# 2019 LASSONDE UNDERGRADUATE SUMMER STUDENT RESEARCH CONFERENCE

August 15, 2019

LASSONDE SCHOOL OF ENGINEERING | YORK UNIVERSITÉ UNIVERSITY

# WELCOME

UNDERGRADUATE SUMMER STUDENT RESEARCH CONFERENCE

Welcome to the 2019 Lassonde Summer Student Research Conference!

The annual conference, now it its 4th year welcomes over 60 undergraduate students from Lassonde School of Engineering and beyond presenting their research projects. The students have been conducting research in both science and engineering with Lassonde professors working on a wide range of projects from *Implantable Chips for the Human Brain* to *Unmanned Aerial Vehicles (UAVs)*.

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)*
*Mitacs Globalink Research Award (Mitacs)*
*Research at York (RAY)*
*Dr. James Wu Research Internship*

Lassonde is excited to welcome students not only from our home Faculty but also from other disciplines at York University and the world. Our Lassonde Undergraduate Research Award (LURA) program is open to all undergraduate students and this year 26 students from the program will be presenting their summer research projects. In addition, there will be 17 students funded by NSERC USRA, 14 by Mitacs, 9 by RAY, and 1 by the Dr. James Wu Research Internship.

"Lassonde is not only committed to producing world class research, but also to fostering an inclusive and accessible space to do it in. Through the variety of undergraduate research programs offered at Lassonde, we aim to grow the available research opportunities to students from all walks of life in order to build a truly diverse community of researchers that mirrors our society. Through your research experience at Lassonde, I hope you've discovered more about yourself, your field of study, and about conducting meaningful research. I know this conference will mark the first stage of many successful research careers – the work you've done this summer is truly inspiring!"

Jane Goodyer, Dean
Lassonde School of Engineering

"Congratulations to all undergraduate researchers! May this be your first step towards a successful career in science and engineering research. Connect what you have learned in the lab with lessons from the classroom and apply it to the real-world problems you are solving every day. Wherever your journey takes you, the skills you learned this summer will help you every step of the way."

Regina Lee, Associate Dean
Research & Graduate Studies, Lassonde school of Engineering

## SCHEDULE

**8.30am - 9.00am**
Guest Registration

**9.00am - 9.15am**
Morning Address

**9.15am - 9.45am**
Keynote Speaker:
Dr. Konstantinos Derpanis
(Research Scientist, Samsung AI & Associate Professor, Ryerson University)

**9.45am - 11.00am**
Undergraduate Student Oral Presentations

**11.00am - 11.15am**
Morning Break

**11.15am - 12.45pm**
Poster Presentation Session 1

**12.45pm - 1.45pm**
Lunch Outdoors on Lower Level

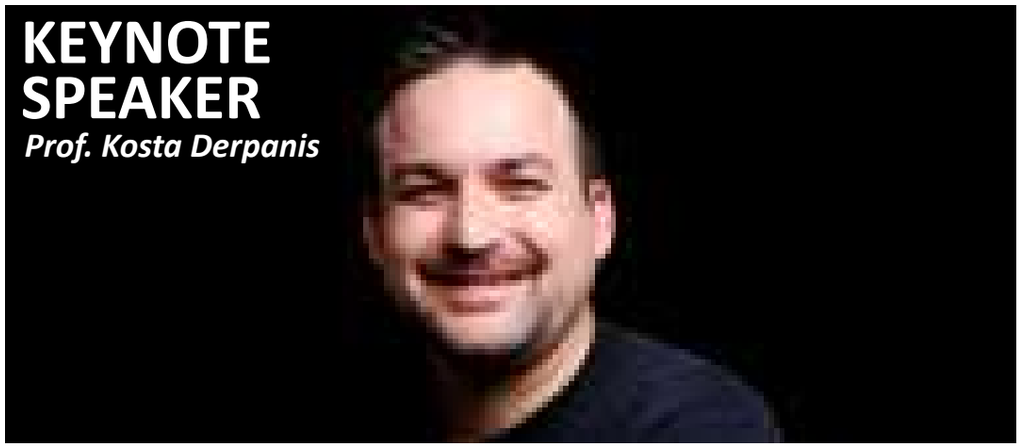
**1.45pm - 3.15pm**
Poster Presentation Session 2

