Lassonde Undergraduate Summer Student Research Conference

Welcome to the 2020 Lassonde Summer Student Research Conference!

Over 60 undergraduate students from the Lassonde School of Engineering and beyond will present their research projects during this conference.
The students have been conducting research remotely this summer on a wide range of projects from simulating the spread of particles during a cough, to modeling autonomous vehicle and human interactions, and even strategies to mitigate the risk of fire in informal settlements.

The research projects are funded through the following programs:

- Lassonde Undergraduate Research Award (LURA)
- Natural Sciences and Engineering Research Council of Canada: Undergraduate Student Research Awards (NSERC USRA)
- Research at York (RAY)
- Dr. James Wu Research Internship

Keynote Speaker
Caroline Floyd

With a background in atmospheric science and meteorology, Caroline has worked for both The Weather Network in Canada and The Weather Channel in the U.S. as a forecaster and weather expert, tracking everything from landfalling hurricanes to ice storms and even radioactive fallout. She's been a lead forecaster for coverage of two Olympic Games and The World Cup finals, producing hour-by-hour forecasts for every continent (excluding Antarctica – so far). More recently, Caroline brought her expertise and passion for inspiring scientific curiosity back to The Weather Network, creating science and weather content for both digital and television platforms. Earlier this year, she joined Catastrophe Indices and Quantification Inc. (CatIQ) after nearly 20 years of being one of the 'they' in "They say it's going to rain."

When not talking about the weather, Caroline enjoys more hands-on, creative pursuits, designing and creating plush toys and textiles with cute-and-nerdy themes. A native of southern Ontario, she currently lives in Hamilton with her equally nerdy husband, Scott, and one very furry, mostly domesticated dog.

CONFERENCE AGENDA

AUGUST 13, 2020
9:00AM - 4:00PM

Event link:
yuevents.easyvirtualfair.com

Morning Session Zoom link:
yorku.zoom.us/j/91415900549?pwd=
VWFBUUs0UmNnK3l0cWlHcU1sNXoyZz09
Meeting ID: 914 1590 0549
Password: 394200

Afternoon Session Zoom link:
yorku.zoom.us/j/97057196137?pwd=
aFhOVVM1TzV1NU5wcUx6V0NuN1pMdz09
Meeting ID: 970 5719 6137
Password: 469177

09:00AM | **Welcoming Remarks**

09:15AM | **Keynote Speaker and Q&A Period**
Caroline Floyd, *Assistant Director of Catastrophic Loss Analysis Catastrophe Indices and Quantification Inc. (CatIQ)*

09:45AM | **Oral Presentations and Q&A Period**

11:00AM | **Morning Break**

11:15AM | **Morning Session - Research Video Presentations**

12:45PM | **Lunch**

01:30PM | **Afternoon Session - Research Video Presentations**

03:00PM | **Afternoon Break**

03:15PM | **Exploring Graduate Studies Presentation**

03:30PM | **Awards Ceremony & Closing Remarks**

2020 Awards

ORAL PRESENTATION AWARDS

First Place
Second Place
Students' Choice Award

VIDEO PRESENTATION AWARDS

First Place
Second Place
Third Place
Best Booth Graphics Award
Students' Choice Award - Morning Session - 1
Students' Choice Award - Morning Session - 2
Students' Choice Award - Morning Session - 3
Students' Choice Award - Afternoon Session - 1
Students' Choice Award - Afternoon Session - 2
Students' Choice Award - Afternoon Session - 3

Oral Presentations

- **Aryan Rashid**, "Mechanistic Understanding of the Effect of Water on Model Asphaltene Aggregation" (Mechanical Engineering - Cuiying Jian)
- **Jack Wawrow**, "Comparison of Convergence Rates and Accuracies of Optimization Algorithms for RSO Attitude Estimation", (Earth & Space Science & Engineering - Regina Lee)
- **Jing Li**, "Epidemic Dynamics on Digitally Traced Contact Networks" (Electrical Engineering & Computer Science - Manos Papagelis)
- **Melissa Spiegel**, "Mitigation Strategies for Informal Settlements in Developed Countries" (Civil Engineering - John Gales)
- **Vladislav Luchnikov**, "Co-segmenting Panoramic Scenes for Virtual Assessment of Spatial Navigation" (Electrical Engineering & Computer Science - Matthew Kyan)

- **Abel Beyene**, "DNA Sequencing Using Hardware Acceleration" (Dept. of Electrical Engineering & Computer Science - Sebastian Magierowski)
- **Alexander Dondish**, "Digital Image Correlation Impact Testing of FDM Manufactured Composites" (Dept. of Mechanical Engineering - Garrett Melenka)
- **Amer Sheikh**, "Self-Sensing FRCM Systems for Combined Strengthening and Monitoring of Concrete Structures" (Dept. of Civil Engineering - Liam J Butler)
- **Anto Nanah Ji**, "Evaluating the Efficacy of Anonymized Virtual 3D Renderings of Human Activity" (Dept. of Electrical Engineering & Computer Science - James Elder)
- **Ariel Tabak**, "Transmission Design for a Piezoelectric Robot" (Dept. of Earth & Space Science & Engineering - Ryan Orszulik)
- **Ariel Yerushalmi**, "Airport Landside Facility Traffic Analysis and the Integration of Advancing Technologies" (Dept. of Civil Engineering - John Gales)
- **Ariyanna Kresnyak**, "A Study of the Formation and Evolution of a Liquid Bridge Between Separating Surfaces" (Dept. of Mechanical Engineering - Alidad Amirfazli)
- **Austin Vuong**, "DIY Actuating Papercraft for Subtle Guidance of Self-Reflection" (Dept. of Electrical Engineering & Computer Science - Melanie Baljko)
- **Brian Diep**, "OCD-Net: Oriented Corner Detection Network" (Dept. of Earth & Space Science & Engineering - Gunho Sohn)
- **Chester Wyke**, "Anomaly Detection Suitability Analysis" (Dept. of Electrical Engineering & Computer Science - Ruth Urner)
- **Daphne-Eleni Archonta**, "A Microfluidic Technique for C. Elegant High-Resolution Imaging" (Dept. of Mechanical Engineering - Pouya Rezai)
- **Daniel Park**, "Towards Understanding the Properties of Training Data in Machine Learning" (Dept. of Electrical Engineering & Computer Science - John K Tsotsos)
- **Dayana Davoudi**, "Tyrosine Kinase Signaling in Tetrahymena Thermophila: An Update" (Faculty of Health - Ronald E Pearlman)
- **Diego Montalvo**, "Light Attenuation from OCT Measurements" (Faculty of Science - Ozzy Mermut)
- **Ellen van Wijngaarden**, "Behavioural Screening of Electrically Stimulated Zebrafish Larvae Using Microfluidics" (Dept. of Mechanical Engineering - Pouya Rezai)
- **Emily Secnik**, "Exploring a future scenario of Blended Learning in engineering and science education" (Lassonde Education Innovation Studio - Jane Goodyer and Llew Mann)
- **Fahad Hannan**, "Finite-Element Design of Faraday Isolators" (Faculty of Science - Anatharaman Kumarakrishnan)
- **Fasil Cheema**, "Improving Multiple Object Tracking of Pedestrians" (Dept. of Electrical Engineering & Computer Science - James Elder)
- **Gabriel Chianelli**, "Star Tracker Attitude Deconvolution from RSO Sidereal Motion" (Dept. of Earth & Space Science & Engineering - Regina Lee)
- **Ivan Mishev**, "Characterization of Hydrated, Layered Deposits at the Valles Marineris Plateau of Mars Using SHARAD Radar" (Dept. of Earth & Space Science & Engineering - Isaac B Smith)

Research Video Presentations
Morning Session

- **Jabavu Adams**, "Physics Integrated Information in Deep Neural Networks" (Faculty of Science - Joel Zylberberg)
- **Kathryn Chin**, "Effect of Radial Cracking in Timber on Fire Resistance" (Dept. of Civil Engineering - John Gales)
- **Kenneth Tjhia**, "Active Components in Streaming Graphs" (Dept. of Electrical Engineering & Computer Science - Manos Papagelis)
- **Kevin Y. H. Hui**, "Automated Tumor Detection in CT Scans of Lungs Using Machine Learning" (Dept. of Electrical Engineering & Computer Science - Suprakash Datta)
- **Koko Nanahji**, "Randomized Lock-Free Bag Data Structure" (Dept. of Electrical Engineering & Computer Science - Eric Ruppert)
- **Lixian Lu**, "Multiple Pedestrian Tracking (MPT) Over Distributed Camera Network (DNS)" (Dept. of Electrical Engineering & Computer Science - Aijun An)
- **Maitriben Patel**, "Experiential Education in Engineering and Science Education" (Lassonde Education Innovation Studio - Llewellyn Mann)
- **Naeem Model**, "Multi-Agent Decision-Making for Autonomous Vehicles Using Reinforcement Learning Under a Game-Theoretic Model" (Dept. of Earth & Space Science & Engineering - Jinjun Shan)
- **Pruthviraj Acharya**, "Seasonal Variation of the Cold And Bright Anomalies on the Northern Polar Layered Deposits" (Dept. of Earth & Space Science & Engineering - Isaac B Smith)
- **Roozbeh Alishahian**, "Long-Range Transport Mechanisms of Microplastics through the Atmosphere: How Geometry of Fibrous Microplastics Influences the Settling Velocity " (Dept. of Mechanical Engineering - Ronald Hanson)
- **Sara Kashanchi**, "3D Printing Manufacturing Methods for Collagen-based Scaffold Production in the Cultivation of Hematopoietic and Mesenchymal Stem Cells for Bone Marrow Tissue Engineering" (Dept. of Mechanical Engineering - Terry Sachlos)
- **Sidharth Sudarsan**, "Augmented Reality-based Indoor Navigation and Visual Cognition Assistant for the Visually Impaired" (Dept. of Earth & Space Science & Engineering - Gunho Sohn)
- **Stephanie Lo**, "Synthesizing Organic Polymers for Rechargeable Battery Electrodes" (Faculty of Science - Thomas Baumgartner)
- **Urooma Samoon**, "The Analysis of Groundwater Recharge Models and Climate Data" (Dept. of Civil Engineering - Rashid Bashir)
- **Venita Sitahal**, "An Investigation into the Sources of PFAS in Canadian Wastewater Treatment Plants" (Faculty of Science - Cora Young)
- **William Chan**, "Modelling Autonomous Vehicle Interactions With Reinforcement Learning and Game-Theoretic Decision Making" (Dept. of Jinjun Shan)
- **Xingye Fan**, "Analyzing Shape Selectivity of Deep Networks Pre-trained on ImageNet" (Dept. of Electrical Engineering & Computer Science - James Elder)

- **Adrianna Van Brenen**, "An Experimental Setup to Stimulate the Martian Polar Climate" (Dept. of Earth & Space Science & Engineering - Isaac B Smith)
- **Alexandre Séguin**, "Motion Extraction of a Piezoelectric Mechanism with Computer Vision (Dept. of Earth & Space Science & Engineering - Ryan Orszulik)
- **Ali Rezaeishahreza**, "Biology SARS-CoV-2 Infection Effects on MAPK Signaling Pathway and Mechanism of the Regulations" (Faculty of Science - Michael Scheid)
- **Antonia Pennella**, "Single Camera High-Speed Stereo Digital Image Correlation Using an X-Cube Prism" (Dept. of Mechanical Engineering - Garrett Melenka)
- **Arjun Kaushik**, "Unsupervised Machine Learning for Use Association in Wireless Networks" (Dept. of Electrical Engineering & Computer Science - Hina Tabassum)
- **Arma Khan**, "Modeling Droplet and Aerosol Spread for Minimizing Airborne Transmission of COVID-19 and other Diseases in public Spaces" (Dept. of Mechanical Engineering - Marina Freire-Gormaly)
- **Austin Martins-Robalino**, "Flexural Behaviour of Ultra-High Performance Concrete Beams Reinforced with Smooth Reinforcement" (Dept. of Civil Engineering - Dan Palermo)
- **Chee Xue Lim**, "21st Century Skills in Engineering and Science Education" (Lassonde Education Innovation Studio - Llewellyn Mann)
- **Constantinos Kandias**, "Design and Optimization of the Contraction and Corner Sections of a Closed Loop Wind Tunnel" (Dept. of Mechanical Engineering - Ronald Hanson)
- **Danika Wagner**, "Perceptions of Languages and Bilingualism" (Faculty of Health - Ellen Bialystok)
- **Fuat Kaan Diriker**, "Design and Implementation of a High-Accuracy Low-Cost Novel Sun-Sensor for Nanosatellite Applications" (Dept. of Earth & Space Science & Engineering - Regina Lee)
- **Harsh Patel**, "Vision Based Localization and Navigation of Unmanned Vehicles in an Indoor Area" (Dept. of Electrical Engineering & Computer Science - Jinjun Shan)
- **Julia Ferri**, "Influence of Environmental Characteristics on Crowd Behaviors for Crowd Simulation Software Applications Explained through Cognitive Biases and PADM" (Dept. of Civil Engineering - John Gales)
- **Karen Abogadil**, "A Comparison of Methods for Calibrating SWMM Rainfall-runoff Models using Genetic Algorithms" (Dept. of Civil Engineering - Usman Khan)
- **Mariam Shamekh**, "Epigenetic Mechanisms of Maternal Care" (Faculty of Science - Sandra Rehan)
- **Melina Tahami**, "The Future of Student as People in Science and Engineering Education" (Lassonde Education Innovation Studio - Llewellyn Mann)
- **Mohammad Sotoudehfar**, "Automatic Segmentation of Breast Tumors in Ultrasound Images using Deep Convolutional Neural Network" (Dept. of Electrical Engineering & Computer Science - Ali Sadeghi-Naini)
- **Mohammadreza Kazemi**, "Transaction Verification for BlockChain in the Power Grid" (Dept. of Electrical Engineering & Computer Science - Pirathayini Srikantha)

Research Video Presentations
Afternoon Session

- **Morteza Ghafar-Zadeh**, "DNA Storage: A Digital Microfluidic Emulator" (Dept. of Electrical Engineering & Computer Science - Sebastian Magierowski)
- **Muzi Li**, "Synthesis of Symmetric Biphospholes for Systematic Structure-Property Studies" (Faculty of Science - Thomas Baumgartner)
- **Naman Jain**, "Performance Analysis of Uplink and Downlink NOMA in a LEO Satellite Communication System" (Dept. of Electrical Engineering & Computer Science - Hina Tabassum)
- **Nikeet Pandit**, "Geomagnetic Storm Influence on Swarm Space Mission" (Dept. of Earth & Space Science & Engineering - Spiros Pagiatakis)
- **Parth Patel**, "InVRQ: A Toolbox for Designing Virtual Reality Questionnaire" (Faculty of Science - Nikolaus Troje)
- **Qijin Xu**, "Action Spotting in Sports Video" (Dept. of Electrical Engineering & Computer Science - James Elder)
- **Quynh Vu**, "Application of Monte Carlo Markov Chain Algorithms in Search of Pattern-Avoiding Affine Permutations" (Faculty of Science - Neal Madras)
- **Rashiq Shahad**, "Probing the Effect of Inhibitors on the Aggregation of Heavy Bitumen Compounds by Molecular Dynamics Simulations" (Dept. of Mechanical Engineering - Cuiying Jian)
- **Richard Robinson**, "Objective Quality Metric for Stereoscopic Video Assessment" (Dept. of Electrical Engineering & Computer Science - Robert Allison)
- **Romina Bahrami**, "Quadrotor Simulation using ROS and Gazebo" (Dept. of Earth & Space Science & Engineering - Jinjun Shan)
- **Samy Elias**, "Study to Assess the Level of Harmonics in Power Systems" (Dept. of Electrical Engineering & Computer Science - Afshin Rezaei-Zare)
- **Sara Hajari**, "Comparative Bioinformatics Analysis Reveals Differentiatial Expression of Integrins Between Normal HSCs and LSCs" (Dept. of Mechanical Engineering - Terry Sachlos)
- **Serah Seo**, "Comparison of Visuomotor Transformation Between the Single- and Multi-unit Activities in the Monkey Frontal Cortex" (Faculty of Health - John Douglas Crawford)
- **Vivek Wadhwani**, "Comparative Study of Machine Learning Models for Credit Card Fraud Detection" (Dept. of Electrical Engineering & Computer Science - Suprakash Datta)
- **Xiang Chen**, "Quantitative Verification of Randomized Java Code" (Dept. of Electrical Engineering & Computer Science - Franck van Breugel)
- **Zahra Zeinolabedin Rafi**, "Automatic Detection and Segmentation of Different Cell Nuclei in Histology Images of Breast Tumour Specimens Using Deep Neural Networks" (Dept. of Electrical Engineering & Computer Science - Ali Sadeghi-Naini)

Meet the Student Researchers

Lassonde Undergraduate Research Award (LURA)

Natural Sciences and Engineering Research Council of Canada – Undergraduate Student Research Award (NSERC USRA)

Research at York (RAY)

Dr. James Wu Research Internship (Dr. James Wu RI)

"Mechanistic understanding of the effect of water on model Asphaltene aggregation"

Aryan Rashid
Dr. James Wu RI | Supervisor: Cuiying Jian
Dept. of Mechanical Engineering

Refining crude oil is a vital process to produce different petroleum products like gasoline, diesel, jet fuel, and so on. However, its efficiency can be deleteriously affected by asphaltenes (the heaviest component of crude oil). For instance, asphaltene aggregation can deactivate catalysts, pollute the crude oil transportation pipelines, create a stabilized oil-water emulsion and block wellbore. The goal of this study is to understand the aggregation behaviors of asphaltenes with the presence of water given its ubiquitous presence at the refining stage of oil productions. To observe aggregation from atomistic level, molecular dynamics (MD) simulations were performed on model asphaltene molecules (Violanthrone-79, VO-79). Initially, VO-79 molecules were immersed in pentane and pentol (a mixture of pentane and toluene) solvents. Afterwards, water was randomly added to probe the effect of water addition in a solution where asphaltenes tend to aggregate. External conditions, e.g. temperature and pressure, were kept constant for all the systems in order to make fair comparisons. We first analyzed the structural orders of the aggregates formed. Consistent with literature works, parallel stackings of polyaromatic cores were formed between adjacent VO-79 molecules. However, in the absence of water, such stackings seem to be mainly of shifted patterns at larger separation distances of VO-79 molecules. With the addition of water, direct stackings were observed to persist even at relatively larger separation distances. Through comparing interaction energies in our systems, the underlying mechanisms for the effect of water can be illustrated. Our results here will help to propose appropriate means to control/reduce asphaltene aggregation in the presence of water.

