UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

UTERC 2023

BOUNDLESS CONNECTIONS

University of Toronto Engineering Research Conference

August 2, 2023
Bahen Centre for Information Technology

GECoS UofT
Graduate Engineering Council of Students
University of Toronto

UNIVERSITY OF TORONTO

Dear Attendees,

It is our absolute pleasure to welcome you to the University of Toronto Engineering Research Conference (UTERC) 2023! After last year's virtual meeting, we are all *very* eager to meet in person at the Bahen Centre for Information Technology at the University of Toronto.

UTERC provides students, researchers, and industry professionals with opportunities to engage with the work of our graduate students while learning more about the leading research done at the Faculty of Applied Science & Engineering (FASE).

This year's theme is ***Boundless Connections***, with the ultimate purpose of providing networking opportunities, encourage collaborative problem solving, and further the community of students, faculty, and alumni across FASE.

As a leading research faculty, FASE is pushing the limits and pioneering initiatives in this increasingly digital world. While continuing to fight against these difficult times, now more than ever it is vital to keep our community connected and meet the needs of our students. Through innovation and collaboration, what we can achieve together is truly boundless.

We hope you enjoy the conference!

Tess Seip

Tess Seip
UTERC 2023 Conference Chair

Schedule-at-a-Glance

All events are at the Bahen Centre

Time	Event Description	Location
9:00 AM - 10:30 AM	Registration Poster Setup Breakfast & Networking	Atrium
10:30 AM - 10:40 AM	Opening Remarks: *Prof. Julie Audet,* *Vice-Dean, Graduate, FASE*	BA 1160
10:40 AM - 11:20 AM	Keynote Speaker: *Prof. Christopher Yip,* *Dean, FASE*	BA 1160
11:30 AM - 1:00 PM	*Oral Presentations:* Analytics and AI Sustainability and Design	 BA1180 BA1210
1:00 PM - 2:00 PM	Lunch & Networking	Atrium
2:00 PM - 3:30 PM	Poster Presentations *Oral Presentations:* Advanced Materials Human Health	Atrium BA1200 BA1220
3:30 PM - 3:45 PM	Break Poster Take Down	Atrium
3:45 PM - 4:30 PM	Closing Remarks Prize Winners Announced	BA 1180

Keynote Speaker

Prof. Christopher Yip
Dean of the Faculty of Applied Science & Engineering
University of Toronto, ON

Dean Yip is a leading scholar in the field of single-molecule biophysics and a faculty member with the Department of Chemical Engineering & Applied Chemistry, the Department of Biochemistry and the Institute of Biomedical Engineering. He is a Principal Investigator with the Donnelly Centre for Cellular & Biomolecular Research at the University of Toronto.

As a former director of the Institute of Biomedical Engineering (BME), he provided leadership to more than 100 research engineers and scientists engaged in discovery and product development in the areas of neuroscience and sensory stimulation, biomaterials and tissue engineering, molecular systems biology and nanotechnology, as well as medical device and drug delivery system design.

Dean Yip is the Vice Chair of the CIHR Institute of Genetics Advisory Board and has served on grant panels at NSERC, CIHR and NIH. He was the first recipient of the Molecular Imaging's Outstanding Young Biological Scanning Probe Microscopy Investigator of the Year award, and since that time has been honoured with a Premier's Research Excellence Award (1999), Faculty Teaching Award, (2000) and Graduate Faculty Teaching Award for Sustained Contribution to Excellence in Graduate Teaching (2008). He was named a Fellow of the American Association for the Advancement of Science (2009), a Fellow of the Engineering Institute of Canada (2014) and held a Tier II Canada Research Chair in Molecular Imaging (2000-2010).

Presentation Schedule

	Time	Analytics & AI (BA1180)		Sustainability & Design (BA1210)	
Morning Oral Sessions	11:30 - 11:40	#1	Yudong Xu	#1	Taylor Edwards
	11:40 - 11:50	#2	Craig Fernandes	#2	Bo Sun
	11:50 - 12:00	#3	Xiaocan Li	#3	Keagan Rankin
	12:00 - 12:10	#4	Shi Tianyu	#4	Fiona Xiong
	12:10 - 12:20	#5	Junxiong Yang	#5	Angel Badewole
	12:20 - 12:30	#6	Dixi Yao	#6	Riyan Roy
	12:30 - 12:40	#7	Katia Ossetchkina	#7	Sherry-Ann Ram
	12:40 - 12:50	#8	Negin Houshmand	#8	Ayesha Patnaik
	12:50 - 1:00	#9	Arjun Sridharkumar	#9	Amin Azad
	Time	***Advanced Materials (BA1200)***		***Human Health (BA1220)***	
Afternoon Oral Sessions	2:00 - 2:08	#1	Peter Serles	#1	Saba Sadatamin
	2:08 - 2:16	#2	Zhixin Meng	#2	Vishal Pendse
	2:16 - 2:24	#3	Niher Sarker	#3	Kimberly Seaman
	2:24 - 2:32	#4	Maryam Fashandi	#4	Saif Rjaibi
	2:32 - 2:40	#5	Raunaq Bagchi	#5	Mahsa Karimi
	2:40 - 2:48	#6	Delaram Sadatamin	#6	Jo Nguyen
	2:48 - 2:56	#7	Julian Rosas	#7	Shana Alexander
	2:56 - 3:04	#8	Janny Wang	#8	Laura Wheeler
	3:04 - 3:12	#9	Amin Jamshidi	#9	Jeffrey Qiu
	3:12 - 3:20	#10	Akib Islam	#10	Matthew Lee
	3:20 - 3:28	#11	Azadeh Vahedi	#11	Vrushali Guruji
	Time	***Poster Group A***		***Poster Group B***	
Afternoon Poster Sessions	2:00 - 2:10	#1	David Li	#8	Lijun Zhu
	2:10 - 2:20	#2	Kevin Perera	#9	Andrew Pan
	2:20 - 2:30	#3	Sophia Lu	#10	Soliman Ali
	2:30 - 2:40	#4	Shay Chavoshian	#11	Sima Zeinali Danalou
	2:40 - 2:50	#5	Anat Usatinsky	#12	Fatemeh Arabyarmohammadi
	2:50 - 3:00	#6	Khaled Gaber	#13	Zahra Kazemi
	3:00 - 3:10	#7	Amel Sassi	#14	Samuel Ugwu

Analytics & AI

Oral Presentations (11:30AM - 1:00PM, BA1180)

#	Time	Title	Presenter
1	11:30 - 11:40	Can GPT Solve Simple Abstract Reasoning Puzzles?	Yudong Xu
2	11:40 - 11:50	Income Pools for Superstar Markets	Craig Fernandes
3	11:50 - 12:00	Traffic Perimeter Control Using Model-Free Deep Reinforcement Learning: Homogeneous Flow Rate Optimization	Xiaocan Li
4	12:00 - 12:10	Reinforcement Learning for Mixed Autonomy Traffic Control and Operation	Tianyu Shi
5	12:10 - 12:20	Automated Extraction of Borehole Breakout Properties from Acoustic Televiewer (ATV) Data	Junxiong Yang
6	12:20 - 12:30	Solving Heterogeneity via Personalized Federated Learning	Dixi Yao
7	12:30 - 12:40	Using Machine Learning Techniques for Fracture Classification and Prediction Based on Geological, Indentation and X-Ray Diffraction Imaging Data	Katia Ossetchkina
8	12:40 - 12:50	Application of AI in Rock Type Prediction	Negin Houshmand
9	12:50 - 1:00	Identifying Delayed Disclosures and Silent Fixes in Open Source Ecosystem	Arjun Sridharkumar

Analytics & AI

Oral Presentation (#1)

Can GPT Solve Simple Abstract Reasoning Puzzles?

Presented by: Yudong Xu

Abstract

We explore the abstraction and reasoning capabilities of GPT by conducting a systematic analysis with the Abstraction and Reasoning Corpus (ARC). ARC serves as a benchmark for quantitatively assessing the gap between human and machine intelligence by evaluating abstract reasoning ability from a limited number of examples. Solving the ARC demands core knowledge of concepts such as objects, goal states, counting, and basic geometry. GPT performs poorly when we use a naive approach. Our failure analysis shows that the ability of GPT to identify objects and reason about them is significantly impacted by the sequential nature of the text that represents an object within the text encoding of a task. To mitigate this problem, we propose an object-based representation achieved through an external tool, resulting in nearly double the performance. Paper, visualizations, and data are available at https://khalil-research.github.io/LLM4ARC.

Analytics & AI

Oral Presentation (#2)

Income Pools for Superstar Markets

Presented by: Craig Fernandes

Abstract

"Superstar" markets, characterized by a small portion of individuals earning disproportionately large salaries, have been identified in industries such as entrepreneurship, sports, music and entertainment. To combat the income uncertainty in these markets, we study income pools - a contract where individuals agree to share a portion of their future earnings if they become a superstar. We develop the first mathematical model to analyze income pools, focusing on stability (i.e., pools where no agents leave or join). We show that no finite-sized stable pool exists. In response, we define bounded stable pools and epsilon-stable pools, proving their existence and Pareto properties. We conduct a case study on professional baseball, where the average annual salaries in the two highest levels are $10,000 and $4.4 million respectively, with only a 14% chance of moving up. Our results show that income pools lead to a 30% increase in social welfare.