**3.15pm - 3.30pm**
Afternoon Break

**3.30pm - 4.00pm**
Closing Remarks & Awards Ceremony

## KEYNOTE SPEAKER

***Prof. Kosta Derpanis***



Prof. Kosta Derpanis received BSc degree in Computer Science from University of Toronto in 2000, and his MSc (supervisors Prof. John Tsotsos and Prof. Richard Wildes) and PhD (supervisor Prof. Richard Wildes) degrees in Computer Science from York University, in 2003 and 2010, respectively. For his dissertation work, he received the Canadian Image Processing and Pattern Recognition Society (CIPPRS) Doctoral Dissertation Award 2010 Honourable Mention. Subsequently, he was a postdoctoral researcher in the GRASP Laboratory at the University of Pennsylvania under the supervision of Prof. Kostas Daniilidis. In 2012, he joined the Department of Computer Science at Ryerson University, Toronto, and is now an associate professor. Currently, he is also a research scientist at the Samsung AI Centre Toronto. His main research field of interest is computer vision with emphasis on motion analysis and human motion understanding, and related aspects in image processing and machine learning.

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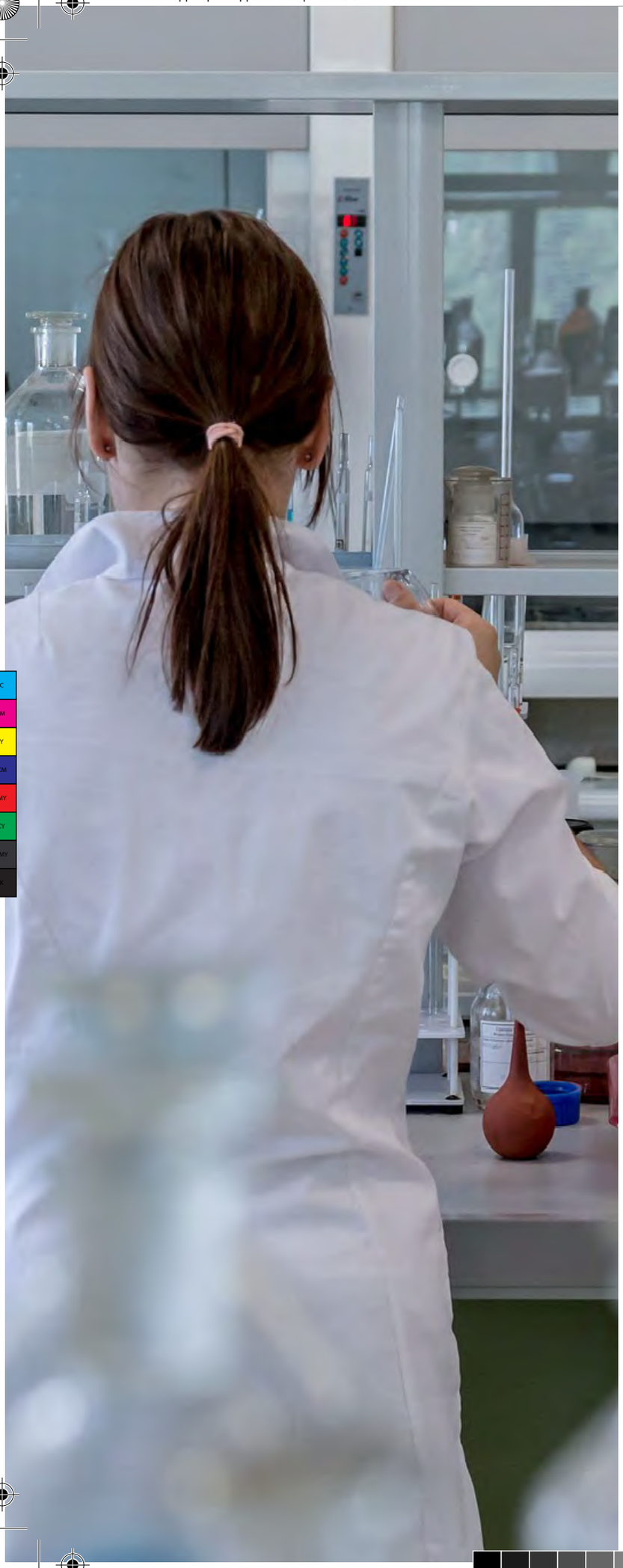