Comparison of Convergence Rates and Accuracies of Optimization Algorithms for RSO Attitude Estimation

Jack Wawrow
NSERC USRA | Supervisor: Regina Lee
Dept. of Earth & Space Science & Engineering

The increasing number of Resident Space Objects (RSOs) has the potential to limit future access to space and increase the risk of collisions in Low Earth Orbit. Improved tracking, identification, and characterization of RSOs is critical in expanding Space Situational Awareness (SSA), the knowledge of both natural and artificial near-Earth objects. Low-cost, frequent, and accurate means of observing RSOs are necessary in improving SSA. Post processing data from existing star tracker images, commonly used to determine the attitude of the host satellite, can enable determination of the attitude of RSOs observed. Using a simulated space environment, developed in MATLAB, the performance of 6 algorithms (Genetic Algorithm, Gradient Descent, Particle Swarm Optimization, Simulated Annealing, Stochastic Hill Climbing Intelligent Step, and Stochastic Hill Climbing Random Step) were evaluated to compare the convergence rates and accuracies of the RSO's attitude from the light curve over a series of images. The suitable Point Spread Function was then determined empirically to calibrate the Fast Auroral Imager (FAI) on the Cascade, Smallsat and Ionospheric Polar Explorer (CASSIOPE) satellite. The performance of the algorithms to determine the attitude of RSOs is currently being performed in a simulated environment, with plans to move to real FAI data in the near future. Currently, the simulated results show that the attitude of an RSO can be estimated within 5 degrees of its true attitude in a given sequence of images. The capabilities of including the RSO's attitude in its characterization have the possibility of reducing the risk posed by an increasing number of RSOs to commercial, government, and military space assets.

Epidemic Dynamics on Digitally Traced Contact Networks

Jing Li
LURA | Supervisor: Manos Papagelis
Dept. of Electrical Engineering & Computer Science

The research aims to improve the understanding of how individual behaviour affects the epidemic dynamics in trajectory networks. With the worldwide outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), multiple actions such as social distancing and lockdown have been taken by authorities to slow the disease spreading. These strategies are effective in terms of disease containment, however, they have given rise to side effects including economic downturn and unemployment. As such, the research attempted to address these drawbacks resulting from a complete or near-complete isolation and lockdown. Given simulated digital contact tracing data, which in real-world situation would be enabled by mobile apps, the research involved modelling the risk of infection of an individual in the trajectory network based on the number of his/her contacts and duration of these contacts. The research then modelled the disease spreading in a community. In the situation that some individuals are infected, the model predicted the disease spreading dynamics in the spatiotemporal network, which allowed to estimate the probability of disease spreading size within an area. Finally, the research simulated the outcomes of deploying some immunization strategies regarding disease containment. The methods of spatiotemporal graph mining and trajectory data mining were used to address technical problems. The research can provide insight into individual risk of infection and the effect of individual behaviours (contacts) on disease spreading in the trajectory network. Such insight would potentially facilitate disease containment. Meanwhile, it would mitigate the problems caused by confinement measures.

Mitigation Strategies for Informal Settlements in Developed Countries

Melissa Spiegel
NSERC USRA | Supervisor: John Gales
Dept. of Civil Engineering

Approximately 1 billion people worldwide live in informal settlements (i.e. shantytowns, slums). This number is not limited to developing countries. Tent cities are often observed to emerge within metropolitan areas of developed countries, such as Toronto. The Covid-19 pandemic has exacerbated the situation as individuals would prefer to remain in their own dwellings than go to public shelters, which have increase risk for the virus. These informal settlements tend to emerge near transit stations and under highways due to the shelter these major infrastructures provide from the harsh Canadian weather. This research focuses on understanding the underlying mechanisms which lead to informal settlements emerging, as the frequency of fire is a consequence of their existence. Through examining root causes, mitigation strategies can be developed to reduce the risk to life and property in the city. This was achieved through analysis of a recent settlement fire within Toronto and the study of newly founded settlements in the aftermath of that fire. The objective of the research is to present a framework for understanding the establishment of settlements and the fire risk associated with them. Addressing this issue is particularly challenging as the dwellings are built without following building code regulations, however the proposed mitigation strategies will try to prevent the settlements from forming, and if they do form, will try to minimize the fire risk to inhabitants and the surrounding built infrastructure.

Co-segmenting Panoramic Scenes for Virtual Assessment of Spatial Navigation

Vladislav Luchnikov
LURA | Supervisor: Matthew Kyan
Dept. of Electrical Engineering & Computer Science

Landmarks play a significant role in one's daily navigation helping the observer determine where they are by recalling previous observations stored in memory. We are interested in examining how degrading certain visual cues in a street navigation experiment conducted in virtual reality (VR) can affect a person's ability to successfully navigate in a known environment. For that we need a tool that will allow us to locate a landmark across the set of images. In our research we examine sets of street panoramic images that cover an area surrounding specific walking routes and can be navigated by a person within a VR navigation experiment. During the experiment we collect head orientation data from a VR headset to estimate points of most interest and treat them as important navigational cues. Then we try to describe these cues by segmenting each image and analyzing content of relevant segments - this allows us to locate and track landmarks across a set of images (co-segmentation). We have successfully deployed a segmentation model for analysis that allows us to separate background (sky, road) from foreground (building fronts, signs) allowing us to start working on landmark retrieval based on the headset orientation data. Our next step is to track the landmark across a series of images and experiment with manipulation of a landmark such as blur/removal. This project is developed in collaboration with a clinical psychology research lab at York who use a similar model of virtual navigation experiment to assess early onset dementia in aging adults. We hope that advanced manipulation of the experiment environment can help to run such assessments with higher precision.
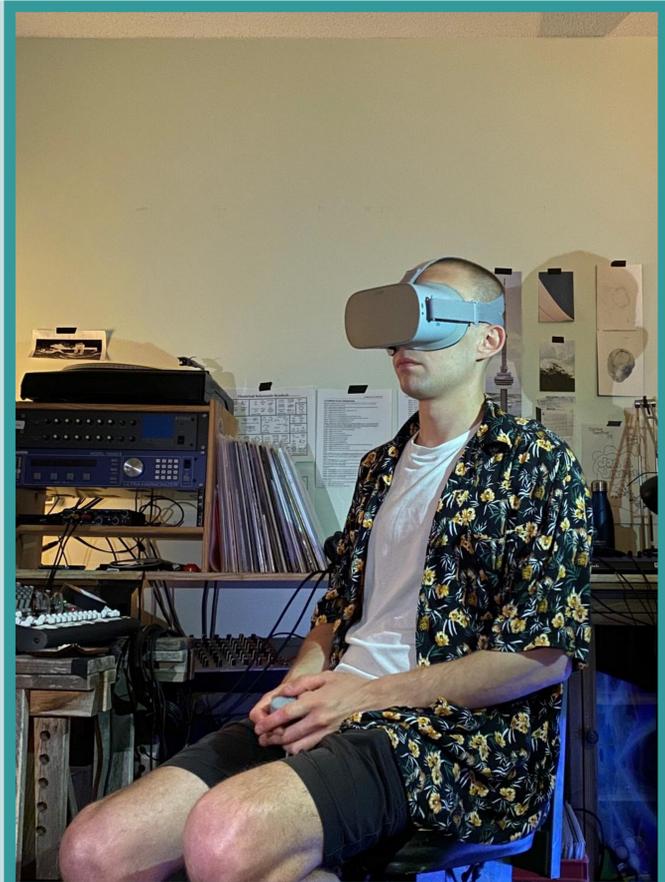
DNA Sequencing using Hardware Acceleration

Abel Beyene
James Wu Internship | Supervisor: Sebastian Magierowski
Dept. of Electrical Engineering & Computer Science

Bioinformatics is an important application domain for high performance integrated circuits. Steady performance gains on IC chips allow important functions such as DNA sequencing to be realized on portable devices. In fact, DNA sequencers as small as smartphones already exist and can process the equivalent of a human genome in roughly 4 hours. However, this process can be computationally expensive and require substantial amounts of power if the sequencer is implemented on general purpose platforms such as commodity CPUs or GPUs. Therefore, custom hardware is needed. In this project, we combine an emerging technology, an open-source RISC-V processor, with custom circuitry and systems to realize a DNA sequencing device with accelerated processing capability and reduced power consumption. The bulk of the work will be focused on customizing the RISC-V chip with additional components that facilitate the streaming and processing of thousands of DNA measurements in real time. These components include high speed memories which provide fast access to the measurement data, communication blocks which quickly move the data throughout the chip, as well as a custom co-processor (i.e accelerator) which implements the main algorithm used to convert a measurement into a DNA base sequence. The accelerator will also use a special interface designed to allow fast and efficient communication with the RISC-V core. Upon fabrication and packaging of the chip, a test platform will also be built to allow complete testing and validation of the device. Throughout the project, state-of-the-art design tools will be used including Synopsys Design Compiler and IC Compiler. Fabrication of the chip will be sponsored by CMC Microsystems in hopes that it will serve as a guide for future RISC-V projects.

Digital Image Correlation Impact Testing of FDM Manufactured Composites

Alexander Dondish
LURA | Supervisor: Garrett Melenka
Dept. of Mechanical Engineering

Three-dimensional digital image correlation (3D DIC) is a method of measurement, primarily used alongside mechanical testing to determine the mechanical properties of materials with complex structures. It typically involves the use of two high-speed cameras in a stereo configuration to measure 3D deformation and strain. Materials suitable for 3D DIC include composites manufactured by fused deposition modelling (FDM), a method of additive manufacturing, which in this instance involves embedding fibres directly into molten matrix material filament to build a part layer by layer. Standard 3D DIC, however, is a costly and difficult task, because high-speed cameras are expensive, and synchronizing multiple of them is tedious. Our focus in this project is therefore on 3D DIC methods using only one camera, which is to be achieved using an optical configuration, for instance one which uses four planar mirrors. This setup will be used in conjunction with Charpy impact testing using an Instron CEAST 9050 Motorized pendulum impact system. The acquired images will then be processed using LaVision Davis to analyze the impact behaviour of FDM manufactured composite specimens. Our bill of materials for the components of the four-mirror configuration indicates that this configuration is about 1.5% the cost of an additional Phantom high-speed camera. The results from this single-camera setup will then be compared against standard 3D DIC measurements to verify its effectiveness. This setup serves to improve accessibility of 3D DIC in both industry and academic applications. This can ultimately bring a deeper understanding of advanced composites as they become more widely available, most notably in the automotive and aerospace industries.

Self-Sensing FRCM Systems for Combined Strengthening and Monitoring of Concrete Structures

Amer Shaikh
LURA | Supervisor: Liam J. Butler
Dept. of Civil Engineering

Canada's fluctuating temperatures plague our steel and concrete infrastructure, requiring frequent maintenance and repair. Engineers are required to develop innovative and cost-effective solutions to monitor, repair and strengthen infrastructure. This research reports and investigates the efficiency of continuous and discrete fiber optic sensing (FOS) arrays for monitoring the performance of four previously tested reinforced concrete (RC) beams coupled with three different types of fabric-reinforced cementitious matrix (FRCM) strengthening systems. The fabrics in the newly developed FRCM materials used to enhance the flexural capacity of the beams were basalt-fiber, glass-fiber and polyparaphenylene benzobis oxazole fibers (PBO). The properties of the FRCM materials were established through a uniaxial testing regimen of FRCM coupons using clevis-type grips. The flexural capacity, failure mechanism, deformation and other notable characteristics of the four RC beams were observed through a four-point loading flexure test, and the results were recorded through four sensors. Several traditional linear variable differential transformers (LVDTs) and strain gauges were used as a traditional discrete data collection methods. In addition, novel discrete fibre bragg grating sensors (FBGs) and continuous Brillouin optical time domain reflectometry (BOTDR) based-sensor cables were used to collect innovative distributed strain data, which detect wavelength refraction changes within the FOS systems. This research aims to validate the effectiveness of using embedded FOS within FRCM composites as a combined sensing-strengthening technique for concrete infrastructure and establish a proof-of-concept for a data-driven monitoring approach for future research and field applications.

Evaluating the Efficacy of Anonymized Virtual 3D Renderings of Human Activity

Anto Nanah Ji
NSERC USRA | Supervisor: James Elder
Dept. of Electrical Engineering & Computer Science

Cameras embedded in our urban environment can potentially contribute to security, traffic safety and efficiency and retail optimization, but the invasion of privacy is a potential drawback. One way to address this problem is to convert raw video to a virtual 3D representation of human activity in which individuals are represented as anonymized avatars, thereby protecting the identity of the individuals in the scene. In previous work, we developed a system that converts raw 2D surveillance video to virtual 3D representations within the Unity 3D software environment. A 3D model of the environment under surveillance is first constructed and cameras are calibrated to allow each pixel of a video frame to be mapped to a point on the ground plane of the model. A real-time multi-person keypoint detection library (OpenPose) is used to detect and to estimate a 2D skeleton for each pedestrian in each frame of the video. The 2D image locations of the skeletons are then back-projected to the ground plane to estimate the 3D ground location of each pedestrian, and these ground plane `footprints' are tracked over time. In this study, our aim is to assess the efficacy of these virtual representations relative to the raw videos. To do this, we created a user study in which both virtual and raw stimuli (videos/images) are evaluated. Observers view each stimulus and are asked to make judgments of 1) the number of people, 2) social distancing, and 3) hurriedness. We assess the correlation between judgments made with the two representations and, where possible evaluate accuracy against ground truth or estimated ground truth. Finally, with virtual 3D representation, we protect people's privacy and thus allow the information derived to be worked in security, marketing, and other applications.
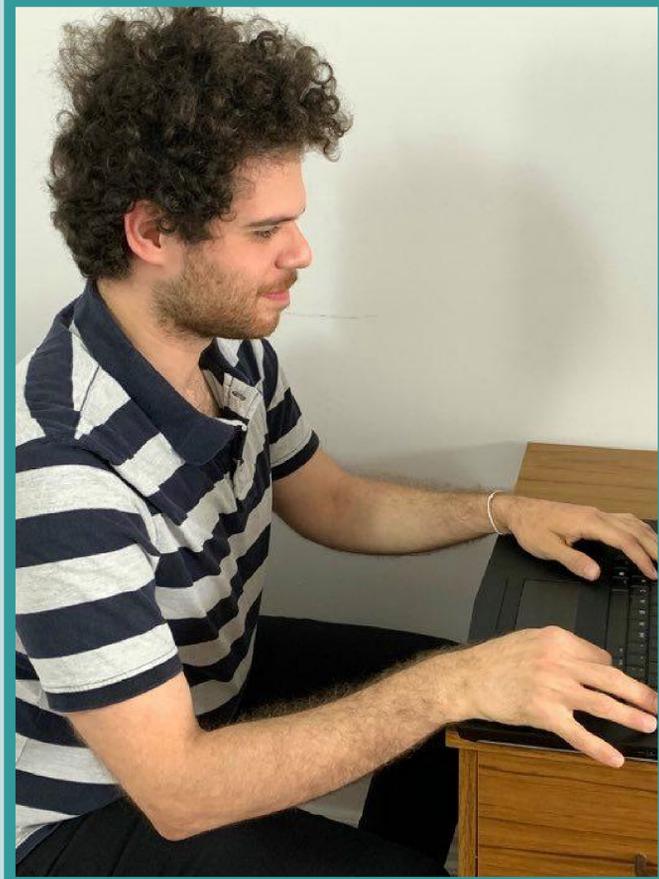
Transmission Design for a Piezoelectric Robot

Ariel Tabak
RAY | Supervisor: Ryan Orszulik
Dept. of Earth & Space Science & Engineering

Piezoelectric bimorph actuators are capable of delivering small but precise high-speed displacements. In order to use these actuators to drive high-speed parallel robots, these small displacements must be amplified via a transmission mechanism. In order to design and fabricate flexible centimeter-scale robots powered by piezoelectric benders, the design of the transmission mechanism is the first problem that needs to be addressed. Taking inspiration from pre-existing designs, new transmission designs are investigated while meeting the tolerances of multi-material additive manufacturing. Incorporating flexible materials in the form of flexures, the small linear displacements of the piezoelectric bimorph actuators are converted into large angular rotations. Finite-element analysis software is used to model commercially available piezoelectric bimorphs and then an interface between the finite-element software and available programming environments is created to perform rapid and iterative parametric analysis of the transmission mechanism. The results of the parametric analyses are reviewed to determine design trade-offs, leading to substantial optimizations. Specifically, flexure parameters such as length, thickness, modulus, and position are identified as the key system parameters. The flexures in the mechanism allow the robot arm to be rotated around the flexure-arm connection, resulting in symmetrical motion of approximately +/- 40 degrees. This transmission mechanism will be utilized in future projects for complex tasks such as object manipulation, in the form of a pick and place robot. Various design tradeoffs have been identified thus far in the project, making the design adaptable for different bimorphs, materials, and methods of manufacture.

Airport Landside Facility Traffic Analysis and the Integration of Advancing Technologies

Ariel Yerushalmi
NSERC USRA | Supervisor: John Gales
Dept. of Civil Engineering

In lieu of advancing transportation systems, it is important to analyze the significance of autonomous vehicles on existing transportation facilities, specifically in airport landside facilities where space is limited. To do so, an airport case study was chosen to investigate the existing traffic of such transportation networks, with the objective of attaining both short-term and long-term improvements. Several aspects of the traffic were investigated where results demonstrate that shuttle buses were the most efficient. To improve the current congestion at Airports, it is necessary to examine methods which will effectuate the network by making use of the available space as well as considering the benefits of autonomous vehicles.

A Study of the Formation and Evolution
of a Liquid Bridge Between Separating Surfaces

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It is important when dealing with processes on a micro scale to be able to identify which processes drive others and which processes are driven. The goal of this research is to apply the same idea to the transfer of micro sized droplets between two surfaces, to identify which natural processes drive the fluid transfer as the bridge breaks, and to identify the markers of such processes to predict the transfer. A fluid bridge is formed when a fluid droplet adheres between two surfaces or particles. A stable shape for the bridge is found as a balance between the fluid's surface tension pulling the shape inward and a Laplace Pressure difference from the inside of the bridge to the outside pushing the shape outward. The shape of the bridge must also balance the forces of adhesion to the surfaces with the force of gravity. Since surface tension is a property inherent to the fluid and gravity is not, the first task of this research is to analyze bridges made from smaller and smaller droplets (order of 0.5 microliters) until effects that can be attributed to gravity are no longer observed. By isolating the effects of gravity away from the bridge descriptive markers of the droplet, such as length, can then be analysed as being indicative of the resulting volume transfer after the bridge breaks. Creating predictive transfer models has direct results in the efficiency of printing technologies. It also creates longer term results in our understanding of topics such as the retention of water in soil due to the formation of fluid bridges between soil particles, and industrial manufacturing processes due to the capacity of the adhesive fluid force being used for picking up ultra-fine mechanical parts.