Analytics & AI

Oral Presentation (#3)

Traffic Perimeter Control Using Model-free Deep Reinforcement Learning: Homogeneous Flow Rate Optimization

Presented by: Xiaocan Li

Abstract

Perimeter control maintains high traffic efficiency within protected regions by controlling transfer flows among regions to ensure that their traffic densities are below critical values. Existing approaches can be categorized as either model-based or model-free, depending on whether they rely on network transmission models (NTMs) and macroscopic fundamental diagrams (MFDs). Although model-based approaches are more data efficient and have performance guarantees, they are inherently prone to model bias and inaccuracy. For example, NTMs often become imprecise for a large number of protected regions, and MFDs can exhibit scatter and hysteresis that are not captured in existing model-based works. Moreover, no existing studies have employed reinforcement learning for homogeneous flow rate optimization in microscopic simulation, where spatial characteristics, vehicle-level information, and metering realizations — often overlooked in macroscopic simulations — are taken into account. To circumvent issues of model-based approaches and macroscopic simulation, we propose a model-free deep reinforcement learning approach that optimizes the flow rate homogeneously at the perimeter at the microscopic level. Results demonstrate that our model-free reinforcement learning approach without any knowledge of NTMs or MFDs can compete and match the performance of a model-based approach, and exhibits enhanced generalizability and scalability.

Analytics & AI

Oral Presentation (#4)

Reinforcement Learning for Mixed Autonomy Traffic Control and Operation

Presented by: Tianyu Shi

Abstract

This proposal aims to introduce and develop algorithms that focus on mixed autonomy control in ITS research. First, we will introduce the definition of micro-efficiency and macro-efficiency. The micro-efficiency is to model microscopic cars following behavior, such as time to collision (TTC), headway, following target speed. On the other hand, the macro efficiency is to model traffic management, which is to reduce shockwave, and total travel time, and improve throughput. Our ultimate goal is to use autonomous vehicles to improve network's total performance. To summarize, our research questions in the project will be: (1) Investigate how to build a full self-driving model with both longitudinal and lateral control (2) Investigate how to optimize both microscopic efficiency and macroscopic efficiency to enhance traffic operations and maximizes total benefits.

Analytics & AI

Oral Presentation (#5)

Automated Extraction of Borehole Breakout Properties from Acoustic Televiewer (ATV) Data

Presented by: Junxiong Yang

Abstract

Analysis of borehole breakouts is a widely used indirect method to estimate in situ stress and assess borehole instability. The Acoustic Televiewer (ATV) is commonly used to log borehole breakouts, but noise inherent to ATV data affects the interpretation of the breakouts. ATV data are usually interpreted manually with associated low efficiency and high cost, and to overcome these deficiencies here we propose a high performance combined de-noising procedure based on the median filter and deep learning techniques. We investigate the use of a convolutional neural network (CNN) method to automate the process of breakout identification, by extracting the underlying relationship between the ATV data and the borehole breakouts. We show that the CNN method can capture breakouts with reasonable accuracy, and when compared to manual procedures the new technique offers both procedural efficiency and reduced interpretation costs.

Analytics & AI

Oral Presentation (#6)

Solving Heterogeneity via Personalized Federated Learning

Presented by: Dixi Yao

Abstract

Federated learning has emerged as an important paradigm in modern distributed machine learning. However, clients in federated learning are placed in a wild environment where clients do not have consensus over data, systems, privacy and others. Personalized federated learning lets clients share particular knowledge and personalize, so as to achieve the best performance over local data. We went through and fairly compared several representative personalized federated learning methods on board with consideration of effectiveness, feasibility and ubiquitousness. We showed that some methods are not so effective and then we delve deeper and find out that federated neural architecture search is a promising direction to solve the heterogeneity problems despite several drawbacks. On the basis of that, we give out several directions for future work about how we can make current federated NAS methods more promising. Finally, we give a discussion about future work on designing better personalized federated learning methods.

Analytics & AI

Oral Presentation (#7)

Using Machine Learning Techniques for Fracture Classification and Prediction Based on Geological, Indentation and X-Ray Diffraction Imaging Data

Presented by: Katia Ossetchkina

Abstract

Numerical simulation is the gold standard across civil engineering rock-modelling applications to understand the effect of existing fractures for different loading behaviours, but creating these models is a labor-intensive process, which can be time-consuming and subjective. In this study, a novel approach of predicting thermal fracture characteristics directly from image data of thermally treated granite samples is investigated. Optical images, geological data and high-resolution x-ray diffraction imaging data was collected from the samples to classify fractures and features, including distribution of hardness characteristics, inter- and intra-granular fractures, mineral grain types, and fracture aperture. After labelled data was generated, machine and deep learning techniques were used to predict fracture formation, location and characteristics on lower temperatures images to simulate their thermal response and generate synthetic images of the thermal loading response. Numerical simulation was used to mimic an expert decision and assess the validity and limitations of the approach.

Analytics & AI

Oral Presentation (#8)

Application of AI in Rock Type Prediction

Presented by: Negin Houshmand

Abstract

This study focuses on automating rock type classification in geological and geotechnical core logging using machine learning and deep learning techniques. By combining visual characteristics, geochemical data, and core images, the researchers developed a concatenation model to mimic geologists' classification procedures. They utilized a multi-sensor core logging system and core scanner to capture petrophysical properties, geochemical data, and 360-degree core images from five distinct rock types. Three approaches were implemented, including ML algorithms, pre-trained deep learning models, and an expert decision procedure that combined rock properties and image-based features. The concatenation approach achieved higher accuracy compared to individual methods, with the image features proving to be the most important. The proposed method has the potential to enhance efficiency and accuracy in rock type classification, serving as a valuable tool for geologists.

Analytics & AI

Oral Presentation (#9)

Identifying Delayed Disclosures and Silent Fixes in Open Source Ecosystem

Presented by: Arjun Sridharkumar

Abstract

Open source software (OSS) contains security vulnerabilities that have resulted in high-profile security incidents recently (HeatBleed,Log4J). Vulnerabilities are communicated using a coordinated-disclosure model (CDM). As per this model's recommendation, information regarding the vulnerability should be released after a certain amount of time ensuring a private disclosure (that allows for the vulnerability to be fixed). A vulnerability in an OSS context is to be disclosed privately following which its fixed. To ensure least public information regarding a vulnerability till it is fixed, the CDM recommends fixing vulnerabilities silently (not mentioning the vulnerability and fix in release-notes). This causes a large time gap to fix the vulnerability misused by hackers. Our work develops a large-scale socio-knowledge graph to identify and predict instances of delayed-disclosures and silent-fixes. The technical-aspect involves the Github issues, pull-requests, and code changes related to the vulnerabilities. The social-aspect of the knowledge graph refers to tweets related to vulnerabilities prior to public disclosure. Our research helps to identify vulnerabilities as early as possible.

Sustainability & Design

Oral Presentations (11:30AM - 1:00PM, BA1210)

#	Time	Title	Presenter
1	11:30 - 11:40	Lane-by-Lane Traffic Impacts on Roadside Airborne Pollution	Taylor Edwards
2	11:40 - 11:50	Renewable Carbon Functioned as a Reservoir for Odorous Volatile Organic Compounds of Bioplastic	Bo Sun
3	11:50 - 12:00	Curbing Embodied Greenhouses Gas under High Growth in Housing and Infrastructure	Keagan Rankin
4	12:00 - 12:10	Microwave-Assisted Activation of Waste Tea Leaves for Energy Storage	Fiona Xiong
5	12:10 - 12:20	Carbon Footprint Assessment of Ethylene Oxide Production via CO_2 Electrolysis	Angel Badewole
6	12:20 - 12:30	Towards Smart Manufacturing: Applying Machine Learning for Effective Fault Detection and Diagnosis in the Process Industry	Riyan Roy
7	12:30 - 12:40	How can Sustainability Be Defined for Engineering and Used to Evaluate Curriculum at UofT?	Sherry-Ann Ram
8	12:40 - 12:50	Using Student Data Analytics to Examine Graduating Student Survey Data	Ayesha Patnaik
9	12:50 - 1:00	Learning Outcomes from Teaching Systems Thinking to Engineering Students	Amin Azad

Sustainability & Design

Oral Presentation (#1)

Lane-by-Lane Traffic Impacts on Roadside Airborne Pollution

Presented by: Taylor Edwards

Abstract

Traffic is one of Canada's largest contributors to both greenhouse gas emissions and urban air pollution. When testing how traffic effects local air quality, researchers use a wide variety of methods with varying levels of detail. To date, however, no research has observed traffic emissions based on the lane a vehicle is travelling in, when driving on multi-lane highways. We measured roadside airborne pollution and lane-by-lane traffic counts at Highway 401 for seven years. We applied a combined principal component analysis and linear regression to identify the highway's collector and expressway lanes different contributions to downwind air pollution. Our findings suggest large vehicles on the expressway emit 80% more CO_2 than large vehicles on the collectors, implying heavier-emitting vehicle drivers prefer the expressway. We explored how moving trucks between collector and expressway can change downwind pollution, and how swapping light vehicles for electric vehicles can reduce roadside air pollution.