# AWARDS

## ORAL PRESENTATION AWARDS

First Place Best Talk Award
Second Place Best Talk Award
Students' Choice Best Talk Award

## POSTER PRESENTATION AWARDS

First Place Best Poster Award
Second Place Best Poster Award
Third Place Best Poster Award
Students' Choice Best Poster Award

# ORAL PRESENTATIONS

### AUSTIN MARTINS-ROBALINO

Civil Engineering
Supervisor: Dan Palermo

An Investigation of Utilizing Smooth Reinforcement in UHPC and ECC and Impact on Flexural Behaviour

### BRITTANY DANISHEVSKY

Electrical Engineering and Computer Science
Supervisor: John Tsotsos

Object Detection in Nursing Homes for Autonomous Wheelchair Software

### DAPHNE-ELENI ARCHONTA

Mechanical Engineering
Supervisor: Pouya Rezai, Khaled Youssef

On-demand Electric Field Induced Egg Laying of Caenorhabditis Elegans

### IVAN MISHEV

Earth and Space Science and Engineering
Supervisor: Sunil Bisnath

Improving Navigation Satellite-based Positioning Software through Signal Simulations

### MOHAMMADREZA KARIMI

Electrical Engineering and Computer Science
Supervisor: Hossein Kassiri

Seizure Detection Using Brain EEG Signal Processing

# POSTER PRESENTATIONS - SESSION 1

**1. Abdallah Alshantaf -** Fan-assisted Trombe Wall (Mechanical - Paul O'Brien)
**2. Adrianna Van Brenen -** Experimental investigations of the optical properties of CO2 ice in a simulated martian environment (ESSE - Isaac Smith)
**3. Affan Behzad -** Investigation of fabric pattern and seam location on the drag characteristics for cycling speed suits. (Mechanical - Ronald Hanson)
**4. Alaa Alborno -** "Compressibilty and Shear Strength of Soil rubber crumb mixture." (Civil - Jit Sharma)
**5. Alessia Sacco, Jenny Kim, Eren Yigit, Morteza Ghafar-Zadeh -** Oral Neutrophils and Artificial Intelligence: an Interdisciplinary Approach to Portable Early Detection of Chronic Diseases (EECS - Ebrahim Ghafar-Zadeh)
**6. Amanda Capacchione -** The Design and Fabrication of a Towing Tank (Mechanical - Ronald Hanson)
**7. Apostolos Vasileiou -** Developing a Safe Water Optimization Tool Using Artificial Neural Networks (Civil - Usman Khan)
**8. Ariel Yerushalmi -** Development of a Wildland Urban Interface Fire Evacuation Framework for Remote Communities (Civil - John Gales)
**9. Ariella Kantorowitz -** Sapers - Illumination Models of Martian Craters to Support Space Exploration (ESSE - John Moores)
**10. Ashar Latif -** Instrument for Real Time Acquisition and Transmission of Ballistocardiogram Signals (EECS - Peter Lian)
**11. Brian Diep -** Developing a Deep Neural Network for Bridge Maintenance (ESSE - Gunho Sohn)
**12. Cezary Kirczuk -** Mechanical and structural properties of boiler grade steel (Mechanical - Aleksander Czekanski)
**13. Chester Wyke -** Survey of Interpretability in Machine Learning and Data Generation Analysis for Model Extraction (EECS - Ruth Urner)
**14. Constantinos Kandias -** Design and Optimization of the Contraction and Corner Sections of a Closed Loop Wind Tunnel (Mechanical - Ronald Hanson)
**15. Dhruvikumari Desai, Antonia Pennella -** Manufacture and Analysis of Braided Composite Structures (Mechanical - Garrett Melenka)
**16. Diana Galindo -** Seismic Performance Assessment of Mid-Rise Concrete Shear Walls Reinforced with Superelastic Shape Memory Alloys (Civil - Dan Palermo, Marina Maciel)
**17. Diana Laura Díaz García -** Numerical prediction of sea fogs over Grand Banks (ESSE - Yongsheng Chen)
**18. Ellen van Wijngaarden -** Drug Screening of Zebrafish Larvae Using Microfluidics (Mechanical - Pouya Rezai, Arezoo Khalili)
**19. Fuat Diriker -** Design and Development of Attitude Detection and Control Subsystem for ManitobaSAT-1 (ESSE - Regina Lee)
**20. Haider Al-Tahan -** The World's Largest Dynamic Scenes Video Database (EECS - Richard Wildes)
**21. Heather Stone -** Calibration of Panoramic Camera for Atmospheric Monitoring on Mars (ESSE - John Moores, Kim Strong)
**22. Hunter Schofield, Harry Zou, James Le -** Navigation and Control Algorithm Development for Customized Self-driving Vehicles (ESSE - Jinjun Shan)
**23. Jabavu Adams, Fasil Cheema -** Neural Networks for Heart Rate Detection in Ballistocardiogram (BCG) Signals (EECS - Peter Lian)
**24. Jia Ying Ou -** Application of Machine Learning Algorithms in Real-Time Access Control (EECS - Amir Chinaei)
**25. Jiefeng Qiu -** Visualizing Structure Health Monitoring of Carbon Fiber Composite Through Electroluminescence (EECS - Gerd Grau, Garret Melenka)
**26. Jinxing Li -** Web-Base Simulator for Advanced Constitutive Models For Geomaterials (Civil - Jit Sharma, Chris Szalwinski)
**27. Jovan Hovey -** Recovery of a Reference Architecture for Computer Vision Projects (EECS - Jack Jiang)