DIY Actuating Papercraft for Subtle
Guidance of Self-Reflection

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This project explores the use of slow actuating papercraft as a means of subtly guiding self-reflection. A common approach in using technology for self-improvement is to collect specific physiological metrics and presenting that data to show areas for improvement. For example, tracking heart rate and step counts to encourage physical activity. Another approach is for technology to encourage a space and time for self-reflection. Examples include meditation apps and biofeedback devices for practicing breath regulation. However, these technologies often rely on dedicated sensors and carefully designed experiences where end-user personalization is an afterthought. In contrast to heavily designed technologies, paper as a material is commonplace and easy to work with. Accompanying low-cost and flexible methods for articulating paper, such as shape-memory alloys and 3D printed layers have been developed. Using those methods, interactive paper interfaces such as paper robots and animated origami have been explored as a low cost way of creating tangible and easily personalizable technology. In keeping with personalizability, sound has been explored as a way to animate the motion of one degree of freedom social robots without the explicit need for technical and artistic expertise. Hard-to-capture concepts such as tone and emotion can be drawn from voice and translated into affective expressions. However, motorless paper actuators react more slowly than motorized robots. In taking these concepts together this project explores how to use environmental noise generated by a person in a solitary space, such as an office, to actuate customizable papercraft devices to subtly guide them towards moments of rest and self-reflection.
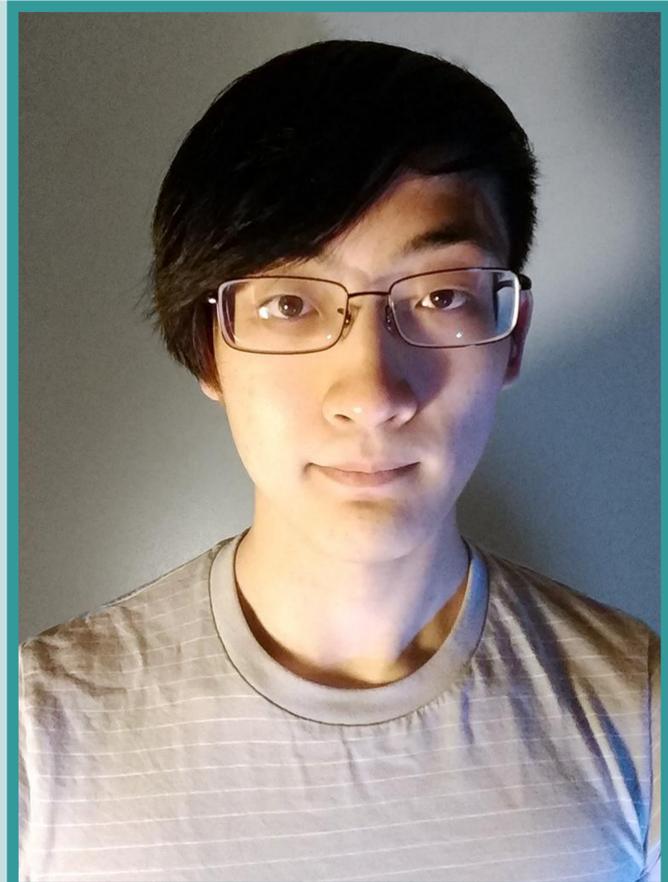
OCD-Net: Oriented Corner Detection
Network

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Perceptual inference for grouping low-level features such as corners and lines is a critical vision task for the primitive-based or data-driven representation of objects. Perceptual inference requires extracting structured visual information and explicit reasoning about their aggregation. Although many solutions already exist in this domain, their focus is on using semantic information. This research is motivated by the belief that semantic information alone is not sufficient to localize and describe corner locations within images. Thus the goal of this project is to propose an orientation regression task that can help improve corner detection as well as allow us to identify structured corners from an image. To incorporate this task into a corner detection framework, we propose a novel end-to-end convolutional neural network (CNN) architecture for efficient perceptual detection of keypoints associated with its surrounding edge information, called OCD-Net (Oriented Corner Detection Network). The proposed network uses a VGG-style encoder backbone and consists of several decoder heads, each trained for the different tasks involved. These include a localization module that learns to find the location of points in an image and an orientation description module that learns to describe the orientation around each interest point. In this study, the problem is simplified such that the oriented corners correspond to corners of building footprints and rooftops. The network is trained and tested on a simulated dataset as well as satellite images of buildings found in the SpaceNet and DeepGlobe challenges. We expect that this network will provide a solid framework for the extraction of structured corners for tasks such as building localization and reconstruction.
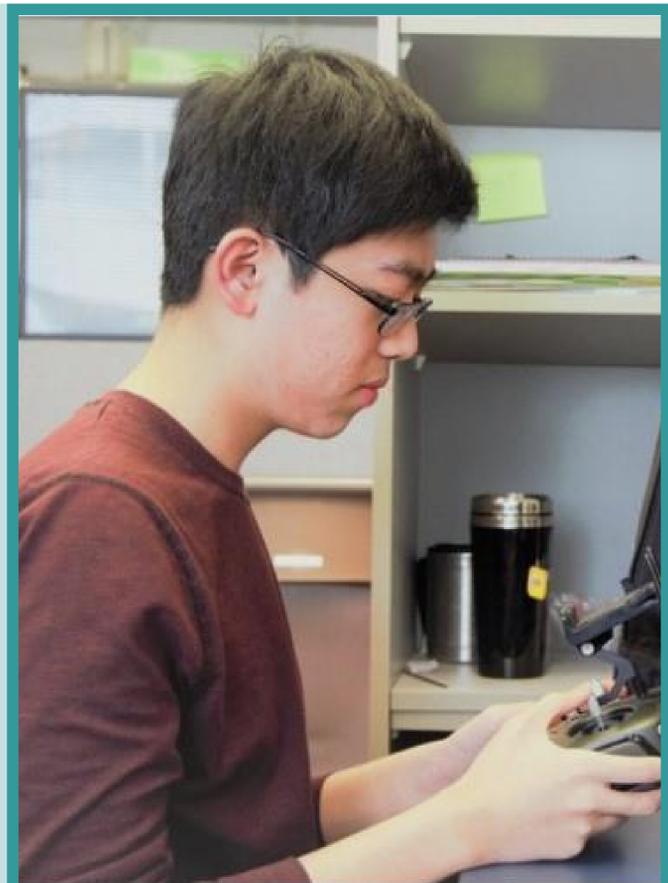
Anomaly Detection Suitability Analysis

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In this project, we compare and analyze current state of the art approaches to the anomaly detection problem. The goal is to develop a better understanding of how characteristics of anomalies impact the effectiveness of a given approach. Anomaly (outlier) detection is important for tasks such as fraudulent transaction detection, irregularity identification in medical contexts as well as out of distribution flagging for input instances to a machine learned predictor. In addition, it is also sometimes used in support of other tasks such as preprocessing for a learning task or as an indicator for some types of dataset shift .From a review of relevant literature several top performing algorithms were selected for empirical review. Effort was made to include algorithms from varying approaches, such as density-based, nearest neighbour based and isolation based approaches. Several synthetic datasets are designed to exhibit changes in output behaviour and therefore in effectiveness of the algorithms. It is expected that different methods, based on their underlying design, are susceptible to different types of anomalies. The ultimate goal would be a formal characterization of outlier specifications and algorithms' detection capabilities as a tool for better matching of context specific task requirements with choice of algorithm. The results of this work are intended to serve towards developing a general guide for which approach should be employed based on the type of outliers present in a given dataset.
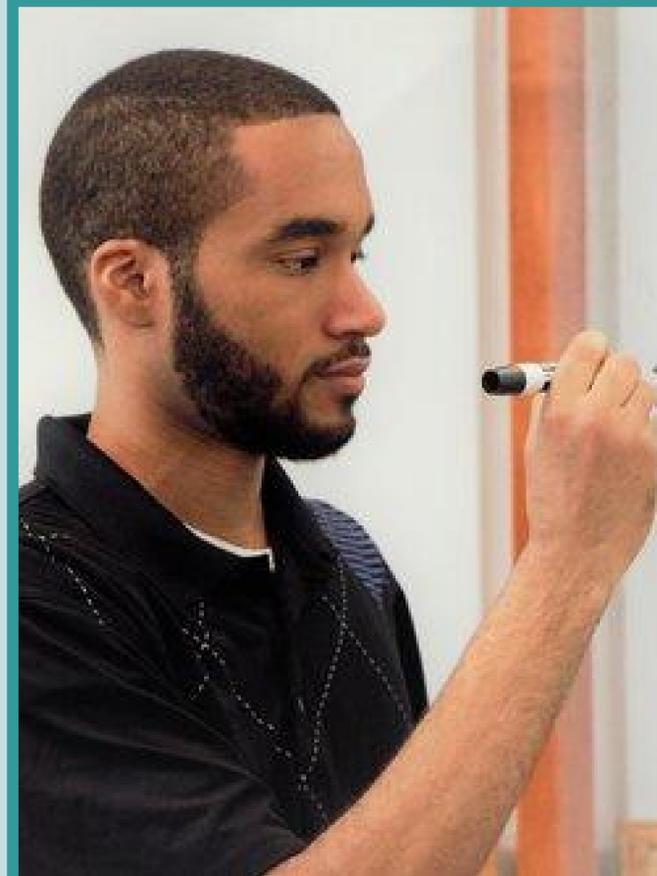
A Microfluidic Technique for C. elegans High-Resolution Imaging

Daphne-Eleni Archonta
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Dept. of Mechanical Engineering

Caenorhabditis elegans (C. elegans) is a widely used millimetre-scale disease model organism with a simple neuronal system that is used for developmental and neurodegenerative drug screening assays. Its genetic tractability and body transparency have aided in studying Parkinson's Disease (PD) through PD-specific mutant generation or fluorescently labelled neurons for neuroprotective compound screening. As immobilization of C. elegans is vital for imaging, different methods have been developed. However, manual assays are time-consuming and influence the worm's physiology, whereas many microfluidic techniques require complex fabrication steps and do not allow high-resolution imaging (HRI) of sub-cellular features. Here, we report a simple microfluidic technique for full-body immobilization of C. elegans with the application of DC electric field (EF) inside a narrow-channel electric trap for on-demand HRI. Numerical simulations were conducted to ensure constant EF across our microchannel. Parametric studies showed that EF of 6V/cm is required for immobilization. To ensure complete cease in locomotion, the worm's body bend frequency (BBF) was quantified before, during, and after exposure. The initial BBF of 0.83±0.03Hz was reduced to 0Hz during exposure (full immobilization) and ameliorated to 1.03±0.08Hz, demonstrating that worms' health is unaffected by EF. To demonstrate imaging during EF-exposure, a mutant strain emitting fluorescence in the hermaphroditic specific neurons was tested and the worms' vulva, progeny, and pharynx were successfully imaged. This provides a novel, on-demand method for drug screening, based on analysed phenotypes observed. Future work includes developing a high throughput screening device and testing of PD-related chemicals.

Towards Understanding the Properties of Training Data in Machine Learning

Daniel Park
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Little effort has been put into understanding how well any particular training data set for machine vision systems represent the population of images for a given visual task. Computer vision based on machine learning methods allows computers to understand images by sampling a scene using a sensing device, extracting meaningful features from the sample image, and then interpreting the contents of the image correctly. Bias has emerged as a problem with such methods (such as a bias for particular skin colour in facial recognition systems). This is likely due to inadequate consideration of how well a data training set captures the full variability of a population. Sampling bias happens when certain values of the variables are systematically under-represented or over-represented relative to the actual population distribution. Statistical sampling theory examines the various sampling techniques and study design to minimize sampling bias and to ensure reliable results. Through understanding the properties of training data in machine learning and the use of statistical sampling theory, we are trying to build better training and test sets that satisfy good statistical principles and examining how any result might impact particular visual tasks with specific interest towards autonomous driving and companion robots for the elderly and assistant robots in manufacturing settings.

Tyrosine Kinase Signaling in Tetrahymena Thermophila: an Update

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Tyrosine phosphorylation signaling in multicellular organisms has long been known to have an important role in the coordination of signal transduction and the regulation of a variety of cellular processes, including in diseases such as cancer. Until recently, phosphotyrosine signaling was thought to be exclusive to multicellular organisms. However, recent studies propose the presence of tyrosine kinase signaling in unicellular eukaryotes such as Tetrahymena thermophila, and therefore suggest the need for the expansion of areas of research in this field. Genome sequencing of T. thermophila and the absence of Src Homology 2 (SH2) domains in its downstream signaling proteins indicate the lack of specific tyrosine kinases in Tetrahymena. However, recent experimental and bioinformatic studies on T. thermophila in the Pearlman lab, as well as available phosphoproteome data (http://tfgd.ihb.ac.cn/tool/phos), and the presence of tyrosine specific phosphatases in this model eukaryote, suggest the presence of multiple dual specific kinases that are capable of phosphorylating tyrosine, serine, and threonine. Our recent focus has been on molecular and bioinformatic analysis of dual-specificity tyrosine kinase-like (TKL) proteins and also a number of phosphorylated proteins in T. thermophila. These proteins include the cyclin-dependent kinase annotated as Cdk13/Rck, which is a possible dual-specific kinase involved in the stress response, cilia metabolism, and sexual reproduction in Tetrahymena. This presentation focuses on the bioinformatic analysis of these sequences to gain a better understanding of the structure and active sites of dual specific kinase enzymes, and to find critical information about the function and evolution of tyrosine signaling pathways in Tetrahymena.

Light Attenuation from OCT Measurements

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Faculty of Science

Optical Coherence Tomography (OCT) is a non-invasive imaging technique that allows us to visualize inner structures in biological matter with a remarkable resolution on small depths (1-2 millimeters). This type of imaging has found clinical applications in various fields of medicine such as ophthalmology, optometry, and quite recently, cardiology and dermatology. OCT works similarly in principle to a Michelson Interferometer. A light beam is split in two, one beam acts as a reference and the other will interact with tissues. Eventually, both will converge at a detector, where information on the sample may be inferred from how these two interfere with one another. However, due the nature of light, the signal detected does not have any units or way of discretely quantifying these structures. Thus, it is up to the medical professionals to identify abnormalities on these images. What motivates this research is the relatively recent development of mathematical models to describe light interactions in OCT. These models allow us to mitigate noise and artifacts that occur from chaotic light behaviour, but most importantly, it assigns a value unique to the particular structure analyzed. This value, called the attenuation coefficient, describes how light will be absorbed or scattered depending on the specific sample. The implications that arise from this quantification yield promise in tissue characterization, mainly identification of oral lesions, and early detection of cancerous tissue. These models, alongside a program that applies them to experimental samples manually or automatically depending on the method, determine their attenuation coefficient where the ultimate goal is maximizing accuracy, and eventually, employment these procedures on live tissues.

Behavioural Screening of Electrically Stimulated Zebrafish Larvae Using Microfluidics

Ellen van Wijngaarden
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Dept. of Mechanical Engineering

Behavioural Screening using an accepted model organism is critical in drug and chemical toxicity research. Various characteristics of Zebrafish (Danio rerio) larvae, including their high genetic homology with humans, make it an ideal model for behaviour screening for disease and drug discovery. The objective was to create a microfluidic device to facilitate the screening of electric-induced behavioral responses of multiple zebrafish larvae simultaneously. The device allows for precise stimulation, control and imaging of four zebrafish larvae to test their sensitivity to various chemicals and drugs. The final device consisted of three polydimethylsiloxane (PDMS) layers, electrodes and various microchannels. Larvae were tested in the device with 3μA electric current per fish at 5-7 days-post-fertilization to stimulate movement, which was quantified as Response Duration (RD) and Tail Beat Frequency (TBF). To ensure electric field uniformity in all traps, the electric voltage and current inside the device were simulated. The shear stresses acting on the fish were likewise simulated to ensure no damage to the fish during the loading process. No significant difference was found between the RD and TBF of fish tested in the multi-fish device and those screened using the previous single-fish design. Using the multi-fish device resulted in a decrease in testing time per fish of ~55%. This tool is therefore suitable for screening of zebrafish larvae, reducing the testing time for chemical screening assays and enabling increased sample sizes. The device can be further modified to increase the throughput for use with larger field of view microscopes. The presented technique will be used in future behavioral, genetic and chemical screening assays for higher speed and efficiency.

Exploring a Future Scenario of Blended Learning in Engineering and Science Education

Emily Secnik
RAY | Supervisors: Jane Goodyer and Llew Mann
Lassonde Education Innovation Studio

The current landscape of engineering and science education is evolving rapidly. In parallel there is a current educational shift that must be adopted due to COVID-19. This research project ties into a larger visioning process that begins to explore future scenarios of engineering and science education in 2030. The research team explored well-established and emerging trends from across the globe and has identified four distinct themes: Blended Learning (BL), Experiential Education (EE), 21st Century Skills and Students as People. This specific project explored how BL can be scaffolded in engineering and science education in the future. Some examples of BL include flipped classrooms and hybrid learning, but simply, blended learning is the ideal combination or 'blend' of in person and online learning. The research team developed an animated video of a future scenario in 2030. The researchers are exploring the reactions and perspectives of stakeholder groups including students, staff, faculty and senior leadership. This video was then shared with stakeholders in a multiple semi-structured focus group, seeking their overall thoughts and specifically on BL. Results were then analyzed looking at emerging themes and reliability was ensured using inter-rater reliability. The researchers anticipate that due to COVID-19 there has been a change in approach that universities have taken regarding BL and are looking to hear the perspectives of stakeholders. Their opinion on BL classrooms is that it is one of the many methods that will support a new learning experience in the future of the Lassonde School of Engineering. The research team sees BL is one of the keys to the future of higher education, as its use and popularity increases globally each year.

Finite-element design of Faraday Isolators

Fahad Hannan
DURA | Supervisor: Anatharaman Kumarakrishnan
Faculty of Science

We present a comprehensive simulation of the performance specifications of Faraday isolators using a finite-element model and a widely available numerical simulation package. The predictions for the magnetic field, Faraday rotation, and isolation ratio produced by a Faraday isolator consisting of an optically active crystal inside a compound magnetic stack are shown to be more accurate than analytical calculations. The simulations also produce better agreement with measured magnetic fields than results of a simplified model that treats the magnets as point-sized dipoles. In addition, it is possible to calculate the Faraday rotation based on averaging over the dimensions of the crystal. As a consequence, it is possible to predict the properties of homebuilt isolators consisting of a 4-magnet stack and gain insight into design improvements involving more complex magnet stacks. In particular, the simulations show that it is possible to design a homebuilt multi-stage isolator with a total isolation of ~120 dB which is better than the performance of any commercially available isolator. Our results also suggest that commercially available isolators have not been modelled in sufficient detail. We find that the performance specifications of these devices can be significantly improved using small modifications to the dimensions of the magnet stack and crystal as well as the placement of the crystal within the stack. The simulations also allow the effects of temperature variations and magnetic coercivity to be modelled to achieve further improvements in performance specifications.