Sustainability & Design

Oral Presentation (#2)

Renewable Carbon Functioned as a Reservoir for Odorous Volatile Organic Compounds of Bioplastic

Presented by: Bo Sun

Abstract

Volatile organic compounds (VOCs), mainly derived from the thermally degraded cellulosic fibers, are the major odor sources for wood-plastic composites (WPCs) that can cause severe environmental hazards and health issues. This project highlights the function of renewable carbon (RC) in VOCs controlling: (1) its highly porous structure can enhance the adsorption of VOCs; and (2) similarities in polarity and functional groups allow RC to be preferably loaded onto cellulosic fibers, thus protecting them from aggressive thermal degradation and minimizing the VOCs production. RC was impregnated into WPCs as a bio-dopant during the compounding of cellulosic pulp with polypropylene (PP). Raman and SEM demonstrated the preferred loading of RC particles on the fibers' surface, and the function of RC in preserving the fibers was verified by TGA analysis, which revealed 2.5% less weight loss of PP-WPCs-RC than PP-WPCs at compounding temperature of 170°C-200°C. A significant decrease of 335% in VOCs concentration from PP-WPCs-RC was confirmed by Headspace-GC, in comparison with PP-WPCs. Adsorption profiles in term of ΔHads of RC with different pore size were determined. Anti-percolation model was applied to quantify the mass transfer of pores, together with the VOCs diffusion simulation based on Fick's second Law. The results showed that RC in mesopores exhibited 12% less of ΔHads and 22.7% lower threshold concentration than in micropores, indicating the higher adsorption capacity. The finding of this project can overcome the odorous VOCs issues of traditional WPCs, thus making the full replacement of plastic one step closer to practical.

Sustainability & Design

Oral Presentation (#3)

Curbing Embodied Greenhouses Gas under High Growth in Housing and Infrastructure

Presented by: Keagan Rankin

Abstract

Embodied emissions from construction are accounting for a large and growing share of global emissions due to globally increasing demand for housing and related infrastructure. Strategies are urgently needed to find ways of both building the infrastructure required for social and economic good while staying committed to emission reductions. Using a new detailed model, we forecast Canadian housing and infrastructure construction under increased future demand and analyze strategies for reducing embodied emissions. With business as usual construction, embodied emissions from housing and infrastructure will reach 200+% of Canada's reduction target in 2030. Reducing cumulative emissions to desired levels by 2030 requires building denser housing and optimizing structural design. Improvements in material production and technology have little CO_2eq reduction potential in the short term. However, providing adequate infrastructure while maintaining a path to net-zero beyond 2030 is highly dependent on reduced demand, material production improvements and CDR deployment.

Sustainability & Design

Oral Presentation (#4)

Microwave-Assisted Activation of Waste Tea Leaves for Energy Storage

Presented by: Fiona Xiong

Abstract

Electrochemical capacitors (ECs) are promising energy storage devices due to their high-power density and long cycle life relative to batteries. The EC electrodes are mostly from activated carbons (ACs) due to their high specific surface areas and excellent chemical stabilities. To ensure the sustainability and low-cost of the ECs, biomass waste derived ACs (e.g., coconut shell, spent tea etc.) have been investigated as EC electrodes. The most common method for AC production involves chemical activation (e.g., KOH, H_3PO_4) with extensive furnace heating, which can take up to 12 hours. To shorten the processing time, microwave heating was studied as a potential alternative. In this study, the performance of the AC derived from waste tea leaves prepared by microwave activation using H_3PO_4 was explored and compared with results from conventional furnace activation. The results from this work could contribute towards utilizing microwave heating as a more effective and sustainable route in future electrode production for energy storage.

Sustainability & Design

Oral Presentation (#5)

Carbon Footprint Assessment of Ethylene Oxide Production via CO2 Electrolysis

Presented by: Angel Badewole

Abstract

Ethylene oxide (EO) is a commodity chemical used for plastic production. Globally, EO production emits 25 megatonnes of greenhouse gases (GHG), roughly 2% of the chemical industry's emissions. Recently, a promising pathway emerged for EO production using CO_2 as a feedstock. However, the environmental impacts have not been studied, therefore, the benefits and trade-offs remain uncertain. Thus, the objective of this project was to quantify the life cycle carbon footprint (CF) of the emerging CO_2 to EO technology. The CF of the process was estimated as 4.5 tonnes CO2-eq/tonne EO. Sensitivity analyses showed that the faradaic efficiency of ethylene has the largest influence on the CF and thus needs to be optimized in order to reduce emissions. A comparison with the conventional EO production pathway showed potential GHG savings up to 52% when the process is coupled with low-carbon electricity. These results show promise to abate the chemicals sector's emissions.

Sustainability & Design

Oral Presentation (#6)

Towards Smart Manufacturing: Applying Machine Learning for Effective Fault Detection and Diagnosis in the Process Industry

Presented by: Riyan Roy

Abstract

The continuous evolution of industrial processes within the framework of Industry 4.0 has paved the way for leveraging artificial intelligence (AI) and machine learning (ML) techniques in the manufacturing industry. In this context, the Tennessee Eastman (TE) process, a representative model of an industrial plant, has served as a popular test bed for process monitoring and fault diagnostic techniques. This project aims to revolutionize process engineering by harnessing the power of ML to detect and diagnose a wide range of faults in the TE process. By capitalizing on advanced ML algorithms, this initiative aims to create robust predictive models trained on extensive datasets. These models possess the capability to detect and diagnose various types of faults, including process malfunctions, temperature-pressure anomalies, and other irregularities. Through continuous monitoring and analysis of real-time data, ML algorithms can proactively detect potential safety hazards, identify abnormal conditions, and provide early warning systems. This proactive approach significantly reduces the risk of accidents, ensuring the safety of personnel and the environment. The TE process, a complex chemical production method employed by the Eastman Chemical Company, forms the basis for this study. The process involves a reactor, heat exchangers, a separator, a stripper, and a compressor, forming a recycling loop. By incorporating material balances, energy balances, and various physical, thermodynamic, and chemical equations, the TE process serves as a realistic standard model for industrial plant simulation. To enable the development and validation of the ML models, a comprehensive historical database of the TE process was generated through a 3000-day plant simulation. This dataset comprises abnormal operation periods, normal operation data, and a wide range of disturbances and setpoint changes. The data encompasses multiple manipulated variables and measured values, providing a rich and diverse set of features for ML modeling. In this study, various ML algorithms, including XGBoost, Random Forest, and AdaBoost, were employed to create predictive models for fault detection and diagnosis. Performance metrics such as accuracy and F1-score were used to evaluate the effectiveness of these models. Additionally, exploratory data analysis and visualization techniques were applied to gain insights into the relationship between faults and process features. The results of this research demonstrate the effectiveness of ML techniques in fault detection and diagnosis within the TE process. The developed predictive models and insights gained from the data analysis provide valuable guidance for process engineers in optimizing operations, ensuring safety, and improving overall performance in industrial settings. By embracing the capabilities of ML, the manufacturing industry can unlock the benefits of Industry 4.0, driving innovation, efficiency, and safety in process engineering.

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Sustainability & Design

Oral Presentation (#7)

How can Sustainability Be Defined For Engineering and Used to Evaluate Curriculum at UofT?

Presented by: Sherry-Ann Ram

Abstract

Engineers are the custodians of our physical world and protection of human life is one of their core responsibilities, thus, it is important for them to be aware of sustainability in their professional practice. Given that the University of Toronto enrolls one of the highest numbers of undergraduate engineering students in Canada, this study aims to understand how the engineering curriculum at UofT prepares students to be responsible practitioners of sustainability by (a) defining a framework for sustainability and then (b) analyzing the curriculum using this framework. (a) To formulate a definition for sustainability in engineering, a framework was developed to define sustainability for the pillars of environment, economic, social and professional responsibility. (b) Preliminary results indicate that environmental sustainability is most prevalent, followed by professional, social and economic. In addition, sustainability tends to be taught in isolation rather than an integrative approach.

Sustainability & Design

Oral Presentation (#8)

Using Student Data Analytics to Examine Graduating Student Survey Data

Presented by: Ayesha Patnaik

Abstract

The Faculty of Applied Science and Engineering (FASE) at the University of Toronto (UofT) conducts an annual survey for the graduating undergraduate engineering students about their career plans, use of university resources, development of self-assessment skills, workload management and a sense of community within the UofT peers. The objective of this research is to adopt a data-centric approach to understanding students' experiences and interactions with the university's resources, and the role of the university in students' journey towards achieving their career goals. I have used descriptive statistics to derive patterns in four years of data, and will later employ correlation analysis and predictive modelling for a deeper dive into the data. A key finding so far is the contribution of the PEY program to graduating students' attaining their first employment. This research informs FASE about undergraduate students' experiences in their final year and their early career outcomes.

