify the success factors to overcome these challenges faced by the quality directors in successfully developing a transition behavior to implement lean in the system. This research is focused on the healthcare industry, where the system needs a great deal of flexibility to quickly respond to the opportunities.

3 The Rapid Lead-Time "Blank" Factory

Harsha Malshe, Brandon Massoni, Karl Haapala, Matt Campbell and David Kim

Design and manufacturing engineers are operating in a locally optimal space of solutions, limited by existing manufacturing technologies. New manufacturing advancements, such as additive manufacturing, are a potential solution to reduce cost by improving material utilization, reducing lead time, and expanding design freedom. Currently, however, there is a lack of knowledge on how to beneficially apply these manufacturing advancements. Therefore, a support tool has been developed to generate alternative manufacturing plans and evaluate their costs. This support tool includes many traditional manufacturing processes, as well as, new manufacturing advancements, such as friction welding and additive manufacturing. The goal is to assist engineers in applying new manufacturing processes efficiently to decrease material utilization.
Multi-criteria Decision Making for Sustainable Bio-Oil Production using a Mixed Supply Chain

Amin Mirkouei, Karl R. Haapala, John Sessions and Ganti S. Murthy

Growing awareness and concern within society over the use of and reliance on fossil fuels has stimulated research efforts in identifying, developing, and selecting alternative energy sources and energy technologies. Bioenergy represents a promising replacement for conventional energy, due to its reduced environmental impacts and broad applicability. Sustainable energy challenges, however, require innovative manufacturing technologies and practices to mitigate energy and material consumption. This research aims to facilitate sustainable production of bioenergy from forest biomass and to promote deployment of novel processing equipment, such as transportable bio-refineries. The study integrates knowledge from the renewable energy production and supply chain management disciplines to evaluate economic targets of bioenergy production with the use of the multi-criteria decision making approach. The presented approach includes qualitative and quantitative methods to address the existing challenges and gaps in the bioenergy manufacturing system. The qualitative method employs decision tree analysis to classify the potential biomass harvesting sites by considering biomass quality and availability. The quantitative method proposes a mathematical model to optimize upstream and midstream biomass-to-bioenergy supply chain cost using mixed bio-refinery modes (transportable and fixed) and transportation pathways (truck–truck and truck–tanker). While transportable bio-refineries are shown to reduce biomass-to-bioenergy supply chain costs, manufacturing and deployment of the transportable bio-refineries is limited due to interoperability challenges of undeveloped mixed-mode and -pathway bioenergy supply chains and quality uncertainty. A simulated case for northwest Oregon, USA is applied to verify the proposed decision making approach.

Manifestation of Human Error in Helicopter Cockpits

Katarina Morowsky and Kenneth H. Funk II

Helicopters are essential for completion of critical missions that are impossible for fixed wing aircraft since they can operate around rough terrain and require minimal ground infrastructure, yet they are thought to be unsafe by the general public. As in many complex environments, human error is thought to be at least partially responsible for seventy to eighty percent of helicopter incidents and accidents. This ongoing research seeks to identify underlying causes of human error that lead to helicopter accidents through the utilization of task analysis models of single and dual pilot helicopter operations across various mission types and two accident report analysis studies. The initial accident report analysis study uses three existing human error frameworks on a stratified subset of helicopter accident reports to identify which framework is best suited for accident analysis within the helicopter domain based on comprehensiveness, reliability, application time, and user confidence. The second accident report analysis study will apply a single framework, determined from the first analysis, to the full set of civilian helicopter accidents in the United States from 2008 to 2014. The second analysis will be used to determine the errors that exist across and within specific helicopter mission sets. By understanding the human errors contributing to helicopter
accidents, researchers and industry are better equipped to design and implement methods to reduce future accidents at lower costs to helicopter operators.

**6 An Evolutionary Approach for a Multi-Objective Location–Inventory Problem for Spare Parts with Time-Based Service Levels**

Prasanna Venkatesh Rajaraman and Hector Vergara

In Spare Parts Logistics (SPL), delivering parts within a time window is as important as reducing cost since customers will be significantly affected by extended equipment downtime. The important decisions that influence cost and service level of a SPL system are facility location-allocation and inventory stocking level decisions. Designing an optimal network will help the manufacturer to offer its customers a quality service at relatively low cost. These decisions have to be integrated together, as making them individually will lead to sub-optimal solutions. However, integrating location-inventory decisions and considering multiple objectives further increase the complexity of this problem. This research provides an approach to model and efficiently solve this problem. The problem is formulated as a stochastic nonlinear multi-objective location–inventory model. The goal is to determine the number and location of warehouses, the allocation of customer demand to warehouses, and the safety stock for parts. The two objectives are: first, minimize the total cost, and second, maximize a time based service level. A non-dominated sorting genetic algorithm (NSGA-II) is developed and used for solving this model. Pareto optimal solutions obtained will be helpful for decision makers to perform trade-off analysis between the two objectives. To the best of our knowledge, the proposed model is the first to incorporate multiple objectives in the formulation of the location-inventory problem with time based service levels in SPL.

**7 Impact of RFID Technology on Replenishment Decisions for Multi-Echelon Supply Chains**

Myrna Leticia Cavazos Sanchez, David Porter and Hector Vergara

This research attempts to develop a better understanding of how radio frequency identification (RFID) technology can enable more effective replenishment decisions in multi-echelon supply chains and proposes a multi-echelon inventory optimization (MEIO) model for decision support. Prior research to leverage real-time RFID data to improve supply chain performance has been conducted using scenarios where RFID is typically considered a perfect technology. Also, most studies are limited to linear supply chains where every echelon has only one participant, and models do not integrate dynamic analysis. To overcome these challenges, several critical supply chain performance (SCP) factors that play a critical role in supply chain performance have been identified. These significant SCP factors will be used to develop a MEIO model for two different supply chain designs with the objective of minimizing cost and achieving a desired fill rate for each supply chain echelon. Particular attention will be given to exploring how the information supplied by RFID technology can be used to improve replenishment decisions at different levels of the two multi-echelon supply chain designs.
Novel Solution Deposition of Anti-Reflective Films Using a Foam-Core Applicator

Venkata Rajesh Saranam and Brian Paul

Anti-reflective coatings (ARCs) on the upward-facing surfaces of solar cell cover glass are known to increase the power output from photovoltaic cells by up to four percent. Most solar cell ARCs are applied in glass factories with heat treatment conditions requiring up to 700°C. More recently, ARCs have been developed that are “sun-curable” in the field at temperatures down to 50°C providing the opportunity to increase the power output of in-field solar cells that either do not have ARCs or have ARCs that have worn off. Challenges include the ability to uniformly deposit 125 nm films in the field from solution over large areas at cover glass production rates. The need to deposit films in the field eliminates more conventional methods for scaling up deposition such as roll coating, slot die coating or even dip coating. In this poster, we introduce a novel foam core brush applicator for solution depositing wet films capable of producing high performance ARCs through sun drying and curing. Results of a 2-k parametric study will be presented identifying the key process parameters and their effect on the optical performance of the films. Based on these results, preliminary efforts are made to explain the physics underlying this process including models that can predict the impact of process parameters on optical performance.

Hybrid Flow Shop Batching and Scheduling with a Bi-criteria Objective

Omid Shahvari and Logen Logendran

This research addresses the hybrid-flow shop batching and scheduling problem where family setup times are sequence-dependent and the objective is to simultaneously minimize a linear combination of the total-weighted completion time and total-weighted tardiness. The former implicitly minimizes work-in-process inventory, and the latter maximizes the customers’ service level. To improve the operational efficiency, it disregards group technology assumptions by allowing for the possibility of splitting pre-determined groups of jobs into inconsistent batches in each stage. Since the problem is strongly NP-hard, a meta-heuristic algorithm based upon tabu search is developed at three levels, which move back and forth between batching and scheduling phases. The algorithm incorporates tabu search into the framework of path-relinking to exploit information on good solutions. The tabu search/path-relinking algorithm comprises several distinguishing features, including two relinking procedures to effectively construct paths, and a stage-based improvement procedure to consider the move interdependency. The initial solution-finding mechanism is implemented to trigger the search into the initial population. A restricted version of the original MILP model is developed to enhance computational efficiency. Comparing the optimal solutions of the restricted MILP model found by CPLEX and the tabu search/path-relinking algorithm shows that the developed algorithm could find solutions, at least as good as CPLEX but in incredibly shorter computational time. A data generation mechanism has been developed in a way that it fairly reflects real-industry requirements including dynamic machine availability times, dynamic job release times, machine eligibility and machine capability for processing jobs, and job skipping.
Materials Science

10 Role of Alloying Elements on Thermal Stability of Duplex Stainless Steel

David Garfinkel, Jonathan D. Poplawsky, Wei Guo, George A. Young and Julie D. Tucker

Thermal embrittlement caused by phase transformation in the temperature range of 204°C - 538°C limits the service temperature of duplex stainless steels. The primary source of embrittlement is $\alpha - \alpha'$ phase separation, however, other less common precipitates, G-phase and $\varepsilon$-phase, may also contribute to thermal instability. The rate of embrittlement varies markedly among commercial alloys. Specifically, alloys with high concentrations of Cr, Ni, Mn, and Mo are thought to demonstrate an enhanced rate of thermal embrittlement. The present study investigates a set of standard and lean grade wrought (2003, 2101, and 2205) and weld (2209 and 2101) alloys in order to enhance the understanding of how various alloying elements affect thermal embrittlement. Samples were aged between 260°C and 427°C for up to 10,000 hours and the embrittlement was assessed via microhardness, nanoindentation, and Charpy impact testing. Furthermore, the microstructural evolution was characterized by scanning electron microscopy, x-ray diffraction, and atom probe tomography. The results show that alloying plays a significant role in the thermal embrittlement of duplex stainless steels. Lean grade alloy 2003 experienced the least phase transformation and embrittlement of all alloys tested, while the weld alloys, 2209 and 2101, experienced the most significant phase separation.