Improving Multiple Object Tracking of Pedestrians

Fasil Cheema
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Object tracking, in general, is a challenging problem. Difficulties in tracking objects can arise due to abrupt object motion, changing appearance patterns of both the object and the scene, nonrigid object structures, object-to-object and object-to-scene occlusions, and camera motion. Specifically, for my project I am focusing on tracking people which faces many occlusions and changing appearance patterns. A full multiple object tracker (MOT) is a pipeline from raw data to unique trajectory for each individual. The pipeline consists of 4 main building blocks which are object detection, feature extraction, affinity and data association, respectively. In the first and second blocks, the frames are fed individually to a detector that will return detected objects of interest (people in our case) and then features of those people such as relative position, height, kinematics etc will be extracted. The next parts of the pipeline are defining affinity between extracted features of different detections and apply data association. A tracker is only as good as its detector, and with state-of-the-art detections with striking accuracy that part of the pipeline can only be improved microscopically. However, there is room for improvement in the data association part as it is an open-ended question on how to best associate different detections to each other best. Especially in the case of occlusion and crowded scenes. For my summer project I propose a methodology to better improve data association as to better improve the accuracy of multiple object trackers. This will in turn help improve technology in autonomous driving, security and surveillance, and other fields implementing trackers such as physics and biology.

Star Tracker Attitude Deconvolution from RSO Sidereal Motion

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LURA | Supervisor: Regina Lee
**Dept. of Earth & Space Science & Engineering**

Space Situational Awareness (SSA) is the study of Resident Space Objects (RSO), categorized as satellites, rocket bodies and orbital debris that are orbiting the Earth. With the increasing number of satellites in Low Earth Orbit (LEO), there is a cause of concern for the overpopulation of RSOs in space. Recent studies have shown the feasibility of the use of star trackers, commonly used for the attitude determination of spacecraft, for RSO detection, tracking and characterization rather than using dedicated space-based payloads or ground-based networks. In order to accurately estimate the orbital parameters of an RSO, it is imperative to determine the rate of change of the star tracker attitude. In this paper, we determine how attitude rate estimation affects the attitude deconvolution from RSO sidereal motion for improving orbital estimation of the RSO. Both absolute and relative attitude rate methods were implemented using a custom empirical simulator to propagate a spacecraft with an on-board star tracker. The former utilized the Quaternion Estimator (QUEST) algorithm followed by a finite difference approximation, where the latter applied a least-squares approach using only body vector measurements. The orbital estimation was evaluated using both attitude rate methods for the deconvolution of the spacecraft attitude. The result of this study indicated the attitude deconvolution maintained sub-pixel accuracy relative to the simulated results. With the improvement of tracking RSOs in LEO using a low resolution star tracker camera, there is an increase in both the quantity and precision of space based observations and the information available to space mission planning and assistance.

Characterization of Hydrated, Layered Deposits at the Valles Marineris Plateau of Mars Using SHARAD Radar

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LURA | Supervisor: Isaac B. Smith
Dept. of Earth & Space Science & Engineering

Hydrated, layered deposits are found across the plateaus of the Valles Marineris (VM) region on Mars, near the canyon rim. These deposits, known as light-toned layered deposits, (LLD) are thought to be composed of pyroclastic ash that was emplaced during volcanic eruptions and then modified by water, either in lacustrine or fluvial sedimentary deposition. Characterizing the hydrated, layered deposits is essential to testing the hypothesis of their formation and may constrain the timing and duration of water activity in this region. Using instruments onboard the Mars Reconnaissance Orbiter (MRO) such as the High-Resolution Imaging Science Experiment (HiRISE), the Context Camera (CTX), and the Shallow Radar (SHARAD), I made a map of the extent of the LLD and other landforms. Due to limitations of surface exposure (deposits are buried by dust and dunes), extent could not be fully determined using imagery alone. To remedy this, I used SHARAD radar data, that sees beneath the surface, to confirm LLD in areas where imagery could not. The flat horizontal topography of the plateaus are ideal candidates for investigation of the subsurface. Focus was placed on mapping the basal reflections of the LLD using SHARAD data and geophysical software, to allow for a more comprehensive characterization of the region. The analysis of SHARAD data also opens the door for investigation of the dielectric properties of the LLD, which we are doing. The fully mapped plateaus give larger context to the geology of VM, which can give insight into the volcanic history and water cycle some 3.7 billion years before present, when VM formed. This, in turn, will aid in determining past climate on Mars and potentially reveal candidate regions for future landing sites.
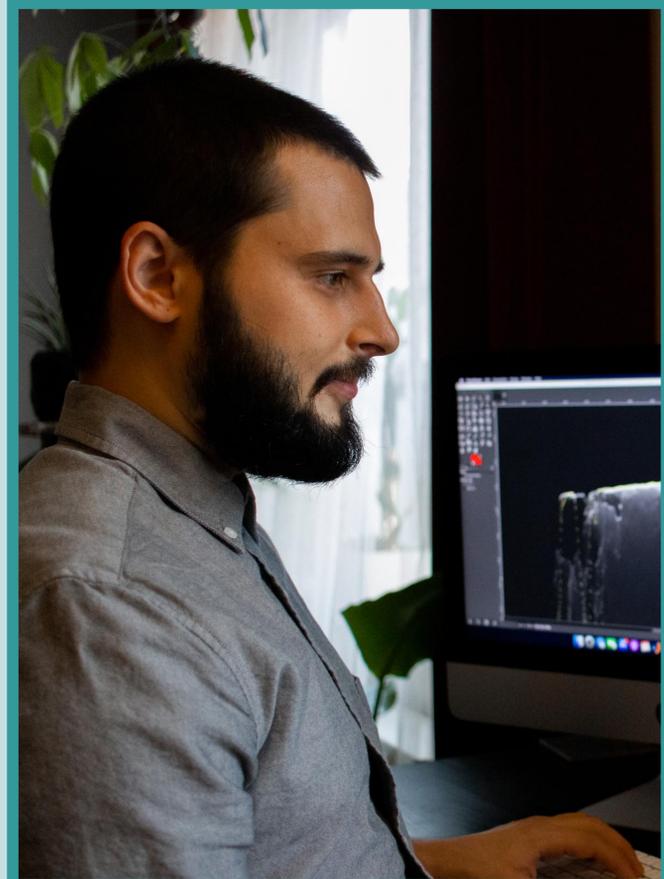
Physics Integrated Information in Deep Neural Networks

Jabavu Adams
**DURA | Supervisor: Joel Zylberberg**
Faculty of Science

Integrated information has been proposed as a testable and computable measure that correlates with consciousness. It can be computed from recordings of brain signals in humans and fruit flies, for example. It goes up when the subject is conscious, and decreases when the subject is unconscious. It can also be computed for engineered mechanisms, such as artificial neural networks. We are estimating integrated information in neural networks before and after they have been trained to perform a task. Our hypothesis is that integrated information should go up during training, as information processing becomes more coordinated between different parts of the networks. We will repeat the analysis on different network architectures, to ask which architectures lead to higher integrated information after training, and (separately) which architectures lead to higher task performance. This could give us clues as to why consciousness might be a selected-for adaptation in animals like us.
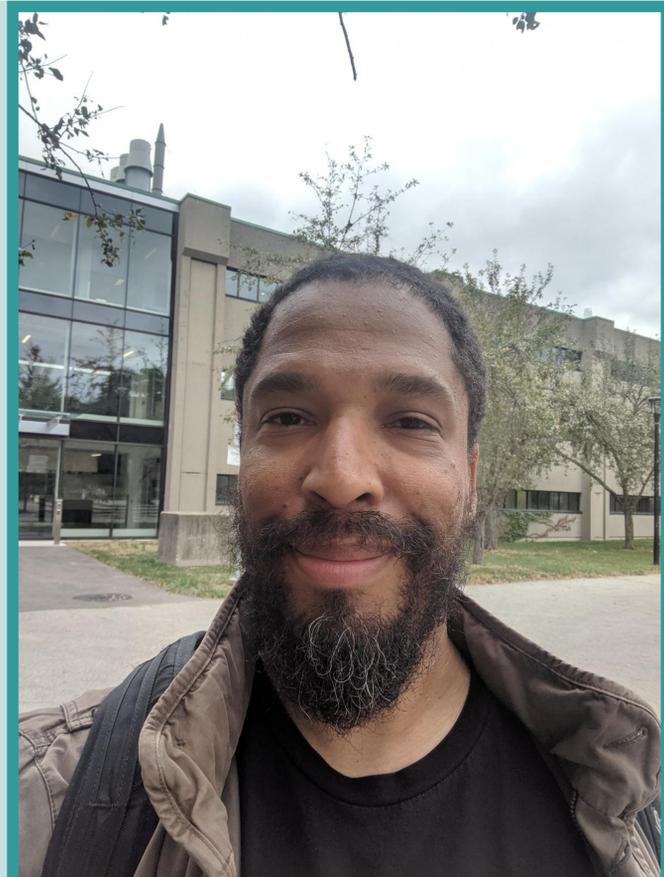
Effect of Radial Cracking in Timber on Fire Resistance

Kathryn Chin
NSERC USRA | Supervisor: John Gales
Dept. of Civil Engineering

There is a growing interest in creating timber structures due to the material's high sustainability. Because little is known about it, the objective of this study is to better understand how radial cracking in timber (an effect caused by a significant decrease in moisture) affects its fire resistance. When timber is exposed to fire, it will chemically decompose creating a char layer and produce combustible vapors. Current practice to try improving fire resistance is to fill radial cracks with incombustible caulking to prevent the volatiles produced from charring along the crack to escape. To determine the impact of radial cracking, a Lateral Ignition and Flame Spread Test (LIFT) was performed on an 800 mm timber beam with a 3 mm artificial radial crack, the expected depth of a real crack. The 18-minute recording was analyzed, aided by the review of other literature to understand the underlying mechanisms of how the fire propagates along the surface and permeates heat into the crack. In the video, the flames spread horizontally on the beam with charring occurring visibly faster on the surface than in the crack. Through analysis, it was determined that the charring on the surface is normal, however, the charring along the crack is more shallow than the charring measured on the surface. Often, at lower temperatures, the charring does not reach the full depth of the crack. At higher temperatures and over time, the cracks will widen. Overall, the strength and fire resistance of the beam will decrease in fire. However, if the crack is only exposed to mild heat, the charring will not propagate to the entire crack. This information can be valuable to those designing and building with timber, as a better understanding of the behaviour of timber with radial cracking is gained.
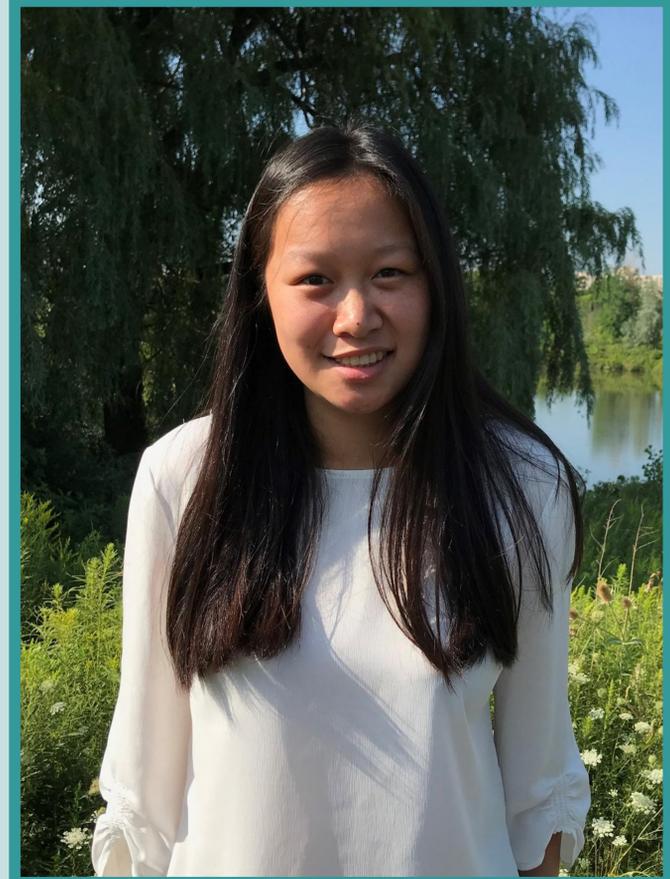
Active Components in Streaming Graphs

Kenneth Tjhia
NSERC USRA | Supervisor: Manos Papagelis
Dept. of Electrical Engineering & Computer Science

Finding the connected components of a static graph is a well-studied problem with many important applications. For many other applications, however, we wish to model phenomena using a dynamic graph whose structure may change with time. In this paper we consider an important class of dynamic graphs that have fixed initial structure, then in each discrete time step some of their nodes become active or inactive. At any particular time step, we call a subset of nodes which is active and connected (a path exists between any two nodes in the set) an active component. We present an algorithm that maintains this set of active components while avoiding a full re-computation of it in each time step. We evaluate the performance of our algorithm, comparing against the state-of-the-art, on randomly generated graphs of different sizes, types, and with different models for labelling nodes active/inactive.

Automated Tumor Detection in CT Scans of Lungs Using Machine Learning

Kevin Y. H. Hui
NSERC USRA | Supervisor: Suprakash Datta
Dept. of Electrical Engineering & Computer Science

According to statistics, 1 in 15 Canadians are expected to be diagnosed with lung cancer in their lifetime. The current method of diagnosis uses computed tomography (CT) scans and interpreted by medical professionals. This process requires 15 to 30 minutes of time for each patient and is subject to human errors. The goal of this project is to create a computer-aided diagnosis system to detect and classify lung tumors from CT scans using machine learning algorithms. Such a system would help a human expert by drawing their attention to the area(s) of interest and providing them with a measure of reliability of the automated predictions, and help to reduce diagnosis time and reduce human errors. Tumors are diagnosed from CT scans by human experts by inspecting shapes, contours and textures. Since human beings cannot easily specify how this process can be automated, we use neural-network-based machine learning algorithms. In our project we design neural networks that learn from data labeled by human experts to classify them as tumors, other types of tissue, or objects that will normally appear in a CT scan. Afterwards, we combine the classification of different parts of a scan image to refine and confirm the detection as well as localization of a tumor. Finally we build a simple, easy-to-use interface to display the results to human experts. Such machine learning based computer-aided diagnosis systems can be improved to greater accuracy if more data is given, and can greatly reduce the time, cost, and chances of error in diagnosing lung tumors in the future.

Randomized Lock-Free Bag Data Structure

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Data structures provide a data management and storage format that enable efficient access and modification. Concurrent data structures allow applications to execute operations in parallel providing significant performance improvements compared to their sequential counterparts. However, designing correct, efficient and scalable concurrent data structures is complicated because processes executing concurrently may interleave their steps in many ways, each with a different and potentially unexpected outcome. One of the most efficient family of concurrent data structures are lock-free data structures as they try to maximize the utilization of the available resources to achieve optimal performance. We present a new lock-free algorithm for concurrent bag data structure in an asynchronous shared memory system that supports Insert and TryRemoveAny operations. Our algorithm is based on the external binary tree data structure proposed by Natarajan and Mittal [PPoPP 2014]. In our algorithm, every insert and delete operation starts from the root node and decides which child node to visit next based on the outcome of a fair coin toss and modifies the tree once it reaches a leaf node. Given the expected symmetric distribution of the processes in the tree we believe that this data structure will be efficient and easily scalable in practice. Since the algorithm is both randomized and lock-free we present an expected amortized analysis with an adversarial scheduler and provide upper bounds on the expected runtime of each operation.
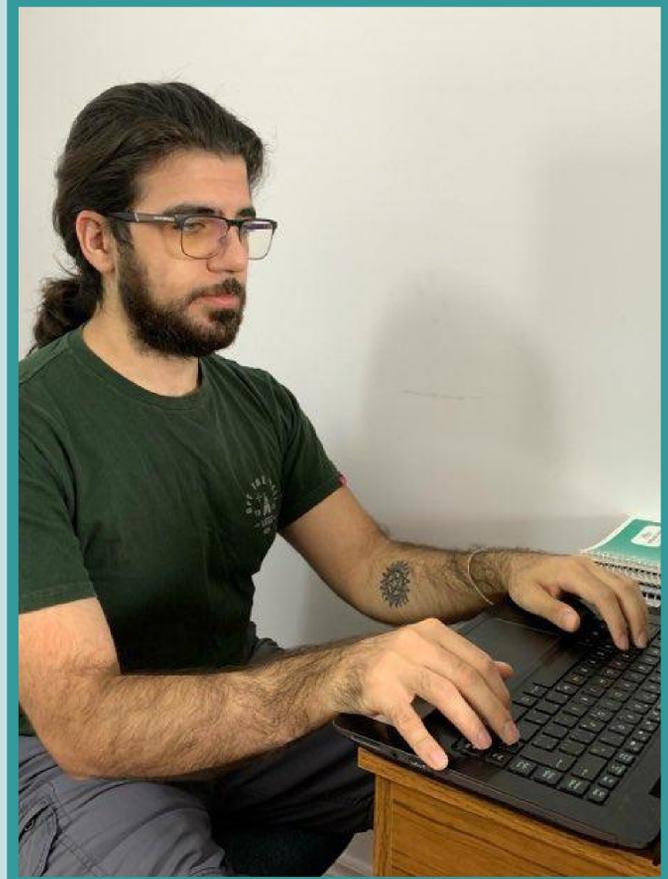
Multiple Pedestrian Tracking (MPT) Over Distributed Camera Network (DNS)

Lixian Lu
NSERC USRA | Supervisor: Aijun An
Dept. of Electrical Engineering & Computer Science

Graphical user interface (GUI) has innovated rapidly since the development of the personal computer, helping to facilitate the use of the computing among daily users, even scientists, with intelligible icons, and clearly navigating interfaces. Before the invention of GUI, computer scientists have to manipulate different data with a command-line interface. However, it acquires a higher level of knowledge of using computers, and it also has limits on displaying complex graphs. The objective of this project is to develop a web-based GUI to present the results of multiple pedestrian tracking (MPT) over distributed camera network (DNS), which is a trend in video surveillance, so that different levels of computer users can see the results of the MPT algorithm. In the project, an MPT algorithm developed by Dr. Al-Shatnawi for detecting and tracking pedestrians over videos is provided. My task is to develop a web application that not only has the function to read and display video frames from different camera feeds, but can also extract the data from a GPU server where the MPT program is run. I first develop a website where the user can select different video resources including live videos, and that can display the corresponding video frames by using Hypertext Markup Language (HTML), Cascading Style Sheets (CSS) and JavaScript. After finishing the GUI of the website, I use Python Flask to deploy the web framework to connect with the server and the website so that we can extract the results from the server, and use the OpenCV module from Python to enable the visualization of the deep learning results from the algorithm. The developed GUI allows the user to see the multi-pedestrian tracking results easily without worrying about the use of computing on the server-side.