Sustainability & Design

Oral Presentation (#9)

Learning Outcomes from Teaching Systems Thinking to Engineering Students

Presented by: Amin Azad

Abstract

The primary focus of Engineering Education programs has been to train engineers in various aspects of problem-solving techniques. However, there have been concerns about the types of problems engineering students are exposed to. Most engineering programs train students on solving routine problems, with extension to originative problems in design courses. However, highly complex or “wicked problems” are more rarely explored at the undergraduate level in spite of the fact that they are some of the most important problems faced in society. Systems Thinking has been suggested as a promising approach to addressing wicked problems. We have designed a course in Systems Thinking at the University of Toronto targeted toward students from all disciplines of engineering. The objective of this course is to encourage students to explore the inherent ambiguity of complex problems while introducing them to tools and approaches to visualize their problem space. This paper evaluates the learning experience of students in the first iteration of this course, through a series of analyses performed on their coursework, personal reflections, and interviews. It was hypothesized that teaching Systems Thinking to engineering students would increase their awareness of the problem space, push them to learn about other disciplines outside of engineering, and increase their ability to visualize the elements in the problem. Our results suggest ways in which Systems Thinking has helped engineering students in their problem solving abilities and looks at the specific skills in which engineering students have significantly improved.

Advanced Materials

Oral Presentations (2:00PM - 3:30PM, BA1200)

#	Time	Title	Presenter
1	2:00 - 2:08	Multi-Objective Bayesian Optimized Carbon Nanolattices	Peter Serles
2	2:08 - 2:16	Synthesis of Super Absorbent Hydrogel Using Biosludge as a Feedstock	Zhixin Meng
3	2:16 - 2:24	Leveraging Liquid Interfaces to Form Membrane Selective Layers Using a Custom-Made 3D Printed Reactor	Niher Sarker
4	2:24 - 2:32	Ambient Pressure Dried Silica Aerogel — Melamine Foam Composite with Superhydrophobic, Self-Cleaning and Water Remediation Properties	Maryam Fashandi
5	2:32 - 2:40	Organic Molecule-Nanocarbon based Redox Active Composites	Raunaq Bagchi
6	2:40 - 2:48	Development of a Smart Textile for Sleep Apnea Monitoring in Individuals with Heart Failure	Delaram Sadatamin
7	2:48 - 2:56	$LiNO_3$-based Polymer Electrolytes for Flexible Electrochemical Capacitors	Julian Rosas
8	2:56 - 3:04	Novel Ion Gel Electrolytes for Printed Field Effect Transistors	Janny Wang
9	3:04 - 3:12	An EIT-based Piezoresistive Sensing Skin with a Lattice Structure	Amin Jamshidi
10	3:12 - 3:20	Strain Engineered Phase Transition of Mono and Bi-Layer WSe_2	Akib Islam
11	3:20 - 3:28	Characterization and Semi-Quantitative Investigation on Materials and Process Variables in order to Maximum Synthesis of Magnetite by Sonochemical Method	Azadeh Vahedi

Advanced Materials

Oral Presentation (#1)

Multi-Objective Bayesian Optimized Carbon Nanolattices

Presented by: Peter Serles

Abstract

Nanoarchitected materials represent the frontier of low-density metamaterials that can achieve specific strengths and specific stiffnesses beyond the theoretical limit for solid materials. These nanoarchitected materials combine three synergistic effects – nanoscale size effects of individual elements, high performance constituent materials, and optimized shape factors – which are enabled through nanoscale additive manufacturing by two photon polymerization (2PP) combined with post-treatment by pyrolysis. In this study, using machine learning multi-objective Bayesian design optimization, spectroscopic analysis of atomic structure, and nanoscale scaling of lattice designs, we optimize all three parameters to produce a mechanical metamaterial with the weight of Styrofoam (~80 g/cm^3) and the compressive strength of mild steel (~240 MPa) making it the highest specific strength of any lightweight material (3100 $kN{\cdot}m{\cdot}kg^{-1}$).

Advanced Materials

Oral Presentation (#2)

Synthesis of Super Absorbent Hydrogel using Biosludge as a Feedstock

Presented by: Zhixin Meng

Abstract

Pulp and paper mills produce large quantities of biosolids in their activated sludge stage of wastewater treatment. Dewatering is typically done by adding cationic polymers and a flocking aid and then pressing or centrifuging the biosludge. However, dewatering in this way is limited due to its complex gel-like structure, extracellular polymers, and highly charged particles. The question behind this work was a hydrogel be formed using the original biosludge as a feedstock and in this way, a higher value product potentially be produced. Biosludge is land applied to farmland in some locations with positive effects. In this work, we used biosludge from a sulfite pulp mill as the feedstock to synthesize superabsorbent hydrogel which can be potential used in farmland as a soil conditioner as well as facilitate root of crops to uptake nutrients.

Advanced Materials

Oral Presentation (#3)

Leveraging Liquid Interfaces to Form Membrane Selective Layers Using a Custom-made 3D Printed Reactor

Presented by: Niher Sarker

Abstract

A novel lab-scale apparatus has been developed using 3-D printing technology to fabricate thin-film composite (TFC) membranes with different materials. This cost-effective and user-friendly apparatus allows for the creation of supported nanofilms as selective layers for membranes. The versatility of the apparatus was demonstrated by forming polyamide thin films through interfacial polymerization for reverse osmosis desalination, PDMS layers via potting mix and hexane dissolution, and polysulfone films through chlorinated solvent evaporation for gas separation. The TFC membranes were characterized using scanning electron microscopy (SEM) and refractometer analysis. These characterization techniques provided valuable insights into the membrane morphology and structural integrity. By showcasing the potential of 3-D printing technology in membrane research, this study introduces a new and accessible method for fabricating high-performance TFC membranes. This breakthrough holds promise for a wide range of applications, paving the way for advancements in membrane technology.

Advanced Materials

Oral Presentation (#4)

Ambient Pressure Dried Silica Aerogel - Melamine Foam Composite with Superhydrophobic, Self-Cleaning and Water Remediation Properties

Presented by: Maryam Fashandi

Abstract

With their low density, high surface area and thermal insulation properties, silica aerogels are proper candidates for water remediation or thermal insulation applications. However, their fragility, lengthy and costly fabrication process restricts their application. The inclusion of a flexible melamine foam (MF) along with a co-precursor system consisting of monomeric methyltrimethoxysilane (MTMS) and polymeric polyvinyltrimethoxysilane (PVTMS) can make the fabrication process feasible and improve the durability of aerogels. Also, PVTMS with a doubly-crosslinked network brings mesoporous structure and high surface area to MF. MTMS alters the hydrophilic nature of MF to superhydrophobic, without surface modification steps. Varying concentration of PVTMS and MTMS were used to fabricate the MF- aerogel composite. Acid and base catalysts were used for the hydrolysis and condensation. The MF-aerogel composite was obtained using ambient pressure drying, and the overall fabrication process took around 48 hrs. The inclusion of MF enabled the ambient pressure drying and brought flexibility for silica aerogels. On the other hand, the presence of mesoporous aerogels improved the thermal insulation properties of MF ($\lambda \sim 0.027\ W{\cdot}m^{-1}{\cdot}K^{-1}$), making it superhydrophobic ($\theta \sim 160°$), self-cleaning, and moisture resistant. Excellent oil adsorption (up to 36 $g{\cdot}g^{-1}$) and oil-water separation performance (oil flux of 120,000 $L{\cdot}m^{-2}{\cdot}hr^{-1}$) of MF-aerogel composite were also confirmed.

Advanced Materials

Oral Presentation (#5)

Organic Molecule-Nanocarbon based Redox Active Composites

Presented by: Raunaq Bagchi

Abstract

The rising demand for clean energy, sustainable transport, and portable devices (e.g., Internet-of-Things) has led to the growing interest in electrochemical energy storage, such as electrochemical capacitors (ECs). Redox-active organic molecule-nanocarbon composite electrodes can deliver high power and energy storage in ECs. To advance these capabilities, the surface functionalities of nanocarbon substrates need to be investigated. The challenge exists in understanding how these redox-active species prefer surface functionalities based on the nature of their interactions. In this work, we conducted a systematic study comparing the effect of surface functionalities on redox-active organic molecule-nanocarbon composites to understand why certain surface functionalities on nanocarbon substrates are favoured. The findings from this study can be used to implement surface modification for redox-active organic-nanocarbon composites to improve energy storage, towards a more sustainable future.

Advanced Materials

Oral Presentation (#6)

Development of a Smart Textile for Sleep Apnea Monitoring in Individuals with Heart Failure

Presented by: Delaram Sadatamin

Abstract

Sleep apnea is a common comorbidity in individuals with heart failure, contributing to adverse cardiovascular outcomes like stroke and hypertension. This study aims to develop a smart textile-based solution for non-invasive and continuous monitoring of sleep apnea in individuals with heart failure. The hardware system, integrated into the textile, enables simultaneous measurement of vital parameters including electrocardiogram (ECG), temperature, oxygen saturation (SpO_2), and body posture. By leveraging these comprehensive measurements, the smart textile provides a holistic assessment of sleep apnea severity and its impact on cardiovascular health. Data collected from the textile are wirelessly transmitted to a monitoring device, enabling real-time analysis and reporting of apnea events. The proposed smart textile offers a convenient and unobtrusive approach to sleep apnea monitoring, facilitating early detection and intervention. This development has the potential to enhance patient care, optimize treatment strategies, and improve overall outcomes in heart failure patients at risk of sleep apnea-related complications.

