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MATH AND COMPUTER SCIENCE
Regularization Method for Solving Block Term Decomposition with an Application

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Tensor decomposition has been extensively applied in many engineering and scientific fields, such as, signal processing and environmental sciences. The canonical polyadic (CP) tensor decomposition, one of the standard factorization of a tensor into a sum of rank-one tensors, is solved by a well-known method called alternating least-squares (ALS) method. In this talk, we introduce a generalization of CP – block term decomposition (BTD) and present a new regularization method for solving it. Additionally, a set of environmental real-life data sets are studied by applying the tensor model BTD.
Comparing Constraint Handling for the Implicit Filtering Method for Derivative-free Optimization

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We consider constraint handling for the implicit filtering algorithm for optimization, which uses a finite difference approximation to the gradient with a decreasing sequence of difference increments and a quasi-Newton approach. We extend the capabilities of implicit filtering for bound constraints using the filter method for linear and nonlinear constraints. The filter method for constraints chooses points based on either decreasing the objective function value or improving a measure of feasibility and is incorporated within the implicit filtering algorithm as opposed to aggregating the original objective function. We give a comparison of the new method to implicit filtering with penalty and barrier methods on a suite of test problems that include jump discontinuities and low amplitude noise.
EQ: A Java Equality Checker

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The standard collection data structures in Object-Oriented languages require their element classes provide a predicate to compare two objects for equality. Among other correctness requirements, this predicate must be an equivalence relation. The chance of mistakes increases when equality is implemented in a type hierarchy. Detection of such problems requires reasoning about the equality at a higher level semantics than code, involving the state, the behavior, and the sub-typing relations in the type hierarchy. We present EQ, a tool that performs path-based, abstraction-oriented program analyses to check the correctness of equality implementation in Java.

In our approach, code patterns on paths are identified and translated into abstractions in Alloy. The Alloy model is then automatically checked to reveal any problems related to the equivalence relation. Our evaluation shows that this approach (1) found problems in production code, and (2) scaled to a project as large as JDK 1.5. We believe that it has the potential to be used on a developer's desktop on a daily basis.
It is well-known that APIs can be hard to learn. Although search tools can help find related code examples, API novices still face the significant challenge of evaluating the relevance of the results. To help address this as well as the more general and broader problem of information needs in using APIs, we propose a critic system that offers explanation, criticism, and recommendation for API client code.

Our system takes API use rules as input from API experts, performs symbolic execution to check that the client code has followed these rules properly, and generates advices and recommendation as output to help improve the client code toward a better solution. To assess the potential usefulness of the proposed critic system, we conducted an initial empirical study on the actual problems that the Java Swing users had while programming GUI layouts. We conclude that the proposed critic system is very promising in helping solve these problems. We plan to support these cases in our first prototype.
Military commanders often operate in a physical *mission space*, while system administrators work in a virtual *cyber space*. Each group in their own space may not fully understand the interactions between the two spaces. This research takes a look at the role that computer security has in assuring that missions are completed effectively, such that the computer network supports the missions. A modular modeling framework is presented.

This research is sponsored by AFRL under agreement number FA8750-10-2-0245.
LivDet 2011- Fingerprint Liveness Detection Competition 2011

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Recent studies have shown that fingerprint systems are vulnerable to artificial reproductions made of silicone, gelatin or other materials. Since that time, the concept of Liveness Detection has been proposed in order to check the vitality of fingers presented to the scanner. LivDet 2011 is to be hosted in order to provide a benchmark of systems in industry. Both software and hardware-based systems will be able to be tested in this competition against a standardized testing database developed by Clarkson University.

LivDet 2011 will create a large public fingerprint database that will be available to research facilities upon completion of the event, and will set a reference point in the field of fingerprint liveness research. The current state of the art in fingerprint vulnerability will be impacted in order to improve security in biometric systems. Results of this competition will be reported at the International Joint Conference on Biometrics in October of 2011.
BIOMETRICS AND REHABILITATION
Fiber Laser Design and Construction

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Fiber lasers are a field of emerging interest and great potential, with advantages over conventional lasers for many applications. This presentation will provide an introduction to fiber lasers, discussing their behavior and applications. Current research work on fiber lasers within the ECE optical signaling group will be summarized. Potential for research partnerships and future collaboration will be highlighted.

The group has designed and constructed a fiber laser, and optimized the design for long-range transmission. Areas of active research include lasing at alternative frequencies; modulation for ranging and communications; and modeling strategies. Status of work, observed laser behavior, and possible applications will be included.
Biomedical Radar for Heart and Respiration Rate Detection

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This study focuses on determining people’s heart and respiration rate. Detecting and monitoring of heart and respiration activity from a distance could be a wonderful tool for health care and surveillance applications, without the need for contact and subject preparation, allowing for wellness monitoring for a large population without known predisposition for risk or harm. Doppler radar remote sensing of vital signs has shown promise to this end, with proof of concept demonstrated for various applications. Unfortunately, this principle has not been developed to the level of practical application, due to lack of an effective way to isolate desired target motion from noise. We are designing a new signal receiving system. For the hardware, the signal hound SA44B is used to receive the radar reflections. For the part of software, GNU radio and OSSIE radio tools are used to give the reflections more sensitive processing. Hopefully, after combining all the components smoothly, more sensitively reflected signals can be gathered and extracting the envisaged heart and respiration signals can become a reality after some follow-up programming.
Comparison of Quality-Based Fusion of Face and Iris Biometrics

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Multi-modal systems have been used for the increased robustness of biometric recognition tasks. A unique strength of multi-modal systems can be found when presented with biometric samples of degraded quality in a subset of the modalities. This study looks at the effect of quality degradation on system performance using the Q-FIRE database. The Q-FIRE database is a multi-modal database composed of face and iris biometrics captured at defined quality levels, controlled at acquisition. This database allows for assessment of biometric system performance pertaining to image quality factors. Methods for measuring image quality based on illumination conditions are explored as well as strategies for incorporating these quality metrics into a multimodal fusion algorithm. This talk provides further evidence in a unique dataset that utilizing sample quality metrics into the fusion scheme of a multi-modal system improves system performance in non-ideal acquisition environments.
Block-Based Compact Thermal Model for Microelectronic Circuits

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Compact thermal models have been widely used in recent years to provide overall temperature information in microelectronic systems to meet thermal requirements for design of microelectronic circuits and systems. The conventional models usually provide average temperatures in some locations of the systems but are not able to capture enough temperature details (such as hot spots) in the systems or circuits.

In this work, a block-based compact thermal model has been developed to describe more detailed temperature profile in a system than the conventional compact thermal model. The developed block-based thermal model has been applied to three-dimensional SOI integrated circuits (IC’s) at 65 nm technology.

In this approach, several building blocks are selected, and a compact thermal circuit is constructed for each selected block. The building block thermal circuits are stored in a technology library and can then be placed together to construct a thermal circuit for a large circuit block. In each building block, interface and interior nodes are selected in the important locations. Thermal resistance via any two nodes is introduced to describe heat flow between the nodes. To extract the resistances accounting for heat flows within the block and across the block boundaries, a random heat source in the block is assigned to each node. The size and location of interface nodes are selected based on the structure of the block. If the interface nodes are selected appropriately and the thermal resistances are extracted correctly, thermal continuity across the interfaces among the blocked can be enforced. The developed model can be applied to any complicated geometry without any assumption on physical structure, heat flow path and thermal elements. The procedure for constructing the thermal circuit of single block and multiple block structures is described in this work. The model is verified against detailed finite element thermal simulation.
Impact of Out-of-focus Blur on Face Recognition

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It is well recognized that face recognition performance is impacted by image quality. As face recognition is increasingly used in semi-cooperative or unconstrained applications, quantification of the impact of degraded image quality can provide the basis for improving recognition performance. This study uses range of real out-of-focus blur obtained by controlled changes on camera across face video sequences during acquisition from the Q-FIRE dataset. The modulation transfer function (MTF) based on a co-located optical chart for measuring sharpness is presented and compared with other sharpness measurements. Face recognition performance is examined at eleven sharpness levels. Experimental results show the quantified impact on recognition performance based on gradually increased sharpness levels. This talk demonstrates that high verification rates for face recognition system can be achieved even by very low sharpness level images.
There have been numerous efforts, with much success, to develop techniques for using speech as a biometric. In recent speaker recognition evaluations organized by NIST, the best-performing algorithms are able to achieve equal-error rates near 1% under favorable conditions with sufficient data, suggesting that the technology is quite advanced. However, there are still challenges presented by variations in the recording channel, both within the available enrollment data for generating speaker models and channel differences in the enrollment / test sessions, resulting in significant degradation of speaker identification recognition rates. This problem posed by environment variability will be addressed using advanced subspace decomposition and machine learning techniques.
Psychophysical Detection Thresholds in Anterior Horizontal Translations of Seated and Standing Blindfolded Subjects

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Comparing standing and sitting conditions, this study determined differences in psychophysical acceleration detection thresholds of blindfolded subjects during short anterior perturbations of 1, 4 and 16mm. A novel perturbation device – the Sliding Linear Investigative Platform for Assessing Lower Limb Stability with Synced Tracking, EMG and Foot Pressure Mapping System (SLIP-FALLS-STEPm), was used along with a 2-Alternative-Forced-Choice (2-AFC) test protocol. For blindfolded standing subjects, a negative power law trade was observed between the peak acceleration detection threshold and the move length (or duration). A positive power law trade was shown between the acceleration threshold and the move length (or duration) for these same blindfolded subjects while seated. The positive power law trade found between acceleration detection threshold and move duration for the seated subjects was also observed by Benson et al `86., who suggested that only vestibular input was used for detection.