Experiential Education in Engineering and Science Education

Maitriben Patel
LURA | Supervisor: Llewellyn Mann
Lassonde Education Innovation Studio

Engineering and Science education has seen many developments in its format recently including many innovative approaches to pedagogy that have proven vital to delivering a first-rate learning experience. The team at Lassonde Education Innovation Studio (LEIS) has been exploring global emerging trends in education, and this project focuses heavily on four key trends: Blended Learning, Experiential Education (EE), 21st Century Skills and Students as People. This research examines EE in greater detail and analyzes examples of universities that have implemented it successfully. The research developed a scenario showcasing ways that EE could be scaffolded into the student experience. In order to collect qualitative results, a short animated video visualizing a possible student experience in 2030 was made and shown to focus groups involving voluntary students, faculty, staff, and senior leadership. After showing the video, they were asked a few questions and their responses were analyzed by identifying emerging themes with validity and reliability ensured through inter-rater coding. The results helped the team develop an understanding of difficulties and opportunities regarding a potential future implementation of the vision. These results informed the broader research agenda of LEIS supporting the curriculum development. Short term, the results would guide the faculty in providing the best experience to students in the midst of a global pandemic. In the long term, the results would aim to guide the faculty by making use of research findings involving work-integrated and community-based learning alongside the traditional course-based model to enhance student experience in a way that makes Lassonde stand out in the landscape of engineering at national and global level.

Multi-agent Decision-Making for Autonomous Vehicles Using Reinforcement Learning Under a Game-Theoretic Model

Naeem Model
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The goal of an autonomous driver (agent) is to maintain a desired speed while preventing collisions with other vehicles and objects in its environment, from one location to another, subject to specific rules. Reinforcement learning (RL) methods continue to prove effective in teaching autonomous drivers (agents) to optimally control vehicles, with respect to a stationary environment. While the goal of a single agent is clear, the challenge of defining a common goal arises when placing multiple agents in the same environment. Furthermore, since the environment becomes non-stationary, every agent must take into account the presence and actions of all surrounding agents. As such, a pure RL approach is not suitable for this problem, for even if a concrete goal is defined, it would be computationally expensive. In this research, we instead consolidate RL using level-k theory, a hierarchical model based in game theory. Using this model, an agent learns to make decisions at a certain level by assuming all other agents to be reasoning at the preceding level. Consequently, two types of drivers, cautious and aggressive, are acquired, and used to train a third type of driver that navigates an environment consisting of both. Achieving cooperability via this method, in a high-fidelity simulation environment using realistic sensory inputs, not only provides further validity for the unification of RL and game theory as a decision-making tool, but also insight into its viability for controlling real-life vehicles.

Seasonal Variation of the Cold and Bright Anomalies on the Northern Polar Layered Deposits

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Polar regions of Mars have been shown to greatly influence the seasonal changes seen on the entire planet because up to 30% of the atmosphere condenses onto the surface each winter (Leighton and Murray 1966). For this reason, there is a large effort to study various aspects of the polar regions. In our project, we aim to better explain the presence and processes of the Cold And Bright Anomalies (CABA) (Kieffer & Titus 2001), that appear during on the northern ice during northern summer. These regions remain more reflective and colder than surrounding regions until autumn, when those bright regions become the darkest locations on the cap within a matter of few hours. To study the anomalous behavior, we employed daily observations from the Mars Color Imager (MARCI) combined with small-scale observations from the Thermal Emission Imaging System (THEMIS) and topographical data from Mars Orbiter Laser Altimeter (MOLA). We supplemented these observations with wind models to create a timeline of processes that explain the CABA. We found that the formation of the CABA is due to reduced wind activity in specific regions (Smith & Spiga 2018; Spiga & Smith 2018), whereas nearby regions have much heavier winds that remove fine-grained (bright) frost. Later in the summer, when the surface rapidly darkens, we observe large scale storms emanating from the CABA locations, now removing the bright frost from the CABA. Our hypothesis matches all observations data and so the next steps are to perform numerical simulations and compare wind patterns and surface temperature. Additional temperature and visual observations will be collected to expand the current timeline.

Long-Range Transport Mechanisms of Microplastics through the Atmosphere: How Geometry of Fibrous Microplastics Influences the Settling Velocity

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Microplastics (MPs), fragments smaller than 5 mm, are a by-product of humanity's mass synthesis of plastics. Unprecedented amounts released into the ecosystem with unknown effects, has caused concern and initiated a great number of research efforts into the field of MPs. However, only 2% of studies focused on the atmosphere (Akdogan et al. 2019). Field observations reported by Bergmann et al. 2019 and Allen et al. 2019 show MP depositions in remote locations (like Arctics), and urban observations reported by Wright el al. 2020, Cai et al. 2017 and Dris et al. 2017 show MP depositions in metropolitan areas. In order to better understand how MPs can travel long ranges and to facilitate back trajectory analysis, the terminal velocity of MPs and factors which could influence it must be studied in detail. Terminal velocity is a nonlinear function of the atmosphere and the MP characteristics. The MP chemical compositions are limited, the geometry of MPs can vary. We developed a model to estimate the terminal velocity, Reynolds number and coefficient of drag of spherical MPs, using an iterative process based on Song et al. 2017 for different latitude characteristics of the atmosphere. The next step was to expand into modeling fibers, with cylindrical shape, using the corresponding sphericity factors and aspect ratios. Parallel to these steps, we also developed two different types of fall chambers and an observation setup to record the terminal velocity of the falling specimens. The experimentation will begin in September and the project will span over several years and it will enhance our understanding of MP distribution mechanisms in the atmosphere.

3D Printing Manufacturing Methods for Collagen-Based Scaffold Production in the Cultivation of Hematopoietic and Mesenchymal Stem Cells for Bone Marrow Tissue Engineering

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This research entails the design and manufacturing of laboratory tools to accelerate and optimize the fabrication of collagen-based, 3-dimensional scaffolds for bone marrow tissue engineering. Hematopoietic stem cells (HSCs) and mesenchymal stem cells (MSCs) reside in the bone marrow tissue within the extracellular matrix (ECM); their proliferation and differentiation are studied in response to the modification of the mimicked ECM to elucidate optimum scaffold composition and architecture for supporting cell viability. The dispensing of collagen slurry is first optimized for ease of use and deposit uniformity by designing a tool attachment on SOLIDWORKS. This tool will be compatible with vinyl tubing connected to a syringe pump, while allowing for the attachment of pipette tips through which the collagen can be easily deposited into a high-throughput dish. In order to account for the back pressure and losses due to the high viscosity of the slurry, suitable tube length and nozzle diameter must be selected through design iterations and prototyping with PLA 3D printing. Micro-vascular designs on SOLIDWORKS are also completed for possible scaffold structures once access to a wax 3D printer is available. The optimization in the production of porous scaffolds through the mechanical design of tools and simulated scaffold structures for additive manufacturing purposes will give the lab better insight into the cultivation of HSCs and MSCs outside of the human body. This novel approach to stem cell research can provide scientists with the means to engineer bone marrow tissue and develop drug screening procedures on bio-engineered collagen scaffolds to identify possible treatments for leukemia and other bone related illnesses.

Augmented Reality-Based Indoor Navigation and Visual Cognition Assistant for the Visually Impaired

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The Intelligent Systems for Sustainable Urban Mobility (ISSUM) project (Sohn, Elder, et al.) aims to create a digital twin of an urban environment by generating a virtual scene of buildings, objects, people and information gathered from the real world. A modular platform is developed for sensing, analysis, assistance and 3D visualization of urban movement in a campus context. The project has five distinct areas of research that will be integrated at the completion. This study focuses on one particular user application of the Augmented Reality (AR) module of the platform that utilizes the stored 3D models to provide location-aware services. Visual impairment affects billions of people and reduces a person's mobility and confidence to navigate. In an aging population, this issue poses a barrier to performing daily tasks such as indoor wayfinding, especially in unfamiliar environments. We develop an AR based solution with the help of Microsoft's wearable headset, the HoloLens 2. This device utilizes the onboard cameras and sensors to convey visual knowledge and assist the visually impaired user to navigate an indoor environment intuitively. The user interacts with the system via voice commands and guidance. The system provides essential aspects of visual cognition like navigation, obstacle avoidance and scene understanding. We utilize 3D indoor models and HoloLens scanned spatial maps for mapping and dynamic wayfinding. The use of 3D models will enable an easier and automated approach to asset creation that will help us to scale the system across the entire platform. On integration with the parent platform, this system can be extended for use with accessible navigation for the disabled and emergency navigation for first responders.

Synthesizing Organic Polymers for Rechargeable Battery Electrodes

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The global demand for energy, which spurs our use of fossil fuels, continues to increase despite the resulting pollution and rapidly changing climate. This has initiated a strong demand for storing energy produced from intermittent renewable sources like wind and solar and to integrate them into city grids. However, present large-scale energy storage practices can only store a fraction of the renewable energy being generated. Further, state-of-the-art rechargeable battery materials contain elements that are toxic, costly and not abundant making them unsuitable to scale for global power consumption. Using organic materials as battery electrodes is beneficial as they are non-toxic, use abundant elements, and materials can obtain unique properties from synthesis techniques and the diversity of organic molecules. My research focus is on creating organic polymers as electrode materials for rechargeable batteries. Viologen is an attractive organic molecule for rechargeable electrode materials due to its highly reversible electrochemical properties. I am incorporating viologen into polymers with varying amounts of molecular structures designed to improve ion conductivity, electron conductivity, and decrease solubility to optimize battery performance. Specifically, I am looking at how the final composition of the viologen polymer can be tuned to maximize how quickly the electrode can be charged and discharged, while minimizing electrode degradation with repeated use. This will increase the power output and reliability of organic electrodes, allowing this technology to be translated into grid-scale energy storage systems that are cheap, sustainable, and non-toxic. Organic electrodes are promising technology that is necessary to achieve a fully sustainable energy economy.

The Analysis of Groundwater Recharge Models and Climate Data

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The climate is constantly evolving and therefore it is important to understand how this change can affect geotechnical and geo environmental applications. The objective of this research is to create user interface programs that can analyze groundwater and climate data from HYDRUS-1D. Groundwater recharge is the flow of water through the vadose zone. If more water is discharged than recharged, then it is possible to run out of groundwater. Climate change can negatively impact groundwater recharge. Dry weather can reduce the amount of recharge and thereby reducing the quantity of water that is available in the ground. Groundwater flow through the vadose zone can be modelled using HYDRUS-1D which can estimate recharge for changing climatic conditions. In order to create the user interface programs, it was important to first understand the results from HYDRUS-1D. Historical climate data and soil information can be inputted to HYDRUS-1D models. One can calculate precipitation, the actual evaporation, evapotranspiration, net infiltration, baseflow, and flux using the output results. The user interface program is a generalized program that can calculate the variables mentioned as well as plot relationships between those variables to further understand and compare annual climate variations. MATLAB was used to generate this program. The results reveal data that can be analyzed further to estimate recharge and understand the impact of climate change. Different soil types possess various hydraulic properties which can affect the groundwater recharge rates. Groundwater is a crucial need for many as it is used as fresh water supply around the world. Understanding the climate impact on recharge will allow us to be better prepared for the future.

An Investigation into the Sources of PFAS in Canadian Wastewater Treatment Plants

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Perfluoroalkyl substances, or PFAS, are synthetic organic compounds that are used in a myriad of everyday items due to their stability. However, it is precisely this innate stability that presents PFAS as an environmental pollutant. PFAS have been proven to bioaccumulate and biomagnify to toxic quantities and have been found in multiple wildlife and human blood samples globally, including in remote areas such as the Arctic. Consequently, it is crucial to determine the sources of PFAS to sensitive environments. Wastewater treatment plants (WWTPs) are an important bridge between humans and the environment since a large proportion of human waste is processed by these plants before being released into rivers. Although WWTPs are intended to remove pollutants like PFAS from treated water, research has shown that the effluent from WWTPs has greater concentrations of PFAS than the influent. Using measurements of WWTP influent and effluent from 14 WWTPs across Canada, we sought to determine how these WWTPs contributed to PFAS in the environment. This was done by conducting correlations between the different PFAS homologues and relating them to WWTP type and influent.

Modelling Autonomous Vehicle Interactions With Reinforcement Learning and Game-Theoretic Decision Making

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In the near future, autonomous vehicles will operate in traffic together with human-driven vehicles. However, modern autonomous vehicles lack the framework to address automation-automation and human-automation interactions. In this paper, the goal is to create a model that enhances interactions between multiple types of vehicles using game theory and reinforcement learning. The environment used for the agent was an open-source traffic scenario simulator. To reflect the noise present in real-time driving observations, the environment's observation space (the agent's input) was customized into a set of discrete values in the following categories: distance, direction, and motion of surrounding cars. In training, the agent learned in a four-way unsignalized intersection using Deep Q Network (a deep reinforcement learning algorithm that has been successful in similar environments). Using the level-k theory (a framework that assumes individuals make decisions based on the predictions of others' actions), the training process was broken down into case studies where the agent learned to interact one-by-one with passive and aggressive drivers. After this, the agent was put in a scenario where it had to interact with multiple types of drivers simultaneously. The goal of this process is for the agent to acquire an adaptive control strategy, allowing it to deploy a strategy based on the type of driver it is interacting with. The results from this research can open a new perspective on implementing reinforcement learning and game theory to create a model that handles interactions between human-driven and autonomous vehicles. This insight also highlights the importance of future research to investigate road safety involving autonomous vehicles.
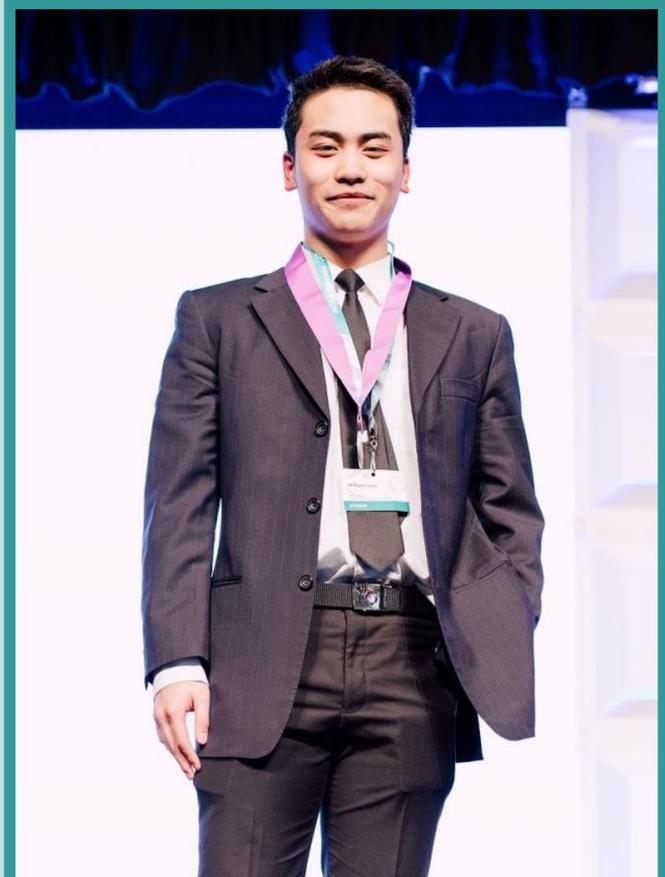
Analyzing Shape Selectivity of Deep Networks Pre-Trained on ImageNet

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Deep convolutional neural networks (DCNNs) achieve excellent performance in computer vision tasks such as classification and object detection. Recent research suggests that DCNNs rely more on objects' local textures rather than global shape when performing these tasks. Humans, on the other hand, rely heavily on shape information. Therefore, a pertinent question is whether we can train DCNNs to better capture shape information. First, I test for existing shape utilization in ImageNet-pretrained DCNNs. Removing global shape information through block-scrambling natural images significantly reduces accuracy, but only if the blocks are small enough to disrupt local texture, suggesting a minimal role for large-scale shape information. To increase the use of shape information, I fine-tuned DCNNs on object silhouettes, which retain only shape information. This improved classification of silhouettes but reduced performance on natural images. To overcome this problem, I froze the parameters in convolutional layers and only fine-tuned the fully connected layers. This led to good silhouette performance and only a slight loss for natural images. This result suggests that maintaining the convolutional "feature extractor" layers is critical to achieving good performance on natural images. I have also trained a multilayer perceptron (MLP) classifier directly on the coordinates of polygons approximating shape boundaries. A VGG16 architecture employing 1-D convolutions attains classification accuracies between 54% - 63%, depending on the resolution of the polygon. My next step is to integrate these shape representations into DCNNs to improve object classification performance.
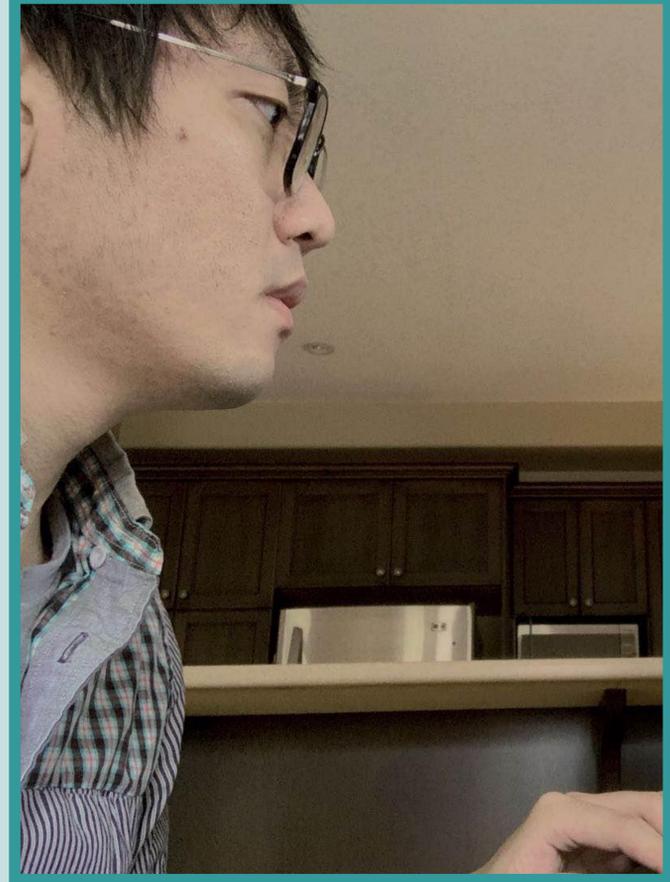
An experimental setup to simulate the martian polar climate

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Mars' polar regions host many interesting processes that have no terrestrial analogues, such as the interacting water and carbon dioxide volatile cycles. The CO_2 cycle in particular lends to forming large ice sheets in the winter, forming in vastly different textures given different pressure and temperature conditions. Metamorphosis of the ice when exposed to light affects the optical properties of the ice, influencing the planetary albedo and energy budget, which are poorly understood. In order to expand our research capabilities, we have designed and put together a chamber capable of reproducing the martian polar climate and condensing CO_2 into ice from the atmosphere using two main pressure and temperature control systems. The pressure is controlled using vacuum pumps and mass flow controllers to add the condensable gas, forming the thin atmosphere. The temperature control uses a combination of liquid nitrogen cooling and electric heating in order to maintain accuracy at +/- 1 K. These systems are being automated in LabVIEW to allow for more focus to be put on the experiments themselves. We have already used this setup to produce CO_2 ice in Martian conditions, recreating many of the textures previously published and intend to enhance this upon resumption of laboratory activities. Our new, much larger chamber will be dedicated to studying planetary ices, and will be conducting reflectivity measurements of CO_2 ice in near UV through IR wavelengths. This chamber will allow for a multitude of different ice-focused experiments to be run and offers great opportunities to deepen our understanding of the icier celestial bodies in our solar system. Our equipment also lends itself to be used for testing technology readiness levels for space instruments that are in development.

