McGill Engineering Research Showcase

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Poster Abstracts 2015

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TABLE OF CONTENTS **PAGE**

ADVANCED MATERIALS AND NANOTECHNOLOGY

Impact of an Extracellular Soil Enzyme on the Stabilizing Coating and Environmental Behavior of Model Engineered Nanoparticles

By Ryan Maliska and Professor Nathalie Tufenkji

Polymeric coatings on the surface of engineered nanoparticles (ENPs) have been shown to control the environmental fate and impacts of ENPs. Upon the release of ENPs into soils and natural aquatic environments, extracellular enzymes may act to transform the ENPs by degrading polymeric coatings, altering their behaviour, fate and toxicity. We investigated the effect of exposure to a common extracellular soil enzyme on the deposition and aggregation behavior of polyethylene glycol (PEG) coated gold nanoparticles. Deposition kinetics of untreated and enzyme treated nanoparticles were determined using the Quartz Crystal Microbalance with Dissipation monitoring (QCM-D). A NanoTweezer was also used to measure the nanoparticle-silicon surface interaction energy profile. Dynamic light scattering (DLS) and darkfield hyperspectral imaging was used to investigate the aggregation regimes. Results to date indicate that the PEG coating is partially degraded following enzyme treatment resulting in increased nanoparticle deposition onto silica but no change in nanoparticle aggregation.

Drag Reduction on Laser-Patterned Superhydrophobic Surfaces

By K M Tanvir Ahmmed and Professor Anne Kietzig

In recent years, significant drag reduction has been achieved by Lotus leaf inspired superhydrophobic (SH) surfaces. The universally accepted no-slip boundary condition does not hold for these SH surfaces. Superhydrophobic surfaces reduce friction drag in fluid flow by supporting a shear-free air-water interface on which water slips. Superhydrophobic surfaces with dual-scale roughness and definite geometrical patterns were fabricated by femtosecond laser micromachining. The effectiveness of these surfaces on drag reduction in liquid flow was investigated in this research. These drag reducing surfaces can be used in microfluidic devices.

Overcoming Brittleness in Ceramic and Glasses using Micro-Architecture and Bioinspiration

By Zhen Yin and Professor Francois Barthelat

Highly mineralized biological materials boast unusual combinations of stiffness, strength and toughness currently unmatched by engineering materials. High mineral contents provide stiffness and hardness, while weaker interfaces with intricate architectures channel propagating cracks into toughening configurations. We applied these ideas to the design of novel types of glasses, ceramics and other brittle materials. Our bio-inspired materials are fabricated through laser engraving technique to carve weak interfaces into the initially continuous materials. These interfaces are infiltrated with deformable polymers with attractive solid and rheological properties. Guiding cracks along weak interfaces offers a great control over deformation and failure modes, enabling large deformations and various toughening mechanism. The bio-inspired approach provides a new pathway to toughen hard and brittle materials, with applications in architectural glass, glass containers or touch screens. The bio-inspired materials we fabricated serve as entry points to a vast design space where micro-architecture and interface behavior govern mechanical performances.

Value Added Poly(ethylene) via Amine-Anhydride Reaction for Industrial Barrier Material Applications

By Khadija Iqbal and Professor Milan Maric

This project aims to widen the applicable poly(ethylene) (PE) polymers for barrier materials and uncover new markets. Methyl acrylate-acrylonitrile copolymers (MA/AN) have desirable barrier properties that are sought after in PE oil tanks; unfortunately a MA/AN phase cannot be dispersed in PE due to their immiscibility. Reactive blending is widely applied to stabilize immiscible polymer blends and has been applied to produce morphologies desirable for barrier applications. PE grafted with maleic anhydride (MAn) is reacted with an amino functional MA/AN polymer and the amine/anhydride reaction allows reactive blending of the two systems. The amino functional monomer added to the MA/AN polymer is IDBA, which is synthesized in the laboratory. This project developed a method for the synthesis of a cheap primary amine monomer as well as an inexpensive, efficient and versatile method of incorporating an amine functionalized polymer as a dispersed-phase barrier material in PE.

Heterogeneous Modification of Chitosan using Nitroxide Mediated Polymerization for the Purpose of Drug Delivery

By Simon Kwan and Professor Milan Maric

Chitosan is derived from deacetylated chitin, which in turn is a natural polymer from biological sources (cell walls of fungi, exoskeletons of crustaceans, internal shells of cephalopods, etc.). Chitosan is bio-compatible, bio-degradable, and hypoallergenic, making it ideal for biomedical applications. However, it is not thermally responsive. My focus is to graft a tailored thermo-responsive polymer onto chitosan that will change conformation upon heating. Such a property can be useful for controlled delivery of drugs, for example. Recent research has shown that the lower critical solution temperature (LCST) can be fine-tuned by adjusting the monomeric ratio between oligo-(ethylene glycol) methyl ether methacrylate (OEGMA) and di-(ethylene glycol) methyl ether methacrylate (DEGMA) in the polymerization. Using nitroxide mediated polymerization (NMP), the OEGMA/ DEGMA monomers were grafted from the chitosan molecule, giving it thermo-responsive properties.

A Class of Low CTE Lattice Materials that Are Stiff and Strong

By Han Xu and Professor Damiano Pasini

Systems in space are vulnerable to large temperature changes when travelling into and out of the Earth's shadow. Variations in temperature can lead to undesired geometric changes in sensitive applications requiring very fine precision, such as sub-reflector supporting struts. To suppress such failures, materials with a low coefficient of thermal expansion (CTE) over a wide range of temperatures are needed. Besides low CTE, these materials should also provide desirable stiffness, strength and extraordinarily low mass.