# POSTER PRESENTATIONS - SESSION 2

**28. Julia Ferri -** Movement Profiles and Accessible Design (Civil - John Gales)
**29. Karen Abogadil -** Estimating Surface Infiltration Rates of Permeable Pavement Systems through Digital Image Analysis (Civil - Usman Khan)
**30. Ken Tjhia -** Learning Interactions of Moving Objects Using Variational Auto-encoders (EECS - Manos Papagelis)
**31. Kevin Joseph -** Phrase Graphs for Multi-Modal Embeddings (EECS - Hui Jiang)
**32. Kourosh Toghrol -** Contactless Solar Evaporation Structures (CSES) for the Purposes of Water Distillation and Purification (Mechanical - Thomas Cooper)
**33. Maeve Wildes, Syyeda Zainab Fatmi, Yash Dhamija -** The world's largest benchmark suite for probabilistic model checking (EECS - Franck van Breugel)
**34. Mahmoud Alsaeed -** Distributed Sweep-line Algorithm for Scalable Geometric Object Intersection Analytics (EECS - Manos Papagelis)
**35. Matteo Timpano -** The Effects of Electrospinning on Triboelectric Nanogenerators for Power Generation and Smart Sensing Applications (Mechanical - Sunny Leung)
**36. Mohamed Karam -** Improvement of Pool Boiling Heat Transfer Using Micro-Structures Manufactured by Selective Laser Melting (Mechanical - Roger Kempers)
**37. Noah Stanton -** Constraining phase function for ice and liquid clouds with DSCOVR's Earth Polychromatic Imaging Camera (ESSE - John Moores)
**38. Olga Klushina -** Detecting and preventing impact concussions in real time. (EECS - Peter Lian, Yang Zhao)
**39. Ori Wiegner -** Automatic labeling of lung tumors in CT scans (EECS - Suprakash Datta)
**40. Peter Caruana -** Reinforcement Learning Based Navigation, and Environment Mapping Using LiDAR (ESSE - Jinjun Shan)
**41. Petr Roganov -** Minimally-invasive Subdermal Implantable Wireless EEG Recording Device (EECS - Hossein Kassiri)
**42. Pruthvi Acharya -** Observations of Atmospheric-Surface interaction for various Mars Years using THEMIS and MARCI (ESSE - Isaac Smith)
**43. Rahmha Khalid, Talha Irshad -** Sorption of hydrogen sulfide through a bentonite barrier (Civil - Magdalena Krol)
**44. Ramein Zahedi -** User Pairing Schemes for Aerial and Terrestrial networks using NOMA (EECS - Hina Tabassum)
**45. Richard Robinson -** Development of Pipeline for Evaluating HDR Compression Standards (EECS - Robert Allison)
**46. Ruben Del Rosario -** Enzyme Cocktails to Trap Heavy Metals from Municipal Wastewater (Civil - Satinder Brar, Dr. Ahmed Eldyasti)
**47. Ryan Karaba -** Non-invasive Micro-Electrode Array Electrophysiological Recordings (EECS - Ebrahim Ghafar-Zadeh)
**48. Saadia Riaz -** Static Volumetric Neutrino Display (IceCube Experiment) (EECS - Robert Allison)
**49. Samy Elias -** Assessment of Dynamic Forces in High-Voltage Substations for Distributed Generations Connection (EECS - Afshin Rezaei-Zare)
**50. Sinan Olcun -** Characterization of Thermal Properties for 3D Printed Continuous Carbon Fiber Composites (Mechanical - Roger Kempers)
**51. Sogand Talebi -** Development of a GNSS-R Sensor for Soil Moisture Determination (ESSE - Sunil Bisnath, Regina Lee)
**52. Theresa Nguyen -** Development of a thermal analytical model for predicting the reliability and accuracy of photovoltaic micro-converters (EECS - John Lam)
**53. Wes Eardley -** Precision Matrix Estimation in Highly Correlated Models (EECS - Gene Cheung)