An Investigation into the Sources of PFAS in Canadian Wastewater Treatment Plants

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When extracting kinematic variables from video footage, camera calibration and object detection and tracking algorithms must be designed to accommodate computational and time constraints whilst also prioritizing precision. As such, this project aims to define a motion extraction methodology tailored for a new flexible centimeter-scale robot powered by piezoelectric benders. Specifically, a simple, accurate, and computationally inexpensive computer vision solution is sought to inform the experimental setup geometry and to quantify performance. Variables such as camera position and orientation, lighting conditions, and the point of interest's physical characteristics are completely controllable. The first step is to calibrate the camera using a checkerboard pattern and MATLAB's Computer Vision and Image Processing Toolboxes. Following this, a high speed video is taken of the mechanism in action and its motion extracted with a Simulink model. Finally, kinematics are computed using outputs from the developed programs. For a scene roughly 50 x 30 cm observed at a distance of 60 cm, a mean reprojection error of 0.6 px +/- 0.39 px (3.0 +/- 1.9 mm) or better is achieved.. A reduction of up to 50% in this metric is expected once this method is implemented with scientific equipment. Furthermore, the tracking algorithm displays a mean error of 1.31 +/- 0.72 px when subjected to an artificial detection polluted with Gaussian, salt & pepper, and speckle noise. Precise kinematic data will allow comparisons between expected and observed motion of this piezoelectric mechanism, which in turn will demonstrate its feasibility and perhaps improve theoretical kinetic models. They will also be used to provide closed-loop feedback for lower rate tasks in the future for small-scale robotics.

Biology SARS-CoV-2 Infection effects on MAPK signaling pathway and mechanism of the regulations

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The pandemic coronavirus infectious disease (COVID-19), caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has infected millions and killed hundreds of thousands of people all around the world and there is an urgent need to develop antiviral therapies.SARS-CoV-2 is a novel coronavirus with unique properties that contribute to its pandemic-scale spread.SARS-CoV-2 infection is commonly asymptomatic and contagious before showing any symptoms. These unique characteristics of SARS-CoV-2 could be explained by changes in the cellular pathways and regulations. Large changes were observed in protein phosphorylation which highlights the fact that SARS-CoV-2 uses post-translational regulation to make changes in cellular signaling. Changes in protein phosphorylation reflect alterations in kinases activities. p38/MAPK signaling pathway is one of the most regulated pathways during infection. An increase in activity of p38/MAPK signaling pathway during infection causes pro-inflammatory cytokine production such as IL-6 and TNF-α. These changes have been observed in many severe COVID-19 cases. In our previous study, we have shown that MEKK2(MAP/ERK kinase kinase-2), a serine/threonine kinase, which is one the kinases in MAPK signaling pathway can be regulated by adaptor protein 14-3-3. We have previously shown that Thr-283 is one of the regulatory sites on MEKK2, and studies have shown that Thr-263 should be the other site of regulation as they both involve in autophosphorylation. We believe finding out the exact mechanism of MEKK2 regulation could be beneficial to produce drugs that can be used in the future. Currently, 87 FDA-approved drugs, that are altering some signaling pathways, are being used in clinical trials in hopes of getting a promising result.

Single Camera High-Speed Stereo Digital Image Correlation Using an X-Cube Prism

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Digital image correlation(3D DIC) is used to determine the deformation and strain field of an observed specimen. Braided composites (BC) are materials composed of an interwoven structure within a resin matrix. In laminated hybrid BCs, different materials are layered together for superior properties over BCs composed only of individual constituents. Due to the non-homogenous structure of BCs, the properties of these materials need to be determined using optical measurement techniques. 3D DIC using high-speed cameras can offer valuable insight into the damage and failure of BCs; however, high-speed DIC is difficult to perform. High-speed cameras are expensive ($100k+) and are difficult to synchronize. Given these factors, a lower cost single-camera 3D DIC imaging setup has been proposed which is 16% the cost of an additional high-speed camera. In this setup, two different views of a sample are reflected into an x-cube, a prism with red and blue filters, enabling the blue and red light from either perspective to be reflected into a camera and recorded as a single image. That image is subdivided into red and blue channels serving as a stereo set using a post-processing algorithm. To determine the effectiveness of this setup, the single camera stereo setup will be used to determine the curvature of a specimen and contrasted with the results from standard DIC imaging with two cameras. Once the quality of this method has been established, the proposed single camera setup will record the damage and failure of laminated hybrid BCs during mechanical testing. Testing methods include tensile testing and pendulum impact testing. This setup serves to increase the accessibility of 3D DIC testing for other advanced materials in industry and academic settings.

Unsupervised Machine Learning for User Association in Wireless Networks

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In this work, we investigate unsupervised machine learning algorithms to solve the fundamental user association problem in a heterogeneous wireless network where conventional radio-frequency (RF), terahertz, and millimeter-wave networks coexist. The user association problems belong to the category of integer linear programming (ILP) problems. Majority of the existing literature considered either reinforcement-learning or supervised learning solutions to determine optimal/near-optimal user associations. However, the reinforcement-learning solutions are not scalable for large dimensions of actions and states. On the other hand, supervised learning methods rely on predefined and computationally-intensive optimal solutions (aka labels) to train the neural networks. As such, our objective is to devise novel low-complexity unsupervised learning algorithm to optimize user associations while maximizing network data rate. The algorithm will capture unique network features of RF, terahertz, and mm-wave networks such as spectrum bandwidth, channel propagation characteristics, and the varying number of users that can be supported across different types of networks. We train the deep neural network (DNN) with the channel state information (CSI) generated synthetically on Matlab and minimize our cost function as a function of hyper parameters (e.g., number of layers, number of epoch, batch sizes, neurons per layer, etc.). The output of the trained DNN will be validated using the solutions from optimal Hungarian algorithm.

Modeling Droplet and Aerosol Spread for Minimizing Airborne Transmission of COVID-19 and Other Diseases in Public Spaces

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The preliminary goal of the research project is to characterize the spread of droplets and aerosols from an average human cough. The purpose of studying cough flow dynamics is to predict and minimize airborne transmission routes for viruses such as the current SARS-Cov-2 (also known as COVID-19) and other airborne disease. Viral particles primarily spread through infected patients' droplets and aerosols, released from coughing, sneezing, talking and other exhalatory actions, leading to airborne transmission. Airborne transmission can especially be exacerbated in indoor spaces, where existing ventilation and filtration measures are not designed to prevent aerosol transmission. This requires further investigation. In this initial study, a numerical analysis using ANSYS Fluent 2019 was used to compute various spread parameters. The simulation was initialized as a transient, turbulent flow with an injection of water particles at an initial velocity, inlet diameter, spread angle, among other parameters at varying ambient conditions. Sensitivity analysis for various turbulent models and solver settings will assist in validating the numerical model, as well as future experimental comparisons. These findings will eventually assist in making indoor spaces safer and providing defensive measures against viral pandemics.

Flexural Behaviour of Ultra-High Performance Concrete Beams Reinforced with Smooth Reinforcement

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This research aims to quantify the impact of ultra-high performance concrete on the load-displacement response of beams with smooth reinforcement. As economic and human losses due to seismic activity increase, researchers have investigated methodologies to improve structural seismic resilience. A promising solution replaces traditional deformed steel reinforcement with Shape Memory Alloys (SMAs); smooth reinforcing bars. While improving seismic performance, unlike traditional deformed steel, SMAs show weaker bonding to the surrounding concrete. To quantify the bonding phenomenon of smooth reinforcement, 8 beams were constructed from normal strength concrete as the control and Ultra-High-Performance Steel Fibre Reinforced Concrete (UHP-SFRC), a high-performance alternative. For each concreting material, 4 beams were cast, varying in reinforcement type, smooth or deformed, with hooked or straight ends. Beams were tested under four-point bending using a Universal Testing Machine (UTM) to determine flexural strength. Simultaneous measurements using a linear potentiometer and Digital Image Correlation (DIC) determined midpoint vertical displacement. Slip displacements were measured in the beams reinforced with straight bars. DIC was found effective in correcting the displacement data reported by the UTM, proven by a high level of agreement to the linear potentiometer data. Use of UHP-SFRC reduced bar slip by 70% compared to conventional concrete for the beams with smooth, straight bars. As well, the peak strength of the UHP-SFRC beam with smooth, hooked bars was comparable to using traditional deformed reinforcement. These findings provide confidence in the potential combined application of SMAs with ultra-high performance concretes to improve seismic performance.

21st Century Skills in Engineering and Science Education

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Lassonde Education Innovation Studio

Calls for engineering and science education transformation have been on rise and now listed among the top priorities for future engineers. The team of researchers in the Lassonde Educational Innovation Studio(LEIS) has identified emerging trends of engineering and science education through investigating engineering education journals and education models across the globe. The four main trends were: Blended Learning, Experiential Education, 21st-Century Skills, and Student as People. 21st-Century Skills are what skills engineers and scientists need to thrive in this rapidly changing society. Despite the importance, few universities manage to implement a curriculum that successfully develops these skills. This research aims to investigate how 21-Century Skills, in particular, life-long learning, interdisciplinarity, collaboration, and creative and critical thinking skills can be implemented in engineering and science education. An animated video of engineering education in 2030 based on emerging trends was created and presented to multiple focus groups of senior leadership, students, faculty members, and staff. The team then applied a qualitative research method that involved conducting a focus group to collect data. All Interviews were recorded to be further analyzed with the team to understand different factors that generated that response. The results gave a basic understanding of how different groups react to the scenario and obtained different perspectives related to 21st-century skills development in the scenario, which supports LEIS in curriculum development in the future. This research also provided LEIS the foundation to expand the research on engineering education for Lassonde to reach the highest level of competitiveness in engineering education globally.
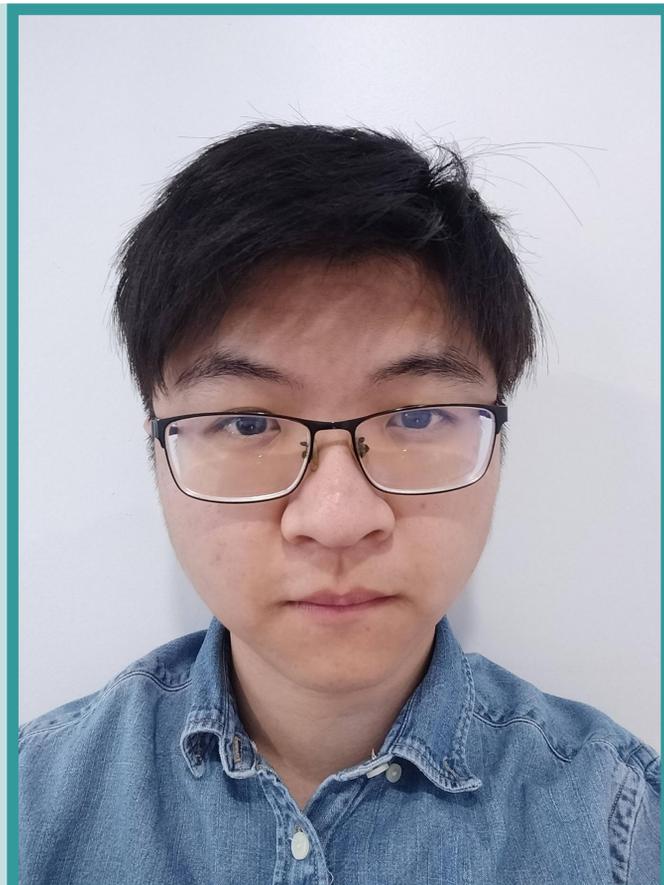
Design and Optimization of the Contraction and Corner Sections of a Closed Loop Wind Tunnel

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LURA | Supervisor: Ronald Hanson
Dept. of Mechanical Engineering

This project aims to progress the research and design of a subsonic, closed loop wind tunnel, focusing on the corner sections and contraction. The components are being designed around a test section of 1m by 0.7m cross section, and limited by the available laboratory space constraints. This work continues previous investigation into the contraction and corners, while adapting to the changing logistical constraints. Design decisions are based on recommendations from the literature and consultations with industry experts. This information provided a starting point for parametric design studies carried out using Computational Fluid Dynamics (CFD) software. By analyzing multiple cases with varied geometric parameters, the simulation study allows for the optimization of the aerodynamic performance of the wind tunnel. Compared to previous results, the contraction inlet size has decreased, leading to reductions in scale of the corner sections and improved diffuser conditions reducing the risk of severe flow separation. The turning vane chord length and spacing were decreased in key areas which improved flow quality. The updated design will allow a larger, more capable wind tunnel to be constructed in the relatively limited laboratory space. Being the first of its kind at York University, the wind tunnel will greatly expand the capability for on-campus experimental research, and reduce our dependence on external facilities. The wind tunnel will allow for experimental testing of aerodynamic phenomena with high levels of precision, flexibility, and repeatability. The simulation results and design decisions will add to the existing state of knowledge of wind tunnel design, which may better inform future wind tunnel designers.

Perceptions of Languages and Bilingualism

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Research on the potential effect of bilingualism on cognition has recently seen much debate around conflicting results. Part of the conflict may be attributable to differences across studies in how "bilingualism" is defined. This includes questions surrounding what types of language skills are required to be considered bilingual and how bilingualism itself is measured. Another aspect of this confusion is absence of a clear sense of what constitutes a language. These issues raise the question of what individuals themselves consider to be the necessary criteria for being bilingual or for a system being a language. Furthermore, questions arise when studies attempt to classify participants into categorical groups (i.e., monolingual vs. bilingual) as there is growing evidence that the actual effects of bilingualism are tied to details of the bilingual experience and not a binary classification into a group. Therefore, the present study explored the ways in which language experiences are fluid and continuous and the perception of individuals around those definitions. Participants were shown hypothetical language and bilingualism scenarios and were asked to judge the extent to which the scenario described a unique language or a bilingual individual. The results revealed great variability in the perceptions of languages and bilingualism, giving more credence to the findings that bilingualism is not categorical and that language experiences are important markers of what constitutes a language and what is the necessary criteria for being bilingual. These results have important implications for future research in that it highlights the importance of clarifying the languages under investigation and the language experiences of the participants.

Design and Implementation of a High-Accuracy Low-Cost Novel Sun-Sensor for Nanosatellite Applications

Fuat Kaan Diriker
NSERC USRA | Supervisor: Regina Lee
Dept. of Earth & Space Science & Engineering

The main objective of this research is to design, characterize, and implement a novel sun-sensor design for nanosatellite applications. Nanosatellites are miniaturized satellites with mass ranging from 1 to 10 kilograms. Sun-sensors are among the most widely used attitude sensors to determine the orbital orientation of a satellite with respect to the Sun; however, due to cost, mass, and implementation complexity of fine sun sensors, CubeSat (a class of nanosatellites with 10x10x10 cm form factors) are often designed with coarse sun-sensors instead, limiting CubeSats' ability to perform missions that require high pointing accuracy. The novel sun sensor design provides an inexpensive and lightweight alternative to commercially available fine sun-sensors. Prototype sun-sensors are scheduled to fly on DESCENT and ManitobaSAT-1 satellites to demonstrate the technology on-orbit. The current project is to fully characterize the prototype sun sensors and design the next generation digital sun sensor as a commercial off-the-shelf product. Numerical simulations along with hardware design, calibration, and software development are included in the scope of the project. The sun-sensor features up to 0.3-degrees accuracy in 1-bit and 0.14-degree accuracy in 2-bit readout modes, with over 100-degrees field-of-view. The new sensor will improve the attitude knowledge of a typical CubeSat, enabling host CubeSats to perform challenging missions such as high accuracy Earth observation and space debris tracking missions.

Design and Optimization of the Contraction and Corner Sections of a Closed Loop Wind Tunnel

Harsh Patel
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Dept. of Earth & Space Science & Engineering

Unmanned vehicles have a wide range of applications from self driving cars to military aircrafts. Most of these applications rely on a Global Positioning System (GPS) for localization and navigation. While GPS is quite reliable outdoors, it is unreliable and inaccurate in an indoor environment. The aim of this research paper is to provide an alternative localization and navigation method for unmanned vehicles in an indoor environment. There are many alternative localization methods such as radar, camera tracking, wifi systems and vision based systems. This research project will focus on vision based localization and navigation systems using April tags as fiducial markers. This decision was made due to its low cost, better reliability, stability and ease of set up. An indoor environment was simulated using Gazebo (a 3D dynamic simulator). A Turtle bot was simulated as an unmanned vehicle. Multiple April tags were simulated as fiducial markers in the environment. These April tags provide the Turtle bot with precise pose estimate upon detection by the Turtle bot's camera. This enables precise navigation. After integrating April tags into the simulated environment, rviz (a 3D visualization tool) is used to map the simulated environment for faster and efficient localization and navigation. This research can provide insight into the merit of using fiducial markers for localization and navigation in an indoor environment.