11 Surface Mount Manufacturing Development for Membrane-based Microchannel Arrays

Steven Kawula

The packaging of membranes adjacent to microchannels is of growing interest for various separations applications such as the purification of nanomaterials made by point-of-use synthesis, the processing of natural gas, and fuel cell development. Recently, our group has partnered with the Fronk Group at Oregon State University (OSU) to consider the use of microchannel technology in the development of a new type of membrane-based microchannel array which aims to reduce the cost of producing membrane-based microchannel exchangers. In this project, our objective is to develop a manufacturing process capable of meeting manufacturing cost targets established by industry partners while enabling high separations efficiencies. Efforts are being made to investigate the use of surface mount adhesives to produce the microchannel array by directly applying the adhesive to the surface of the separation membrane. Results to date include the use of mechanical modeling to generate preliminary device design specifications under anticipated pressure differentials, the identification of applicable adhesives, and the use of cost models to evaluate the economic feasibility of full scale production. Future work includes investigation into the deposition and mechanical characteristics of the adhesives, followed by the development and testing of a full-scale prototype to verify our manufacturing process.
Chemical Solution Deposition of Bi-based Ternary Compositions and their Role in Developing Pb-free Piezoelectric Thin Films

Ashley D. Mason, Joel Walenza-Slabe and Brady J. Gibbons

Piezoelectric materials convert mechanical strain into a dielectric displacement, as well as the converse, allowing these materials to be used as sensors, actuators, and transducers. Currently, lead zirconate titanate (PZT) is the primary material used in these applications. Due to environmental toxicity and safety concerns associated with Pb, development of alternative materials is necessary. Bi-based systems are an attractive area of research in both bulk ceramic and thin film form factors, partially because of the similarities in the electronic structure of Bi and Pb. For thin films, chemical solution deposition is a relatively low-cost technique which can be used to study potential alternative materials as a proof-of-concept and a starting point for other deposition techniques.

This work focuses on the fundamental structure-process-property relationships within Bi-based thin film systems; more specifically how precursor solutions and deposition parameters impact the thin film structure, and ultimately their ferroelectric and piezoelectric properties. Primary analytical techniques used for these studies are: x-ray diffraction (XRD) and atomic force microscopy (AFM) for structure, traditional hysteresis, loss, and dielectric constant measurements, and piezoresponse force microscopy (PFM) and double beam laser interferometry (DBLI) for piezoelectric measurements on the micro- and macroscopic scale. Phase pure BNT-BKT-BZT thin films produced slim polarization-electric field (P-E) loops with small values of both remanent polarization and coercive field. These samples are able to withstand fields over 400 kV/cm and the dielectric loss is approximately 5%. Ongoing work to decrease dielectric loss, improve hysteretic behavior at higher fields, and further characterization is presented.

Temperature Stable Dielectrics Based on BaTiO3-Bi(Zn1/2Ti1/2)O3-BiScO3-NaNbO3

Connor McCue and David Cann

High performance dielectric materials are needed for high power SiC- or GaN-based electronics which combine the best features of high energy density, low dielectric loss and high reliability. To achieve ceramic capacitors with temperature-stable permittivity characteristics, lead-free perovskite ceramic solid solutions were investigated with the aim of achieving a temperature coefficient of relative permittivity near zero. Samples were synthesized from oxide and carbonate precursors and calcined in air at temperatures ranging from 700 to 900°C and sintered in air at temperatures ranging from 1050 to 1150°C. This work involves the synthesis and characterization of compositions based on the compound BaTiO3-Bi(Zn1/2Ti1/2)O3 along with additives BiScO3 and NaNbO3. These materials have excellent temperature stable dielectric properties due to a relaxor dielectric mechanism which is derived from cation disorder. Initial results focused on the BaTiO3-Bi(Zn1/2Ti1/2)O3-BiScO3-NaNbO3 quaternary system show a minimal temperature
dependence with a temperature coefficient of permittivity (TCE) as low as -387 ppm/°C and a transition temperature near 0°C. Future work involves compositional modifications aimed at increasing the relative permittivity which would allow device miniaturization as well characterization of the dielectric properties at high electric fields (E > 100 kV/cm).

14 Role of Stoichiometry on Material Degradation in Nuclear Applications

Fei Teng and Julie Tucker

Mechanical property degradation due to isothermal ageing is of potential concern for alloys based on the Ni–Cr binary system (e.g., Inconel 690, 625), particularly in nuclear power applications where component lifetimes can exceed 40 years. In the present research, the disorder–order phase transformation, which is the primary mechanism of embrittlement during ageing, has been studied in Ni–Cr model alloys with varying stoichiometry. The samples have been isothermally aged up to 10,000 hours at three different temperatures to understand the kinetics of the phase transformation. Samples are periodically evaluated for changes in lattice parameter via X-ray Diffraction (XRD) and changes in hardness via nanoindentation. Select samples are analyzed via Transmission electron microscopy (TEM) to confirm the presence of the ordered phase. Results of this study show that: 1) decreasing the Cr concentration enhances the rate of ordering at 373°C. 2) At 418°C, ordering behavior is similar for all compositions. 3) At 475°C, stoichiometric samples order faster than off-stoichiometry samples. 4) Hardness and TEM analysis describe the ordering behavior better than XRD because they are less sensitive to surface effects.

15 Introducing a Green Material to Soft Robotics

Steph Walker and Yigit Menguc

We introduce the use of poly(glycerol sebacate) with calcium carbonate (PGS-CaCO3) as an environmentally benign and degradable elastomer alternative for soft robotics. The introduction of green materials into soft robotics leverages the innate advantages of rapid fabrication and safe disposability. Our PGS-CaCO3 preliminary synthesis is accessible for roboticists and uses safer chemicals when compared to raw materials from some other elastomers. The chemicals used (sebacic acid and glycerol in a 1:1 molar ratio with 1 wt% calcium carbonate) are non-hazardous, readily available, and inexpensive. Maximum elongation at ultimate tensile strength of PGS-CaCO3 was 306%, average ultimate tensile strength was 56 kPa, and average modulus was 33 kPa. Resilience of the polymer at 100 cycles was 86%. Three robot designs were made with PGS-CaCO3 and pressurized with air as an actuation demonstration. A 34 mm diameter accordion actuator (AccordionBot) curled by 185% at 0.5 psi. A 20 mm wide gripper (PetalBot), held a 0.2 g leaf, a 0.8 g seed, a 2.6 g stick and a 3.1 g wood chip when inflated at ≤ 0.6 psi. A froglike (FrogBot) leg extended 30 mm at 0.4 psi. PGS’s strength, elasticity, biodegradability and chemical safety make it a desirable option for roboticists looking to leverage sustainable materials. PGS may also prove a potential green alternative beyond tissue scaffolds and robotics – into ubiquitous environmental and infrastructure sensing and even exoplanetary exploration.
Mechanical Engineering

16 Parametric Evaluation of Governing Heat and Mass Transfer Resistances in Membrane Based Heat and Moisture Exchangers

Paul D. Armatis and Brian M. Fronk

To provide a healthy environment inside buildings, there must be some exchange of indoor conditioned air with fresh outdoor air. The outdoor air is then mechanically conditioned to a comfortable temperature and humidity. Research suggests human health increases with the amount of fresh air available in buildings. This conflicts with the desire to reduce building energy use since the conditioning process is energy intensive. Reductions in energy consumption can be obtained by preconditioning the supply air with the previously conditioned exhaust air using a porous polymer membrane heat and moisture exchanger. The convective heat and mass transfer resistances in the airstream can become the dominant resistance in these devices.

The objective of this study is to develop an analytical model of a counterflow membrane based heat and mass exchanger with different internal flow geometries using the Engineering Equations Solver (EES) platform. The exchanger consists of multiple supply and exhaust air streams flowing in counterflow, separated by a thin membrane layer. The model is discretized to more accurately calculate the air and vapor properties along the exchanger length. Conservation of energy and mass in each segment provides closure to the model.

The model is then used to evaluate the effect of various exchanger dimensions and operating conditions on the heat and mass transfer resistances, sensible and latent effectiveness, and pressure loss of the exchanger. The operating parameters including air flow rate, water diffusivity of the membrane and allowable pressure drop on system performance and dominant transport mechanisms are also explored.

17 Incremental Forming of Polymers

Mohamad Ali Davarpanah and Rajiv Malhotra

Single Point Incremental Forming (SPIF) is a process in which a completely peripherally clamped sheet of material is locally deformed by a/two small hemispherical ended tool/s moving along a predefined 3D toolpath. SPIF of polymers can simultaneously reduce thermal energy consumption and costly tooling for forming of thermoplastic polymer surfaces that are extensively used in the automotive, aerospace and consumer products industries.