Acceleration detection thresholds at 1mm were higher in standing than for sitting. For 16mm perturbations, acceleration thresholds for standing subjects were lower than the thresholds for these seated subjects. These differences in responses between the standing and seated conditions at 1 and 16mm indicated that the vestibular system's contribution to a power law trading relationship mainly exists in the seated condition. For the standing condition, the somatosensory system contributed significantly to the negative trading relationship between threshold and move length, where the subjects might have made the detection based on both somatosensory and vestibular systems. These observations can help us understand the contributions of the somatosensory and vestibular systems to balance control.
MECHANICAL ENGINEERING
Improving Long Term Storage Efficiency of a micro-CAES System for the Electric Grid

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This research project studies the possibility of using a hybridized micro-CAES/flywheel system to improve long term storage efficiency and potential power quality for the electrical grid, especially as it pertains to the utilization of alternative energy sources. Improved electrical energy storage would allow better utilization of the variable nature of alternative energy sources. The addition of the flywheel should improve the micro-CAES system and make it more suitable for a micro-grid.
In an effort to mitigate the disparity between renewable energy production and consumer demand, a Hybrid Renewable Energy System (HRES) is proposed that uses wind turbines and solar panels for power generation. The proposed storage method uses electrolysis to separate water molecules into hydrogen and oxygen via excess DC currents produced by the wind and solar. The hydrogen is compressed, buffered, and stored in tanks, and when demand exceeds intermittent generation, power is provided by a Proton Exchange Membrane Fuel Cell (PEMFC), which has a quicker startup time compared to other types of hydrogen fuel cells. A physics-based model of the HRES is constructed in order to improve its efficiency, and statistics-based reliability models are formed to evaluate its loss of power supply probability (LPSP). Efficiency of a HRES can be viewed as balancing the energy production with user consumption. For this purpose, realistic models of all subsystems are created. Models of the AC loads are also required; this includes models of a performance optimized data center (POD) and the power demand of a small community. On the reliability side, investigation will be made to optimally size the HRES based on past, site-specific environmental data with the goal of minimizing the total cost of operation of the system over the course of twenty years.
Design, Manufacturing and Testing of a Research Unmanned Aerial Vehicle

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Unmanned Aerial Vehicles (UAVs) provide the ability to perform a variety of experimental tests of systems and unproven research technologies, including new autopilot systems and obstacle avoidance capabilities without risking the lives of human pilots. A fixed-wing UAV was constructed using a variety of composite materials and manufacturing processes for the purpose of testing integrated systems. The aircraft is designed for high-volume and high-weight payloads so as to accommodate a variety of experimental systems. The UAV features a 110 inch (2.7 meter) wing span with an 18 inch (0.46 meter) chord and utilizes a Clark Y airfoil. The power plant for the system is a single 7.5hp 2-stroke petrol engine, with a digital electronic ignition, mounted to the rear of the fuselage in a pusher configuration. An 18V DC generator provides power to the instruments and to supplement the control system, autopilot, and ignition batteries. The aircraft tail is supported by twin booms and features a split elevator and dual rudders for redundancy. Since the intended function of the UAV will be to conduct numerous experiments involving unproven systems, we anticipate the potential requirement for rapid field maintenance and repair. For this reason, our design and manufacturing processes focus on minimizing construction, repair, and replacement costs. In the interests of safety and liability, this aircraft conforms to both the FAA “model aircraft” guidelines and those anticipated for the Airworthiness Certificate for small Unmanned Aerial Systems (sUAS). In order to comply with the “model aircraft” requirements, our UAV will have to operate with a max speed below 100 mph (161 km/hr or 87 knots), have a max takeoff weight less than 55 lbs (24.9 kg), and operate below altitudes of 400 ft (122 meters) above ground level. This presentation details the novel manufacturing processes for an experimental, all-composite, research UAV to be used by Clarkson University. Discussions will include an in depth report on the selection of materials, manufacturing methods, and the implementation and results of the fabrication procedures for the structural components along with the challenges of constructing an aircraft capable of meeting multiple FAA regulatory requirements.
Fluid flow and temperature field in gas tungsten arc welding is investigated in this study. To predict important welding characteristics such as weld pool geometry, heat source efficiency, thermal stress residues and mixing rate, especially in dissimilar metal welding, one needs to study heat transfer and fluid flow in the welding process. Transport phenomena should be studied in three separate domains, which are simulated in a unified method. The first domain is the arc plasma, which includes flow and heat transfer in the argon protective layer and passes current density and heat flux to the second domain, the weld pool. Various driving forces, which circulate fluid in the weld pool should be considered. These forces are surface tension force in the weld pool and arc interface, buoyancy force, electromagnetic force and shear drag from the argon flow on the surface. Study of this domain leads to prediction of weld pool shape and accordingly welding penetration. The third domain to be studied is the solid plate, which is to be welded. The solid plate acts as a heat sink and plays an important role in heat dissipation from the weld pool. Besides, temperature field in the part is to be used for thermal stress analysis. The three above-mentioned domains are solved simultaneously through a numerical simulation.
Wave Propagation Analysis of Composite Plates with a Transverse Crack Using Wavelet Based Spectral Finite Element Method

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This work presents a novel wavelet based spectral finite element (WSFE) for studying wave propagation in composite plate structures with a transverse crack. The spectral element model captures the exact inertial distribution as the governing partial differential equations (PDEs) are solved exactly in the transformed frequency-wavenumber domain. Therefore, the method results in large computational savings compared to conventional finite element (FE) modeling, particularly for wave propagation analysis. In this approach, Daubechies scaling function approximation is used in both time and one spatial dimension to reduce the coupled PDEs to a set of ordinary differential equations (ODEs). The localized nature of the compactly supported Daubechies wavelet allows easy imposition of initial-boundary values. This circumvents several disadvantages of the conventional spectral element formulation using Fast Fourier Transforms (FFT) particularly in the study of transient dynamics. The transverse non-propagating crack has arbitrary length and depth, and it is located parallel to one principal axis. The elasticity of the crack is formulated correlating bending flexibility and slope discontinuity on both sides of the crack. Both time and spectral domain results will be presented and discussed.
The proper orthogonal decomposition (POD) is a reduced-order modeling technique that is used to represent unsteady flows. Flow properties can be calculated with high precision compared to the direct numerical simulations using only a small number of modes while still retaining all of the essential flow physics. The method has a broad range of applications, such as design of closed-loop control stabilization of wake in turbulence flow or generating simple equations for describing instantaneous turbulent flows which ordinary models can not provide. In earlier applications of POD for reduced order modeling of flow, stabilization of equations were ignored and linearized equations were used. In this study, we use the POD for two equations to show that the reconstruction of flow without stabilization is impossible. We study the Navier-Stokes and the Burger equations for various velocities and initial conditions. Reduced-order models are created by performing a streamwise-upwind-Petrov–Galerkin (SUPG) projection of the equations onto the space spanned by the POD modes.
Experimental and Full Scale Investigation of Base Cavity Drag Reduction Devices for Use on Ground Transport Vehicles