In this work, we introduce a systematic strategy that uses triangular/tetrahedron tessellation to develop low thermal expansion lattices with low mass, and high specific stiffness and strength. Selected lattice samples are fabricated by a simple snap-fit method from Al 6061 and Ti-6Al-4V alloy sheets. A combination of experiments and theoretical analysis is used to test proof-of-concept lattices that achieve zero CTE.

Out-of-Autoclave Processing of Composite Sandwich Structures for Space Applications

By Diane Liu and Professor Pascal Hubert

Common space structures are: optical benches and antenna reflectors, providing intergalactic information for space research and communication, such as radio, television, and telephone. These structures can be made with metal, but due to higher costs for heavier launches, there is increasing interest in composite materials, especially composite sandwich structures, which are able to achieve high strength to weight ratios and high rigidity. Being able to meet the stringent requirements for space and have low manufacturing cost is a continual challenge. A manufacturing process that reduces cost is Out-Of-Autoclave (OOA), where an autoclave is not used to cure the resin. This process has been known to reduce mechanical properties due to voids in the part and foaming of the adhesive. Research on ways to improve the quality of sandwich structures for the purpose of meeting the requirements for space and reducing manufacturing cost continue.

Multiscale Modeling of Methane Hydrate Mechanical & Thermophysical Properties

By Zeina Jendi, Professor Alejandro Rey and Professor Phillip Servio

Methane hydrates are crystalline compounds which consist of cages of hydrogen-bonded water molecules that entrap methane at high pressures and/or low temperatures. They exist naturally near continental margins and in permafrosts and are believed to contain an energy content that is twice that of all other fossil fuels combined. Their mechanical and thermophysical properties have been primarily determined experimentally in which the effects of different parameters have been lumped together. This work studies individual crystals using ab initio Density Functional Theory and classical force-field simulations. Elastic constants, ideal strengths, and key thermophysical properties, such as heat capacity, have been calculated and compared to the values of ice Ih due to their similar hydrogen bonding arrangement. The differences between poly- and single-crystals are highlighted, and gas hydrates were found elastically and plastically isotropic as opposed to ice. Finally, the Peierls stress of individual edge and screw dislocations has been studied.

Atomistic Modeling of Structure II Gas Hydrate Mechanics

By Thomas Vlasic, Professor Phillip Servio and Professor Alejandro Rey

Gas hydrates are crystalline solids composed of an outer water cage and a small non-polar gas molecule (e.g. methane) or volatile liquid (e.g. neohexane) trapped within. Naturally occurring, they are a mostly untapped potential source of natural gas, which could be an important next generation fuel supply. They may also provide a more effective method to store and transport natural gas. A significant problem associated with gas hydrates is their potential to plug natural gas pipelines where high pressure and low temperature conditions are favorable for hydrate formation. Therefore, in order to develop better methods of hydrate detection, extraction, transport, and inhibition, a fundamental understanding of their properties is required. My current work focuses on determining the mechanical properties (e.g. bulk modulus) of structure II gas hydrates using density functional theory as a simulation tool.

Implementation of Iron Loss Model on Graphic Processing Units

By Sajid Hussain and Professor David Lowther

Design engineers are always looking for extra computational power to speed up the execution of their tasks. One way to achieve this speed up is to identify tasks with a high degree of parallelism and process them with graphic processing units (GPUs). The steps involved in a finite element (FE) electromagnetic simulation are computationally very expensive. One such step is the communication between FE solver and the material loss model that takes place for all the elements in the mesh for each time step. This work is a first step towards the implementation of material loss models in GPUs. A physics-based material model, the Jiles-Atherton (JA) model, is implemented in a GPU to compute the B-H hysteretic relationship which can be directly incorporated in FE simulations. The performance of the GPU is compared with the given microprocessor in terms of computational time. A time gain of 13.8 times has been achieved.

AEROSPACE ENGINEERING

Structural Design of Aerospace Composites with Hybrid Fibre Architectures

By Swaroop Visweswaraiah and Professor Larry Lessard

Continuous fibres (CF) exhibiting excellent mechanical performance are limited in use in aerospace industry due to the low formability characteristics and are often confined to simple shell-like geometries with minimal curvature and thickness variations. On the other hand, short fibre (SF) preforms such as randomly oriented strands (ROS) offer high formability but exhibit low mechanical performance. The current research examines a hybridization approach through experimentation and numerical models to integrate the formability and performance in aerospace composites. By controlling the contents, position and arrangement of individual phases, both formability and better mechanical performance can be achieved. Carbon/thermoplastic matrix with compression molding technique has been used for the fabrication. Hybridization results in improved stiffness and strength, enhanced load-to-weight ratio, reduction in the randomness, and a better control on failure initiation, damage and propagation. The research would allow for an increase in the TRL and is funded by Bell Helicopter Textron.

Design and Analysis of Bonded-Bolted Aircraft Structural Joints

By Kobye Bodjona and Professor Larry Lessard

The term structural joint signifies the region where two or more distinct parts of a physical structure are fused and held together. Traditionally, this holding together is achieved using either bonding or bolting. Such joints represent weak spots in the structure and impact structural mass, resulting in the need for stronger and lighter joining techniques. Recently, it has been suggested that a combination of bonding and bolting can potentially create a structural joint that is stronger than the underlying bonded and bolted joints separately. The current research explains from a theoretical perspective how and when this is possible. A special purpose analysis method is developed for this purpose. The theoretical predictions are corroborated by experimental measurements. Absolute strength improvements of at least 30% are observed. Furthermore, the specific strength improvement (strength per unit mass) is at least 22.5%. It is concluded that bonded-bolted joints are potentially useful in select design situations.