The aim of this research is to improve understanding of the polymer SPIF process, so that key technical issues impeding the use of this process in industry can be resolved. These challenges include (1) understanding the modes of failure of the sheet during SPIF and their dependence on the process parameters; and (2) understanding the changes in microstructural and mechanical
behavior of the polymer due to forming with SPIF. This work experimentally investigates the two failure modes of the sheet during SPIF, one of which is unique to polymer SPIF. It is shown that the mode of failure depends significantly on key process parameters in SPIF. The microstructural properties and mechanical behavior of the formed polymer are compared to that of the unformed polymer, in terms of the key process parameters. Future planned work, in terms of modeling the mechanical and microstructural evolution of the polymer during SPIF as well as the development of an advanced Double Sided Incremental Forming machine for forming polymers, are briefly described.

Investigation of the Effects of Inclination on Flow Regimes in Two-Phase Pipe Flow

Connor B. Dokken, Matthew B. Hyder, Tabeel A. Jacob and Brian M. Fronk

Two-phase flow is the prevalent flow type in oil pipelines, where oil and natural gas are transported as a liquid/gas mixture. It is well established that the morphology of the two-phase flow affects the hydraulic resistance. Oil pipelines traverse many elevation changes over long pumping distances, changing the local flow angle of inclination. The changing angle of inclination can affect the flow regime and pressure loss. These effects of inclination angle on two-phase flow regime are characterized in the present study using a test section developed to study a two-phase flow of air and water. First, a variety of liquid and gas superficial velocities were investigated for a horizontal flow, to achieve a wide range of flow regimes. Then, the same range of conditions were explored for increasing angles of inclination. The flow was inclined in steps of 5 degrees, up to 15 degrees of inclination. High speed video was taken of the flows, and the resulting shift in flow regime compared to flow regime map developed for horizontal flow.

Characterization of an Electrically Assisted Grinding Process

Michael Doran and Karl R. Haapala

Hardened steels such as D2 have material properties such as high hardness and toughness that makes them excellent candidates for products such as knives and chainsaw cutters. However, these material properties also make them difficult to machine. To machine these materials, one must either use large volumes of cutting fluid or reduce production rates, both of which have negative consequences for the manufacturer. One process that could potentially increase machinability is Electrically Assisted Grinding (EAG). This process combines abrasive grinding with localized heating produced by electrical sparks between the wheel and the workpiece. Air is used as the dielectric fluid. The research presented here shows that EAG does not have appreciable effect on surface roughness or hardness of a workpiece that is already processed at optimal parameters (i.e. table speed, wheel speed, depth of cut). The grinding wheel wear tests showed that the grinding ratio without electricity was about 10 times higher than the results with electricity. This implies applied electricity leads to deleterious spark erosion.
Effects of Heat Treatment on the Mechanical Properties and Microstructure of CPM-M4 Tool Steel

Cody Fast, Sidi Lian, Hector Vergara, David Kim, Martin Mills and Julie Tucker

Knife blade performance is affected by several characteristics including edge geometry, surface finish, and the parent material’s mechanical properties as well as the heat treatment used. In this project, the effect of changing heat treating parameters of CPM-M4 tool steel is studied. The project objective is to better understand how blade steel heat treating parameters can be controlled to enhance specific blade performance features, such as edge retention or hardness. The approach utilized will be experimental and will involve hardness, impact toughness, 3-point bend, and CATRA tests to characterize knife blade performance, as well as scanning electron microscopy, electron backscatter diffraction, and nanoindentation to characterize the microstructure. Data from SEM and EBSD will be correlated to the measured mechanical properties by comparing nanohardness to macrohardness. The data generated in the project can be utilized to evaluate the ideal heat treatment combination to produce desired blade properties as well as to relate mechanical properties to microstructure evolution. Based on this study, a treatment using lower austenitizing and tempering temperatures provided the most ideal set of properties. However, the choice of preferred heat treatment will be dependent on which mechanical properties are deemed most important for a specific application.

Optimization of Floating Offshore Wind Energy Systems using an Extended Pattern Search Method

Caitlin Forinash and Bryony DuPont

An Extended Pattern Search (EPS) approach is developed for offshore floating wind farm layout optimization while considering challenges such as high cost and harsh ocean environments. This multi-level optimization method minimizes the costs of installation and operations and maintenance, and maximizes power development by selecting the size and position of turbines. The EPS combines a deterministic pattern search algorithm with three stochastic extensions to avoid local optima. Three advanced models are incorporated into this work: (1) a cost model developed specifically for this work, (2) a power development model that selects hub height and rotor radius to optimize power production, and (3) a wake propagation and interaction model that determines aerodynamic effects. Preliminary results indicate the differences between proposed optimal offshore wind farm layouts and those developed by similar methods for onshore wind farms. The objective of this work is to maximize profit; given similar parameters, offshore wind farms are suggested to have approximately 24% more turbines than onshore farms of the same area. EPS layouts are also compared to those of an Adapted Genetic Algorithm; 100% efficiency is found for layouts containing twice as many turbines as the layout presented by the Adapted GA. Best practices are derived that can be employed by offshore wind farm developers to improve the layout of platforms, and may contribute to reducing barriers to implementation, enabling developers and policy makers to have a clearer understanding of the resulting cost and power production of computationally optimized farms.
Direct Numerical Simulation of Turbulent Flow in a Porous, Face-centered Cubic Unit Cell

Xiaoliang He and Sourabh Apte

Turbulent flows through packed beds and porous media are encountered in a number of natural and engineered systems; however, our general understanding of moderate and high Reynolds number flows is limited to mostly empirical and macroscale relationships. In this work the porescale flow physics, which are important to properties such as bulk mixing performance and permeability, are investigated using Direct Numerical Simulation (DNS) of flow through a periodic face centered cubic (FCC) unit cell at pore Reynolds number of 300, 500 and 1000. The simulations are performed using a fictitious domain approach [Apte et al, J. Comp. Physics 2009], which uses non-body conformal Cartesian grids, with resolution up to D/\Delta=250 (354^3 cells total). Early transition to turbulence is obtained for the low porosity arrangement of packed beads involving rapid expansions, contractions, as well as flow impingement on bead surfaces. The data are used to calculate the distribution and budget of turbulent kinetic energy and energy spectra. Turbulent kinetic energy is found to be large over the entire pore region. The structure of turbulence along different path lines is characterized by using the Lumley triangle. Eulerian and Lagrangian correlations are obtained to find the integral length and time scales. The Lagrangian time-scales are also estimated using the Eulerian correlations based on the Tennekes and Lumley model (Tennekes and Lumley, 1972) to evaluate the effectiveness of the model. Finally, the data obtained is used to test the effectiveness and applicability of the standard two-equation turbulence closure models based on the gradient diffusion hypothesis.

Decision Making in Design-Stage Function-Based Failure Analysis

Sean Hunter and Irem Tumer

System safety and reliability are key performance parameters of complex engineered systems. Functional modeling methods have been applied to the design of complex systems to improve the designers’ ability to evaluate system performance with respect to these metrics at increasingly early stages of the design process, conserving resources and resulting in more robust system alternatives. Function–based failure methods have been used to shift decision making to the conceptual design stage. However, the abstraction required to perform function–based failure analysis can result in insufficient levels of detail in the outputs of the analysis. Presented here is an evaluation of the metrics that can be used to compare the ability of model–based methods to identify potentially hazardous scenarios and enable the designer to make more informed design decisions. Several system design alternatives are explored in this case study. Each design alternative is evaluated at three different levels of functional abstraction and the relative safety characteristics of each design are compared within the levels. The degree to which information is lost as abstraction increases allows the designer to select the appropriate level of detail to enable informed decision making.
Aircraft Wing Optimization using B-spline Models and Panel Methods

Danielle Jackson and Chris Hoyle

The shape characteristics of airfoils describe how an aircraft acquires the lift needed to fly and depicts how an aircraft will be affected by drag forces and pressure distributions from a surrounding fluid. This information leads designers to insights concerning the behavior of an aircraft due to lift and drag. It has been observed that a higher lift to drag ratio is desired to achieve a greater performance of an aircraft. A study of the shape optimization process, using b-spline models and panel methods to achieve a high lift to drag ratio, is described here. The optimization process begins with inputs defined by a user to determine a random shape constructed from a clamped-closed b-spline curve, with a specified number of control points and order to the curve. The curve data is then entered into a panel method simulator, which outputs the lift and drag characteristics which are compared to a desired ratio. The user then implements an optimization method to refine the solutions and create new ones using various techniques. These solutions are sent back through the simulator to acquire a new set of solutions until a desired ratio is met. Designs based on optimal topology have benefits over other methods. The initial shape of the curve is of no consequence, unlike that seen in trial and error methods where the preliminary guess needs to have a level of accuracy to continue. Optimal topology can lead to improvements on previously implemented designs through the use of optimization techniques.