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Comparison studies have been conducted on a 1:16th scale model and a full scale tractor trailer of a variety of sealed aft cavity devices as a means to develop or enhance commercial drag reduction technology for class 8 vehicles. Sixteen base cavity geometries with pressure taps were created for the scale model. Drag data were acquired on the models using a custom designed single axis internal force balance for a range of yaw sweeps and at two Reynolds numbers for each base cavity. Base pressure surveys for selected base cavities were also used to quantify the change in base pressure. The scale model force data indicated a marked decrease in drag at up to 15% for multiple base cavity shapes, however most base cavities reduced drag by 5% to 10%. Pressure data indicated the base cavities increased the base pressure over baseline with a $\Delta C_P$ of up to 0.3. Moreover, drag computed from pressure data implied that although the base cavities decreased the base drag due to a pressure increase, the drag may have increased elsewhere on the model. Fullscale tests were also completed using SAE Type II testing procedures. Full-scale tests indicated a fuel savings of over 6.5%. Overall, the use of these devices shows to be a viable, effective and economical way to reduce fuel consumption on ground transport vehicles.
When using a high-order continuous finite element method for unsteady simulations, one must invert a global mass matrix even for an explicit time advancement scheme. To overcome this a local mass matrix inversion procedure is developed for \( p = 2 \), \( C^0 \) finite elements and also show that, unlike on triangles (Helenbrook, 2007), this procedure does not generalize to higher order. For the \( p = 2 \) basis, the local mass matrix inversion procedure allows efficient explicit computations as well as the development of fast and low memory iterative algorithms. It is demonstrated that the accuracy of the local inversion is better than any previous mass lumping scheme. We also show the efficiency of using the approach as an iterative relaxation scheme for solving the Helmholtz equation. Iterative results are compared to more standard approaches such as a multigrid Jacobi relaxation to demonstrate the efficiency. Lastly, the local mass matrix inversion is used to march the unsteady heat equation explicitly with spatial third order accuracy.
A semiconductor circuits thermal model is developed that uses a hierarchical function space, rather than physical space. The function space is derived using the Proper Orthogonal Decomposition (POD) and does not require any assumptions about the physical geometry, dimensions, or heat flow paths, as usually done in compact/lumped thermal models. The approach can be applied to arbitrary complex geometries and provides detailed thermal information at a computational cost comparable to that of lumped thermal models. The developed model is applied to a thermal simulation of a 2D SOI structure and verified against direct numerical simulation (DNS). It is shown that a steady POD thermal model based on 4 POD modes can nearly duplicate the temperature solution derived from DNS in the 2D SOI structure. The hot spot and large temperature gradients along the extremely thin device island can be captured with high accuracy using only 3 POD modes. In addition, a dynamic POD model of the SOI structure was constructed. A POD model incorporating 10 modes yielded a virtually identical solution when compared to corresponding DNS results. Furthermore it was shown that the temperature profile of a transient solution could be depicted using only 4 POD modes.
The Effect of Electro-Hydraulic and Electro-Hydrostatic Actuators Dynamics on the Adaptive Control of Chaotic Motions of a Nonlinear Aeroservoelastic (ASE) System

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A nonlinear airfoil equipped with a trailing edge flap that is coupled to a flight control actuator (electro-hydraulic or hydrostatic) will be examined for its aeroservoelastic response and interaction to a reference free adaptive feedback controller augmented with time-delay. The internal response of each type of actuator to the designed control signal presented as the global aeroelastic response. In addition to these simulations a study of the actuator and controller parameter will be provide to complete the study.
Closed-Loop Feedback Control Algorithms for Flow Control over NACA 0015 Airfoil

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The aim of this study is to develop closed-loop feedback control algorithms for turbulent flow separation phenomena over 2-D airfoil equipped with leading-edge synthetic jet actuators (SJAs). The control objective is to delay flow separation or stall by actuating the SJAs through a closed-loop control algorithm using surface pressures as sensor data. Fluent simulation results are validated by wind tunnel test data of turbulent flow over a NACA 0015 airfoil at Re=1x10^6. A model-based control approach is investigated in this work implementing the proper orthogonal decomposition (POD) technique. A synthetic jet actuator model is employed and controller design follows the standard PI algorithm for single-input single-output system. The control algorithm uses stochastic estimation technique and proper orthogonal decomposition for multiple surface pressure sensor measurements. Real-time instantaneous low-dimensional estimates of the pressure field over the airfoil are computed from the unsteady surface pressure. These estimates provide direct information about the flow state over the airfoil. As a result of this low-dimensional modeling approach, the first static pressure-based POD coefficient is chosen as control variable. It is shown that POD based proportional and proportional-integral multiple-input single-output feedback control delays flow separation at high angles of attack (above 16 degrees). The benefits of closed-loop control versus open-loop control are thoroughly investigated. Parametric studies for the effect of velocity profile configuration of synthetic jets on airfoil aerodynamic performance parameters, effect of synthetic jets frequency upon stability and robustness of the proposed controller will be included in the talk. The control design methods reported in this work will be used for wind tunnel testing in future.
The goal of this study was to determine the feasibility of using a whole field optical flow measurement known as Molecular Tagging Velocimetry (MTV) in two-phase (gas/liquid) flows. This was achieved using a 7.63m long horizontal tunnel with an aspect ratio of 7.4:1. A combination of 1-bromonaphthalene, β-cyclodextrine, and cyclohexonal was used to form a phosphorescent chemical complex that was used as the tracer for the experiments. A 266nm laser was used to induce phosphorescence. Air was injected into the flow using a diffuser that generated bubbles with a diameter that ranged from 0.1 to 0.5mm. Three air flow rates were used in conjunction with three tunnel speeds to generate nine distinct tunnel conditions. A velocity and corresponding rms profile were generated for each of the nine tunnel conditions, each with a different air-water void fraction. From the data collected it can be seen that as the void fraction increases the scatter of the velocity and rms profiles increases. Also the overall magnitude of the rms profiles increases as the void fraction increased. It was concluded that the introduction of the bubbles caused the laser beam scatter which led to the increased scatter in the velocity and rms profiles.
CFD Model of Velocity Field and Net Momentum Output of a Synthetic Jet Actuator

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Synthetic jet actuators have been used for control of flow separation in high performance airfoils for high lift and low drag. The synthetic jets have zero net mass flux but impart net momentum to the flow. In this study, LES simulations were used to study the time history of the outlet velocity profile and net momentum imparted to the flow by a synthetic jet actuator (SJA). The SJA studied is not symmetric and operates with the aid of a piezoelectric (PZT) ceramic circular plate actuator. A three-dimensional mesh for the computational domain of the SJA and surrounding volume was developed and was used to evaluate the details of the airflow conditions inside the SJA as well as at the outlet. The vibration of the PZT ceramic actuator was used as a boundary condition in the computational model to drive the SJA. Particular attention was given to the time evolution of the SJA outlet velocity profile. The time history of the outlet velocity profile of the synthetic jet was curve-fitted to an empirical equation. The resulting outlet velocity will be used as an inlet velocity for active close loop control of airflow separation around an airfoil at high angle of attack.
Air Flow Simulation around a Wall-mounted Cube with a Comparison of LES and Reynolds Transport Turbulence Models with Experiment for a Realistic Model of a Building

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Simulation of flow field around a simple geometry of a wall mounted square cylinder is a classical problem which still plays an important role in validating the numerical solutions of turbulence models. In this talk, the accuracy of the results achieved by using the two turbulence models, the Reynolds averaged Navier-Stokes equation of Stress transport and large eddy simulation at high Reynolds number of 80000, are examined and compared with the experimental data of H. Hussein and R. Matinuzzi (1996). The geometry of study is 3D, and the influence of the wakes at the side walls of the cube as well as the effect of vortexes in front and at the back of the cube on the flow field is investigated. On the other hand, as implementing LES model is so expensive regarding the time and the fine mesh it needs, the ultimate purpose of this talk is to find if Reynolds stress transport model of turbulence is accurate enough in predicting the flow field around a complicated geometry of a realistic building model.
An Optimized Design Strategy for Small Horizontal Axis Wind Turbines

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Wind turbine efficiency is measured in terms of power output, usually at a specific operating point. Although the theoretical maximum efficiency for a horizontal axis wind turbine is 59%, smaller wind turbines typically achieve values in the range of 35% to 40%. A more effective strategy is being developed that optimizes the amount of energy extracted over a given period of time rather than power at a specific operating condition. A blade element moment code is being used to generate blade geometries and is being coupled to an optimization algorithm that is used to select the optimal design. Preliminary results from the studies will be shared.
Vortex Projectiles Ejected by Shoaling Internal Waves of Elevation

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Internal solitary waves and their interactions with shelf topographies are important mechanisms in the transport of sediment and circulation in the Earth's density stratified oceans and seas. In the present study, the interactions of internal solitary waves of elevation with a sloped shelf are investigated. This event is simulated using numerical solutions to the two-dimensional Navier-Stokes and convective-diffusion equations with the Boussinesq approximation applied. When internal solitary waves of elevation encounter a shoal, a “vortex projectile”, or concentration of vorticity, is produced and protrudes off the front of the wave. These are similar to the boluses observed in flow visualizations of shoaling internal waves performed by Helfrich [Helfrich 1992].