Processing Study of Composite Bonded Repairs

By Mathieu Préau, Kavish Bujun, Nadine Auda, Andrew MacLean and Professor Pascal Hubert

In service, popular carbon-fibre-reinforced thermoset polymers experience damage and are in need of repair. Bonded scarf repairs provide excellent strength recovery; however, the processing of repairs in service environment is challenging. In particular, heat, air and moisture transport, evolving during the repair process, must be precisely assessed to ensure a reliable process with in service repair equipment. First, heat transfer and thermo-mechanical models are presented to simulate the repair process. They are used to provide repair depots with useful process charts to efficiently cure the repair patch and adhesive. Then, various air evacuation strategies are investigated to perform high performance repairs with recently developed vacuum-bag-only prepregs materials. It was found that when the adhesive film was textured better air evacuation was achieved, leading to void-free repairs, and overall higher mechanical performance.

Characterization of the Degree of Impregnation of Out-of-Autoclave Prepreg

By Marc Palardy-Sim and Professor Pascal Hubert

Out-of-autoclave prepreg contains partially impregnated fibres to create paths for air evacuation. The degree of impregnation of as-received material can affect part quality and rejection rates. The aim of this research is to study different methods to quantitatively measure the degree of impregnation of out-of-autoclave prepreg. Three methods are compared: X-ray computed tomography, the water uptake test, and active infrared thermography. The first two methods serve as a baseline for accuracy and simplicity, respectively, while the latter method shows promise as a quick, non-destructive evaluation technique.

Vacuum-Bag-Only Processing of Complex-Shape Prepreg Laminates

By Nicolas Krumenacker and Professor Pascal Hubert

High-quality flat composite parts can now be readily manufactured via out-of-autoclave prepregs and vacuum-bag-only processing. However, more complex shaped regions exhibit severe thickness variations and porosity.

Relationships between fibre architecture, local thickness deviation and macro-porosity, and interlaminar tensile behavior were examined for right-angled parts. Corner thickening and void morphology were quantified via a novel thickness profile measurement approach in Matlab and micro-CT scans respectively. In turn, these findings are correlated to interlaminar tensile behavior. Processing deficiencies do not appear to significantly influence convex corner thickening, which is primarily driven by inter-ply friction; however, they do lower curved beam strength given higher observed porosity.

A novel manufacturing technique is proposed whereby the laminate is heated using an infrared lamp to lower the resin viscosity during compaction. This lowers the inter-ply friction, encouraging plies to more readily slip toward the desired final geometry, resulting in a significant reduction in corner thickening.

Conic-Sector-Based Control

By Leila Bridgeman and Professor James Forbes

The study of control is crucial to many fields, but is especially aerospace engineering, where precise behaviour is demanded with little or no human intervention. Input-output stability theory is an indispensable tool in these applications. However, classic results cannot be used to ensure controllers are effective in some important cases, including the control of non-minimum phase and open-loop unstable systems. This poster presents extensions to classic results incorporating these challenging cases, along with novel methods to synthesize the required controllers.

On the Simulation of Tether-Nets for Space Debris Capture with Vortex Dynamics

By Eleonora Botta and Professor Arun Misra and Professor Inna Sharf

Tether-nets are a promising method for the active removal of space debris, but the dynamics of this type of systems in space is still not well-known. The focus of our study is on the simulation of the deployment and capture phases of a net-based active debris removal mission, and on the effect of including the threads' bending stiffness on the dynamical characteristics of the net. Lumped-parameter modeling of the net, with and without bending stiffness representation, and of contact dynamics in Vortex is introduced. The outcome of net deployment simulation, as well as of capture of a derelict spacecraft, is analyzed. It is found that, when bending stiffness is included, the net resists more to the changes in its shape that are being introduced both by the motion of the corner masses and by the contact with the debris.

Dynamics of Quadrotor Impacting a Wall: Modeling, Simulation and Experiments

By Fiona Chui, Gareth Dicker and Professor Inna Sharf

We have developed a model for a quadrotor with protective bumpers that captures its dynamic response due to a non-destructive collision with a vertical wall. This work is motivated by the significant risk of collision with surrounding objects, particularly in unknown, unstructured environments during UAV flight. Towards the goal developing control methods to allow for automatic recovery from a non-destructive collision, we formulate the dynamics model of a quadrotor equipped with protective bumpers around its propellers, undergoing an arbitrary collision with a vertical wall: no prior assumptions are made regarding the points and number of impacts, nor the impact speed, nor the orientation of the vehicle at the instance of collision. The model is exercised through a series of simulations for different pre-impact attitudes of the platform and different approach speeds. Comparison to simulated responses mimicking the experimental pre-impact conditions and command inputs for one test-case show excellent qualitative agreement.

Biomimetic Design of Air Transportation System-of-Systems

By Ibrahim Chamseddine and Professor Michael Kokkolaras

Airports, airplanes, crew, passengers, cargo, and fuel are necessary components to transport people or material by air. In the contrary of considering these systems as independent units, the recent research has been designing each of them with the vision that it will be interacting with the other systems. So far, aircraft sizing, route network design, and aircraft-to-route allocations are integrated together to design a costly minimized air transportation system-of-systems (ATSoS). This research mimic analogous biological transportation to expand current ATSoSs by incorporating additional systems that will be designed according to principles extracted from the human body structure; representing one of the early efforts in the biologically inspired SoS designs. It also enhances the present components by relaxing some of the assumptions and by considering the environmental and the demand uncertainties. The resulting ATSoS is expected to minimize the duration of the transport in addition to minimizing the operational cost.