# 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)**

Mitacs Globalink Research Award **(Mitacs Globalinks RA)**

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

## Compressibilty and Shear Strength of Soil rubber crumb mixture.

**Researcher(s): Alaa Alborno**
**Dept. of Civil Engineering**
**Research Program: LURA**
**Supervisor: Jit Sharma**

With the growing interest of sustainability in Engineering practice, rubber tire crumbs are being used in several Civil Engineering practices. They have been used in concrete mix, aspalt mix and embankment fills. Rubber tires have strong elasticity giving them higher compressibility than soil grains, which leads to challenges regarding the usage of such material in soil mixes, such as understanding its stress-strain relationship and shear strength behavior. Therefore, this project main objective is to correlate between the percentage of rubber tire crumbs in soil mixes and its shear strength and compressibility behavior. In order to achieve this, the rubber tire crumbs were tested alone using a permeameter, Direct shear test, oedometer test and triaxial compression test. Afterwards, the rubber tire crumbs were mixed with nepheline syenite (quartz sand) and tested for compressibility and shear strength. Rubber crumb tires replaced from 10%-50% by volume in the mixes for testing. Testing rubber tire crumbs mixes for compressibility showed that as the percentage of rubber tire crumbs increase in the mix, the compressibility increases. Moreover, regarding shear strength, the rubber material alone has been showing no failure in shear as it displays horizontal displacement continuously as the shear load increases. Therefore, further testing is needed to understand the shear strength of rubber crumb mixtures. The results from this project will be used to create a comprehensive method of investigation of the stress-strain deformation behavior for several kinds of compressible geomaterials in the future.

## Development of a Wildland Urban Interface Fire Evacuation Framework for Remote Communities

**Researcher(s): Ariel Yerushalmi**
**Dept. of Civil Engineering**
**Research Program: NSERC USRA**
**Supervisor: John Gales**

Wildland Urban Interface (WUI) communities are situated at the interface between human development and wildland fuel. In addition to its proximity to susceptible regions, routes of evacuations in WUIs are often limited, posing great risks to these communities in the event of a natural disaster. The validity of predictive models of evacuation is limited by the confounding effect of Human Behaviour in Fire (HBiF). A behavioural methodology known as the Protective Action Decision Making (PADM) was constructed to better understand the factors impacting an individual's decision-making process during an evacuation. Considering the significant impact of behavioural factors on evacuation times, it is crucial to consider PADM when assessing the risk on a community, as it reduces uncertainty and the amount of simulations required. A WUI community in Saskatchewan was selected as the first case study of its kind to investigate assembly and evacuation patterns while accounting for the PADM and HBiF. Simulations of evacuations were performed in the traffic simulation software PTV VISSIM, which extracted useful data including evacuation times and related parameters. The results demonstrate that the addition of an extra back cabin road does not impact the total evacuation time, while an extra highway access road does. Validating these findings through additional simulations to increase predictive power is crucial to the formation of strategic evacuation plans for communities at risk. Results pending, this case study may lay the groundwork for other WUI communities in ensuring their safety and preparation in case of an evacuation.