The wave of elevation contains a significant amount of vorticity, and, as it hits the shoal, the shape of the wave is distorted. The vorticity accumulates at the front of the wave by a combination of convection and production by enhancement of horizontal gradients of density as it shoals. The properties of the formed vortex projectile are studied as it rises up the shoal and also as it is deposited along a shelf. The vortex projectile contains denser fluid than its surrounding fluid as it rises up the shoal, and therefore eventually diminishes in size by draining this fluid back down the incline. The projectile transports bottom layer fluid effectively to locations far up along the shoal. Therefore, these vortex projectiles are of significant importance, especially while studying transport mechanisms in various bodies of water.
MATERIALS SCIENCE
Human Elbow Joint Stiffness Measurement

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The research on joint stiffness is very helpful in a variety of fields including modeling of human body motion (Faber et al., 2000). This research is focused on measuring stiffness of the human elbow joint. The test device was first developed to measure ankle and knee joints compliance by C.J. Robinson et al., (1994). The joint stiffness, K, can be calculated as the change in joint position due to a change in applied torque (Faber et al., 2000), and it can also be determined via the least square fit (LSF) of a mathematical model:

\[ T(t) = J\alpha(t) + Bv(t) + K\theta(t) + C \]  

(1)

in which, \( T(t) \) = torque, \( J \) = moment of inertia, \( \alpha(t) \) = angular acceleration, \( B \) = viscous damping coefficient, \( v(t) \) = angular velocity, \( K \) = stiffness coefficient, \( \theta(t) \) = angular displacement, and \( C \) = constant torque bias (C.J. Robinson et al., 1990). Similar to C.J. Robinson et al., (1994), the metal support for the human forearm is mounted on the motor shaft and can be driven by the motor to rotate in the horizontal plane. The center of the elbow joint is aligned with the axis of rotation using an axis finder. By computer control, two kinds of motions can be applied to the subjects’ forearms. One is to rotate with random amplitude and speed within a small range (5°-10°) and the other is to rotate with constant speeds within specified angular ranges. Both motions can be conducted with different initial elbow joint flexion angles. The subjects’ elbows will be under relaxation for both methods. Three different transducers measure \( T(t) \), \( \alpha(t) \), \( \theta(t) \); \( v(t) \) can be calculated from \( \theta(t) \). By a LSF of (1), \( J \), \( B \), \( K \) and \( C \) can be estimated. At least 6 healthy subjects’ elbow joints stiffness will be measured in vivo. The values for \( B \) and \( K \) should be consistent across subjects and change with different angular velocities.

References

Recrystallization of the grain structure of metals into nano-sized grains by using mechanical means has received significant attention in the last two decades. It is well known that materials with a fine-grain crystal structure have favorable properties compared to the same materials with course-grained crystal structure. Surface Mechanical Attrition Treatment (SMAT), a technique developed in the early part of this decade, has been successfully used to recrystallize the surface grains of metals into nano-crystals on the order of 10 to 100 nanometers from their original grain sizes on the order of 10 to 30 microns. Resulting enhancement in surface properties has quite interesting applications, varying from materials with improved fatigue resistance to medical devices.

In this study, our focus is on experimental characterization of the enhancement in mechanical properties of surface nano-crystallized metals. An apparatus for the treatment of copper samples utilizing a SMAT technique has been developed. The changes in grain structure are investigated using SEM and AFM imaging techniques. Nano-indentation techniques are conducted to characterize various mechanical properties. Several interesting phenomena have been found to occur during nano-indentation of the non-SMAT and SMAT samples and are being further investigated.
Failure of Castlegate Sandstone under True Triaxial Loading

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A series of tests were performed to investigate the effect of the intermediate principal stress on the stress-strain response and failure of Castlegate sandstone under true triaxial states of stress. Constant mean stress tests were run at five different Lode angles ranging from 30° to -30°, axisymmetric compression to axisymmetric extension, respectively. Failure occurred either through deformation band formation or bulk compaction. Acoustic emissions (AE) recorded during testing were used to locate failure events in three-dimensional space within the sample. This allowed for more detailed investigation of the formation and propagation of the band within the specimen when a band was present. Specimens that underwent bulk compaction showed AE data that was randomly distributed throughout the sample. Results gleaned from the bulk material data show that as Lode angle decreases so does peak stress for a given mean stress. Additionally, for a given Lode angle, peak stress increases with increasing mean stress. Band angles tend to increase with decreasing Lode angle, and decrease with increasing mean stress. Results from the AE data shows that the band angle evolves during testing and the band that is expressed on the surface of the specimen at the conclusion of testing is not always the band that initially formed. Also, results show that low angle bands tend to be more diffuse than higher angle bands.
Effect of pH, Temperature, Flow Rate and Anti-Corrosives on the Corrosion of Copper-Nickel

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This work discusses an experimental study on how water quality affects the corrosion rate of Cu-Ni alloys, such as those used within a heat exchanger system. Various types of water suitable for the heat exchanger operation have been tested to predict the duration during which corrosion would become a risk. Since corrosion is governed by electrochemistry, an electrochemical experimental setup was designed, consisting of a three-electrode electrochemical cell designed to simulate the on-site state and conditions of a 90/10 Cu/Ni tube bundle inside the heat exchanger. The working electrode used was a 90/10 Cu/Ni Rotating Disk Electrode (RDE). The electrolyte solution was varied with different pH values, temperature and compositions. The corrosion rate was measured by using the Tafel method. Experiments were performed with two solutions; de-ionized water (DIW) and tap water. Further, experimentation with anti-corrosives was also performed. All measurements were produced using a G300 Gamry® Potentiostat (computer controlled) conjugated with two general purpose electrochemical softwares: Gamry Framework® and Gamry Echem Analyst®. Trends of the corrosion rate as a function of pH and temperature were analyzed. Field Emission Scanning Electron Microscope (FE-SEM) tests have also been performed to determine the products, methods and elemental effects of the corrosion. Methods, results and discussions are provided with pertinent conclusions.
Development of a structural health monitoring (SHM) system to be integrated with composite horizontal axis wind turbine blades using fiber Bragg grating (FBG) strain sensors is reported. The system will be fully integrated with the wind turbine. FBGs are an attractive option as a SHM sensor for composite wind turbine blades because of their small size, inherent multiplexing and resistance to electromagnetic interference. SHM systems for wind turbine blades can minimize maintenance inspections of the blade. Data acquired by the SHM system can provide feedback for the designers of the blades to improve performance. Developing a real-time SHM system provides more data to a possible control law for wind turbine blade pitch. This presentation will discuss the laboratory scale experiments designed to validate the FBG as a SHM sensor for wind turbine blades.
Electrodeposition of CuGaSe$_2$ from Thiocyanate-Containing Electrolytes

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CuGaSe$_2$ (CGS) thin films are electrodeposited with a stoichiometric composition from electrolytes containing thiocyanate (SCN$^-$) as a complexing agent. The standard reduction potentials of uncomplexed Cu(II) and Ga(III) differ by about 870 mV. The complexing agent cathodically shifts the reduction potential of Cu (II) so that the reduction potentials of Cu(II) and Ga(III) differing by only 80 mV. During cyclic voltammetry, a strong cathodic peak is observed in the presence of all three elemental species that is anodically shifted from those for the individual species. This arises due to the induced co-deposition mechanism, observed in the past during electrodeposition of CuInSe$_2$. As a result, stoichiometric CuGaSe$_2$ deposits are obtained at -300 mV vs. SCE and pH 2.75 from electrolytes with Cu:Ga ratios ranging from 0.5 to 1.5. Electrodeposition of stoichiometric CuGaSe$_2$ appears to be immediately followed by Ga oxidation, since O incorporation into the deposit is observed only when Ga is present. Methods for removing oxygen from the film will be discussed.

Protic Ionic Liquid Membranes for High-Temperature PEM Fuel Cells

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Current proton exchange membrane (PEM) fuel cells operate in the temperature range of 50 to 80 °C. However, operating a fuel cell at temperatures greater than 100 °C has several advantages, which include the avoidance of complicated water management subsystems, a higher rate of reduction at the cathode, and improved tolerance to CO leading to less stringent hydrogen feed purity requirement. However, conventional perfluorosulfonic-acid membranes, such as Nafion®, show a marked loss in conductivity at temperatures greater than 80 °C because proton conductivity of Nafion® is greatly dependent on the level of hydration.

A goal of this project is to develop novel ionic-liquid–ionomer hybrid PEMs that have high proton conductivity even under dehumidified conditions. Several fluorinated and non-fluorinated protic (Brønsted acid–base) ionic liquids based on protonation of the the Brønsted bases, trialkylamines and imidazole, with the Brønsted acids, methanesulfonic acid and perfluoromethanesulfonic acid were synthesized and their thermophysical and electrochemical properties were characterized. Properties such as density, viscosity, self-diffusion coefficient, conductivity, and the temperatures of glass-transition, crystallization, melting, and decomposition were determined, and correlated to the chemical structures of the cation and the anion. Fluorination of the anion was found to have a strong effect on all the transport properties. Moreover, it was found that the protic ionic liquids of the present study differed notably from the non-protic imidazolium iodide ionic liquids that have been studied recently [1]. The orders of dependence of molar conductivity on viscosity, or diffusion coefficient, were significantly lower than 1 suggesting deviations from the Nernst-Einstein behavior noted for the non-protic ionic liquids studied previously. A detailed analysis of these results will be presented in this talk.