Effects of Alloying Elements on Formation and Segregation of Vacancy-Hydrogen Complexes at Coherent Twin Boundaries in Nickel

By Xiao Zhou and Professor Jun Song

Hydrogen embrittlement (HE) has been a persistent problem in Ni alloys. Despite much work on HE of Ni, studies on the role of alloying elements on HE are largely absent. In this study, we examined several common alloying elements (Cr, Mo, Nb, Al and Ti) and their effects on the formation and segregation of single vacancies (SVs) and vacancy-hydrogen complexes (VHxs) at the coherent twin boundary in Ni. The presence of these alloying elements was shown to significantly reduce the formation energies of SVs and VHxs. The reduction was found to be correlated with the solute-induced lattice distortion. Our results demonstrate that the alloying elements can potentially contribute to the local aggregation of vacancies to promote (albeit indirectly) the nucleation of micro-voids or micro-cracks along coherent twin boundaries in certain Ni-based alloys under hydrogen charging, providing a new perspective towards the understanding of HE in Ni alloys.

Mobility Assessment of Wheeled Robots Operating on Soft Terrain

By Bahare Ghotbi, Professor Jozsef Kovecses and Professor Jorge Angeles

Optimizing the vehicle mobility is an important goal in the design and operation of wheeled robots intended to perform on soft, unstructured terrain. Poor mobility may result in the entrapment of the vehicle or limited manoeuvring capabilities. This work discusses the effect of normal load distribution among the wheels of an exploration rover and proposes strategies to modify this distribution in a convenient way to enhance the vehicle ability to generate traction.
The reconfiguration of the suspension and the introduction of actuation on previously passive joints were the strategies explored in this research. The effect of these actions on vehicle mobility was assessed with numerical simulations and sets of experiments, conducted on a six-wheeled rover prototype. Results confirmed that modifying the normal load distribution is a suitable technique to improve the vehicle behaviour in certain manoeuvres such as slope climbing.

BIOENGINEERING

A Phono-Mimetic Bioreactor System for Vocal Fold Tissue Engineering Applications

By Neda Latifi and Professor Luc Mongeau

The human vocal folds (VFs) are subjected to complex biomechanical stimulation during phonation. The aim of the present study was to develop a phono-mimetic bioreactor, which mimics the mechanical microenvironment of the human VFs in vitro. The bioreactor consisted of two synthetic replicas loaded into a silicon body. A cell-scaffold mixture was injected into cavities within the replicas. The bioreactor was operated with no phonatory stimulation for three days after injection. Beginning from the fourth day, the bioreactor was phonated for two hours each day over a period of four days. A similar bioreactor without mechanical excitation was used as control. The cell-scaffold mixture was harvested for cell viability and immunohistochemistry tests seven days after injection. The flow-induced self-oscillations of the bioreactor produce mechanical excitations that are typical of those involved in human phonation. The results confirmed that the present bioreactor support cell viability and cellular functions of protein production.

Highly Bioactive Sol-Gel Derived Borate Glasses

By William Lepry and Professor Showan Nazhat

Attributable to their ability to bond to bone, bioactive glasses have long been used as bone repair materials. The lower chemical durability of borate glasses allows for quicker degradation and more rapid conversion to bone-like mineral (hydroxy-carbonated apatite, HCA) in physiological environments. To further enhance bioactivity, the sol-gel process is often implemented which creates glasses with increased porosities and surface areas. In this study we examine the different processing characteristics and in vitro bioactivity of a wide range of sol-gel derived bioactive borate glasses (36 – 61 mol% B2O3). HCA conversion in simulated body fluid occurred in as little as 3 hours according to infrared-spectroscopy and x-ray diffraction. The rapid conversion was verified by ion chromatography which showed composition determined ion release rate. To the best of our knowledge, this is the first report demonstrating the potential use of sol-gel derived bioactive borate glasses for tissue engineering applications.

Stenosis Eccentricity has a Significant Effect on Coronary Bifurcation Lesion Functionality

By Catherine Pagiatakis and Professor Rosaire Mongrain

The treatment of coronary bifurcation lesions (CBLs) is high risk; overall, their dynamics are not well understood. The objective was to investigate the effect of lumen eccentricity on the functionality of CBLs. Eight lesion configurations, with four diameter reductions (41%-68%) and both eccentric and concentric stenosis profiles (61 cases total) were considered within planar, 3D geometries of the bifurcation of the left main coronary artery into the left anterior descending artery and the left circumflex artery. Each case was coupled to an electrical analog model of the rest of the cardiovascular system using a partitioned geometric multiscale algorithm, which allowed the calculation of a clinically-relevant functional index, namely the fractional flow reserve. The multiscale computational fluid dynamics simulations were implemented within ANSYS Fluent (Canonsburg, PA, USA) using an in-house subroutine. It was found that for configurations with a stenosed supplying vessel, lumen eccentricity could be an important predictor of functionality.

Contributions to Contact Simulation and Human Motion Analysis

By Farnood Gholami and Professor Jozsef Kovecses

In this research, multiple topics with the applications in contact simulation and human motion are addressed. Human foot kinematics and dynamics are studied based on the experimental data to identify the effects of human foot modelling on the predicted kinematics and dynamics. An interpolated function which is capable of predicting the directional changes of the ankle axis is proposed. Furthermore, gait analysis of patients with multiple sclerosis disorder is conducted. We developed a framework using a Kinect camera to quantify the level of gait abnormality of patients. Finally, contact dynamics for simulation of multibody systems is studied. Contributions to contact dynamics can have direct benefits for human body simulation too. A novel contact dynamic algorithm based on the Box friction model and a complementarity contact formulation with regularized friction model are proposed. These formulations result in faster and more stable simulations of multibody systems with multiple contacts.