## Developing a Safe Water Optimization Tool Using Artificial Neural Networks

**Researcher(s): Apostolos Vasileiou**
**Dept. of Civil Engineering**
**Research Program: RAY**
**Supervisor: Usman Khan**

Water quality in refugee camps is important but current guidelines are not suitable due to water often being stored in households and consumed several hours after chlorination. These guidelines suggest that the free residual chlorine (FRC) level in water should be at least 0.2 mg/L. This is difficult to control because FRC level decays over time, imposing a risk of unsafe water. A safe water optimization tool is developed to eliminate this risk. This tool helps with predicting what the FRC level at the water source should be, to have safe water at the households 24 hours later. Current prediction models are inadequate and do not account for site-specific characteristics such as local temperature and sun exposure, which assist the FRC level to decay. Thus, an Artificial Neural Network is utilized to model the decay and help with the prediction of the optimal FRC level at the source based on site-specific conditions. The goal of this research is a web-based tool that will help with adjusting the FRC level at the source to ensure a safe FRC level at the point of consumption. The tool will be globally accessible from any site, and will create real-time results, providing safe drinking water and improving the quality of life in refugee camps.

## An Investigation of Utilizing Smooth Reinforcement in High Strength Concretes and the Impact on Flexural Behaviour

Researcher(s): Austin Martins-Robalino
Dept. of Civil Engineering
Researcher Program: NSERC USRA
Supervisor(s): Dan Palermo

The aim of the research is to strengthen the understanding of how use of smooth reinforcement in reinforced high-performance concrete beams affects the overall flexural behaviour of the structural element. With the emergence of Shape Memory Alloys (SMAs), which are smooth reinforcing bars, as a promising material to increase the seismic resilience of structures, the differences in structural behaviour compared to conventional deformed steel reinforcement must be quantified. As part of these comparisons, the research involved designing 12 beams constructed from conventional normal-strength concrete, Engineered Cementitious Concrete, and Ultra High-Performance Steel Fibre Reinforced Concrete, with the conventional concrete as the control and the latter two materials being used in structures sensitive to seismic activity. Each material consisted a set of 4 beams which varied in reinforcement type, smooth or deformed, with hooked or straight ends. In order to determine the flexural strength, beams were tested under four-point bending using a universal testing machine. Midpoint deflection was simultaneously measured using a linear potentiometer and digital image correlation. In addition, beams reinforced with straight bars involved the measurement of slip of each reinforcing bar. As a complementary study, the beams were also modelled in a finite element analysis program, VecTor2, to determine which theoretical models best predict the observed experimental results. These results can provide insight into the merit of using SMAs as reinforcement in high strength concretes to overcome the loss of bond-slip strength inherent with the use smooth reinforcement. Such insight would prove valuable to the future of improving seismic design and understanding of such promising materials.

## Effect of salts on Anaerobic ammonium oxidation

Researcher(s): Chendur Malavikaa Thinagaran
Dept. of Civil Engineering
Researcher Program: Mitacs
Supervisor(s): Eldyasti Ahmed

A lot of anthropogenic activities have led to an increase in nitrogen pollution in water. The drawbacks of the conventional nitrification-denitrification process like long retention time and large reactor volume, high oxygen requirements for the nitrification process, external carbon source for maintaining the COD/N ratio and low removal efficiency can be overcome by the Anaerobic ammonium oxidation (ANAMMOX) – an innovative add on to the nitrogen cycle. This reaction is carried out a set of chemolithoautotrophic bacteria. Despite the slow growth rate of this bacteria, the ANAMMOX process has been successfully implemented for the side stream wastewater treatment in various countries. But the application of ANAMMOX in the mainstream treatment has various challenges involved in it. In this project, a series of batch reactors were set up to analyse the effect of various ions on the bacterial activity. The ANAMMOX species from the continuous UASB reactor were augmented from the batch reactor setup and a series of samples were made by adding 500, 1000 and 1500 mg/L of salts to the feed and the seed. All these samples along with the RAS, control systems and ANAMMOX blank systems were measured for their pH, BOD, ammonium, nitrate and nitrate before and after the reaction in the batch reactor setup. From the results, we will be able to obtain optimal concentrations to enhance ANAMMOX reaction in the mainstream process. This, in turn, will reduce the high oxygen and chemical requirement thereby reducing the cost required for the treatment process.