Field Enhanced Recrystallization and Densification of CIGS Precursor Materials for Thin-Film for Photovoltaic Applications

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The world’s growing energy concerns have led to an outbreak in renewable and alternative energy research. Thin-film photovoltaics have been one focus of this research due to negligible material costs and the potential to reach grid parity. These device architectures take advantage of materials with high optical absorption coefficients allowing the absorber layer to be as thin as a few microns. Copper indium gallium diselenide (CIGS) is one material that has shown excellent promise for terrestrial thin-film solar applications. In fact, world record efficiencies for thin-film solar cells have been achieved using CIGS based devices. While these achievements are exciting, difficulty achieving large area uniformity has limited the commercialization of CIGS based technology. Particulate based processes provide the opportunity to lower production cost and achieve large area uniformity by using roll to roll processing. While extensively researched, limited densification and recrystallization of porous precursor materials has been achieved. However, we present an effective process for the recrystallization and densification of particulate CIGS precursor materials into dense thin films.
Development and Characterization of Oriented Polyacetylene Thin Films toward Application in Low-Cost High-Efficiency Solar Cells

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The impending energy crisis demands exploration of novel methods for obtaining alternative and renewable energy. The conversion of solar energy into electric power is not only a sustainable means of energy production, but also an environmentally benign approach because of potential reduction in greenhouse gas emission. The goal of this research is to develop solar cells using polymer antennas. Specifically, stretch-oriented polyacetylene films prepared from poly(vinyl alcohol) are studied. After casting poly(vinyl alcohol) thin films, mechanical stretching and a reaction with hydriodic acid and iodine leads to the formation of iodine-doped polyacetylene thin films. Fourier transform infrared spectroscopy (FTIR) is used to monitor the extent of the dehydration reaction of poly(vinyl alcohol), and ultraviolet-visible spectroscopy is used to investigate dichroic properties of the resulting films. We seek to develop high efficiency photovoltaic cells using these conducting polymer films. This presentation will discuss the effect of reactions conditions on the extent of polyacetylene formation, and the light-polarizing properties of the resulting films.
Galvanic/Electroless Deposition of Compact Si onto 6061 Al Alloy from Aqueous HF and 80% Formic Acid

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We report galvanic/electroless deposition of Si onto 6061 Al alloy from 80% formic acid solutions containing HF. The overall reaction involves reduction of $\text{SiF}_6^{2-}$ to Si coupled with two oxidation reactions, oxidation and dissolution of Al and oxidation of formic acid. The Si film is about 7-10 µm thick after 24 hr. of deposition. High resolution scanning electron microscopy (SEM) shows that these Si films are compact, rather than nanoporous. Elemental analysis by energy dispersive x-ray spectroscopy (EDX) demonstrates that the as-deposited film contains 1-3 atom% Al, 3-6 atom% Cu, and 90-95 atom% Si. Al is incorporated in the deposit due to Al dissolution and transport through Si during thin film growth. In other words, the Al 6061 alloy substrate is a reactant. Cu also arises from the 6061 Al alloy substrate, and enhances Si film adhesion. This Si deposition process is accompanied by copious bubble formation, and the reaction does not proceed without vigorous agitation to dislodge the bubbles. Omission of formic acid results in nanoporous Si deposits. We believe that this is the first report of electrochemical deposition of Si thin films that does not involve organic solvents or molten salt electrolytes.


CIVIL ENGINEERING MATERIALS
Carbon dioxide sequestration and storage is a potential solution for the mitigation of greenhouse gas emission into the atmosphere from targeted industrial sites such as cement plants. The CO$_2$ concentration in the atmosphere was reported to be at 384 ppm in 2007, with an annual average growth rate of about 2 ppm since 2000. CO$_2$ sequestration generally refers to the capture and permanent, safe storage of CO$_2$. This study evaluated the potential of a few alkaline industrial waste materials of large tonnage that are currently land-filled, in sequestering CO$_2$ through the process of mineral carbonation and thus forming stable end products. Mineral carbonation is a chemical process which provides a reaction with the CO$_2$ to form carbonates with alkaline minerals. The waste materials that were chosen for this study are cement kiln dust (from cement plants), Class C Fly ash, circulating fluidized bed combustion (CFBC) fly ash (from coal powering thermal power plants), ground granulated blast furnace slag (GGBFS-from steel manufacturing plants), and fine glass powder (from industrial and highway safety glass bead manufacturing operations). These materials are chosen for this study because they contain significant amounts of free alkaline earth metal oxide or its hydroxide. The pre-carbonated and carbonated specimens were characterized using derivative thermogravimetric (DTGA) and X-ray diffraction analysis (XRD). Depth of carbonation was determined using phenolphthalein indicator. Depending on the sequestration efficiency and the end product chemistry, the resultant products from these waste streams have potential applications in construction such as carbonate binders, filler materials in high-performance and self-consolidating concretes, concrete blocks etc. The carbonated end products were used as a cement replacement material in cement pastes to evaluate the properties of the cement pastes incorporating these materials. The results of this study show that a 10% replacement of cement with carbonated alkaline waste did not compromise the fresh and hardened properties of the cement paste significantly.
Alkali Activated Cement Free Slag Binder: Influence of Type and Dosage of Activator

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The cement manufacturing process accounts for 4-5% of global CO₂ emission and touches on a wide range of sustainability issues including climate change, pollution, solid waste land filling and resources depletion. Reducing the amount of cement usage by increasing the volume fractions of supplementary cementitious materials, such as ground granulated blast furnace slag (GGBFS or slag) is very promising from the sustainability perspective. Using high volumes of slag (typically 50% or more) in concrete has an added advantage of beneficiation of an industrial waste materials that otherwise need to be land filled. However, the low reactivity of slag is a major hindrance to the development of such binders consisting of large volume of slag. A method to overcome this low reactivity property that has demonstrated great promise and has received wide attention of late is the activation process of slag using alkali containing external agents (activators). Using this process, concrete with no cement can be produced by using only slag as the binding material. In this study, preliminary results of the influence of two types of activators (sodium silicate and sodium hydroxide) and their dosage on the hydration process, setting time and strength development of activated slag systems are discussed. It is found that sodium silicate activator is beneficial for the later age strength development whereas, sodium hydroxide is beneficial for the early age property development.
Environment-assisted Subcritical Debonding of Epoxy-concrete Interface

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Interface debonding can grow slowly within the FRP-to-concrete interface in aggressive environment even the energy release rate at the crack tip is only a fraction of the critical energy release rate of the interface. This slow debonding process is called environment-assisted subcritical debonding, which could be a dominant mechanism for the failure of the FRP-to-concrete interface in service loads and aggressive environments. In this study, environment-assisted subcritical debonding of the epoxy-concrete interface was first observed and characterized using the wedge-driven testing. It has been found that aggressive environmental species can substantially increase the debond growth rate along the epoxy-concrete interface. Fracture surface analysis suggests that the debonding mode can change from the cohesive failure within the concrete in critical debonding to the adhesive failure along the epoxy-concrete interface in subcritical debonding. The proposed subcritical debonding testing closely simulates the failure occurring during the service-life of the FRP-to-concrete interface, allows interaction with environmental species during testing, and reduces ambiguity associated with fracture energy due to competitive effects of concrete curing, long-term concrete strength gaining, and epoxy curing. Subcritical debonding testing provides a new approach to understand the degradation mechanism and to assess the long-term durability of the FRP-to-concrete interface.
In this talk, an in-situ scanning electron microscope (SEM) fatigue testing was performed to measure the crack growth kinetics and corresponding crack tip opening displacement (CTOD) at the very small time scale under the constant cyclic tensile loading. The objective of the experimental study are to verify the fundamental hypotheses of a small time scale fatigue crack growth model. During the testing, one loading cycle is divided into a certain number of steps, and at each step images of the crack tip are taken by SEM. The Imaging analysis is used to quantify the crack growth kinetics and crack tip deformation behavior at any time instant in a loading cycle. Crack closure phenomenon is observed during the crack growth process. And crack growth is not uniformly distributed within a loading cycle and only happens during a small portion of loading path.
Cementitious systems incorporating phase change materials for thermal management of the built environment

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Increasing energy demand is one of the important 21st century challenges for the developing and the developed world. A significant portion of the energy used in commercial or residential buildings is spent on heating or cooling the interior space. Considerable energy savings can be realized if the heating and cooling loads in buildings can be controlled. One potential methodology to attain this objective is through the use of phase change materials (PCM) in building components. PCMs are latent heat thermal storage materials that store energy when subjected to temperatures in excess of their melting point by changing from the solid to the liquid state. The stored energy is released when the temperature drops below the melting point of the PCM. This study investigates the feasibility of using PCMs in cementitious systems to control the indoor thermal environment. Two different PCM incorporation methods – one using a microencapsulated powder, and another through impregnating porous aggregates with PCM – are evaluated. Differential scanning calorimetry (DSC) is used to understand the enthalpies associated with the pure PCM and the cement paste system incorporating the PCM. Semi-adiabatic calorimetry results are used to understand the influence of the PCM in altering the early age cement hydration reactions, which might beneficially influence early-age thermal cracking. Studies on small-scale slab systems to quantify the internal temperature reduction efficiency as a function of PCM type, dosage, and incorporation method will also be reported.
ENVIRONMENTAL ENGINEERING
Evaluation of a Green Courtyard: Stormwater Reduction and Treatment at an Aluminum Smelter