Self-Updated Resilient Design Approach

Elham Keshavarzi and Chris Hoyle

Most engineered systems are high in cost and incorporate highly sophisticated materials, components, designs and other technologies. Therefore, they face different uncertainties from technical issues to market changes. Due to increasingly dynamic markets, it has become important for systems to cope with uncertainties to complete the defined missions. Developing resilient engineered systems is of increasing interest in the design community. Resilience is defined as the ability of a given system configuration to recover after an uncertain event has occurred. A major deficiency in current design methodology is that it is formulated primarily to address robustness, which refers to a system’s ability to perform adequately in the presence of uncertainties, but does not address system recovery in the presence of failures. This research objective is to formulate a new theory of resilient system designs and support automated analysis in the presence of various uncertainties and failure modes to ensure that requirements are met throughout the system lifecycle. To achieve the goals of the project, fault scenarios that system might face are identified and optimal designs that can meet the system requirements after fault occur are identified. For the resilient design research, a resilient design model based upon the Kalman filter is required to provide the necessary state estimation, as well as to provide a model of how design actions can influence operating state. The validation will be achieved by applying the resilient design approach to an example of Mono Orbiter, provided by NASA Ames Research Center.
Water Injection into an Internal Combustion Engine

Sean Kirkpatrick and James Liburdy

Water injection has been used historically in aviation during World War II and during the American muscle car era. However, with the advent of turbocharging and intercooling water injection went to the wayside. Recently there has been a modern resurgence into water injection techniques and water/fuel blends. The state at which water is directly injected into an internal combustion engine cycle will have a substantial effect on the overall performance of the cycle, potentially increasing power and efficiency while reducing emissions. Additionally, water can be used to recover waste heat from the engine and exhaust energy to either reduce or eliminate the parasitic power needed to bring the water up to the injection state. The state of water is varied from a liquid to a supercritical fluid to determine its effect on the internal combustion engine cycle performance and emission characteristics.

Design of Metal Organic Responsive Frameworks

Charlie Manion, Ryan Arlitt, Irem Tumer, Matt Campbell and Alex Greaney

Metal Organic Responsive Frameworks (MORFs) are a proposed new class of smart material consisting of a Metal Organic Framework (MOF) with photoisomerizing beams (also known as linkers) that fold in response to light. These would permit new light responsive materials with properties such as photo-actuation, photo-tunable rigidity, and photo-tunable porosity. However, conventional MOF architectures are too rigid to allow isomerization of photoactive sub-molecules. We propose a new computational approach for designing MOF linkers to have the required mechanical properties to allow the photoisomer to move by borrowing concepts from de novo molecular design and engineering design automation. Here we show how this approach can be used to design compliant linkers with the necessary flexibility to be actuated by photoisomerization and used to design MORFs with desired functionality.

Comparison of CPU- and GPU-Based Immersed Boundary Methods for Fluid-Structure Interaction

Christopher Minar and Kyle Niemeyer

Many engineering applications require fast, accurate solutions for flow around freely moving bodies. Traditionally, fluids solvers are sped up by using more CPU threads, but the continual development of graphics processing units (GPUs) provides a promising alternative. Fully harnessing the processing power of GPUs requires the development of specialized algorithms and computing strategies—a highly efficient CPU solver might not translate well to the GPU. This work aims to compare two different immersed boundary method solver types for simulating fluid-structure interaction on the GPU and CPU. The first is the direct forcing method proposed by Fadlun et al. in 2000 and the second is the projection method proposed by Taira and Colonius in 2007. Both of these solvers were modified to incorporate
freely moving bodies. The solvers were validated using lid-driven cavity flow for basic flow physics, impulsively started flow over a cylinder for the immersed body, and vortex-induced vibrations (VIV) for freely moving bodies.

Adaptable Rectangular Subsets Normalize Displacement Precision in Digital Image Correlation with Anisotropic Texture

Daniel P. Mosher, Melissa I. Champer and Brian K. Bay

Digital image correlation (DIC) is an established deformation mapping technique that estimates full-field displacements by tracking unique intensity subsets between reference and deformed digital or tomographic images. When the DIC technique utilizes natural material texture as the tracking mechanism, instead of a controlled speckle pattern, it is referred to as texture correlation (TC). To analyze material behavior using TC, the DIC algorithm must rely on naturally occurring material texture to obtain distinguishable subsets. For this reason, selecting subsets in TC samples presents challenges beyond the scope of subset selection strategies used for speckled DIC samples. The predominant issue in TC resulting from inadequate subset selection is a discrepancy in measurement precision between coordinate directions, which occurs when equilateral subsets are used to map displacements in images with anisotropic texture. This paper presents a subset selection strategy for TC applications that employs adaptable subsets and a novel texture-balancing growth algorithm. Numerical simulations are used to evaluate how well eliminating texture bias within subsets translates to balancing measurement precision. Results demonstrate that the adaptive method normalizes displacement precision, and reduces limiting errors, in images with anisotropic texture compared to traditional methods used for speckled DIC samples.

DNS with Discrete Element Modeling of Suspended Sediment Particles in an Open Channel Flow

Pedram Pakseresht, Sourabh V. Apte and Justin R. Finn

Interactions of glass particles in water in a turbulent open channel flow over a smooth bed with gravity perpendicular to the mean flow is examined using Direct Numerical Simulation (DNS) together with lagrangian Discrete-Element-Model (DEM) for particles. The turbulent Reynolds number based on the wall friction velocity is 710 corresponding to the experimental observations of Righetti & Romano (JFM, 2004). Particles of size 200 microns with volume loading on the order of 10⁻³ are simulated using four-way coupling with standard models for drag, added mass, lift, pressure, and inter-particle collision forces. The presence of particles affect the outer as well as inner region of the wall layer where particle inertia and concentration are higher. The DNS-DEM is able to capture the fluid-particle interactions in the outer layer accurately. However, in the inner layer, an increase in mean as well as rms fluid velocity, as observed in the experiments, is not predicted by the DNS-DEM model. It is conjectured that particles slide and roll on the bottom wall, creating slip-like condition. Predictions using different models for drag and lift forces, as well as strong torque coupling are explored and compared with experimental data.
Topology Optimization of Hyperelastic Continua

Trung Pham, Christopher Hoyle, Yue Zhang and Tam Nguyen

Topology optimization (TO) aims to find a material distribution within a reference domain, which optimizes an objective function and satisfies certain constraints. However, topology optimized designs often possess complex geometries and intermediate densities making it difficult to manufacture such designs using conventional methods. Additive Manufacturing (AM) is capable of handling such complexities. Common AM materials are rubber-like ones, which can be modeled by hyperelastic constitutive laws. However, most research on TO has focused on linear elastic materials, which has severely restricted applications of TO to hyperelastic structures made of, e.g., rubber or elastomer. While there is some work in literature on TO of nonlinear continua, there is no work which investigates the different models of hyperelastic material. The contribution of this paper is an investigation of the different models of hyperelastic material and their influences on the resulting topologies. This paper would consider different isotropic hyperelastic models including Ogden, Arruda-Boyce and Yeoh model under finite deformations, which have not yet been implemented in the context of topology optimization of continua. The Solid Isotropic Material with Penalization method is used to formulate the problem while the Method of Moving Asymptotes is utilized to update design variables iteratively. The proposed method would be tested on two numerical examples. The first one is a common benchmark model, which is a simply supported beam subject to a concentrated force at the midpoint of top edge. The second example is a simple tire model, which demonstrates capability of the method in solving real-world design problems.

Graph-based Automated Assembly Planning from Tessellated Models

Nima Rafibakhsh and Matt Campbell

Automated Assembly Planning (AAP) is the process of generating optimal assembly plans from an assembly model. Our approach is a graph based assembly planning where nodes represent assembly parts and arcs denote the relationship between them. The most significant point that makes this work outstanding comparing the existing AAP works is its intelligent geometric reasoning process. This process contains two main subgroups: primitive classification and fastener detection. Primitive classification begins with tessellated assembly parts, where every solid is represented by a set of connected triangles, and classifies them into a set of common used primitives, including flat, cylinder, sphere and cone. These classified primitives are then used to detect blocking information between every pair of solids and generate the liaison graph. Several novel approaches are presented to detect fasteners in a tessellated assembly. This helps to remove the fasteners from the set of assembly parts and create a smaller liaison graph. The liaison graph is then used to generate valid options to assemble different subassemblies. Every option is evaluated using a powerful evaluation tool and the optimal assembly plan is found using a recursive search method. The generated assembly plan is a complete assembly instruction which contains a series of subassemblies where each is represented with three actions: Install, Secure and Rotation. These actions contain every useful information to install two subassemblies including install direction, install point, fasteners between the two subassemblies and also the orientation of the solids.
A Multi-Objective Real-Coded Genetic Algorithm Method for Wave Energy Converter Array Optimization

Chris Sharp and Bryony DuPont

For consumers residing near a coastline, and especially for those living or working in remote coastal areas, ocean energy has the potential to serve as a primary energy source. Over the last decade, many wave energy converter (WEC) designs have been developed for extracting energy from the ocean, and with the progression of these devices’ ocean deployment, the industry is looking ahead to the grid integration of arrays of devices. Due to the many factors that can potentially influence the configuration of an array (such as device interaction and system cost) optimal positioning of WECs in an array has yet to be well understood. This poster presents the results of a novel real-coded genetic algorithm created to determine ideal array configurations in a non-discretized space such that both power and cost are included in the objective. Power is calculated such that the wave interactions between devices are considered and cost is calculated using an analytical model derived from Sandia National Laboratory’s Reference Model Project. The resulting layouts are compared against previous array optimization results, using the same constraints as previous work to facilitate algorithm comparison. With the development of an algorithm that dictates device placement in a continuous space so that optimal array configurations are achieved, the results presented in this poster demonstrate progression towards an open-source method that the wave energy industry can use to more efficiently extract energy from the ocean’s vast supply through the creation of array designs that consider the many elements of a WEC array.