The Role of the Microtubule Cytoskeleton in Regulating Intracellular Transport

By Linda Balabanian and Professor Adam Hendricks

The motor proteins kinesin and dynein transport organelles, mRNA, proteins, and signaling molecules in the cell. These motor enzymes convert the chemical energy from ATP hydrolysis into mechanical work to move cargoes along the microtubule cytoskeleton. In addition to serving as tracks for transport, the microtubule cytoskeleton regulates the activity of motor proteins through the architecture of the network, microtubule-associated proteins (MAPs) and tubulin post-translational modifications (PTMs). To examine the influence of the cytoskeleton on motor protein motility, we isolated intact, native microtubule networks from cells and tracked the motility of single fluorescently-labeled motor proteins with high resolution using Total Internal Reflection Fluorescence (TIRF) microscopy. In this way, we can systematically examine the effect of network organization, MAPs, and PTMs on motor binding and motility.

High Throughput Traction Force Microscopy and Diseases

By Haruka Yoshie and Professor Allen Ehrlicher

Cell migration is a highly integrated process and essential in many biological processes. Cells apply traction forces to their environment as they crawl. Traction forces allow cells to move throughout animal organisms in a myriad of process from development to immune response and cancer metastasis. However, no technology has provided a high throughput solution for measuring these contractile forces to date. Here we present a multi-well traction force assay employing soft (~1-10 kPa) silicone rubbers with embedded fiduciary particles, allowing high throughput traction force measurements. By measuring the cell-induced deformations of these substrates, we calculate the cellular forces and work. We utilize this system to examine the changes in forces during cancer metastasis and aging, finding that traction forces change in both of these biological states, however we anticipate that this technology will be of broad utilities in many quantitative biological and health science applications.

Real-Time Monitoring System for Medical Ultrasound Imaging

By Mehdi Ahmadi and Professor Warren Gross

Ultrasound system is widely utilized in diagnostic applications. Successful ultrasound imaging depends on skills of users with high hands-on experience. Therefore, a real-time monitoring system which allows doctors to remotely control inexperienced trainees is the great of importance. The goal of the project is to develop a system to provide the ultrasound images along with the location of the ultrasound probe for doctors. To this end, ultrasound images are transmitted through a wireless network in real-time to computers, smart-phones and tablets. In addition, the system is equipped with a camera to track the position of the ultrasound probe. Machine learning techniques can also be applied to assist users in the interpretation of ultrasound images.

Hardware Advancements for a Low-Cost Microwave Medical Device for Breast Health Monitoring

By Adam Santorelli and Professor Milica Popovic

We highlight the most recent advancements of custom-built hardware solutions to reduce the size, cost, and complexity of a microwave system for breast health monitoring. We design, fabricate, and test a flexible circuit that features an integrated solid-state switching network and 16 wideband antennas. Additionally, we present the recent design and testing of an equivalent-time sampling circuit to replace expensive off-the-shelf oscilloscopes. These hardware advancements represent steps toward more patient-friendly, compact, and cost-effective systems that can improve a patients' accessibility to the diagnostic equipment.

INFORMATION AND COMMUNICATIONS TECHNOLOGY

Multi-Armed Bandits for Reliability in MPSoC Design

By Ma Calvin, Professor Aditya Mahajan and Professor Brett Meyer

Reliability in integrated circuits is becoming a more prominent issue with the miniaturization of electronics. Smaller process technologies have led to higher power densities, higher temperatures, and earlier device wear-out. One way to mitigate failure is by over-provisioning resources and remapping tasks from failed components to the components with slack. Since the design space is large, brute-force approaches are impractical and finding the optimal slack allocation is difficult. Device lifetimes are typically evaluated using Monte-Carlo Simulation by sampling each design equally; this method is inefficient since poor designs do not need to be evaluated as accurately as good designs. A better method will focus the sampling time on the designs that are difficult to distinguish; this can be accomplished using Multi-Armed Bandit algorithms. This work evaluates the feasibility of using Multi-Armed Bandits as an alternative to Monte-Carlo Simulation for lifetime simulation.

Half-Occluded Regions and Detection of Pseudoscopy

By Jonathan Bouchard and Professor James J. Clark

We propose that left- and right-half-occlusion regions contain information that can distinguish between stereoscopic and pseudoscopic display conditions. A machine vision method is presented based on this idea, which detects pseudoscopy using only the histograms of left and right half-occlusion pixel locations.

Two psychophysical experiments are described which study the ability of human viewers to detect, or be influenced by, pseudoscopic display. The results of this study show that, during free viewing of HD 3D video imagery, humans judged pseudoscopic imagery to be of lower quality than stereoscopic imagery. Subjects performed at a 72% rate in deciding whether a short 5-second video clip was presented stereoscopically or pseudoscopically. Subjects were observed to fixate on half-occlusion regions with a frequency of 15.8%, as opposed to a frequency of 7.8% indicated by random chance. Viewers more frequently (17.4%) fixated on half-occlusion regions when making correct decisions then when they were incorrect (11.9%).