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An in-situ passive treatment system was incorporated to treat the stormwater at an aluminum smelter to avoid process inefficiency and the high cost associated with conventional end-of-pipe treatment. Passive treatment is a treatment technology that can function with little or no operational or maintenance costs over long periods of time and minimizes the facility's environmental footprint. During smelting, cryolite (Na$_3$AlF$_6$) used in electrolysis, and fluoride together with other air pollutants, are emitted. Although these emissions are treated a small amount is still released into the atmosphere in the form of HF and particles consisting mainly of NaAlF$_4$, which are deposited on nearby roofs. This material is then washed off during rain events. The goal of this project was to evaluate a novel passive treatment system removing fluoride from stormwater so that the water eventually could be reused. The green courtyard was designed to intercept roof run-off. It was comprised of gravel layer, a top soil layer and green grasses which are native to the area. The first flush during a rain event, which contains the highest fluoride concentration, was captured and then passed through the green courtyard and an activated alumina bed removing fluoride via adsorption. Additional rainwater was captured in the porous media allowing for flow equalization to occur. A pilot system was operated for two field seasons and results were compared to a traditional paved surface courtyard. Flow rates were measured and grab samples taken at preset time intervals during rain events. The samples were analyzed for pH, aluminum, total fluoride and solids concentrations. The treatment efficiencies were above 80% and the results showed that the influent fluoride concentrations in the green courtyard system were reduced and met regulatory requirements. Evapotranspiration from the vegetated area reduced the volume of stormwater to be treated. Supporting test in the laboratory was used to measure adsorption capacities and hydraulic conductivity of several types of activated alumina using small-scale rapid column tests.
The chemically activated luciferase expression (CALUX) in vitro bioassay has been used to quantify the toxic equivalency (TEQ) of aryl hydrocarbon receptor (AhR) compounds in Laurentian Great Lakes lake trout. In this study, the genetically modified H1L6.c3 cell lines were used to establish dose-response curves by adding serial concentrations of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) solution. The TEQs of Great Lakes fish sample extracts were determined based on measured activated luminance and the linear relationship of the dose-response curves. Furthermore, the TEQs determined by this bioassay method were compared with the TEQs calculated for known concentrations of aryl hydrocarbon compounds in fish samples. The TEQs measured by this CALUX method were also compared with traditional chemical analysis. The CALUX bioassay has provided a rapid, economic and reliable alternative for assessing the toxic potency of AhR-active compounds in fish samples, which is a valuable asset to Great Lakes fish monitoring.
Upper Hudson River Watershed Monitoring and Modeling Using HSPF

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Many hydrologic models exist that provide essential information towards a better understanding and analysis of watersheds. These models consist of algorithms and codes that attempt to simulate natural processes within the hydrologic realm. In the upper Hudson River watershed we chose to use Hydrologic Simulation Program Fortran (HSPF) to model this region. In the simplest form, HSPF correlates precipitation to river discharge through the use of hundreds of parameters. The most critical input time series to HSPF is precipitation followed by air temperature. We are currently working on a low cost, high accuracy, low energy, year-round meteorological station. HSPF provides stream flow information at any point in the watershed, relieving the need for stream gauges throughout the watershed. HSPF has potential for flood forecasting and simulating snowmelt conditions, particularly practical in evaluating springtime loading of constituents of concern. Most importantly one can analyze how the watershed will respond to changes in land use, point and non-point source loading, etc. Pollutant fate and transport can be tracked at any point within the watershed. The availability of water quantity and quality data throughout the watershed aids in a better understanding of the river system on a high spatial scale and temporal resolution.
Influence of Shear and pH on Flocculation of Chlorella Cells using Chitosan

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Before algal based fuels can be considered a viable alternative to petroleum based products, it is necessary to maximize the net energy obtained from the algal biomass. Flocculation and gravitational settling are relatively energy efficient technologies that can be applied to concentrate biomass to maximize net energy yield from algae bio-fuel production processes. Microalgae have a tendency to form stable suspensions due to electrostatic repulsion between adjacent particles. Cationic polymers are effective in destabilizing algal suspensions by combination of charge neutralization and particle bridging mechanisms. This study evaluates flocculation efficiency of *Chlorella protothecoides* as a function of pH, a natural cationic polymer (chitosan), and mixing shear. Based on preliminary results for dilute cultures, it was observed that flocculation was effective at pH-4.0 and 1 mg/L chitosan dosage. By increasing the shear rate from 57 s⁻¹ to 99 s⁻¹, the equilibrium floc size and the collision efficiency increased. However, at high shear rates the energy consumption for the process increases. Therefore, it is essential to optimize the physiochemical and hydrodynamic characteristics of the system to achieve an energy efficient harvesting process.
Impacts of Manure Spreading on Downwind Air Quality: Particles, Ammonia, and Bioaerosols

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Ammonia, particulate matter, and bioaerosols are being monitored at edge-of-field following land application of dairy manure to determine the impacts of application technique and anaerobic digestion on emission, transport, and deposition of these pollutants. Our goal is to produce data and improve models useful for the development of science-based emission reduction targets to improve air quality and protect human and environmental health. Here, we present data from our first sampling season of the three year study. Ammonia emission flux from manure-amended soils and downwind deposition were measured following conventional splash-plate spreading, direct injection, and drag-hose application of manure at a dairy CAFO in northern New York. Ambient particle concentrations were measured in four size bins during each event. Size-segregated samples were collected for both microbial cultivation and molecular analysis using real-time quantitative polymerase chain reaction (qPCR) to measure populations of total bacteria, Enterococcus spp., and fecal Bacteroidales. Results of this work will serve as the basis for future fate and transport modeling, which will lead to an improved understanding of air quality implications of manure application for farm workers, nearby residents, and local environmental systems.
Evaluation of Particle Resuspension Rate using a Consistent Test Mechanism

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Human walking influences indoor air quality mainly by resuspending dust particles that have previously deposited on the floor, which is believed to contribute a considerable portion of human particulate matter (PM) exposure indoors (Yakovleva et al. 1999). Exposure to dust particles is linked to several human health concerns, such as allergen-induced asthma. In this study, resuspension rate coefficient $r$, which is defined as the fraction of particle surface concentration resuspended per unit time, was selected to quantify resuspension phenomena.

We estimated particle resuspension rate coefficient as a function of flooring type, flooring condition, relative humidity (RH), particle type and particle size. Experiments were conducted using a mechanical resuspension device in a controlled indoor air chamber to improve experimental reproducibility and eliminate the variability caused by walking style on resuspension. The resuspension mechanism is able to mimic human step and provide consistent and controllable stepping rate (50 step min$^{-1}$).

A Taguchi parameter experimental design with flooring type as the primary factor and others as robustness factors was conducted, and data were statistically analyzed to determine the effects of the factors. Four types of flooring, including vinyl, hardwood, high density carpet and low density carpet, were selected, while robustness factors were set with two levels each. 64 experiments in total were conducted with duplicates. Resuspension rates were estimated based on the change in concentration of airborne particles following stepping motion of the resuspension mechanism.

Results from this study would contribute to a better understanding of indoor particle exposures and a reduction of pollutant and allergen exposure through material selection and indoor environmental conditions.
WATER RESOURCES
A Numerical Model Study on St. Mary’s River Winter Flow Regulations