Vortex Dynamics and Wake Structure of an Oscillating Flexible Foil

Firas Siala and James Liburdy

Flow physics of flying animals has received significant attention in the context of developing bio-inspired micro air vehicles and oscillating flow energy harvesters. Of interest is understanding the impact of foil flexibility on flow physics. Research showed that some degree of surface flexibility enhanced the strength and size of the leading edge vortex. However, there’s few experimental studies that investigate the influence on wake dynamics. In this paper, an experimental study explores the effect of surface flexibility at the leading and trailing edges on the vortex-shedding dynamics in near-wake region of a sinusoidal heaving foil. Particle-image velocimetry measurements were taken at a Reynolds number of 25,000 to describe the mean flow characteristics as well as the phase-averaged vortex structures and their evolution thorough the oscillation cycle. The results demonstrate that flexibility at the trailing edge has a minimal influence on the mean flow when compared to the rigid foil. The mean velocity deficit for the flexible trailing edge and rigid foils remains constant for all reduced frequencies tested. However, the trailing edge flexibility increases swirl strength of small-scale structures. Flexibility at the leading edge generates a large-scale leading edge vortex for at-large oscillation frequencies. This results in a reduction in swirl strength due
to complex vortex interactions when compared to the flexible trailing edge and rigid foils. Furthermore, the large-scale leading edge vortex is responsible for extracting a significant portion of the energy from the mean flow, resulting in a substantial reduction of mean flow momentum in the wake.

**Validation of Arc Position Sensing Method for Vacuum Arc Remelting Furnaces**

**Miguel Soler and Kyle Niemeyer**

Vacuum arc remelting (VAR) is a secondary melting process for the production of metals that exhibit higher material homogeneity. The melting process of the input ingot, or electrode, is driven by electrical arc formation between the electrode and the melted ingot in a vacuum environment, with an applied current load. Observing the phenomena is difficult due to the harsh environment, but the surrounding magnetic field can provide information to determine the arc location. Being able to locate arc formations is important because it leads to insights of imperfections, solidification patterns, and current loss. This research focused on modeling the VAR furnace to validate a previously developed arc location prediction approach, by investigating the effect of various phenomena—not originally considered—on the magnetic field. A finite element approach is applied using commercially available software COMSOL Multiphysics. First, a baseline model was established that accurately reproduced prior published results; the current model matched results with a maximum error of less than 4%. Then, we studied the change of the magnetic flux density at sensor locations for different scenarios or the removal of previously made assumptions. The effects of vertical sensor position, varying electrode–ingot gap size, ingot shrinkage, and using multiple sensors were studied. We found that neither gap size nor ingot shrinkage affect arc location prediction, although prediction error increases significantly with increasing vertical distance between gap and sensor.

**Design of Complex Engineered System using Multiagent Coordination**

**Nicolas Soria, Irem Y. Tumer, Chris Hoyle, Kagan Tumer and Mitchell Colby**

In complex engineered systems, complexity may arise by design, or as a by-product of the system’s operation. In either case, the root cause of complexity is the same: the unpredictable manner in which interactions among components modifies system behavior. Our approach is based upon implicitly managing interactions and providing mechanisms through which the system level impact of decisions can be estimated without explicitly modeling such interactions.

Traditionally, two different approaches are used to handle such complexity: (i) a centralized design approach where the impacts of all potential system states and behaviors resulting from design decisions must be accurately modeled; and (ii) an approach based on externally legislating design decisions, which avoid such difficulties, but at the cost of expensive external mechanisms to determine trade-offs among competing design decisions.
Our approach is a hybrid of the two approaches, providing a method in which decisions can be reconciled without the need for either detailed interaction models or external mechanisms. A key insight of this approach is that complex system design, undertaken with respect to a variety of design objectives, is fundamentally similar to the multiagent coordination problem; component and interaction decisions lead to global behavior. A design of a racing car will be the case study; the agents will make the decisions at the component level and the interactions among those components, which will lead to global objective. A key research challenge is to determine what each agent needs to do so that the system as a whole achieves a predetermined objective.

Improving Sustainable Design Theory in the Early Design Phase

Addison Wisthoff and Bryony DuPont

Sustainable product design is becoming an important aspect of the development of consumer products. Currently, there is limited design resources to aid in the creation of sustainable products in the early design phase. The purpose of this research is to present a new method for integrating sustainable design knowledge into the early design phase of new products and processes. A novel organized search tree—consisting of sustainable product design guidelines, empirical design knowledge, international design regulations and preliminary consumer preference information—is constructed to enable application of sustainable design knowledge before and during concept generation. To further facilitate its application, this search tree is embedded in an easy-to-use web-based application called the GREEn Quiz (Guidelines and Regulations for Early design for the Environment). The quiz provides users with weighted questions pertaining to the design or redesign of a product concept, with a list of possible pre-generated responses to choose from. As a designer progresses through the quiz, user responses are compiled and weighted, and a final report that displays the top ten design attributes contributing to the eventual environmental impact of the product are provided to the user. Accompanied by the top ten list, is a list of design decisions are also provided to better help inform the designer to make improvements that can make the product more environmentally sustainable.

Robotics

Cassie: Legged Mobility in Unstructured Environments

Patrick Clary, Andy Abate, Pavel Zaytsev and Jonathan Hurst

Walking and running outside of a controlled laboratory environment is a difficult problem in robotics. The Dynamic Robotics Laboratory at Oregon State University is designing Cassie, a new bipedal robot, to demonstrate agile and efficient locomotion in challenging environments. Building upon lessons learned from ATRIAS, the DRL’s previous biped, Cassie will be better
prepared for operating in the real world. With an advanced leg design, a crash-proof composite exoskeleton, and powerful custom-designed actuators, Cassie aims to be the most agile and efficient biped in the world. Measuring roughly 4 feet tall and 60 pounds, Cassie is expected to be capable of walking continuously for over an hour and running a 9-minute mile. Successors to Cassie could assist humans in tedious and dangerous tasks that involve terrain too difficult for wheeled robots, including door-to-door package delivery, mobile reconnaissance, and disaster response.

Capturing Human-Planned Robotic Grasp Ranges

Saurabh Dixit, Ravi Balasubramanian, Cindy Grimm, Jackson Carter, Brendan John and Javier Ruiz

There is an enormous amount of research going on in the field of robotic grasping. We propose leveraging human abilities to teach a robot how to grasp. Humans are excellent at physical manipulation, compared to a robot. This is not because they are using different types of manipulators (human hand versus robot hand). Humans generally tele-operate robotic manipulator better than automatic algorithms for many unstructured grasping tasks. Unfortunately, humans are not good at describing how they do what they do, so most training system rely on some kind of human demonstration of specific grasp examples for specific tasks. Hence, robust data capture protocol is needed to collect more general data in less time.

In this poster, we present a data collection protocol that addresses several issues in collecting human-generated grasp examples. Concretely, this protocol: 1) Captures the regions of interest instead of single instance of a good/bad grasp. 2) Captures additional human-centric information to elucidate: how the participant arrived at a specific grasps, what is participant thinking during specific grasp, and where is participant looking during performing grasp. 3) Supports capture of multi-handed manipulation tasks even if there is only one physical robot hand.

We used a think out loud protocol, prompting questions, and eye-tracking of human subjects to capture human thought process and visual attention while the human performed the manipulation task with the robot. This captures both high-level cognitive process and low-level actions performed by human subjects to move the robot hand, and thus ensures robustness.

Jumping Spider

Hossein Faraji, Ramsey Tachella and Ross Hatton

Jumping spiders are capable of targeted jumps by using their front legs to guide the release of energy from their rear legs. In this poster, we present a simplified model of the jumping spider based on the anatomy of the real spider. The immediate goal of this model is to understand how the geometry of the legs affects the jumping motion, with the further goal of using this geometry in the future development of jumping robots. Through a set of simulations, dynamic analysis, and experiments with a physical realization of our model, we identify several features of the spiders’ jumping mechanism, most notably that “vaulting” with the front legs allows the system to generate flatter take-off trajectories than could be achieved by simple aiming of a
spring-release mechanism. Jumping spiders have also been observed to use anchored draglines to achieve maneuvering capabilities while in the air, therefore in second phase of our research we are considering that effect. The momentum of a projectile in free flight can be redirected by using a tether to create a “virtual wall” against which it bounces. The direction of this bounce can be controlled actively through braking modulation, or passively through placement of the tether anchor and the orientation of the projectile at impact. Hence, we consider the ways in which holding the tether away from center of mass at different angles can contribute to changes in speed and direction of motion after the bounce.

41 Geometric Mechanic Analysis and Control of a Suspended Hexapod

Lucas Hill and Ross Hatton

Palm-sized, hexapod, tethered robots have application in heavily unstructured environments, e.g. collapsed buildings and caves. A primary challenge with controlling these small machines is pose manipulation in the suspended state, as the system is under-actuated. We apply geometric mechanic methods to design cyclic gait trajectories capable of controlling the yaw of the robot, demonstrated in both simulation and the physical system.