Advanced Materials

Oral Presentation (#7)

$LiNO_3$-based Polymer Electrolytes for Flexible Electrochemical Capacitors

Presented by: Julian Rosas

Abstract

With a growing demand for thin and flexible wearable electronics, solid electrochemical capacitors (ECs) are promising power sources with high power density and long cycle life. Polymer electrolytes are the key enablers for solid ECs that can be seamlessly integrated in future electronics. A novel $LiNO_3$-poly(vinyl alcohol) electrolyte enables efficient ion transport with excellent mechanical stability. The optimized electrolyte achieves high ionic conductivity and is functional at low temperature down to -40 °C. The resulting solid EC devices using carbon nanotube electrodes showed a comparable capacitive performance to the liquid standards, with a wide voltage window of 1.6 V and high rate capability. Notably, it surpasses the liquid counterpart with lower leakage current and enables a solid-state, safe, and flexible energy storage.

Advanced Materials

Oral Presentation (#8)

Novel Ion Gel Electrolytes for Printed Field Effect Transistors

Presented by: Janny Wang

Abstract

There is a growing interest in devices for real-time continuous health monitoring. Printed electrolyte gated field effect transistors (EGFETs) utilize high dielectric electrolytes to enable flexible low–power devices for seamless integration into wearable electronics. Silver is an attractive electrode material due to its high printability and low cost, enabling high throughput and cost-efficient EGFETs. However, silver is sensitive to corrosion and dendrite formation leading to device failure. Thus, the integration of silver into printed EGFETs requires careful selection of suitable electrolyte material. In this study, the use of ionic liquids (IL) as electrolyte for EGFETs was explored. Imidazolium-based ILs and their respective ion gels were evaluated for electrochemical properties with silver electrodes using cyclic voltammetry and electrical impedance spectroscopy. The optimized ion gel demonstrated superior capacitive and corrosion performance relative to comparable polymer electrolytes. These results indicate that IL-based ion gels are a promising electrolyte for printable transistor devices.

Advanced Materials

Oral Presentation (#9)

An EIT-based Piezoresistive Sensing Skin with a Lattice Structure

Presented by: Amin Jamshidi

Abstract

Human skin plays a significant role in shaping how we interact with the world. Inspired by natural skin, we developed a soft sensing skin with a novel structure that can measure pressure location, duration, and intensity. The sensing skin comprised a carbon black/silicone composite lattice structure embedded in a silicone sheet. The lattice-patterned structure is a distinct departure from conventional uniform sensing skins. Electrical impedance tomography (EIT) was employed to reconstruct electrical resistance over the sensing area, which was then mapped into pressure distribution based on the piezoresistivity principle. EIT offers continuity and design simplicity as it eliminates internal wiring, making it a promising technique in the wearable industry. Sensing skins were prepared in curved structures that could be worn by patients as wearable liners to monitor their residual limb health.

Advanced Materials

Oral Presentation (#10)

Strain Engineered Phase Transition of Mono and Bi-Layer WSe_2

Presented by: Akib Islam

Abstract

By applying controlled mechanical strain using Atomic Force Microscopy (AFM)-based nanoindentation techniques, it is possible to modulate the band gap of 2D materials, thereby influencing their potential applications in electronics and optoelectronics. This study specifically focuses on investigating the effect of controlled mechanical strain on the electron transport properties of mono and bi-layer WSe_2, a 2D TMD that undergoes a transition from a semiconductor to a metallic phase with applied strain due to low energy barrier. We employed AFM-based nanoindentation techniques to apply strain to a suspended monolayer of WSe_2 on etched micro wells and observed the resulting change in bandgap. Furthermore, we also applied very high local pressure to mono and bi-layer WSe_2 on an Au coated substrate to observe the phase transition of WSe_2 to metallic phase. The findings of the study were validated using Finite Element Analysis (FEA) and Density Functional Theory (DFT) calculations.

Advanced Materials

Oral Presentation (#11)

Characterization and Semi-Quantitative Investigation on Materials and Process Variables in order to Maximum Synthesis of Magnetite by Sonochemical Method

Presented by: Azadeh Vahedi

Abstract

This study focuses on the semi-quantitative characterization of magnetite nanoparticles synthesized through sonochemical methods. By systematically varying material and process variables, such as sonication time, temperature, and precursor concentration, we aimed to measure the percentage of magnetite in each step and optimize the synthesis process for maximum yield of pure magnetite nanoparticles. The synthesis was performed using $FeCl_2 \cdot 4H_2O$ and aqueous NH_3 solution as precursors, employing a simple surfactant-free sonochemical reaction. The resulting nanoparticles were subjected to characterization techniques, including XRD for purity confirmation and TEM for microstructure investigations. Our findings highlight the significant impact of material and process variables on the synthesis of pure magnetite nanoparticles, ultimately enabling the production of highly pure nanoparticles. This study provides important insights into the sonochemical synthesis of highly pure magnetite nanoparticles and can facilitate their use in fields such as photo catalysis and environmental remediation.

Human Health

Oral Presentations (2:00PM - 3:30PM, BA1220)

#	Time	Title	Presenter
1	2:00 - 2:08	AI-based Modeling for Mapping Thermometry and Anatomical MRI for MR-guided Laser Interstitial Thermal Therapy	Saba Sadatamin
2	2:08 - 2:16	Preliminary Characterization of the Design of the Three-quarter Northwestern-style Transradial Prosthetic Socket	Vishal Pendse
3	2:16 - 2:24	Assessing Age-related Changes in Primary Osteocyte Mechanosensitivity	Kimberly Seaman
4	2:24 - 2:32	Studying Muscle in a Dish: Around the World in 80 (Degrees Below Zero)	Saif Rjaibi
5	2:32 - 2:40	An Active Microfluidic Wound Dressing for Wound Care	Mahsa Karimi
6	2:40 - 2:48	Skeletal Muscle Micro-Niche Compression Stress is Dependent on Tendon Proximity	Jo Nguyen
7	2:48 - 2:56	origamiFISH-Flow, Single-cell Detection of DNA Origami via in situ Hybridization and Flow Cytometry	Shana Alexander
8	2:56 - 3:04	In-Ear EEG Device for Auditory Brain-Computer Interface Communication	Laura Wheeler
9	3:04 - 3:12	Skeleton-based Body Geometry Reconstruction from Sparse Image Sequences using a Single Depth Camera	Jeffrey Qiu
10	3:12 - 3:20	Development of Convolutional Neural Network for Motion Artifact Mitigation in Wearable PPG Devices	Matthew Lee
11	3:20 - 3:28	Echocardiogram-based Detection of Heart Valve Malformations	Vrushali Guruji

Human Health

Oral Presentation (#1)

AI-based Modeling for Mapping Thermometry and Anatomical MRI for MR-guided Laser Interstitial Thermal Therapy

Presented by: Saba Sadatamin

Abstract

Magnetic resonance-guided laser interstitial thermal therapy (MRgLITT) is a minimally invasive thermal therapy for drug-resistant focal epilepsy and brain tumors. In this Intervention, the surgeon needs to insert the laser fiber into the target along a fixed trajectory. Thermometry prediction using artificial intelligence (AI) modeling will help the surgeon determine whether the selected laser position is the ideal location to treat the tumor before starting the surgery, as both repositioning and predicting thermal spread close to heat sinks are difficult. Specifically, we focused on 81 patients who had temporal lobe thermal ablations for epilepsy. The mapping between the two modalities was modeled for 2D images. Four U-Net-based models were trained and validated using the structural similarity index (SSIM) and mean squared error (MSE) and the best SSIM was 0.8870/1.00 and the MSE was 7.5038 $°C^2$. By having the patients' anatomical MRI, the surgeon will access the AI-based heat propagation distribution in predicted MR thermometry images to better choose the ideal laser position.

Human Health

Oral Presentation (#2)

Preliminary Characterization of the Design of the Three-quarter Northwestern-style Transradial Prosthetic Socket

Presented by: Vishal Pendse

Abstract

Achieving proper fit and comfort when wearing a prosthetic socket is crucial for the use of transradial prostheses. However, the conventional design process depends greatly on the skills of the prosthetist. Hence, it is imperative to translate the qualitative skills of prosthetists into quantifiable parameters to enable a more data-driven approach and standardize clinical practice. Therefore, this study aims to characterize the design of the three-quarter Northwestern transradial socket. Overall, ten pairs of unrectified and rectified residual limb models were analyzed. Consistent trends were observed when analyzing the global volumetric variations and geometric profiles. In addition, common rectification zones were identified across all models, further suggesting that there were general design strategies employed by expert prosthetists despite the uniqueness of each residual limb. This work establishes a foundation for improving the design process and patient outcomes in transradial prosthetic care.