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A numerical model study was conducted on St. Marys River ice conditions for winter flow regulation to estimate the maximum allowable Lake Superior outflow to avoid ice jam flooding. The effect of increasing the wintertime flow limit in the Lower St. Marys River is examined using a two-dimensional river hydro-thermo-ice dynamics model. Simulations of freeze-up, undercover frazil transport and accumulation, and ice breakup jams with selected inflow water discharges and downstream water levels were simulated. Simulations were first conducted using a current maximum wintertime flow of 2495 m3/s selected based on the maximum wintertime flow over the last 8 years and a possible high winter flow of 2725 m3/s. The high flow case distribution routed the excess flow through the Compensating Works. The simulation results showed that with the high winter flow there are significant increases in water levels in the area of the Little Rapids gauge and the US Slip gauge downstream of the US Locks. The water level at the Cloverland Electric Cooperative (CEC) may increase above the limit of 177.77m (IGLD 1985), i.e. 582.85 ft, which is the flood threshold at the Cloverland Electric Company Hydro Plant (i.e. top of the tailrace tunnel). A series of breakup simulations was run to determine the safe discharge for breakup. These simulations show that the winter flow limit could be increased to 2690 m3/s if flow regulation is managed with care by avoiding rapid changes in flow rate and water level to prevent premature ice cover breakup, which could result in thick ice jams and flood risk.
The effects of ice on the New York Power Authority’s proposed Habitat Improvement Projects (HIPs) in the Upper Niagara River were simulated using the two-dimensional river hydro-ice dynamics model DynaRICE. The HIPs include improvements to Strawberry, Frog, and Motor Islands. The proposed plan is to: 1) create approximately 7 acres of new habitat for, and increase long-term stability of, Strawberry Island; 2) restore the Frog Island area to a complex of high-energy marsh and submerged coarse substrate; and 3) provide shoreline protection measures, incorporating bioengineering methods wherever possible and practical, for Motor Island. Simulations were carried out for flow and ice conditions using both the existing bathymetry and the bathymetry with the revised design for the proposed HIPs. The simulation results showed that the proposed HIPs structures will not cause significant changes in ice movement in the Upper Niagara River. In the HIPs area ice usually accumulated in front of Strawberry Island, but the effect on the proposed riprap groins is negligible. The proposed Frog Island will experience ice effects and ice force on the berms but only for one of the analyzed cases. However, the ice effects should be considered in the design process.
Elbe River is one of the major rivers in central Europe originating in Czech Republic and traversing through Germany. It is used for navigation and recreation purposes. Ice related flooding is a common problem in the German portion of the river. A one-dimensional river hydraulic/ice simulation model, RICE-E was developed to simulate the hydraulic and ice conditions in the Elbe River. The model domain extends over a 580 km reach of the river from the Czech/German border upstream of Dresden to Geesthacht, upstream of Hamburg. The model can simulate hydraulics, water temperature, ice concentration, ice cover thickness and ice cover progression in river networks with natural cross sections. The model is capable of simulating hydraulic conditions in cross sections with floodplains having different roughness than the main channel. Ice breaker effects are also considered in the model.
Numerical Simulation of Hydraulic Characteristics Around Fixed-Cone Valve

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In this presentation, a numerical two-phase flow model combined with the Realizable k-ε turbulence model for compressible viscous fluids is presented for the simulation of the flow around a fixed-cone valve. The equations were solved using the finite volume method. The free fluid surface was simulated using the VOF method. The function of the fixed-cone valve for energy dissipation was examined by analyzing the computed pressure field, velocity field and streamline distribution. Compared with the experimental data, the simulated results show that the proposed model is reliable and can be applied to the numerical simulation of turbulent flow around a fixed-cone valve.
A Numerical Model Study on Ice Boom in a Lake-Harbor System

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Lake Notoro, near the coast of the Okhotsk Sea, is connected to the Sea by the Notoro Fish Harbor. The Lake has salinity similar to that of the Okhotsk Sea. It is ideal for aquaculture of scallops, oysters and other marine products. In winters, ice floes drift into the Lake through the Notoro Fish Harbor connecting to the Sea which can cause damage to aquaculture facilities. An ice boom has been proposed to be installed near the entrance of the Lake to prevent the ice from moving into the Lake. A numerical model study on the dynamic transport of ice, the effect of the boom, and the ice load on the boom spans are presented. The numerical model is a coupled hydrodynamic and ice dynamic model. The ice dynamics component uses a Lagrangian discrete parcel method based on smoothed particle hydrodynamics. The hydrodynamics component uses a finite element method for shallow water hydrodynamics. Results for conditions with steady state as well as unsteady simulations for various wind, ice, and tidal conditions will be presented.
Hydrothermal vents are the releases of hot buoyant fluid (vent fluid) forming fast or slow plumes at the bottom of the oceans. They are generally located closer to the plate boundaries, where the depths ranges from 1000-3000 m. The vent fluid released are at temperatures varying from 100 to 500 degrees Celsius and the pressure at those depths are as high as couple of hundreds of atmospheres. Once vent fluid is released, it mixes with seawater and a number of chemical reactions take place creating many new compounds, based on the composition of the fluid. Many deep sea vents are habitats of animals which are thriving on the energy released from the vents. These animals are varying from many types of Bacteria and Archia to different varieties of shrimp and worms. There are tube worms living in these harsh environments which can grow as long as a couple of meters in length.

The objective of this study is to develop a numerical model to simulate underwater hydrothermal vents. The model is capable of simulating hydrodynamics, thermodynamics, and physico-chemical processes of underwater thermal vents. The hydrodynamics of the model considers the momentum and the buoyancy forces of the plume. Thermodynamics include the change in plume temperature and its related properties such as density and the heat capacity of the thermal vent fluid. Physio-chemical processes are the chemical reactions that occur in the plume due to vent fluid mixing with entrained ambient water into the plume. These chemical reactions form new compounds and changes to properties of the plume, which in turn changes its behavior. Currently, it considers three identified chemical reactions namely the formation of Phyrrhotite - FeS, Pyrite. In addition, it is expected to study the biological environment in associated with the vents in the future.
Improvements to Modeling Gas and Hydrates in Deepwater

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The search for energy resources from deepwater has been expanding in the recent years. One of the major efforts is the exploration for methane hydrate deposits and search for commercially viable ways to bring methane gas to the surface. Gas hydrates in many cases are close to the stability limits near the sea floor. The production activities have the potential to cause these hydrate to dissociate (decompose) and release methane gas into water. If methane gas is released into water, it will start to travel upwards since it is lighter than water. However, due to high pressure and colder temperatures in the deepwater, these gases can be converted to hydrates. Methane hydrate is lighter than water.

The first version of MEGADEEP is a model developed to simulate methane gas and hydrate transport and their fate in the ocean when released from deepwater. This model was tested with available field data and found a good comparison. But the previous version did not have the capability to simulate the fate and transport of dissolved gas or produced water. The new work in progress extends its capability to simulate the fate of dissolved gas in the water column. The model is also being improved to do simulations under unsteady flow for longer periods of time. The model takes into account complete plume hydrodynamics and thermodynamics in addition to gas and hydrate kinetics and thermodynamics. Processes like hydrate formation and dissociation, gas dissolution, hydrate dissolution, break-up and coalescence of gas bubbles, and the possible separation of gases from the main plume are included in the model. This talk presents the model improvements on aspects such as dissolved methane transport from free gas and hydrates, and dissociated hydrates. Methane is dissolved in water from three different processes; gas dissolution directly into water, direct hydrate dissociation, and dissolution of hydrates.
A model to simulate slow CO\(_2\) gas releases from moderate ocean depths is developed. It can simulate CO\(_2\) releases from a single point, or releases spread over an area (non-point source). The model uses multi-species Lagrangian parcels approach to model CO\(_2\) in both gas and dissolved gas phase. The physico-chemical processes included are: gas expansion during upward travel due to pressure changes; gas dissolution and its impact on bubble volume; continuous recalculation of bubble buoyant velocity based on the volume and density changes; and tracking the transport and dispersion of dissolved and free gas. The buoyant velocity and dissolution computations take the non-circular nature of the bubble into consideration. The model calculates dissolved CO\(_2\) concentration, pH, and pCO\(_2\) in water. The model is used to calculate and compare the pH values in Kagoshima bay, Japan where field data are available. The comparisons are reasonably good. The model is then used to simulate dissolved CO\(_2\) concentrations, pH, and TCO\(_2\) changes in seawater for different practical scenarios of CO\(_2\) releases. The results show that pH value in seawater can change slightly after many hours of release for the cases considered.
A Study on the Need of Ice Sluice for St. Lawrence/FDR Power Project

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There are six ice sluice gates at the St. Lawrence Power Project for ice handling and sluices. The project has been in operation since 1958, and there has been no need to operate these ice sluice gates. The maintenance of these ice sluice gates is costly. A numerical model study was conducted to provide an understanding on the dynamics of ice transport and accumulation process in the upper St. Lawrence River and the need of the ice sluice gates. These results, as well as the historical evidence since the operation of the Power Project in 1958, showed that the ice sluice gates are not needed and will not be needed. In addition, the thermal ice process during the freeze up period is simulated with a numerical model to gain better understanding of freeze up phenomena in rivers. By comparing numerical model results with the observed data, the criteria for border ice, skim ice and ice floe formation are examined.
Simulation of Pancake Ice Impact on Offshore Structures in a Wave and Current Field

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The impact of ice floes on cylindrical piles due to superimposed wave and current actions is simulated with DEM (discrete element method). Three-dimensional disk-shaped particles were used as model ice floes as developed in Hopkins and Tuhkuri (1999). Different cases under different wave heights (3.5-5m) and constant wavelengths (100m), with current or without current, are simulated. Two different cylinder diameters are analyzed. From the simulation result we determine the average force over a wave period, and the total forces for every time step. Comparing these different impact forces we find that the impact forces increase with the wave height and the pile size. When current is present in addition to waves, the impact force increases greatly. The current increases not only the average but also the peak impact force on the pile. The presence of a current also increases the collision frequency between the floes and the pile.

Comparing the average ice impact forces with the hydrodynamic force from the linear wave theory (Dean and Dalrymple, 1991), results show that the hydrodynamic forces are much greater than ice impact forces. But the magnitudes of the peak ice forces are close to the wave forces.