## Seismic Performance Assessment of Mid-rise Concrete Shear Walls Reinforced With Superelastic Shape Memory Alloys

Researcher(s): Diana Galindo
Dept. of Civil Engineering
Researcher Program: Mitacs
Supervisor(s): Dan Palermo, Marina Maciel

The objective of this project is to investigate the seismic performance of hybrid mid-rise concrete shear walls reinforced with superelastic shape memory alloys (SMA) in the plastic hinge. SMAs are metal alloys that have the unique ability to sustain large amounts of deformation and return to the original shape when loading is removed or when heat is applied. This type of wall permits self-centering with high levels of energy dissipation and significant reduction of permanent deformations. The current design codes around the world only ensure life-safety after an earthquake, implicating in large economic losses due to multiple issues, such as inactivity of the building for a long period of time. Using the finite element program VecTor2, 10-story shear walls were modeled with conventional steel reinforcement and SMA reinforcement in strategic locations. In addition, three different walls were investigated employing different lengths of SMA bars in the plastic hinge region, in order to determine an optimal length of SMA reinforcement to ensure the self-centering effect but provide a more cost-effective design. Various analysis parameters were investigated, and the response of the walls with conventional and hybrid SMA-steel reinforcement were compared. Static and dynamic analyses were performed with the use of natural and simulated earthquake records representative of different seismic zones in Canada. The response of the walls was evaluated in terms of lateral displacements, residual displacements, strains in the truss bars, and cracking pattern. The outcome of this research project could aid the use of this novel material as reinforcement in concrete building structures, reducing and simplifying repairs and minimizing post-earthquake costs.

## Web-Base Simulator for Advanced Constitutive Models For Geomaterials

Researcher(s): Jinxing Li
Dept. of Civil Engineering
Researcher Program: LURA
Supervisor(s): Jit Sharma, Chris Szalwinski

The objective of the project was to develop a web application to compare its experimental data with theoretical predictions. It provides an online sandbox for physicists, academics, and engineers to test predictions of the mechanical behavior of a geomaterial against empirical data obtained in a laboratory. The web application consist of two parts: a web interface and a simulator, and will be into a larger system for analysis and design by members of the geotechnical engineering community. The interface is the visualization engine for the simulator. The simulator predicts stress histories based on user input and a suite of user-selectable constitutive models. The interface accepts the user input, sends it to the simulator, accepts stress history predictions from the simulator, and displays the output in a graphical format. The interface supports direct user interaction with the graphical output. My research focused on refactoring existent React code, using Python Flask framework to instead of Nodejs for authorization in the back-end, merging React and Python together, and using C++ to write HTTP server.

## Movement Profiles and Accessible Design

Researcher(s): Julia Ferri
Dept. of Civil Engineering
Researcher Program: LURA
Supervisor(s): John Gales

Statistics Canada claims that about 20% of the population has had one or more disabilities that limit their movement ability. To accurately model pedestrian flow, establish fire codes and regulations, and ultimately ensure a safe and accessible environment, engineers require a database of comprehensive and readily available statistics on human behavior and movement. In recognizing the importance of incorporating impaired human movement in design, research still is needed to quantify these movement statistics to support accessible environment design. The study herein analyses 21 hours of high resolution video footage of normal circulation and egress of a Canadian Tennis Stadium and adjoining Pedestrian Village over three days. Focusing on mobility patterns of persons with accessibility requirements (cane, crutches, electric wheel chair, family with young children, manual wheelchair, mobility scooter, oversized luggage, persons requiring assistance, rollator, roller suitcase, walking stick, etc.), the research provides a provision of contemporary walking speeds - a foundational reference to set computational model movement speeds in various software. Of the recorded disability profiles, resulting walking speeds were expectedly below the average ranges indicated in the SFPE Handbook. The study documented average movement speeds at 0.68 to 1.41 m/s. Results of the circulation and egress study revealed that only 0.31% (n = 2566) of the overall attendance (n = 69276) presented a type of mobility impairment. This low percentage pointed towards situations where the promotion of a more accessible environments would be required. This stadium case study allows the opportunity to examine through modelling, these features or lack of features particularly in an egress context.