Human Health

Oral Presentation (#3)

Assessing Age-related Changes in Primary Osteocyte Mechanosensitivity

Presented by: Kimberly Seaman

Abstract

Aging is associated with bone loss, partially attributed to changes in osteocyte mechanosensing from impaired lacunocanalicular fluid dynamics. Effects of age on osteocyte mechanosensitivity at the cellular level are not well understood, as primary osteocytes are difficult to isolate. We aim to determine whether age-dependent changes in osteocyte mechanosensitivity can be observed through response to mechanical loading and regulation on bone and cancer cells. Osteocytes were extracted from the long bones of young (yOCY) and aged (aOCY) adult mice. Response to oscillatory fluid flow was assessed through calcium imaging and dendrite elongation. Conditioned media from primary osteocytes were used to examine osteoclast formation and breast cancer migration. Results indicate decreased aOCY calcium response and dendrite elongation. While loaded yOCYs significantly reduced the formation of osteoclasts, aOCYs under loading conditions did not reduce osteoclast formation. This study provides insight into osteocyte aging and an in vitro model system for bone metastasis studies.

Human Health

Oral Presentation (#4)

Studying Muscle in a Dish: Around the World in 80 (Degrees Below Zero)

Presented by: Saif Rjaibi

Abstract

3D tissue-engineered models are poised to facilitate progress in understanding skeletal muscle pathophysiology and identify novel therapeutic agents to improve muscle health. Yet, barriers to widespread adoption of such models include: methodology complexity, limited throughput, and requirement of cell culture expertise, and/or specialized reagents, instruments, or software. To alleviate these barriers, we engineered a 96-well model to study Muscle Endogenous Repair ("mini-MEndR") that is amenable to robotics-based manufacturing, high-content imaging, and open-access image analysis pipelines. Herein, we demonstrate that mini-MEndR can be cryopreserved with commercially available reagents, and validate the preservation of muscle cell viability, differentiation, and function. Furthermore, we show proof-of-principle by shipping cryopreserved mini-MEndR tissues to intra-provincial and international collaborators, allowing trainees without expertise in 2D or 3D skeletal muscle cell culture to successfully generate muscle microtissues. Taken together, cryopreservation in mini-MEndR offers researchers an easy-to-learn "off-the-shelf" platform for studying novel modulators of skeletal muscle health.

Human Health

Oral Presentation (#5)

An Active Microfluidic Wound Dressing for Wound Care

Presented by: Mahsa Karimi

Abstract

Serious burn injuries typically cause devastating wounds which require both early treatment strategies and consistent care to regenerate healthy tissue. Due to the lack of resources in autologous skin grafts and limitations of current wound treatments which are time-consuming and costly, burn wounds have a critical impact on the health and quality of patients' life in particular severe pain, function, and mobility loss, social stress and isolation, depression, prolonged hospitalization, financial burden, and high rates of mortality. We have developed an active microfluidic non-adhesive wound dressing to enable long-term control of the wound environment by seeding cells and collecting exudates regularly. We hypothesize this control will facilitate and accelerate wound closure hence wound healing and reduce rates of infection and scar tissue formation. An array of microfluidic channels enabled in situ 3D bioprinting, as therapeutic cells including fibroblasts and keratinocytes were deposited through multiple outlet ports in vitro and in vivo on a mice dermal skin surface at an early point in wound treatment to study the cell clustering and proliferation at each delivery points by DAPI, Live/Dead staining, and Masson's trichrome staining. An 'H-tree' network design was chosen to provide uniform flow and delivery to 2 and 32-port devices. The fluid flow rates and uniformity have been studied by particle tracking (PIV) measurements and numerical simulations. We hypothesize that our microfluidic device will provide dynamic control of the wound environment as well as enhance the rates of skin regeneration and reduce infection to significantly improve therapies for burn and wound care. The effect of hydrogel (e.g., Collagen and gelatin) substitutes as well as cell-laden hydrogels as ECM for delivering dermal cells have been studied and showed that hydrogel carriers can promote cell clustering at the outlets that can accelerate wound closure and healing process.

Human Health

Oral Presentation (#6)

Skeletal Muscle Micro-niche Compression Stress is Dependent on Tendon Proximity

Presented by: Jo Nguyen

Abstract

Skeletal muscle is the largest organ in the human body, enabling our mobility and posture maintenance. The biomechanics of skeletal muscle force production at the tissue level have been extensively studied, however, there is surprisingly little known about the mechanobiology at the cellular level. Skeletal muscle tissues owe their self-repair ability to a population of resident stem cells termed satellite cells (SCs). Several studies in vitro reported that mechanical stresses and physical properties of the environment can influence SCs behavior, necessitating the quantifications of these mechanical cues in the in vivo SC niche. Hence, our team developed methods to stably engraft polyacrylamide stress sensors into the murine extensor digitorum longus muscle and found that compressive stress inside the muscle is dependent on the proximity to the tendons. In summary, this study provides the first-ever quantification of in vivo stress in skeletal muscles at the cell-relevant scale.

Human Health

Oral Presentation (#7)

origamiFISH-Flow, Single-cell Detection of DNA Origami via in situ Hybridization and Flow Cytometry

Presented by: Shana Alexander

Abstract

DNA origami is a technique that employs DNA as a structural tool to create 2D and 3D nanostructures for use in biological applications. The programmability of DNA nanostructures allows for the deliberate design of their binding and uptake by cells, which is crucial for the development of effective DNA nanostructure therapeutics. Despite its widespread use, DNA origami lacks a reliable method for its detection within cells. To address this, a new imaging method called origamiFISH has been developed in our lab, which is 10,000 times more sensitive than traditional dye-labeling. To expand on the types of analyses possible with origamiFISH, we have adapted the method to be compatible with flow cytometry, origamiFISH-Flow. OrigamiFISH-Flow allows for multiparametric analysis of cellular DNA origami detection and protein expression at the single-cell level, previously not possible with microscopy-based methods. We have demonstrated that origamiFISH-Flow is compatible across a variety of cell types and DNA nanostructure shapes. The method uses HCR initiator probes designed to hybridize to the M13 DNA scaffold, present in most DNA origami nanostructures, and therefore, does not require structural-dependant optimization. This research will improve our understanding of the in vivo biodistribution and cellular interactions of DNA nanostructures, leading to more effective nano-therapeutics. Additionally, it provides a platform for developing guidelines for the rational design of delivery platforms for other applications.

Human Health

Oral Presentation (#8)

In-Ear EEG Device for Auditory Brain-Computer Interface Communication

Presented by: Laura Wheeler

Abstract

Brain-computer interfaces (BCIs) enable communication using signals generated by the brain. Electroencephalography (EEG) is often implemented to non-invasively record these brain signals using scalp-based electrodes, which are uncomfortable for long-term use and conspicuous. In-ear EEG devices address these limitations and can measure brain activity from within the ear canal. To investigate the viability of an in-ear EEG device for BCI control we designed, constructed, and piloted a portable in-ear EEG device using commercially available components. We are conducting data collection sessions involving 15 participants to evaluate device viability. Sessions involve: (1) acquisition of motion artifacts, (2) acquisition of alpha waves, (3) a BCI paradigm, and (4) surveys to assess device characteristics. Pilot sessions show the device can record EEG data wirelessly in real-time for BCI control. As EEG BCIs have demonstrated potential, we conclude that this novel in-ear EEG BCI device is a viable control method.

Human Health

Oral Presentation (#9)

Skeleton-based Body Geometry Reconstruction from Sparse Image Sequences using a Single Depth Camera

Presented by: Jeffrey Qiu

Abstract

Depth cameras enable personal 3D scanning for applications in various virtual and imaging systems. However, accurate scans can be cost-prohibitive for consumers and require specialized hardware. To this end, we propose an accessible and cost-effective solution that utilizes a single commercial depth camera. Our fusion algorithm reconstructs a 3D model of the human body from a sparse set of depth images, tackling the following challenges: (1) complex body geometry; (2) non-rigid motion; and (3) self-occlusions with little image overlap. We leverage a skeleton prior to track non-rigid body motion and a visual hull prior to promote spatial consistency. Our method is evaluated on a synthetic dataset with simulated motion. Furthermore, we simulate joint estimation errors and demonstrate algorithm robustness to joint estimation. In comparison with existing techniques, our algorithm uses a simpler setup with fewer input images while maintaining low reconstruction error, a crucial step towards accessible 3D scanning technology.

Human Health

Oral Presentation (#10)

Development of Convolutional Neural Network for Motion Artifact Mitigation in Wearable PPG Devices

Presented by: Matthew Lee

Abstract

Bicuspid aortic valve disease (BAVD) is characterized by the fusion of two of the three leaflets of the aortic valve. In BAVD patients, the aorta can become enlarged, increasing the risk of fatal complications like aortic rupture. Our hypothesis is that abnormal blood flow patterns in the aorta cause changes in the proteins present, which elevate the risk of developing aortic dilatation in BAVD. To study this, we developed an echocardiogram protocol to characterize 4-week-old mice with either normal tricuspid aortic valves or BAVs. The echocardiography data helped us identify BAVD-related symptoms like blood recirculation, regurgitation, and peak systolic velocities >1500 mm/sec. Images of the mice's heart anatomy showed hemodynamic dysfunction was associated with stenotic and thickened valves, as well as the presence of a BAV. Movat's pentachrome staining was used to examine cross-sections of the heart, which revealed a spectrum of BAV fusions like those seen in human BAVD.