Wireless Communications in Power Substations

By Fabien Sacuto and Professor Fabrice Labeau

Installing wireless technologies in substation environments requires studying the Radio Frequency (RF) noise coming from power equipment. During our measurement campaign in Hydro-Quebec substations, we have collected impulsive noise samples in the band of existing wireless technologies. We have designed a new impulsive noise model by using a specific configuration of the Partitioned Markov Chain (PMC) in order to represent substation RF environment. The proposed model can be implemented in a Maximum a Posteriori (MAP) receiver that uses the BCJR algorithm to mitigate the impact of correlated impulsive noise. We show that by using a simpler configuration of our PMC model, the receiver is able to mitigate impulsive noise from existing substation.

Diffusion Networks with Spatially Correlated Observations and Noise

By Saeed Ghazanfari Rad and Professor Fabrice Labeau

Decentralized estimation problems can be found in several applications within the area of multi-agent networks where each agent has access to noisy observations of a common process and the network seeks to estimate the unknown parameter vectors. Adaptive networks consisting of a number of nodes, each of which equipped with an adaptation rule and communication capabilities, can be designed to solve estimation and inference problems in a fully distributed manner. In practice, it is possible that correlation exists among the observations at different agents. For example, in a dense network, data collected by neighboring agents can be highly correlated over space. We answer the question of how the performance of a diffusion network with correlated observations and noise compare to the one with independent observations and noise.

Optical Modulator with an Integrated Loop Mirror

By Fatemeh Soltani, Michael Menard and Professor Andrew Kirk

The theory, DC and large signal characterization of a loop mirror Mach-Zehnder interferometer (MZI) is reported. We demonstrate that this device is capable of 20 Gb/s modulation rate with reduced power requirements in comparison to a conventional MZI.

A Computationally Efficient Algorithm for Rotor Design Optimization of Synchronous Reluctance Machines

By Mohammad Hossain Mohammadi and Professor David Lowther

A generalizable algorithm is proposed for the design optimization of Synchronous Reluctance Machine rotors. Only single-barrier models are considered to eliminate the number of flux barriers variable, reduce the algorithm's computational complexity, and relatively compare rotors with different slots-per-pole combinations. Two objective values per sampled design (average and ripple torques) are computed using 2D Finite Element Analysis. Non-linear regression or surrogate models are trained for the two objectives through a Bayesian Regularization Backpropagation Neural Network. A Multi-Objective Genetic Algorithm is used to find the validated Pareto front solutions. At last, an analytical ellipse constraint for optimal high average torque designs is suggested to restrict the sampling region of the future search space. Final rotor solutions may then be converted into multiple-barrier versions for further torque ripple reduction.

A New Robust Dominance Criterion for Multiobjective Optimization

By Rodrigo Silva and Professor David Lowther

This paper discusses robust design issues in the multi-objective design of electromagnetic devices. A Pareto front of the worst cases of the solution due to the perturbation of the design variables is used to describe the robustness of a design. A robust dominance (r-dominance) relationship between two solutions of a multi-objective problem is defined. To reduce the computational cost of evaluating the robustness, a local response surface model is built on the uncertainty set. This robust multi-objective design scheme was applied to the design of an interior permanent magnet machine, where a trade-off exists between the average torque and the torque ripple as the rotor angle is varied. The results show that the proposed r-dominance, when embedded in a multi-objective optimization search method, is able to find robust solutions to multi-objective design problems.

Haplet: An Open-Source, Portable and Affordable Haptic Device for Democratizing Haptic Technologies

By Colin Gallacher, Arash Mohtat and Professor Jozsef Kovecses

Our interaction with computers and digital worlds is limited to keyboards, mice and more recently flat passive touch surfaces. By adding the feeling of forces and tactile clues, haptics can break this limitation and provide an extremely more natural way of interaction. Graphic designers use force feedback-enhanced 3D mice to sculpt an organic shape out of simulated digital clay; and, surgery students use state-of-the art haptically-enabled medical robots to feel pulpation and cutting of simulated body tissues before working on a real body. Everyone else's experience in haptics, however, is limited to only some vibrations of a smartphone or a gaming controller. Platforms that are capable of generating a rich force feedback and tactile content are expensive, bulky and proprietary protected. In an attempt to change these rules, we have created the Haplet: an open-source, portable and affordable haptic device. The Haplet features a small-form transparent robotic arm that clips on a tablet or computer screen and provides rich 2D force feedback experience to the user. The robotic arm is actuated by small DC motors that can be programmed to generate appropriate forces based on the desired haptic experience. For a simulated pong game, for example, the user who is holding the end-point of the robotic arm can be made to feel the forces from the ball hitting the racket attached to the end-point. All the electronics required to create this programmability is encapsulated in a custom designed board. This board is based on the Arduino-Due chip and can interface the computer simulation to the Haplet hardware. This board is so versatile that can be used for a wide variety of robotic projects with a requirement of up to four motors and encoders. Our research for further development of the Haplet and other similar devices, as well as creating mainstream applications for these technologies, is ongoing.

SUSTAINABILITY IN ENGINEERING AND DESIGN

Evaluating a Bicycle Education Program: Findings from Montreal, Canada

By Dea van Lierop and Professor Ahmed El-Geneidy

Many cities are developing policies that promote cycling due to the positive environmental, economic, and health benefits. This research evaluates a bicycle education program for school-aged children in Montreal, Canada with the goal of understanding how education influences children's and parents' cycling behavior and attitudes. Using qualitative measures and summary statistics this paper analyses pre- and post-program survey results from children who participated in the program and their parents. Results show that children's knowledge of bicycle safety increased, and half of the parents included in the post-program survey stated that their behaviors and/or attitudes towards cycling had positively changed as a result of their child's involvement in the bicycle education program. The findings of this study are useful for school-boards and bicycle educators to better develop and assess bicycle education programs in the future with the goal of motivating children and adults to engage in active and healthy lifestyles.