42 Robotic Deburring: Using ‘Feel’ to Achieve Micron Precision

Francis James, Saurabh Dixit, Ravi Balasubramanian and Burak Sencer

For several decades, human labor has been employed for manufacturing high quality, ultra-precise parts. Some of the most precisely machined objects, including the silicon sphere made for the Avogadro project, require human operators to play an active role. Robots have much higher positional accuracy than humans but despite this, in critical manufacturing processes such as deburring and buffing where sophisticated responses to complex, varying forces are required, human workers retain an edge. However, these non-value adding operations can be quite expensive. Manual deburring, for instance, can contribute to as high as 30 percent of the total cost of a final part. Consequently, automated deburring is required, especially in the aerospace industry where the use of high strength materials such as titanium makes parts harder to debur. For robotic deburring, it is important to first dissect the nature of responses that human workers display when encountering burrs which are unpredictable in both size and location. To a large extent, these responses are based on the ‘feel’ of the surface. To achieve similar performance, the next generation of robot arms will have to incorporate force control. Additionally, they must include elements such as tunable damping and compliance which make the dynamic response required for deburring possible. In our work, we look at both the mechanism by which humans perform deburring and the design and control principles that would allow robots to do the same.
Real-time Contamination Modeling for Health Care Support

Kory Kraft, Tiffany Chu, Patrick Hansen and Bill Smart

Health care acquired infections are a perennial source of danger. Real-time contamination monitoring in health care settings would allow health care workers and robots to know when they and/or other objects are in contaminated areas. We demonstrate and evaluate an end-to-end, real-time contamination tracking system. The system models contamination of the environment and people, alerts users when encroaching contaminated areas, and optimizes the cleanup efforts of a simulated decontamination robot. We outline our transmission model design choices, as based on the Ebola Virus Disease, and evaluate the system using real fluids.

Learning Persistent Deep Classifiers for ROS

Austin Nicolai, Geoff Hollinger and Bill Smart

In recent years, Deep Learning has been shown to perform well in a wide variety of tasks, including object recognition and classification. Despite the potential benefits of Deep Learning, applications are often not readily available to the average end user. Reasons for this include computing time and data set size requirements for training as well as complex network design. The work presented here attempts to bridge this gap and provide an accessible method for end users to leverage Deep Learning for object classification in the ROS framework. Specifically, the aforementioned challenges are addressed as follows: The proposed system is largely autonomous, requiring only minimal user input at the beginning of the learning process, in order to reduce the burden of data set generation. Additionally, pre-trained network architectures are “fine-tuned”, negating the need for network design as well as reducing training time, before being made accessible to the end user via the standard ROS node architecture. The final output of the system, a ROS node, subscribes to robot sensor data and publishes identified objects.

Physical and Computational Models of Spider Web Vibrations

Andrew Otto, Griffin Alberti, Damian Elias and Ross Hatton

Due to their poor eyesight, spiders rely on web vibrations for situational awareness. Web-borne vibrations are used to determine the location of prey, predators, and potential mates. The influence of web geometry and composition on web vibrations is important for understanding spider’s behavior and ecology. Studies in web vibrations have experimentally measured the frequency response of web geometries by removing threads from existing webs. The influence of silk material properties as well as arbitrary web structures on web vibrations; however, has not been addressed in prior work. Furthermore, little attention has been given to developing dynamic models for web vibrations. We have constructed computer models and artificial
webs to better understand the effect of web structure on vibration transmission. A dynamic substructuring based approach was used to model vibrations in the web as an interconnected network of strings. An instrumented test stand was built for artificial web construction, control of web tension, and vibration analysis. Artificial webs of 1.2 m (48 in) in diameter were made of different types parachute cord to mimic the elastic properties of various spider silks. Accelerometers placed radially around the hub of the artificial web were used to measure vibration response. This work presents initial results on model correlation, prey detection, and implications of basic changes in web geometry on vibration transmission.

46 Evaluation of Physical Marker Interfaces for Protecting Visual Privacy from Mobile Robots

Matthew Rueben, Frank J. Bernieri, Cindy Grimm and Bill Smart

We present a study that examines the efficiency and usability of three different interfaces for specifying which objects should be kept private (i.e., not visible) in an office environment. Our study context is a robot “janitor” system that has the ability to blur out specified objects from its video feed. One interface is a traditional point-and-click GUI on a computer monitor, while the other two operate in the real, physical space: users either place markers on the objects to indicate privacy or use a wand tool to point at them. We compare the interfaces using both self-report (e.g., surveys) and behavioral measures. Our results showed that (1) the graphical interface performed better both in terms of time and usability, and (2) using persistent markers increased the participants’ ability to recall what they tagged. Choosing the right interface appears to depend on the application scenario. We also summarize feedback from the participants for improving interfaces that specify visual privacy preferences.

47 Using Map Inference to Improve Multi-Robot Coordinated Exploration

Andrew Smith and Geoff Hollinger

As robotic platforms and sensing technology continue to reduce in price, the opportunity to use teams of autonomous robotic agents in field applications is increasing; one such application is the exploration and mapping of unknown environments. Current methods for multi-robot exploration are largely restricted to research environments and either assume perfect communication and unlimited battery life or restrict the system to enforce these assumptions. To move these systems into the real–world autonomous robots must coordinate their actions to maximize system–wide efficiency while accounting for both limited communication and battery life; both of which severely restrict their ability to coordinate. We propose a novel exploration coordination method that utilizes map inference to improve real–world multi–robot coordination. This method uses previously observed map structures to make inferences about the structure of unexplored areas. The robots will then use these inferences to coordinate the remainder of the search. To capitalize on the information provided by the inferences, the robots will transition through a series of roles that change their
reward structure between frontier exploration and collecting information from other robots. These methods will allow the robots to efficiently coordinate with only periodic connectivity and restricted battery life in preparation for moving multi-robot exploration from the research environment into the real world.

**Collaborative Planning for Human-Robot Science Teams**

**Thane Somers and Geoff Hollinger**

In this work, we develop two novel methods for learning a human’s preferences when planning robotic missions in aquatic domains. Planning for these missions, such as monitoring an oil spill or searching for a lost vessel, requires considering many different variables, including the weather, risk of collision, power budget, and the quality of the information gathered. Furthermore, the lack of communications and long mission durations place a large burden on the human operator. In order to increase the efficiency and effectiveness of these missions, we develop two algorithms that allow the robot to quickly learn the human’s preferences and then use those learned preferences to plan missions without the need for further input. Our algorithms learn an expert’s preferences based on iterative feedback about a set of simulated trajectories. The coactive learning method uses an expert’s modifications to the trajectories to learn a linear importance weighting of the given environmental variables. The multi-objective optimization method uses a rating of each trajectory to construct a Pareto front of good reward functions. We evaluate these algorithms using simulated human input as well as in user trials. We find that the algorithms quickly learn an expert’s preferences and plan trajectories that perform similarly to those planned by the expert without the need to explicitly specify the parameters for planning. These results demonstrate that collaborative autonomy has the potential to greatly increase the efficiency and accuracy of aquatic robotics missions.

**Path Smoothing Algorithm for High Speed Motion Systems with Confined Contouring Error**

**Shingo Tajima and Burak Sencer**

Typically, reference toolpaths for manufacturing equipment such as machine tools and industrial robots consist of linear motion segments, or so-called point-to-point (P2P) position commands. This approach exhibits serious limitations in terms of achieving desired part geometry and productivity in high-speed contouring. P2P commands only satisfy position continuity. As a result, velocity and acceleration discontinuities occur at the junction points of consecutive motion segments. In order to generate smooth and continuous end-effector motion, a kinematic smoothing algorithm is proposed in this research, which plans smooth acceleration and jerk profiles along series of P2P segments to realize continuous velocity transition. The proposed path-smoothing algorithm eliminates the need for geometry-based path-blending techniques and presents a computationally efficient real-time interpolation.
scheme. The smoothened path contain a confined deviation from the original segmented path. This path “smoothing” error tolerance can be specified and controlled by the end-user. Drive’s acceleration and the jerk limits are fully considered in the algorithm to minimize overall travel duration along the given tool-path. This delivers a “time optimal smooth interpolation” within user specified path error tolerances. Simulation studies are used to demonstrate the effectiveness of proposed high-speed contouring.

Building Soft Encoders for Soft Robots

Osman Dogan Yirmibesoglu and Yigit Menguc

Measuring joint angles plays a significant role for robotics. In the existing technology, the joint angles are being measured with embedded encoders into corresponding motors. Current encoder systems are not applicable for soft body segments with angular joints. In this research, we present a soft encoder for measuring a soft robot’s joint angles. The soft encoder includes two IMU sensors and a hyperelastic strain sensor. The main body of the soft encoder is made of silicone elastomer with embedded microchannels filled with conductive liquid. IMU sensors are placed at the edges of the soft encoder. A KALMAN filter is used to fuse information between the strain sensor and IMU’s. Joint angle recordings were done over various subjects from soft bodies to rigid bodies. Demonstration of the results were done in comparison with a ground truth optical motion capture system. Soft encoders have potential in applications such as rehabilitation, sports medicine and measuring joint angles of soft robots.