Human Health

Oral Presentation (#11)

Echocardiogram-based Detection of Heart Valve Malformations

Presented by: Vrushali Guruji

Abstract

Skeletal muscle is the largest organ in the human body, enabling our mobility and posture maintenance. The biomechanics of skeletal muscle force production at the tissue level have been extensively studied, however, there is surprisingly little known about the mechanobiology at the cellular level. Skeletal muscle tissues owe their self-repair ability to a population of resident stem cells termed satellite cells (SCs). Several studies in vitro reported that mechanical stresses and physical properties of the environment can influence SCs behavior, necessitating the quantifications of these mechanical cues in the in vivo SC niche. Hence, our team developed methods to stably engraft polyacrylamide stress sensors into the murine extensor digitorum longus muscle and found that compressive stress inside the muscle is dependent on the proximity to the tendons. In summary, this study provides the first-ever quantification of in vivo stress in skeletal muscles at the cell-relevant scale.

Posters

(Presentations 2:00PM - 3:30PM, Atrium)

#	Time	Title	Presenter
1	2:00 - 2:10	Bioresorbable Hydrogel-Nanoparticle Release System for the Controlled Delivery of Therapeutics to the Central Nervous System	David Li
2	2:10 - 2:20	Development of a Multifactorial Joint-on-a-Chip Device for the Inflammatory and Mechanical Disease Modelling of Osteoarthritis	Kevin Perera
3	2:20 - 2:30	Engineering an Affinity-based Hydrogel System for the Controlled Release of Insulin-like Growth Factor 1	Sophia Lu
4	2:30 - 2:40	Pressure-Volume Curve Analysis in Adults with/without Asthma	Shay Chavoshian
5	2:40 - 2:50	Battery-Free, Bluetooth-Enabled, Optical Implant for the Remote Monitoring of Physiological Biomarkers	Anat Usatinsky
6	2:50 - 3:00	High Throughput Deposition of Jammed Bioinks in Reduced Gravity	Khaled Gaber
7	3:00 - 3:10	Investigating the Effects of Vibration on Prostate Cancer Invasion using a Novel Microfluidic Platform	Amel Sassi

(continued next page)

Posters

(Presentations 2:00PM - 3:30PM, Atrium)

#	Time	Title	Presenter
8	2:00 - 2:10	Elucidating the Role of Flow Fields in Bubble Removal from Porous Transport Layers for Polymer Electrolyte Membrane Water Electrolyzers	Lijun Zhu
9	2:10 - 2:20	Direct Tensile Measurement for Cemented Paste Backfill	Andrew Pan
10	2:20 - 2:30	Inference Algorithms for Mitigating Adversarial Agents in Partial Information Networks	Soliman Ali
11	2:30 - 2:40	Improving Quantitative Analysis of Porous Membranes using Electron Microscopy	Sima Zeinali Danalou
12	2:40 - 2:50	Characterizing Uncertain Elastic Properties of Materials 3D-Printed by the Fused Filament Fabrication Method for Applications in Topology Optimization	Zahra Kazemi
13	2:50 - 3:00	Distance Correlation Market Graph	Samuel Ugwu
14	3:00 - 3:10	Advancing CO_2 Electrolysis via Voltage Diagnostics	Fatemeh Arabyarmohammadi

Posters

Presentation #1

Bioresorbable Hydrogel-Nanoparticle Release System for the Controlled Delivery of Therapeutics to the Central Nervous System

Presented by: David Li

Abstract

Designing a local, controlled drug release strategy is critical for spinal cord injuries (SCIs) because the blood-spinal cord-barrier limits diffusion from systemic delivery. Hydrogels are ideal vehicles for delivery as they can be bioresorbable, injectable, shape-forming, and tuned to match the rheological properties of target tissues. I hypothesize that a bioengineered delivery system of small molecule drugs, fusicoccin-A (FC-A) and epothilone-B (Epo-B), will promote axonal growth while preventing scar formation in SCIs. To test this hypothesis, I propose synthesizing a bioresorbable hyaluronan (HA) hydrogel-nanoparticle release system to co-deliver FC-A and Epo-B. I will use oxime chemistry to formulate HA-oxime hydrogels. The drugs will then be encapsulated in poly(lactic-co-glycolic) acid (PLGA) particles and incorporated into the HA-hydrogel. Further, I will evaluate the bioactivity of the released compounds in vitro and in vivo. This work will advance the development of minimally invasive, combinatory delivery strategies that show promise for treating SCIs.

Posters

Presentation #2

Development of a Multifactorial Joint-on-a-Chip Device for the Inflammatory and Mechanical Disease Modelling of Osteoarthritis

Presented by: Kevin Perera

Abstract

Osteoarthritis (OA) is a major burden on our healthcare system that impacts 1 in 7 Canadians. OA is a degenerative disease of whole joints wherein cartilage degradation and joint inflammation occur because of the complex interplay of joint tissue and mechanical interactions. There is a need for an OA joint model that encapsulates the multiple driving mechanical, tissue, and immune factors that characterize OA. This research focuses on developing and validating a novel multi-culture Joint-on-a-chip (JOC) microfluidic device that incorporates compressive mechanical stimulation, multi-tissue interactions, and inflammatory cell signaling to better mimic the native OA knee microenvironment. To date a preliminary prototype has been developed for hype physiological compression, and has been assessed for soluble GAG content, and RNA expression with total knee replacement explants. The current focus is to conduct the preliminary development, and validation of the synovium-on-a-chip model alongside our compression platform by characterizing the most optimal hydrogel-to-media area ratio and mobilization method required to achieve realistic synovial monocyte diffusion in a grown vascular network. Where past models failed to accurately mimic more than one joint microenvironment condition that progresses OA, the goal with this device is to more realistically mimic OA with its numerous introduced disease factors as a clinical disease model. As a result, this work has the potential to reduce the performance disparity witnessed between pre-clinical and clinical drug validation studies, and reduce the need for animal based modelling.

Posters

Presentation #3

Engineering an Affinity-based Hydrogel System for the Controlled Release of Insulin-like Growth Factor 1

Presented by: Sophia Lu

Abstract

Insulin-like growth factor 1 (IGF-1) is a pleiotropic hormone that exerts proliferative and anti-inflammatory effects within the central nervous system, making it a promising therapeutic for treating neurodegenerative diseases. However, there are barriers to its clinical use including poor pharmacokinetics, tissue penetration, and off-target effects. Localized IGF-1 delivery using hydrogels is one method of overcoming these challenges. The Shoichet laboratory has developed a biocompatible hydrogel functionalized with an IGF-1-binding affibody to control IGF-1 release. Despite these advancements, the chemistries used yielded a low degree of hydrogel substitution. My project aims to develop an affinity-based controlled release system for IGF-1 with improved hydrogel substitution to extend IGF-1 release at therapeutic levels. We were able to functionalize the affibody to hyaluronan-ketone (HAK) hydrogel with a 3.1-fold increase in substitution compared to previous polymers. The affibody solubility currently limits further increases in HAK functionalization. Accordingly, we seek to derive alternative IGF-1 binders with increased solubility.

Posters

Presentation #4

Pressure-Volume Curve Analysis in Adults with/without Asthma

Presented by: Shay Chavoshian

Abstract

Computational modeling of the lung provides information regarding underlying respiratory abnormalities. The best assessment of lung properties is to derive a pressure-volume curve. In this study, airflow and pressure (via esophageal catheter) were measured continuously before and after repetitive upper airway obstruction in adults with/without asthma. Volume signal was estimated as integral of airflow signal. To address baseline biases, such as sex differences, the volume signal was normalized. Noise removal, validation algorithms, and curve fitting techniques were employed to reduce pressure signal irregularities. We implemented an algorithm to calculate the average pressure-volume curve for two groups of healthy and asthma. Subsequently, a multiple linear regression model was also used to estimate the lung's elastic and resistive properties. Through this procedure, together with improvements in the technique of processing pressure, we concluded that lung elasticity is less in asthma than in healthy after upper airway obstruction (Δ = -1.9±1.3 $cmH_2O/L/s$, $p = 0.03$). Loss of elastic recoil in asthma during obstructive episodes may predispose to reductions in airflow.

Posters

Presentation #5

Battery-Free, Bluetooth-Enabled, Optical Implant for the Remote Monitoring of Physiological Biomarkers

Presented by: Anat Usatinsky

Abstract

Real-time monitoring of research animals' hemodynamics helps scientists study the physiological effects of diseases and interventions. Conventional wired sensors tether the animal, inhibiting natural mobility and behavior. Wireless skin-based sensors also modify behavior and add stress. Recent advancements in optical sensors and microprocessors led to miniaturized wireless Bluetooth systems. We demonstrate an implantable sensor that measures hemodynamic vital signs over time comparable to commercial wired references during controlled gas challenges and occlusion trials, mitigating problems present in conventional systems. The miniature optical sensors consist of a printed circuit board, wireless Bluetooth microcontroller, and a vital signs optical sensor powered through radio frequency inductive coupling. Devices were implanted subcutaneously in rat models to quantify heart rate, respiratory rate, and tissue oximetry via occlusion trials and gas challenges in real-time through an IOS application. Such technology may translate to advance optical implants for human health tracking, early disease detection, and improved prognosis.