The Pursuit of Happiness: Variation in Satisfaction with Bus Transit Services among Different Riders

By David Verbich and Professor Ahmed El-Geneidy

Transit agencies continuously survey riders to learn how to improve services and understand what leads to rider satisfaction. Transit riders are not a homogeneous entity and understanding the distinctions between groups of riders can help transit agencies maintain and grow ridership. We use data from a large-scale, multiyear bus satisfaction survey from London, UK, to understand how encumbered riders and riders with disabilities value different aspects of bus services. For riders traveling with large items, shopping bags, or children, we find that satisfaction depends on the presence and condition of a bus shelter and the availability of a seat. Satisfaction of riders with disabilities depends on information availability at a bus stop, as well as trip speed and reliability. Our findings indicate that improving waiting area conditions can specifically increase the satisfaction of riders with disabilities and encumbrances, offering insights into the satisfaction of previously overlooked riders.

The Road to Productivity: An Analysis of Commuters' Punctuality and Energy Levels

By Charis Loong and Professor Ahmed El-Geneidy

The strain of daily commute can negatively impact work productivity. This study differentiates how various modes of commuting influence productivity at work and school. The data for this study come from the 2013 McGill Commuter Survey, a university-wide survey in which students, staff and faculty described their typical commuting experience to McGill University, located in Montreal, Canada. Ten logistic regressions are used to determine the factors that impact 1) a commuter's feeling of being energized when he or she arrives at work or school and 2) his or her punctuality. Our results show that weather conditions and mode of transportation have the greatest influence on energy at work and punctuality of individuals. The models indicate that driving is less conducive to productivity than taking the metro, and that bus riders experience the most energy-draining commute. On the other hand, cyclists have the greatest likelihood of feeling energized and are the least likely to experience negative impacts on their punctuality. With these findings in mind, transit agencies need to find ways to improve the experience for those using the bus, and schools and employers need to promote the habit of commuting by bicycle in order to enhance academic performance and work productivity.

Is Complexity Better? Assessing Accessibility Measures that Account for Daily Fluctuations in Transit and Jobs Availability

By Genevieve Boisjoly and Professor Ahmed El-Geneidy

Accessibility to jobs by transit is increasingly incorporated into transportation and land-use planning objectives. With a rise in time-sensitive accessibility measures, choosing the appropriate measure is increasingly challenging for engineers, planners and policy-makers. This research presents a comparative analysis of three accessibility measures varying in their level of complexity, two of which are time-sensitive. Relative accessibility measures are generated for five time periods based on a) constant transit service and number of jobs; b) variable transit service and constant number of jobs and c) variable transit service and variable number of jobs available. Findings show that all three measures are highly correlated and behave similarly when incorporated in transit share regression models. The study suggests that the most simple and commonly used accessibility measure is representative of the relative accessibility over the course of the day and is thus appropriate and meaningful for planning, namely with regards to social equity.

Clean Combustion of Metal Powders

By Keena Trowell, Professor Jeff Bergthorson and Professor David Frost

Metal powders, processed using renewable energy such as solar, can be used as an energy carrier. The energy density of metal powders is higher than that of hydrocarbons per unit volume and is comparable on a per unit mass basis. The power generated would be zero-carbon, clean and renewable. The solid oxide products recycled back into metals using clean primary energy.

Two cycles are proposed: A dry cycle and a wet cycle. In the dry cycle, metal-air combustion is coupled to external-combustion engines for power generation. The metal-air reaction produces only solid oxides and hot nitrogen as combustion products.

The wet cycle uses a high-temperature metal-water reaction to generate hydrogen and steam, both of which can be used in power applications. The metal-water reaction produces no noxious products giving it a unique advantage for use in underwater or underground applications where air-quality is a concern.

Removal of Perfluoroalkyl and Polyfluoroalkyl Substances from Impacted Water following the Lac Mégantic Disaster

By Guowei Zhong and Professor Jinxia Liu

Following the Lac Mégantic derailment accident, aqueous film-forming foams (AFFFs) containing polyfluoroalkyl and perfluoroalkyl surfactants (PFAS) were used to control fires. During the cleanup efforts, water contaminated by crude oil and AFFFs was treated through various physical treatment processes intended for hydrocarbon removal, but significant PFAS removal was also achieved. This study will present results of PFAS removal in lab-scale and full-scale treatment systems, evaluation methods used and their limitations. For a small and large modular treatment systems employed at Lac Mégantic, PFAS removal efficiencies were 87.3% and 99.9%, respectively, when assessed using a advanced oxidation (TOP) assay. A lab-scale system, which was operated to elucidate PFAS removal mechanisms, achieved comparable total PFAS removal, but most of it was attributed to activated carbon adsorption, due to the lack of colloids in the mimic lab environment. Surface tension measurement suggests that it can approximate PFAS levels for AFFF-impacted waters.

Optimum Design of a Three-Limb Full-Mobility Parallel-Kinematics Machine

By Wei Li and Professor Jorge Angeles

A novel three-limb full-mobility parallel robot is proposed as a simpler alternative to six-limb Stewart-Gough platforms (SGPs), currently the most widely used in machine tools, motion simulators, etc. The proposed architecture features a simple, symmetric structure, which should lead to low inertia, and a large workspace. The three-limb architecture eliminates limb-interference, thereby greatly simplifying its control, while enlarging its workspace. Our tripod utilizes a novel "isotropic" cylindrical drive, which makes it possible to locate all the actuators on the base, greatly reducing the power requirements. Moreover, the moving plate can cross the base platform, which greatly enlarges the workspace. Its forward-displacement analysis, kinematics, singularity analysis, and fixed-orientation workspace analysis have been conducted. The results of these analyses show a large workspace and excellent dexterity.