School of Nuclear Science and Engineering

Nuclear Engineering

Steady State Modeling of the Minimum Critical Core of the Transient Reactor Test Facility

Anthony Alberti and Todd Palmer

With the advent of next generation reactor systems and new fuel designs, the U.S. Department of Energy (DOE) has identified the need for the resumption of transient testing of nuclear fuels. The DOE has decided that the Transient Reactor Test Facility (TREAT) at Idaho National Laboratory (INL) is best suited for future testing. TREAT is a thermal neutron spectrum, air-cooled, nuclear test facility that is designed to test nuclear fuels in transient scenarios.
These specific scenarios range from simple temperature transients to full fuel melt accidents. DOE has expressed a desire to develop a simulation capability that will accurately model the experiments before they are irradiated at the facility. It is the aim for this capability to have an emphasis on effective and safe operation while minimizing experimental time and cost. The multiphysics platform MOOSE has been selected as the framework for this project. The goals for this work are to identify the fundamental neutronics properties of TREAT and to develop an accurate steady state model for future multiphysics transient simulations. In order to minimize computational cost, the effects of spatial and angular homogenizations were investigated. It was found that high degrees of anisotropy are present in TREAT assemblies and, in order to capture this effect, explicit modeling of cooling channels and inter-assembly gaps are necessary. For this modeling scheme, single assembly calculations at 293K gave power distributions 0.076% different than that of reference SERPENT calculations. The minimum critical core configuration with identical gap and channel treatment at 293 K resulted in a root mean square, axially integrated radial power distribution of 0.22% when compared to reference SERPENT solutions.

2 Scaling of the Direct Reactor Auxiliary Cooling System for use in the High Temperature Test Facility at OSU

Grant Blake and Brian Woods

The Direct Reactor Auxiliary Cooling System (DRACS) is an inherent safety system used to cool the core of a nuclear reactor in the event of an accident. The DRACS was derived from the Experimental Breeder Reactor-II (EBR-II) and has been adopted and adapted by several generation IV (gen-IV) reactor designs. Scaled test facilities are constructed to demonstrate the performance of a design without having to build a full-scale prototype. The High Temperature Test Facility (HTTF) is an existing scaled integral test facility on Oregon State University campus which models the Modular High Temperature Gas Reactor; a gen-IV Very High Temperature Reactor (VHTR). The purpose of the research being conducted at this time is to provide a scaled-down DRACS which will be used with the HTTF in order to demonstrate the performance of DRACS in simulated accident conditions. These tests could provide data for gen-IV VHTR or Gas-cooled Fast Reactor (GFR) designs which employ the DRACS as part of their safety system. The process of scaling involves non-dimensionalizing governing equations for a system and processes using time-independent values. From this, scaling parameters are obtained for both the full-scale prototype and the scaled-down model. These scaling parameters would ideally be equal for the prototype and model, but scaling distortions arise when they cannot be matched. Presented will be the scaling factors and their distortions for a preliminary scaled DRACS design to be used with the HTTF.
Design of a Compact and Low Cost Detection System for Atmospheric Radioxenon Detection

Steven Czyz, Abi Farsoni and Lily Ranjbar

Several radioxenon isotopes (131mXe, 133mXe, 133Xe, 135Xe), each with a unique beta-gamma coincident decay signature, are characteristic byproducts of nuclear explosions. Due to the difficulty of containing noble gases, the detection of atmospheric radioxenon has been reliably utilized by the Comprehensive Nuclear Test Ban Treaty Organization (CTBTO) to confirm the nuclear nature of explosions. Each isotope can be separately identified by utilizing a coincident detection system. To this end, a prototype compact radioxenon detector is being designed by the Radiation Detection Group at Oregon State University. The detector consists of a gas cell surrounded by a well type organic scintillator. This scintillator is used to detect beta radiation and conversion electrons. The base of the scintillator is coupled to an array of silicon photomultipliers for light readout, chosen for their low-cost, low-power demands, and ruggedness. A CZT crystal, chosen for its excellent energy resolution and room temperature operation, is coupled to the outer wall of the scintillator in order to detect coincident gamma radiation. The inner wall of the scintillator is coated with a thin layer of Al2O3, which reduces memory effect by an estimated three orders of magnitude. The goal of this work is to produce a detection system with a minimum detectable concentration (MDC) for the radioxenon isotopes of interest comparable to other state-of-the-art radioxenon detection systems, such as the Swedish Automatic Unit for Noble gas Acquisition (SAUNA) and the Automated Radioxenon Sampler and Analyzer (ARSA), at a fraction of the cost.

An Overview of the Design of the Stratified Flow Separate Effects Test Facility

Joshua Graves, Andy Klein and Ian White

High temperature gas reactors are poised to comprise a major portion of the next generation of nuclear power reactors, given their operational flexibility and passive safety features. Experimental efforts are currently underway to produce data to support current and future high temperature gas reactor design efforts. The Stratified Flow Separate Effect Test Facility seeks to experimentally characterize the vertical propagation of a stratified gas front immediately following a design basis accident, specifically a double-ended guillotine break of the concentric cross duct, which provides the inlet and outlet for the primary coolant. Experimental outcomes will include estimates of the time to the onset of natural circulation, a key component in the safety analysis of these reactors, as well as mitigation strategies that will leverage passive safety characteristics to further protect future facilities.
5  Thermal Conductivity Prediction in Uranium Dioxide with Xenon Impurities

Jackson Harter and Todd Palmer

One of the fundamental quantities characterizing the safe and efficient operation of nuclear reactors is thermal conductivity in the fuel, which governs heat transfer throughout the core structure and into the moderator. In addition to heat transfer, thermal conductivity is coupled to many other processes in the reactor core and shifting thermal gradients are primarily responsible for the displacement of macroscopic cross sections of interaction for neutrons. Phonons are responsible for heat transport in ceramics based materials, such as uranium dioxide. The Boltzmann transport equation derived in the Self-Adjoint Angular Flux (SAAF) formulation is applied to simulate phonon transport. The neutron transport code Rattlesnake is leveraged in this fashion, slightly modified to accept input from variables consistent with phonon transport simulations. We use Rattlesnake to predict thermal conductivity in materials with heterogeneity and isotopic fission products affecting thermal transport. Xenon is produced in the fission process and the presence of xenon greatly hinders heat transport in nuclear fuel. The xenon can coalesce into bubbles, which act as scattering centers for phonons. We perform simulations of phonon transport in uranium dioxide with xenon bubbles at temperatures between 300 K and 1500 K. A high amount of thermal boundary resistance is encountered at the uranium-xenon interface, attributed to the highly differing properties between the two materials. Local heat flux at the bubble is decreased and this effect is amplified at higher temperatures. Rattlesnake shows thermal conductivity in uranium dioxide decreasing by up to a factor of four at elevated temperatures.

6  Neutronic Analysis of Use of HANARO Fuel in WWR–SM Reactor

Lara Peguero and Todd Palmer

Stability in fuel supply for any reactor is vital to reliable and continuing operation. Currently, IRT-4M plate-type fuel assemblies used in the WWR–SM reactor at the Institute of Nuclear Physics of the Academy of Sciences of Uzbekistan are fabricated and sold by a sole supplier. For this reason, the high-power research reactor is exploring the use of assemblies comprised of Korean HANARO fuel rods. The goal of our research is to evaluate possible replacement fuel assemblies and to perform neutronic analyses to show that the safety and performance characteristics are equivalent to or better than the existing fuel. We have modeled an infinite water lattice of HANARO fuel rods as a single rod and in assembly configurations, as well as fresh assemblies with 16 fuel rods in the WWR–SM core using the Monte Carlo N-Particle Transport code (MCNP6). A core loaded with 20 assemblies, each with 16 HANARO fuel rods, has a multiplication factor of $1.14413 \pm 0.00050$. Further analysis will demonstrate the viability of this core.
Development of Four-Equation Drift Flux Model for RELAP-7 in MOOSE Using Jacobian-free Newton-Krylov Method

Darin Reid and Andy Klein

This project details the efforts involved in developing a flow model for describing two-phase flow in nuclear reactors for RELAP-7 (Reactor Excursion and Leak Analysis Program), an application of MOOSE (Multiphysics Object-Oriented Simulation Environment). The RELAP-7 software is developed to model thermal hydraulic flow in nuclear reactors for the purposes of safety evaluation and systems analysis. MOOSE provides a flexible framework for solving computational engineering problems in multiphysics environments. The four-equation drift flux model derived by Isshi is implemented into MOOSE to provide a wider range of operating conditions for the RELAP-7 program. Characterization of the governing equations in their weak form is performed to provide the basis for implementing the core physics kernels into MOOSE as well as the boundary conditions of the flow model. Closure relations for Ishii’s drift flux model are included to account for frictional pressure drop, mass transfer between phases in the bulk of the fluid and at the wall, and the drift velocity. Many of these constitutive correlations are used in RELAP5-3D and others are extracted from Ishii’s documents. The completed flow model is benchmarked in both timing and model accuracy against other flow models implemented in RELAP-7, including the 7-equation model and the homogeneous equilibrium model. In addition, the four-equation flow model is used to examine simple bubbly flow in a vertical pipe in comparison to experimental data from the common Bartolomei test case for validation. Initial benchmarking is executed using the basic Jacobian solver native to the MOOSE libraries but implementation of the complex analytical Jacobian matrix is performed to improve accuracy and runtime. The results of complex Jacobian implementation is compared to those of the basic matrix generation method as well as the Bartolomei test case, RELAP5-3D, and other flow models in RELAP-7.