Influence of Environmental Characteristics on Crowd Behaviors for Crowd Simulation Software Applications Explained through Cognitive Biases and PADM

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Crowd movement software is an emerging technology used to model pedestrian dynamics. This software can be used for verification and validation of engineered designs. Egress modelling of stadia, for example, can display crowd behaviors in different scenarios to ensure safe egress of all occupants. Modelling crowd behavior requires a comprehensive understanding of pedestrian, building and environmental characteristics, and their interdependent relationships. Models additionally rely on project-specific input data to accurately represent the population demographic and the corresponding vagaries in human behaviors. The current state of research however does not provide the extensive data required for all project-specific applications. Moreover, there is little work done to thoroughly address how variances in environmental characteristics, such as motivation differences in normal egress scenarios versus emergency evacuations, influence crowd movement and the individualistic behaviors within it. The research herein, analyzes and compares crowd egress of three events displaying the following variances in evacuation urgency at Canadian stadia: standard post-game egress, egress under high-motivation conditions (rain), and emergency (fire) egress. Two additional case studies of other notable fires are also included. Observations regarding egress behavior, pre-movement, and other factors are highlighted. Results indicate the egress behaviors differ in relation to the level of urgency. Dominated by behavior and decision making, the results are further explained through Cognitive Biases and Protective Action Decision Modeling (PADM).

A Comparison of Methods for Calibrating SWMM Rainfall-Runoff Models Using Genetic Algorithms

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Hydrological models are important for forecasting floods and predicting surface runoff. However, the calibration, validation, and verification of these models is difficult since these models rely on simplified mathematical representations of complex natural systems. The calibration process can be very time-intensive, especially when done manually, and can result in inaccurate estimates of flood forecasts. Various algorithms have been used to automate the calibration process, however, these models require several user generated inputs, such as the number and type of rainfall events. This research focuses on comparing different event types and combinations for calibrating SWMM (Storm Water Management Model, a widely used hydrological model), within a calibration framework that uses genetic algorithms. The effect of different event types on calibration performance is measured and compared. Initial results suggest that significant differences exist when using single events compared to multiple events. Future research involves investigating other calibration scenarios, such as using n events in a sequence.
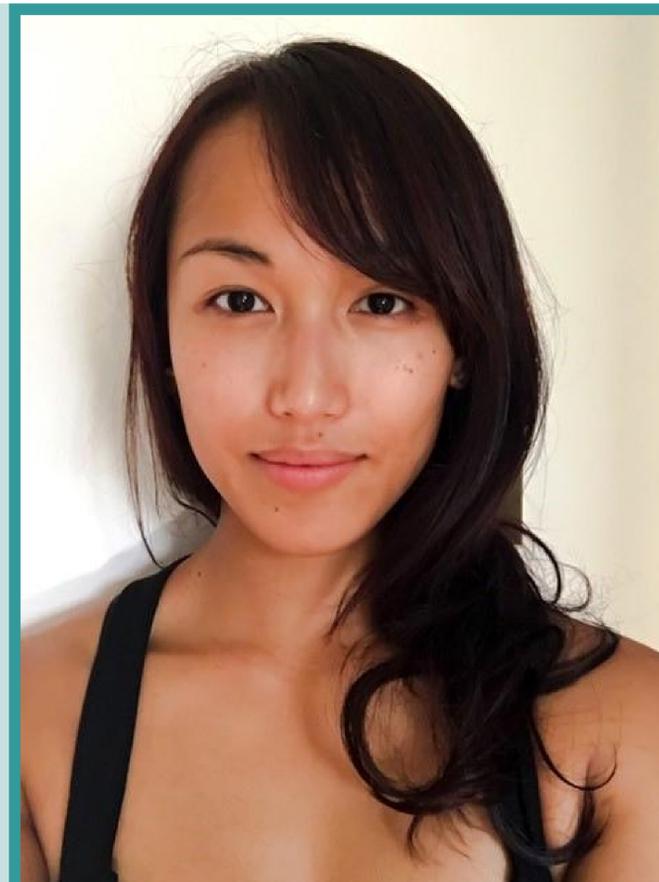
Epigenetic Mechanisms of Maternal Care

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Maternal care is a phylogenetic precursor to social behaviour in many animals. While most animals are solitary, some remain with their offspring to provide prolonged maternal care due to harsh selective pressures in their environment. This prolonged investment in offspring is thought to have evolved because of the fitness benefits it provides to the mother. However, little is known about the molecular mechanisms underlying care behaviour and the lasting effects on offspring. Studies on rodents have shown that prolonged maternal care results in developmental changes in offspring, supported by genetic data that revealed associated differential gene expression and DNA methylation patterns responsible for fear and anxiety responses. The Rehan lab has developed the small carpenter bee, Ceratina calcarata, as a model insect system to examine the mechanisms for mutual tolerance and early childhood development. Here we characterize if the loss of maternal care alters brood development, and determine which stages of maternal neglect yield pronounced behavioural and gene expression differences in young adults. We are developing lab based protocols to experimentally observe bees reared in the absence of maternal care to determine their likelihood to engage in maternal care towards their own offspring. The heritability of epigenetic changes remains an open question in the field of behavioural genetics. Preliminary data suggest the same neurodevelopment and metabolic pathways are conserved between mammals and insects. Studies on insect sociality will not only inform hymenopteran social evolution specifically, but cooperation and conflict generally. These data can be used to inform early childhood development, maternal care, stress and anxiety response in insect and human societies.

The Future Scenario of Student as People in Science and Engineering Education

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Lassonde Education Innovation Studio

With the advancement of technology and the rise of 21st century global challenges, the science and engineering education field has globally recognized the need for curriculum development to accommodate these changes. This research is a component of a project within Lassonde Educational Innovation Studio (LEIS) where emerging global trends in engineering and science education were explored to create a possible scenario of educational experience at Lassonde in 2030. The scenario incorporated the four key trends: Blended Learning, Experiential Education, 21st Century Skills, and Students as People. This research focuses on Student as People and humanistic developments throughout the years of education. Topics such as Empathy, Socially Engaged Engineering and Peace Engineering have been investigated. Furthermore, focus groups were formed with stakeholders such as students, faculty and staff, and senior leadership. During focus groups, an animated video of the scenario was shown and a series of questions were asked on Students as People and the other three trends, to understand each group's view on the futuristic vision. The responses were analyzed as a team to identify factors such as actuality and challenges of working towards making the vision achievable. As a result, empathy appeared to play a key role in a student's career success. Additionally, core values such as compassion and interests which form one's self-identity appeared to urge concern for public welfare. These traits can be built into the curriculum through classroom exercises and socially engaged community development projects. The final results support additional research at LEIS in the journey of aiding faculty and staff at Lassonde during the process of curriculum development in the years leading to 2030.

Automatic Segmentation of Breast Tumors in Ultrasound Images using Deep Convolutional Neural Network

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Automatic tumor segmentation is one of the most demanding areas of research in the interface of cancer imaging, machine learning and AI. The tumor segmentation process is similar in nature to any other image segmentation task, however due to uncertainties in detecting the tumor borders in medical imaging it is a challenging task in clinic. For this reason, tumor segmentation has traditionally been performed manually by expert clinicians with years of training. The overarching goal of this research is to develop a robust and reliable framework for automatic segmentation of breast tumors in ultrasound images using deep learning methods. Here, we present a Unet-based deep neural network (DNN) architecture that inputs ultrasound data frames acquired from the breast, and outputs accurate tumor segmentation masks in near real-time. The Unet is a recently introduced DNN architecture that is well-known for its advantage in providing an optimum solution to the trade-off between context and localization accuracy in image segmentation. The data used to train, validate, and test our segmentation framework was acquired from two breast ultrasound databases containing images of 287 patients. The dataset was randomly partitioned into subsets of 202, 30, and 55 patients for training, validation, and testing the developed framework. The data was pre-processed to obtain an input frame size of 512×512 pixels using a bi-linear interpolation based down-sampling. The results of this study can pave the way for development and optimization of automatic systems for non-invasive tumor characterization and therapy response monitoring. Studies such as this contribute to the cutting-edge research in tumor segmentation to enhance patient care and act as substitutes for when human resource is scarce.

Transaction verification for BlockChain in the Power Grid

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Due to the concerns raised by the global warming and given the recent technological advances made, the need to utilize clean and sustainable energy and to harness the potentials of renewable energy sources, have become increasingly popular. Every day, more households are switching to generating their power from solar panels, and governments invest more in hybrid systems, such as wind and solar electric networks. However, one of the challenges that push us back from fully implementing hybrid power networks is the inconsistency of the generated power. It can change based on season, weather, and the time of the day. With more residentials switching to solar panels, they can sell their excess energy by injecting it into the power grid. With hybrid power networks, there is a need for an effective mechanism to measure the amount of power added to each line, especially when it's being sold. Previously, there have been some works done with an attempt to address this issue by a centralized approach, assuming that they have access to all the information regarding the network. In our study, our focus is on a decentralized approach, meaning that we tackle the problem with having access to the information of only a few nodes (buses) of the network. Then using Data-driven methods we try to solve this problem. We evaluated the results of several learning models. The outcome is promising on small-sized grids. By the end of this project, we hope we can expand our work to large-scale power grids. This project increases the pace at which the old power generators are changed and upgraded with green ones and at the same time enhancing the security of the network and creating financial incentives for both government and citizens.

DNA Storage:
A digital microfluidic emulator

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Every year, the need for more data storage becomes increasingly critical. Current data storage technologies such as hard drives are reaching their physical limits. Nonetheless, our ancient biological storage: DNA, holds the key to this escalating data storage problem. DNA storage promises to be a high-density data storage and can maintain its overall integrity for thousands of years. However, the physical storage of DNA material, a long sequence of nucleotides presents a challenge. To address this challenge, Newman et al. reported a DNA storage method using digital microfluidic (DMF) techniques to move and store the DNA material. To store a large amount of data, many physically isolated positions are required to share the same addressing scheme. This research aims to develop a novel emulator with addressable read and/or write (R/W) operations. This emulator consists of a microcontroller connected to a LED array that mimics a DMF electrode array. This emulator also includes a graphical user interface allowing the development of a set of R/W micro-operations such as load the address, shift/move the sample via a pathway, leave/latch the sample in the parking. The achieved results of this project include the design and implementation of an emulator using Arduino Mega 250, a 32 X 16 RGB array and a JavaScript program. Using the developed platform, two complete R/W strategies were developed. This programmable emulator proves critical for investigating various strategies dedicated to the development of universal DNA memory architecture by developing a novel emulator. The outcomes of this research have created a unique interdisciplinary training opportunity to take the first step toward the leadership role in the field of DNA storage.

Synthesis of Symmetric Biphospholes for
Systematic Structure-Property Studies

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There is currently a global energy crisis that calls for scientists to seek out environmentally friendly, sustainable energy technologies. To combat this crisis, organic electronics, such as OLEDs, are developed to replace traditional devices. The performance of these sustainable devices is governed by the efficiency of electron-donating (p-type) and electron-accepting (n-type) materials used in their development. There is a demand for more stable, high performing n-type material considering corresponding well-established p-type materials. Phosphole systems are intriguing easily modifiable, electron accepting scaffolds that serve as highly fluorescent building blocks for P-P bridged dimers. The step-conjugated architecture in these dimers enables 3D-electron conductivity that imparts strong charge-transfer capabilities. The electron-accepting property of these scaffolds can be further improved by the incorporation of functional groups on the main framework. The symmetric functionalization can efficiently improve the optical properties and the stability of these systems, which is verified computationally by Density Functional Theory (DFT) calculations.
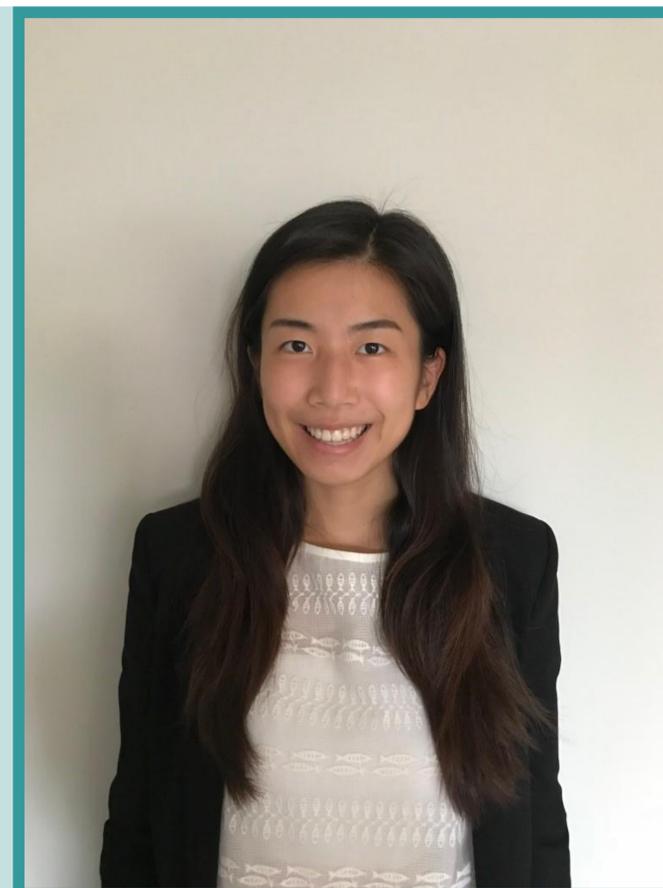
Performance Analysis of Uplink and Downlink NOMA
in a LEO Satellite Communication System

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Non-orthogonal multiple access (NOMA) differs from orthogonal multiple access (OMA) schemes as it serves multiple users in the same frequency/time block and has the potential to provide enhanced resource utilization in wireless networks. NOMA is therefore a promising strategy to enable massive connectivity and reduced-latency in satellite communication networks with limited wireless resources. Compared to geostationary earth orbit (GEO) satellites, a low earth orbit (LEO) satellite network has distinct characteristics such as reduced round-trip transmission latency and a higher Doppler shift due to the satellite's high velocity. We investigate the bit error rate, outage probability and ergodic capacity of users in the downlink and uplink NOMA considering dynamic LEO satellite communication system. The performance is measured as a function of user location, visibility time, and elevation angle of the satellite. For simplicity, we considered the coverage area of one LEO satellite and two users i one spot beam. User pairing schemes are then developed to ensure the performance gains of NOMA over OMA achieved by each user in a NOMA cluster. A use case study of satellite NOMA will be finally considered in mobile edge computing applications where it is important to guarantee that the user will be able to complete its tasks before losing its connection from the satellite.

Geomagnetic Storm
Influence on Swarm Space Mission

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The Swarm Space Mission investigates Earth's magnetic field and upper atmosphere. On August 25-26 2018, a major geomagnetic storm occurred. It is known that intense space weather events have undesirable effects on operation of spacecraft instrumentation. Namely, Swarm's accelerometer (ACC), which measure non-gravitational accelerations (solar radiation pressure, thruster activations, etc.), show severe disruption during the storm characterized by intense spikes. This project performs a rigorous Least-Squares Cross Wavelet Analysis (LSCWA) to determine coherency localized in the frequency and time domain simultaneously to investigate how ACC measurements are affected from electromagnetic disturbances. The analysis is concentrated on an orbit-by-orbit polar region separation and it investigates coherency between Swarm's ACC and magnetic products and its derivatives. Prior to the LSCWA, orbital periodicities have been removed from the signals through least-squares spectral analysis (LSSA) and a low pass filter is employed based on the highest frequency detected in Swarm's magnetic field data products. The LSCWA is conducted during August 23-29 to understand the non-gravitational acceleration and its relation to the geomagnetic storm versus nominal space weather conditions. LSSA allows researchers to analyze unequally spaced time series, in presence of datum shifts and trends with associated covariance matrices. This allows for a spatiotemporal understanding in presence of spikes, bias jumps and gaps, all of which are prevalent in Swarm's data products. As a result, this research would not be possible with classical spectral analysis. A comparative analysis will be demonstrated. Results will derive from this coherency analysis between the geomagnetic storm and ACC data.

InVRQ: A Toolbox for Designing
Virtual Reality Questionnaire

Parth Patel
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Virtual reality (VR) systems are increasingly gaining popularity among researchers from a variety of disciplines. These systems allow researchers to create 3D virtual worlds that offer a reasonable compromise between expensive real-life experiments and simplified experiments conducted on computer screens. A critical aspect of some virtual reality experiments is measuring the participants' experience using questionnaires. However, designing and displaying questionnaires in VR is typically time-consuming and requires advanced coding skills. Therefore, researchers often present paper questionnaires at the end of VR experiences but transitioning from VR to the physical world can disrupt VR presence, lead to disorientation in users, and cost time. As a solution, we are designing a VR asset that will assist researchers in collecting data from users in virtual environments. This asset includes a designer module for designing and presenting questions along with a response module for gathering the data. Thus, the toolbox will provide researchers with a simple interface for designing questionnaires and collecting responses in the Unity Game Engine. It will include options for Likert scales, yes/no questions, and interactive slider-based questions. The feedback retrieved from these questions will also be stored separately so it can be used for further evaluation. This asset will enable researchers to quickly and easily set up questionnaires in the VR scene without the need for any additional coding. The asset can be integrated within an existing VR scene or it can be used as a standalone asset. This asset will also be beneficial for conducting assessments in the virtual world as it will ease participation and avoid disruption of presence.

Action Spotting in Sports Video

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My current research is about action-spotting: detecting specific events happen in a video footage. Particularly, the research I am assisting in is detecting attempts on goal in a hockey video. We extracted frame based features from deep neural network, used a context aware function to try to mine the pattern of a shot.

Performance Analysis of Uplink and Downlink NOMA in a LEO Satellite Communication System

Quynh Phuong Vu
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Faculty of Science

Pattern-avoiding affine permutation represents an interface between combinatorics and group theory, which has been a topic of research interest for decades. Following the attainments made previously, this project, under the supervision of Professor Neal Madras, focuses on assessing various conjectures on the features of a permutation of a given size that avoids a certain pattern. Specifically, the 4231-avoiding permutation is at the center of this project. The Markov chain Monte Carlo methods are implemented using MATLAB and Visual Studio. Well-defined algorithms are programmed into computer software with the aim of executing the long-run performance of Markov chains and graphical illustrations. The initial chain, preferably the one avoiding either 321, 4321, or 4231 patterns, is modified over time using deletion and insertion algorithms until it reaches the stationary state. The significant complexity of the work is to deal with the more intricate nature of affine permutations, which can be viewed as infinite periodic extensions of ordinary finite permutations. Upon present completion, the inspection of typical shapes of pseudo-random permutations avoiding a given pattern, as well as the validity of coded algorithms, is being performed to eliminate systematic errors. Once accomplished, mathematical and other probabilistic methods are employed to examine the properties of a class of 4231-avoiding permutation. The simulation result is important since it not only verifies theoretical assumptions but also provides an intuitive sense and thorough guidance for further research in combinatorics and probability theory.