Multi-Physics Modelling and Robust Force Control of a Solenoid Actuator with Application to Electric Vehicle Transmission System

By Rana Tahmasebi and Professor Benoit Boulet

According to Canadian Environmental Assessment Agency report, transportation sector was responsible for 21% and 23% of Canada greenhouse gas emission in 1990 and 2013, respectively. Therefore, at least in the last 25 years, Electric vehicles (EVs) have been regarded as the solutions to the air pollution problem caused by internal combustion engine vehicles. Automated manual transmission is an advantageous transmission system which facilitates the flow of energy in an EV. Solenoid actuator is selected to provide the required force in this transmission. The generated force is controlled in a closed-loop system to ensure the desired force profile for gear shifting is achieved. In this study, considering the actuator operation sensitivity to the transmission system temperature, a coupled multi-physics thermal-electromagnetic approach is applied to the force control problem of the solenoid system. This approach establishes a basis for robust controller design using μ-synthesis optimal control method.

Rheology of Green Plasticizers: Master Curves of Selected Green Plasticizers

By Roya Jamarani, Professor Milan Maric and Professor Richard Leask

Plasticizers are small organic molecules that are blended with polymers in order to make them more flexible and improve their processing capabilities. One of the most commonly used plasticizers, di(2-ethylhexyl phthalate) (DEHP), has been linked to male infertility and is a suspected endocrine disruptor. Since plasticizers are not chemically bound to the polymer and have been found to leach into the environment, this is of concern to human health. As such, there has been an effort by our group to synthesize new biodegradable green plasticizers that are nontoxic.

My research aims to document the rheological behaviour of polyvinyl chloride (PVC) plasticized with our green plasticizers and to compare this with commercial plasticizers such as DEHP. Rheological data was collected at various frequencies, temperatures, and plasticizer loadings, in a nitrogen environment. Time-temperature superposition was used to extend the measurement range of the experiments to produce master curves for each plasticizer.

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MIAE is an initiative of the Lorne Trottier Chair in Aerospace Engineering to foster interest in Aerospace Engineering among undergraduate and graduate students and awareness of the multi-disciplinary and multi-cultural environment in which they may work as future engineers working in the Aerospace Industry. Students accepted into the Institute will be given the opportunity to participate in a number of 500 to 1000 hours Research Projects proposed by the Aerospace Companies. The Institute is also creating at McGill a special environment where the students will have access to a secure room with complete computer facilities, so that they will be able to work in their projects with the support of their professors. The MIAE students will also be given the opportunity to participate in other activities, organized to give them a comprehensive view of the Aerospace Industry and its challenges, such as plant visits and specially designed courses.
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MIAM was established by the Faculties of Science and Engineering to act as a focal point for research into all forms of advanced materials. Engineering innovation and materials creation have led to important developments in communications, information technology, transportation, clinical diagnosis and care, and energy generation, for example. New materials are considered by knowledge-based economies to be a precursor to many technological developments necessary for development and growth, and have been identified as one of Canada's strategic areas of research, and a priority area for McGill. http://www.mcgill.ca/miam/

The Centre for Intelligent Machines (CIM) is an inter-departmental inter-faculty research group which was formed in 1985 to facilitate and promote research on intelligent systems. Intelligent systems and machines are capable of adapting their behaviour by sensing and interpreting their environment, making decisions and plans, and then carrying out those plans using physical actions. The mission of CIM is to excel in the field of intelligent systems, stressing basic research, technology development and education. The members of CIM seek to advance the state of knowledge in such domains as robotics, artificial intelligence, computer vision, medical imaging, haptics, systems and control, computer animation and machine and reinforcement learning. http://www.cim.mcgill.ca/

Innovations Catalyst in Engineering (ICE) has been established in the Faculty of Engineering thanks to a major gift from Engineering alumnus William Seath (B.Eng. Mechanical Engineering, 1952). Its two-fold missions are to build and strengthen the Faculty's relationships with industry, and to encourage entrepreneurship and commercialization of innovative research. http://www.mcgill.ca/engineering/research/ice

McGill Engineering is ranked one of Canada's top two Engineering Schools in rankings published by the U.S. News & World Report, and on the international level scores higher than well-known U.S. schools such as Columbia, Yale, Northwestern, Penn State and Texas A&M University. The 2011 ranking breakdown by discipline varies between 15th spot and 34th in the world in the fields of Chemical, Civil, Computer, Electrical and Mechanical Engineering. Our Faculty places 29th overall in the U.S. News & World Report listing of the world's 300 engineering and technology schools. http://www.mcgill.ca/engineering/

The **McGill Engineering Student Centre (MESC)** offers many services to undergraduate students, integrating the Student Affairs Office (SAO), academic advising and peer tutoring, and the Engineering Career Centre (ECC).

The **Student Affairs Office (SAO)** is an engineering student's one-stop-shop for advising, peer tutoring, scholarships and awards, exchange and study abroad programs, counselling, orientation, administrative questions, and many other student services. The office is responsible for administering policies on student records, student assessment, and implementing the accreditation process on programs. Students are encouraged to contact MESC in all matters related to their student experience, and is also a primary resource for information on other services within the Faculty and across the University.

Advising and assisting students in program planning and in the proper selection of courses, so that all students understand the education goals of the University and follow programs that coincide with their talents, interests and goals.

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