Advanced Computational Analysis of Nuclear Power Plant Safety Margin Economics

Thomas Riley, Andy Klein and Jonathan Nordahl

The goal of the SMEE project is to pave the way for more data-driven decision making when considering safety within nuclear engineering. To do this, the project will perform a simple, if extremely detailed, cost–benefit analysis of potential nuclear power plant upgrades related to safety. In this analysis, the cost of the upgrade is the direct monetary cost of implementing the upgrade. The benefit of the upgrade is the risk avoided by implementing it, where risk is the probability the upgrade will prevent or mitigate a radionuclide release, multiplied by the economic consequences of the unprevented or unmitigated radionuclide release. Offsite economic consequences have been found to scale largely linearly with the magnitude of the radionuclide release.

To find the probability of a nuclear power plant upgrade preventing or mitigating a radionuclide release, Monte Carlo sampling of accident scenario stochastic parameters is to be used. By taking
advantage of modern super computing capabilities to account for randomness within accident scenarios, a more in-depth and detailed view of safety can be attained than is possible with older, more binary approaches. By mapping out the ‘failure space’ comprised by all possible combinations of stochastic parameters that lead to radionuclide release in an accident scenario, both with and without an upgrade, the likelihood of the upgrade positively impacting the accident scenario outcome can be analyzed. By comparing the costs and benefits of various potential power plant upgrades, the project aims to find the most cost-effective ways of improving nuclear safety.

9 High-Order Finite Element Radiation Transport in the Diffusion Limit on Curvilinear Meshes in X-Y Geometry

Doug Woods, Todd Palmer, Tom Brunner and Teresa Bailey

BLAST is a shock hydrodynamics code under development at Lawrence Livermore National Laboratory designed to solve high energy density physics problems using higher-order finite element basis functions and meshes with curved surfaces. Using the same finite element library (MFEM), we are developing a radiation transport solver to integrate with BLAST. Our code solves the high-order finite element transport equations on regular and unstructured meshes with curved surfaces in Cartesian coordinates. We have solved several test problems to demonstrate the behavior of this approach including problems with analytic solutions, multiple material regions, optically thick media, and problems that expose negative fluxes. A convergence study was performed on meshes of increasingly higher order (cells with sides that include increasing curvature) and the results demonstrate a reduction of error with increasing number of unknowns. Two test problems produce negative fluxes in optically thick regions. In addition to the traditional source iteration method, we employ a direct solve method in which the scattering source term is moved to the left hand side of the transport equation and one large linear system is solved directly for the angular fluxes.

Radiation Health Physics

10 Study of Proximity Charge Sensing in CZT Detectors

Abdulsalam Alhawsawi, Abi Farsoni, Lily Ranjbar and Eric Becker

Proximity charge sensing is a relatively new technique for semiconductor radiation detectors that has a few distinct advantages over directly-deposited electrodes. The first advantage is that it eliminates the need to deposit electrodes on the semiconductor crystal, which can simplify the fabrication process and reduces the overall cost of the detector. Second, proximity charge sensing reduces the leakage current associated with directly depositing the electrodes.
on the semiconductor surface. Finally, in position sensitive systems, it can be used to improve the position sensitivity of the device via signal interpolation. The advantages of using proximity electrodes have been previously demonstrated by their implementation in Ge and Si-based detectors. Though the energy resolution of HPGe detectors has not yet been surpassed, room-temperature semiconductors such as CZT offer a significant advantage over HPGe since they do not require expensive, high-maintenance cooling systems.

The study proposed here explores the use of proximity charge-sensing on CZT crystals. It includes simulations to calculate the weighting potentials and electric fields for different coplanar electrode designs and fabricate proximity electrodes on compound semiconductors, such as: (1) a high resistivity contact to be applied on the proximity surface (anode side) that should not affect the induced charge generated from radiation interaction and should not trap charges at the detector surface, (2) a proper metal to serve as an ohmic contact to dissipate charges accumulated on the crystal surface, (3) dielectric material to isolate the detector from the electrodes, and (4) proximity-electrodes that are implemented in this research on a PCB (Rogers 4350). The weighting potentials ($\phi$) of proximity-sensing electrodes and directly-deposited electrodes were generated using ANSYS Maxwell and quantitatively compared using a Figure of merit (FOM). The FOM compares the designs in terms of uniformity and similarity of the generated weighting potential. The most promising proximity-sensing electrode design is being fabricated and characterized using a (19.4 mm x 19.4 mm x 5 mm) CZT crystal, and its performance compared to directly-deposited electrodes.

A Direction-Sensitive Radiation Detector for Low-Altitude, UAV-based Radiological Source Search

Eric Becker and Abi Farsoni

Many devices and methods for radiological searches are currently being developed, including scanning using simple detectors, mapping using large-volume detectors, and Compton imaging using 3-D position sensitive detectors. However, these devices are typically expensive and the methods used require long periods of time to generate a direction or location. The Radiation Compass, currently being developed at Oregon State University, is a low-cost detector designed for dynamic use on an unmanned aerial vehicle (UAV) and will generate a most probable source direction that will be used to guide the motion of the UAV.

The prototype detection system is composed of sixteen detection elements based on a BGO crystal coupled to a SiPM and arranged in a circular array. A specific detector response pattern of radiation count rates is generated based on the passive masking of detection elements on opposite sides of the array, and each of the detector panels is able to rotate to optimize its efficiency with respect to the Radiation Compass altitude. Three direction estimation methods were investigated and used to study the performance of the Radiation Compass. The Radiation Compass is able to detect the presence of a 10 µCi 137Cs source in under 8 seconds with 95% confidence at a background rate of 25.5 counts per second at ground level at a distance of 100 cm from the center of the Radiation Compass. The device also achieved an accuracy of 1.8° and a 95% confidence width of 8.6° for a 12.3 µCi 137Cs source in 60 seconds at ground level, at a background rate of 13.12 counts per second, and a distance of 100 cm from the center of the detector.
Radiological protection has historically focused on the protection of humans, but there is now a focus on including interactions between radionuclides and the environment. The Oregon State University Radioecology Research Group focuses on exploring the importance of these relationships and how they relate to current regulatory guidelines throughout the world. Areas of interest currently include work on developing voxel phantom models of representative non-human biota to better estimate the potential radiation dose effects in ecosystems receiving radiological discharges, monitoring and modeling of the introduction of Fukushima-sourced radionuclides into marine ecosystems along the United States’ West Coast, and seeking better understanding of the differences in dose-effect relationships between different phyla. As more and more nations continue to build nuclear power production facilities and take advantage of medical isotopes, there is a pressing need for a full understanding of the potential effects of releases, planned or otherwise.

This research responds to the public concerns about radiation contamination to the environment. The objective is to develop a model of the honeybee hive using Monte Carlo N Particle (MCNP) computer code, and calculate absorbed fractions for multiple energies and multiple incident radiation types. This model could be of great value to the radiological community when being used in dose calculations to the environment, due to the critical role the honeybee plays in the ecosystem. Through their daily routines of collecting pollen, the honeybee may come into contact with radioactive material and subsequently contaminate its hive. Future work will examine a beehive located near a nuclear accident or test site, and determine the levels of contamination present. Additionally this research could be utilized to better understand the travel of nectar and pollen throughout the hive, aid in examining the insect partitioning of radionuclides, and speculate how much radiation deposited on a flower or pollen that bee collects.

Detection of radioxenon escaping from underground nuclear explosions (131mXe, 133mXe, 133Xe, 135Xe) has been shown to be a very powerful method for verifying whether or not a detected explosion is nuclear in nature. These isotopes are among the few with enough mobility...
and with half-lives long enough to make their detection at long distances realistic. Existing radioxenon detection systems used by the Comprehensive Test Ban Treaty Organization (CTBTO) are based on either coincidence methods or high-resolution energy spectroscopy. Detectors using coincidence methods typically use a plastic scintillator to distinguish beta particles and conversion electrons from gamma rays and X-rays, introducing a "memory effect." High-resolution energy spectroscopy is performed by HPGe detectors, which require expensive, high-maintenance cooling systems.

To address these problems a prototype two-element coplanar CdZnTe (CZT) detector was designed and developed at the Radiation Detection and Dosimetry Lab at Oregon State University. This detection system deploys beta-gamma coincidence technique for radioxenon measurements and uses only coplanar CZT detectors, eliminating the memory effect and improving the energy resolution compared to current scintillator materials. Additionally, CZT can be operated at room temperature, which makes the system lower maintenance compared to radioxenon detection systems relying on the energy resolution of HPGe detectors. The detection system was characterized with radioactive lab sources and 135Xe was measured. The energy resolution of 250 keV gamma rays was measured to be 4.4%. This radioxenon detection system is small and compact with a minimal number of channels. In addition, all coincidence detections in this system are completed in the FPGA. These features reduce the complexity of the detection system which along with its lower maintenance need make it a good candidate to be installed in IMS station for remote monitoring.