Reference:
How a river restoration structure will resist ice action or affect the local ice regime are poorly understood. This talk presents a numerical model study focusing on the performance of rock vanes and cross vanes under ice run conditions. The two-dimensional river ice dynamics model, DynaRICE, was extended to study the effect of ice runs on cross vane structures as well as the effect of these structures on ice transport, ice jamming, and sediment transport in the channel. Results for long, straight, trapezoidal channels with and without cross vanes, show increased sediment transport and ice jam potential for the with-structures case. The simulated bathymetry with the cross vanes in place showed the desired effects of upstream sedimentation, downstream scour and increased flow diversity. The results indicate that the layout and spacing of the cross vanes are important in terms of ice conveyance and ice jam formation in the project reach.
CHEMICAL ENGINEERING
Validation of Vapor-Liquid Equilibria Calculation for Methanol-Water System with the CPA Equation of State

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Cubic-Plus-Association Equation of State (CPA EoS) combines classical Soave-Redlich-Kwong (SRK) equation with association term based on perturbation theory. For multicomponent system, the van der Waals mixing rules are employed for attractive and co-volume parameters, while the additional association term is mainly represented by $X_{Ai}$, the site monomer fraction. CPA EoS provides very satisfactory estimates of phase equilibria for aqueous system. Methanol-water system widely exists in petroleum industry and methanol always used as inhibitors to reduce the risks associated with gas hydrate formation. Recent work focused on vapor-liquid equilibria (VLE) of this system using CPA EoS, but the algorithm still needs to validate. According to Rachford-Rice Procedure, this work will calculate isothermal flash for methanol-water system using CPA EoS. After comparing with reported results and experiment data, the reliability and accuracy of CPA in this system will be discussed.
Electrochemical properties of Novel PEGylated Electrolyte Blends for DSSCs and Lithium Ion Batteries

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There is currently a rapid increase in interest in the use of non-volatile room temperature ionic liquids as electrolytes for various energy conversion and storage devices such as dye-sensitized solar cells (DSSCs), lithium ion batteries, and electrochemical supercapacitors. To overcome the problems associated with the use of liquid electrolytes in these devices, we are interested in developing polymeric electrolytes with low fluidity but high ionic conductivity. An optimization of the chemical structure of the electrolyte is required because ionic conductivity, based on the Nernst-Einstein mechanism, is usually found to decreases with a decrease in electrolyte fluidity (that is, an increase in viscosity). In this work, imidazolium iodide and imidazolium bis(trifluoromethylsulfonyl)imide ionic liquids with poly(ethylene glycol) (PEG) and perfluoroalkyl segments were synthesized, and their transport properties were measured and compared with those of the conventional 1,3-dialkylimidazolium ionic liquids. Lithium iodide and lithium bis(trifluoromethylsulfonyl)imide salts were blended with the ionic liquids, in different concentrations, to find a suitable concentration for the desired electrochemical applications. Differential scanning calorimetry was used to study thermal transitions, such as glass transition, crystallization, and melting, in the electrolyte blends. The viscosities of the blends were measured at different temperatures using a cone and plate viscometer, and electrochemical impedance spectroscopy was used to determine the ionic conductivity of the pure electrolytes as well as the blends. The electrolytes were found to have a non-Newtonian, shear-thinning flow behavior. The ionic conductivities were strongly correlated to the viscoelastic properties of the blends. At a given shear-rate, the viscosity of the electrolyte blends increased with an increase in the lithium salt concentration, but the trend for ionic conductivity was the opposite. Ionic conductivity increased with an increase in temperature, and the values in the range of 1 to 10 mS/cm were achieved. These liquid or paste-like blends, with desirable properties such as low fluidity, low vapor pressure, and high thermal stability, are promising for use in a variety of electrochemical devices for energy conversion or energy storage. A detailed analysis of these results will be presented in this talk.
Adsorption Dynamics of Naphthalene onto PoraPak Resin

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Understanding the adsorption characteristics of organic contaminants being captured onto polymeric adsorbents is critical in environmental sampling for monitoring of dissolved phase concentrations. This work examines the dynamics of naphthalene adsorption onto PoraPak resin. Using naphthalene as an adsorbate, column experiments were performed in a 4 cm long \times 1 cm ID stainless steel column at flow rates of 1 to 3 ml/min. Equilibrium sorption experiments revealed that the adsorption of naphthalene onto PoraPak follows the Freundlich isotherm model. The adsorption behavior of naphthalene was modeled using the constant pattern wave propagation approach, and showed a 90% breakthrough time of between 40 to 200 hours depending on the flow rate. The effect of increasing flow rates and varying bed depths on the adsorption characteristics is presented.
Low Cycle Fatigue of Aluminum Foam

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An increased demand for multipurpose lightweight materials, such as aluminum foam, has caused these materials to be subjected to loading conditions for which they have not yet been fully characterized, such as fatigue. In order to safely utilize these materials in engineering applications, a comprehensive knowledge of their failure modes under these new loading conditions must be obtained. To this end, low cycle fatigue experiments were conducted on Alporas aluminum foam (Shinko Wire Co.). Specimens were loaded axially under fully reversed tension/compression at nominal total strain amplitudes between 0.05% and 0.175%. Results show that the material exhibits minimal strain hardening, regardless of amplitude, and follows a Coffin-Manson relationship relating strain amplitude to fatigue life. Digital image correlation analysis was used to investigate crack propagation and failure modes at the mesoscale. It was determined that failure occurred due to crack propagation through a compaction assisted crack propagation process.
Self-assembled Hydroxypropyl Cellulose Particles for the Sustained Release of Glucose

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Temperature and pH responsive microparticles have proven useful platforms for targeted sustained release of oral delivery bioactives. In this way, substances sensitive to pH or temperature change can be protected from the changing environments of the digestive system until reaching the desired location whereupon sustained release can be initiated. In this study, self-assembling particles were formed from a polysaccharide backbone cross linked with trisodium trimetaphosphate (TSTMP) and encapsulated in sodium alginate to resist highly acidic environments, such as those experienced in the stomach. The particles were formed in aqueous solution at temperatures above their lower critical solution temperature (LCST) before being saturated with dextrose to form stable solutions capable of sustained glucose release. Sustained release from the particles was analyzed in vitro using a diffusion cell at 37 °C and at a pH intermediate to that of the stomach and small intestine. Release kinetics profiles for particle formulations were studied by sampling over ten hours and were compared against control glucose solutions of equivalent concentration. Sample concentration was analyzed using ultraviolet-visible spectrophotometry by enzymatically converting aqueous glucose solution to gluconic acid and hydrogen peroxide, which reacts with colorimetric substrate to form a colored solution. Release kinetics profiles showed that the rate of glucose uptake in the receptor compartment of the diffusion cell was lower for formulations containing the polymer particles than for the control solutions (that did not contain particles). The equilibrium concentrations in the receptor compartment were also lower, indicating that the glucose preferentially partitioned in the particle phase relative to the aqueous phase.

This talk will discuss the formation of the stimulus-responsive polymer microgels, the morphology of the ‘core-shell’ particles, and the influence of temperature and pH on the kinetics of release of the entrapped glucose.

References:
Effect of Convective Hindrance Factor On Predictions of the Rejection of Rod Shaped Particles from Porous Membranes

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For the last few decades, membranes are highly incorporated in industrial water treatment systems to remove bacteria and other pathogens to produce biologically stable water. Several research studies show the shape and size of the microbial contaminants are extremely important to assess the rejection capacity of the membrane. In spite of fact that rod-shaped bacteria and non-spherical viruses are commonly encounter in the filtration process, detailed investigation of the filtration of non spherical particles has not yet been performed, especially from a theoretical view point.

In the present study an attempt has been made to develop a more comprehensive model of particle transport that includes both the steric constraints on the position and orientation of the particles within a cylindrical pore and the convective hindrance (lag coefficient) experienced by rod shaped particles within the pores. As a first approximation, we have incorporated predictions for the lag coefficient for spherical particles into our previous model that includes steric restrictions for rod shaped particles. Predictions are made using different size parameters to describe the hydrodynamic resistance of the rod: the diameter of a sphere with equivalent volume, the rod length and the rod diameter. The results show that adding the lag coefficient to predictions of the rejection coefficient has a greater effect for particles with small aspect ratio (i.e, close to spherical shape). We have also begun to perform CFD calculations to predict the lag coefficient for capsule shaped particles within a narrow channel. The idea is to simulate the fluid particle interaction to evaluate the translational motion of the particle in a confined channel by calculating the hydrodynamic forces and torque on the particle boundary induced by the fluid [1]. The ratio of the translation velocity of the particle to the maximum fluid velocity yields the lag coefficient. The Arbitrary Lagrangian -- Eulerian (ALE) algorithm is employed to simulate the system [1]. Results from both modeling approaches will be presented in this presentation. The ALE method is verified with the reported standard benchmark problems.