Posters

Presentation #6

High Throughput Deposition of Jammed Bioinks in Reduced Gravity

Presented by: Khaled Gaber

Abstract

Addressing full-thickness burns poses significant challenges, including limited autologous graft availability, delayed wound healing, and greater susceptibility to infection, owing to a compromised skin barrier function. These difficulties are further intensified in isolated environments such as space flight missions. Our lab previously developed a handheld bioprinter capable of printing 100 μm bio-sheets at 3 mm/s. With alterations like gelatin-based bio-ink and the need for millimeter-thick extrusions similar to human skin, improvements were necessary. We introduce an optimized bioprinter, capable of printing 1mm thick bio-sheets at 1.9 cm/s, reducing required sheet deposition time. We demonstrate the feasibility of our redesigned bioprinter in microgravity (near zero g) environments aboard the Falcon-20 parabolic aircraft as part of the PoSSUM/IIAS flight campaign, operated inflight by medical and non-medical professionals. We achieved successful printing of n=5, mm+ acellular bio-ink sheets. Sheets were hydrated throughout by a custom sample holder and laser scanned for thickness measurements.

Posters

Presentation #7

Investigating the Effects of Vibration on Prostate Cancer Invasion Using a Novel Microfluidic Platform

Presented by: Amel Sassi

Abstract

Prostate cancer commonly metastasizes to the bone, leading to bone pain and skeletal-related complications. While chemotherapies can slow tumour progression, a cure for prostate cancer bone metastasis does not currently exist. However, whole body vibration has shown promise as a potential treatment for cancer and its associated morbidities. We hypothesize that mechanical loading of osteocytes through low magnitude, high frequency (LMHF) vibration can decrease prostate cancer bone metastasis, given the role of osteocytes as mechanosensors. Using a microfluidic co-culture platform that mimics the bone-cancer microenvironment, we observed that LMHF vibration administered over three days resulted in a significant reduction in prostate cancer cell invasion. Additionally, mechanical vibration increased apoptosis compared to prostate cancer cells in static culture. Further exploration of the effects of vibration on bone remodelling and cell viability will enhance our understanding of how prostate cancer patients can potentially benefit from whole body vibration as a treatment option.

Posters

Presentation #8

Elucidating the Role of Flow Fields in Bubble Removal from Porous Transport Layers for Polymer Electrolyte Membrane Water Electrolyzers

Presented by: Lijun Zhu

Abstract

Accelerating bubble removal from the porous transport layer (PTL) is the key to reaching high current densities and cell efficiencies for polymer electrolyte membrane (PEM) water electrolyzers by improving catalyst utilization through reduced bubble accumulation. In this study, we elucidated the effects of the PTL/flow field interface on bubble transport in the PTL and bubble removal from the PTL. We showed a dramatic non-uniform bubble distribution within the PTL when using an outlet condition with a flow field, while a uniform bubble distribution occurred in the PTL when using an outlet condition without a flow field. We attributed this to the existence of flow fields that lead to longer gas transport pathways through the PTL land regions. This study demonstrates the effects of flow fields on hindering bubble transport within the PTL and informs the need of tailored designs of flow fields for accelerating bubble transport in the PTL.

Posters

Presentation #9

Direct Tensile Measurement for Cemented Paste Backfill

Presented by: Andrew Pan

Abstract

Cemented paste backfill (CPB) plays a vital role in the mining industry, particularly in the hard rock mining. Accurate tensile strength measurements are crucial for understanding CPB's mechanical properties and ensuring the effectiveness and safety of design and development of undercuts. This study introduces an innovative technique for directly measuring CPB tensile strength, offering enhanced reliability and repeatability compared to existing methods. The approach features optimized geometry for increased load capacities, a durable mold design, an advanced test apparatus, and a thorough stiffness analysis. Tensile strength measurements were obtained for CPB samples with curing times from 3 to 28 days, reporting a first-in-literature 3 days of curing and tensile strength of 1.4 MPa after 42 day curing time. This novel method contributes to a more precise understanding of CPB's mechanical properties, ultimately promoting safer and more efficient mining practices.

Posters

Presentation #10

Inference Algorithms for Mitigating Adversarial Agents in Partial Information Networks

Presented by: Soliman Ali

Abstract

My undergraduate final year capstone project explored distributed Nash equilibrium seeking algorithms. Many real-world engineering systems can be modeled as multi-agent networks with distinct observation paths and communication channels. These agent networks are composed of rational agents who work towards achieving some sort of common goal, for example, a network of drones aiming to follow a reference trajectory, a fleet of self-driving cars aiming to reach their destinations without collisions. The focus of the project was designing practical algorithms that seek convergence under partial information conditions with a range of possible adversaries (henceforth referred to as the NE-PI-A problem). We introduce two novel algorithmic approaches and compare them to a baseline algorithm published for the same problem in 2021. After evaluating the algorithms' convergence speed, robustness, and scalability, we apply the algorithms to real-world engineering systems where the NE-PI-A problem occurs.

Posters

Presentation #11

Improving Quantitative Analysis of Porous Membranes Using Electron Microscopy

Presented by: Sima Zeinali Danalou

Abstract

Providing people worldwide with good quality water supplies is becoming increasingly challenging. High-pressure reverse osmosis (HPRO) membranes have emerged as a promising technology. Nonetheless, RO membranes, despite their potential, are not robust enough and suffer dramatic compaction (i.e., densification of the porous support) when exposed to high pressures. There is minimal understanding of (i) the actual pore structure changes during compaction and (ii) how the structure changes impact performance. Therefore, my current mission involves working towards the establishment of this correlation. We intend to employ advanced visualization methodologies to capture 2D (Aim 1) and 3D images (Aim 2) of membrane layers for quantitative and qualitative evaluation of pore structure densification occurred under high pressure. By conducting a comprehensive analysis of the pores at varying compaction pressures, we aim to help to develop membranes that exhibit optimized pore size and distribution, thereby increasing the process efficiency.

Posters

Presentation #12

Characterizing Uncertain Elastic Properties of Materials 3D-Printed by the Fused Filament Fabrication Method for Applications in Topology Optimization

Presented by: Zahra Kazemi

Abstract

The layering approach associated with fused filament fabrication (FFF) additive manufacturing technology allows for complex designs generated by topology optimization to be manufactured. However, defects associated with the layer-by-layer process and commonly observed in the fusion regions (the thin layers connecting deposited filaments) introduce considerable variability in the local elastic modulus that must be addressed when designing with topology optimization. Accurate quantitative measurements of the distribution in the elastic modulus of printed materials are essential to achieve robust optimized designs. Surface strain fields of FFF-printed materials, measured by digital image correlation (DIC), show that the random distributions for the bulk (the deposited filaments) and fusion regions are different. An efficient neural network model is trained that accurately measures distributions in the bulk and fusion elastic modulus fields of the printed material given its DIC calculated strain field. The measured distribution will be used in topology optimization to achieve robust designs.

Posters

Presentation #13

Distance Correlation Market Graph

Presented by: Samuel Ugwu

Abstract

This study investigates the use of a novel market graph model for equity markets. Our graph model is built on distance correlation instead of the traditional Pearson correlation. We apply it to the study of S&P 500 stocks from January 2015 to December 2022. We also compare our market graphs to the traditional market graphs in the literature, those built using Pearson correlation. To further the comparison, we also build graphs using Spearman rank correlation. Our comparisons reveal that non-linear relationships in stock returns are not captured by either Pearson correlation or Spearman rank correlation. We observe that distance correlation is a robust measure for detecting complex relationships in financial data. Networks built on distance correlation networks, are shown to be more responsive to market conditions during turbulent periods such as the Covid crash period.

Posters

Presentation #14

Advancing CO_2 Electrolysis via Voltage Diagnostics

Presented by: Fatemeh Arabyarmohammadi

Abstract

Electrochemical conversion of CO_2 is a promising technology that uses renewable electricity to produce valuable chemicals and fuels. The economic viability of CO_2 electroreduction technology is limited by high full cell voltage and low energy efficiency. To make this technology commercially viable, it is crucial to run CO_2RR below 3V while maintaining current densities higher than 200 mA/cm² in systems that do not suffer carbonate loss, as determined by techno-economic analysis. In this study, we designed an analytical cell to measure voltage losses within emerging carbon-efficient CO_2RR approaches: CO_2RR in acidic media, CO_2 regeneration via bipolar membrane, cascade CO_2RR-CORR and CO_2 reactive capture. We evaluate each system and identify the specific overpotentials associated with each cell component in each system. Among all the approaches, the cascade CO_2RR-CORR demonstrates the highest energy efficiency with minimal component overpotential. These findings can inform the development of more energy efficient CO_2 electrochemical conversion technologies.

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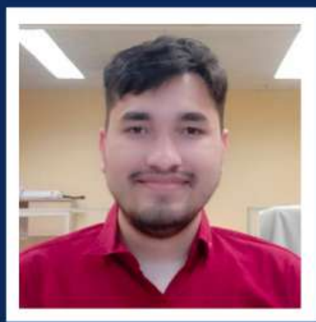

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