Probing the Effect of Inhibitors on the Aggregation of Heavy Bitumen Compounds by Molecular Dynamics Simulations

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This study aims to investigate the effects of inhibitors (e.g. dodecylbenzenesulfonic acid, DBSA) on suppressing model asphaltene aggregation via molecular dynamics (MD) techniques. Asphaltenes are the heaviest components readily found in crude bitumen. The Canadian oil industry identifies asphaltene aggregation as a key catalyst for downstream issues, such as pipeline clogging during oil transportation. It has been proposed that π-π interactions between the polyaromatic cores of asphaltene molecules are responsible for their aggregation behaviours, and inhibitors, such as DBSA, can disrupt these clustering patterns through providing binding sites with asphaltenes. However, direct evidences from the molecular level are needed to validate the aforementioned mechanism. MD techniques can simulate intricate, atomic-level environments to effectively capture DBSA's performance, which, otherwise, would be difficult to replicate via in vitro studies. In this study, using GROMACS (a predominantly used MD simulation package), a series of simulation systems were generated, containing varying amounts of DBSA inhibitors, model asphaltene molecules, and organic solvents. Through analyzing solvent-accessible surface area, potential energy differences, and radial distribution functions, we can clarify the effects of different functional groups in DBSA on inhibiting model asphaltene aggregation at the molecular level. These results will provide fundamental explanations regarding the roles of asphaltene inhibitors, and thus help to mitigate problems caused by asphaltene aggregation during oil production.

Objective Quality Metric for Stereoscopic Video Assessment

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To support the development and evaluation of state-of-the-art compression codecs we are developing workflows to process and present high-dynamic range (HDR) test media in a repeatable and precise manner. The focus of this research project is the development of such a pipeline for standards testing by the VESA association. High Dynamic Range Imaging, or HDR, is an image standard in which pixel data may exceed the typical 8-bit range of 0 to 255, to a minimum range of 10 bits, 0 to 1023. In doing so, HDR media are capable of representing a much broader dynamic range of brightness. In previous phases of this study, objective and subjective assessments of HDR images were conducted. In this phase, the goal is to evaluate stereoscopic video quality using objective metrics. We first compare several such metrics, including PSNR, SSIM, SCIELAB, and others. After having selected an objective metric, it will be adapted to handle HDR stereoscopic videos in the BT 2020 color space, including linearizing the luminance relationship. The chosen metric will then be used to test whether display stream compression algorithms DSC and VDC-M are able to provide visually lossless quality. We hypothesize that the results of the objective quality metric will be predictive of artifacts appearing in the compressed videos after having been encoded in DSC and VDC-M. If this proves true, then this would imply that the chosen metric is indeed a valid measurement of the quality of the compression algorithms. The results of this project will be important as displays and media become increasingly more commonplace, especially those in Virtual Reality and Augmented Reality headsets, where there is a lot of compression and where clarity is key.

Quadrotor Simulation using ROS and Gazebo

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This project aims to provide a high fidelity simulation environment, featuring high-quality graphics and a robust physical engine for quadrotors using the Robot Operating System (ROS) and Gazebo simulator. Any failure in software or hardware occurring during the experiments and flight tests can cause severe damage to the quadrotor. Hence, having a practical and realistic simulation environment is critical for testing Unmanned Aerial Vehicles (UAVs). Some of the crucial factors affecting the flight of a quadrotor are environmental conditions, vehicle dynamics, control algorithms, and function of sensors such as LiDAR devices, RGB-D, and stereo cameras. Gazebo provides the ability to simulate these factors simultaneously. Compared to existing quadrotor simulations done with Gazebo and ROS, this project provides insight to expand the simulation to more complicated scenarios. Two of these scenarios are having a quadrotor carrying a mass load by a cable or a scene involving multiple quadrotors flying and communicating simultaneously while carrying a single mass load with each other. The model used for this project is a quadrotor from the Gazebo database, and its parameters are adjusted based on the features of the quadrotor (Qdrone) in our laboratory, SDCNLab. This quadrotor can be driven manually, or it can fly in a fully autonomous mode if connected to a controller. In both cases, ROS provides the information required by Gazebo for running the simulation. ROS acts as a bridge and provides communication between the controller or user and the high fidelity Gazebo model.
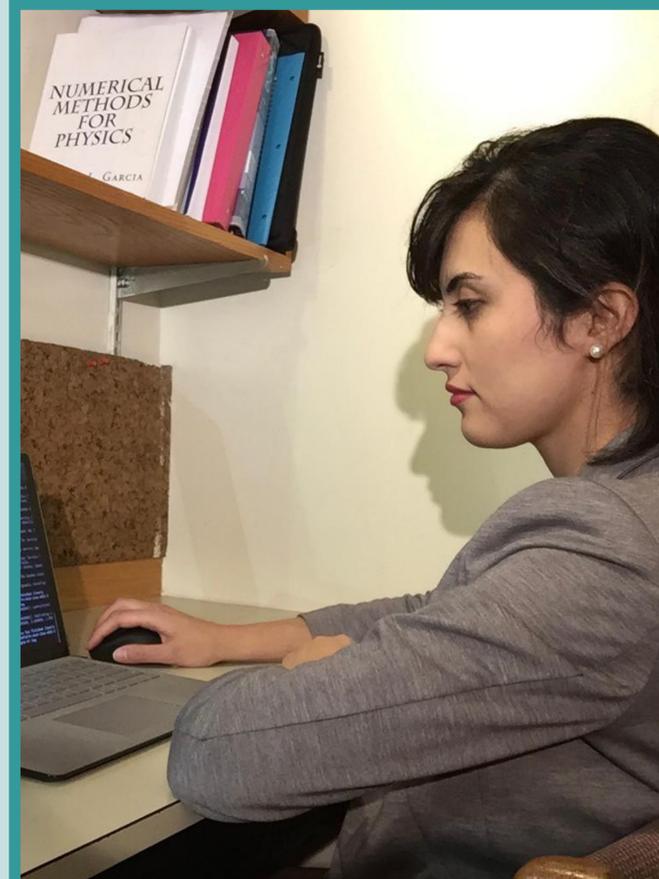
Study to assess the Level of Harmonics in Power Systems

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Dr. James Wu RI | Supervisor: Afshin Rezaei-Zare
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This study aims to assess the level of harmonics in power systems. In a power system, current harmonics are currents with frequencies that are multiple of the fundamental frequency which is 60 HZ in Canada. Current harmonics have undesirable effects on a power system. They cause the power loss to increase and the equipment to heat up, and therefore need to be mitigated as much as possible. The harmonics occur due to transformer saturation or due to the necessary power electronics that are connected to the system. The effects of harmonics are more pronounced in micro grids. Two case studies are examined: operation at transformer energization, and operation in a solar storm. Our approach is to first write a program in C++ to calculate the line parameters for the harmonics in different circuits/cables configurations. We can then use those values to assess the current harmonics with the help of an appropriate power system simulation software.

Comparative Bioinformatics Analysis Reveals Differentiatial Expression of Integrins Between Normal HSCs and LSCs

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LURA | Supervisor: Eleftherios Sachlos
**Dept. of Mechanical Engineering**

Normal hematopoietic stem cells (HSCs) and leukemic stem cells (LSCs) interact with the bone marrow (BM) microenvironment or "niche" in a bi-directional manner. This interaction can govern survival, proliferation, differentiation and homing capabilities of these stem cell populations. Integrins are key cell surface adhesion molecules that act as receptors to mediate the interactions between the extracellular matrix (ECM) and intracellular environment. Remodeling of the BM niche is commonly observed in acute myeloid leukemia (AML), that protects the AML cells from chemoradiotherapy and ensure LSC survival. It was also shown that various integrins on AML cells can influence drug sensitivity, adhesion-mediated chemoresistance and relapse. Emerging evidence highlighted the importance of understanding cellular and molecular determinants of the interaction between leukemic and HSC cells and their microenvironment. This research aims to analyze and compare expression profile of integrins between populations of LSCs and normal HSCs, using bioinformatic methods. For this analysis, the microarray dataset GSE17054 was downloaded from the Gene Expression Omnibus (GEO) database. In this dataset, genome-wide expression of 4 control HSCs groups and 9 LSCs groups were analyzed. Using GEO2R analysis tool, differentially expressed genes (DEGs) were screened and genes related to integrin subunits were selected. It was found that several integrin subunits were significantly down-regulated in LSC populations. In conclusion, current study that compares expression of surface receptors associated with ECM in HSCs and LSCs, can provide a direction for further investigating the therapeutic potential for integrin antagonists in AML and also offer a better understanding of leukemogenic mechanisms.

Comparison of Visuomotor Transformation Between the Single- and Multi-Unit Activities in the Monkey Frontal Cortex

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Faculty of Health

In systems neuroscience, it is a central goal to relate neuronal activity to behavior. First, the neuronal [single-unit (SU)] activity is isolated from the multi-unit (MU) activity, which refers to the average firing of neurons recorded from a microelectrode. However, as neurons work in coordination with one another, there is an increasing trend toward analyzing MU activity (Trautmann et al. 2019). Here, during a cue-conflict memory-guided saccade task (where a target-fixed landmark shifted during the delay) performed by head-unrestrained monkeys (Macaca mulatta), we simultaneously recorded spiking activity (visual, memory and motor) from the frontal (FEF) and supplementary eye field (SEF) neurons. We then employed a model fitting approach (Keith et a. 2009) on the MU response fields (RF), along a target (T) to gaze (G) continuum, to examine if the MU activity carries the same information as the isolated SU activity. Similar to the SU activity (Bharmauria et al. 2020a,b), in both areas, we found that: 1) the MU visual (FEF = 88; SEF = 45) and motor (FEF = 90; SEF = 49) activities best coded for the target-in-eye (Te) and future gaze-in-eye (Ge) coordinates, respectively. 2) Along the spatiotemporal domain (spanning visual-memory-motor activity), there was a progressive transition from T to G coding. 3) In the FEF, along the T-G continuum, MU activity better predicted the gaze than SU activity ($p < 0.05$), suggesting the robustness of population signals. Collectively, these results suggest that: 1) neurons in these areas work in concert (with overlapping RFs) for a common gaze goal, and 2) MU activity can be used as a reliable marker for translational purposes in medical settings to detect functional/dysfunctional sensorimotor transformations.
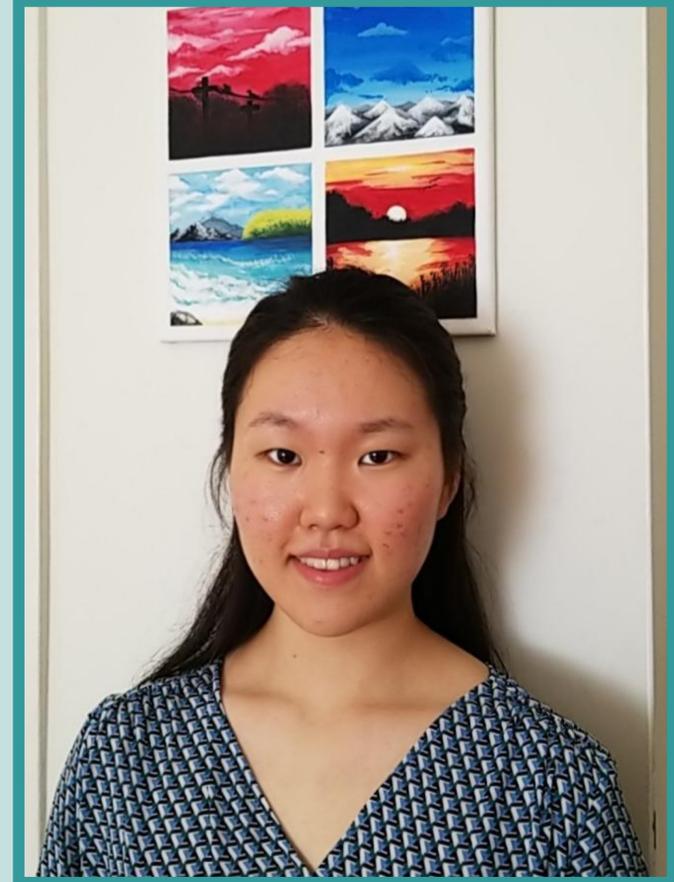
Comparative Study of Machine Learning Models for Credit Card Fraud Detection

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Dept. of Electrical Engineering & Computer Science

Rapid growth in ecommerce technology has led to an increase in credit card transactions all over the globe, as a result fraud has risen substantially. Fraud tends to cost billions of dollars every year to both, consumers and financial institutions alike. It is difficult to enumerate a set of rules that accurately describe fraudulent transactions. Therefore, it is better to use supervised machine learning for this purpose. A supervised machine learning algorithm learns how to classify transactions as fraudulent or not, given only enough instances of fraudulent and non-fraudulent transactions. There are several problems that need to be solved in order to get high accuracy fraud detection. There are many available learning algorithms, each algorithm has many hyper-parameters to be selected and there are issues with the datasets that are used. This research investigates the performance of commonly used classifiers like Random Forest Classifier and Gradient Boosted Decision Trees. We will explore parameter tuning of these algorithms and dataset conditioning to create favorable conditions for learning algorithms. We will use a real publicly available data set from Kaggle containing over half a million transactions made over a year, and labeled by human experts. We will evaluate the performance of learning algorithms for different hyper-parameters based on precision, recall and area under receiver operating characteristic curve score (roc_auc_score).

Quantitative Verification of Randomized Java Code

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LURA | Supervisor: Franck van Breugel

Dept. of Electrical Engineering & Computer Science

Randomized algorithms (i.e., algorithms that rely on randomness, alike rolling a dice, for their performance mostly) are widely used in a large range of areas such as Machine Learning (ML) and Artificial Intelligence (AI). If we roll a dice many times, we are not guaranteed to see all six different sides. Similarly, if we run an implementation of a randomized algorithm many times, not all parts of the code are necessarily tested. Hence, testing is usually insufficient to verify the correctness of randomized algorithms. Besides verifying that a randomized algorithm is correct, one is often also interested in the actual probability that a desirable property holds. The latter is an example of quantitative verification. Our research aims at quantitative verification of randomized algorithms implemented in one of the most popular programming languages, namely Java. For this, we use the tools Java PathFinder (JPF) and PRISM in tandem. JPF has been initially developed by NASA and is currently an open source project. Our research group has made numerous contributions to JPF, including the extensions jpf-label and jpf-probabilistic, that play a central role in our current research. PRISM has been developed at Oxford University. For a dozen randomized algorithms we have applied the following recipe: (1) implement the algorithm in Java (2) formulate interesting properties of the algorithm (3) determine those points in the code that are needed to express the properties (4) use JPF and PRISM to compute the probabilities that the properties hold. Not only did we compute some interesting quantitative properties of the randomized algorithms. We also found some bugs in the tools and corrected them.
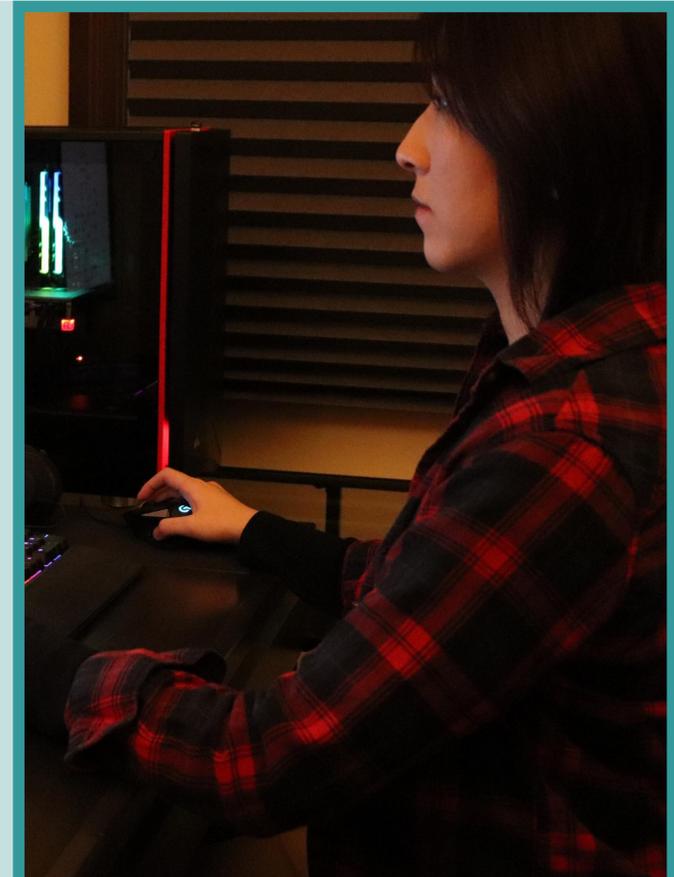
Automatic Detection and Segmentation of Different Cell Nuclei In Histology Images of Breast Tumour Specimens Using Deep Neural Networks

Zahra Zeinolabedin Rafi

NSERC USRA | Supervisor: Ali Sadeghi-Naini

Dept. of Electrical Engineering & Computer Science

Breast cancer is the most common cancer among women worldwide. Machine learning approaches can help scientists to improve the diagnosis of diseases and the analysis of cancer treatment options for individual patients. The overarching goal of this research is to detect and segment different cell nuclei in digital histology images of breast tumour specimens using deep learning models. To train such models, a large amount of data is required with ground truth labels. To generate a precise and reliable dataset, nuclei segmentation is done manually in this project for a large set of breast tumour histology images using Sedeen software package. Specifically, three types of cells identified by a pathologist are accurately segmented, each with a specific label: malignant (cancerous) cells, lymphocytes (immune cells) and normal cells. In order to distinguish nuclei from non-nuclei and the three types of cells, a hint file was provided for each patch to minimize ambiguities during the manual segmentation and ensure generating highly-accurate segmentation masks for the dataset. The valuable dataset being generated in this project potentially paves the way for development of intelligent frameworks to detect and segment automatically various cell nuclei in digital histology images. Such frameworks can substantially streamline the analysis of digital pathology images in the clinic for rapid tumour characterization and treatment planning. Further, automatic detection of different cell nuclei in a tumour specimen facilitate automatic feature extraction to develop AI-based models that can potentially predict the outcome of standard treatments for individual patients. Such predictive models can guide health care providers in tailoring the best treatment options for cancer patients.

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