## Estimating Surface Infiltration Rates of Permeable Pavement Systems through Digital Image Analysis

Researcher(s): Karen Abogadil
Dept. of Civil Engineering
Researcher Program: LURA
Supervisor(s): Usman Khan

Urbanization has led to an increasing amount of impervious surfaces, which disrupts the natural water cycle causing a number of detrimental effects. Following precipitation, stormwater is unable to infiltrate and instead flows along the streets collecting pollutants and ultimately drains into water bodies that are a source of drinking water. This inevitably leads to lower water quality and a higher risk of floods, and when combined with the effects of the climate crisis, will disproportionately affect vulnerable populations the most. Low impact development (LID) such as permeable pavement systems (PPS) provide a way to mitigate these effects. However, PPS are prone to clogging and measuring their surface infiltration rate (SIR) is cumbersome and not widely performed. Thus, maintenance is rarely performed, meaning that many PPS operate below the standards they were designed for. This research aims to create a mobile application that can estimate the SIR of PPS through a simple digital photograph. This requires a database of laboratory and field SIR values of different types of PPS. In this research, laboratory models of PPS are created and clogged with sediments to mimic the annual sediment loading in an urban area. Images and SIR tests are simultaneously done and compared for multiple types of PPS. The data will be used to create an Artificial Intelligence-based model to predict SIR using photographs of PPS and be embedded in a user-friendly mobile application. This application can replace the time-consuming SIR standard test methods and help in the maintenance of PPS, allowing this LID to function as it was made.

## Social Justices for Flood Risk Reduction: Three Distributive Models for SUDS Implementation

Researcher(s): Nadja Couratte-Arnaude
Dept. of Civil Engineering
Researcher Program: Mitacs
Supervisor(s): Usman T. Khan

Flood risk prevention presents a major issue in Toronto due to the damaging impacts of recent floods. Sustainable Urban Drainage Systems (SUDS) are a new group of engineering technologies design to reduce the impact of floods in urban areas. Additionally, recent research has shown that SUDS offer several economic, environmental and social co-benefits. Therefore, the purpose of this research is to find optimal SUDS placement within Toronto to reduce flood risk, while increasing the other co-benefits. Three social justice models (egalitarian, utilitarian, and prioritarian) are used to spatially distribute SUDS within Toronto to demonstrate the difference in flood risk under these fundamental theories. Data from 16 communities within Toronto was collected and used to run the models (built in MATLAB and ArcGIS). Results demonstrate that each distributive theory places SUDS uniquely within the study region. This highlights the importance of including philosophic and economic reflections in flood risk management. Note that the co-benefits and externalities of SUDS are only roughly quantifiable, which means that the real impact of SUDS on society may be variable.

## Modification of Thermal Properties of Bentonite Using Sand and Carbon Materials.

Researcher(s): Pausali Pradhan
Dept. of Civil Engineering
Researcher Program: Mitacs
Supervisor(s): Rashid Bashir

Containing a significant amount of montmorillonite mineral, bentonite is a type of clay with high water absorption and swelling index which make it an effective material to be used for sealing underground nuclear waste repositories. However, the dissipation of heat from the nuclear wastes becomes a matter of concern because of the poor thermal properties of bentonite. Studying and researching ways to improve the thermal properties of bentonite is the major objective of this project. Focusing on this aspect, the thermal conductivities and volumetric heat capacities of pure bentonite were examined at different moisture contents using samples prepared by Modified Proctor test. The samples were prepared at optimum moisture content and maximum dry density of the soil. Further, these tests were performed on soil samples by addition of silica sand,3-mm long carbon fibers and graphite flakes (materials having inherently high thermal conductivity) to enhance the thermal properties of bentonite. The compacted samples were allowed to dry and the variation of thermal conductivity and heat capacity values were recorded at different moisture contents using KD2-pro thermal probe. The results indicate that the thermal conductivity is significantly increased by addition of 10% to 20% sand. The addition of carbon fibers to bentonite also showed up to 50 % increase in thermal conductivity. Based on the results obtained to date, it can be concluded that an optimum amount of silica sand and C-fibers can significantly help in achieving the goal of using bentonite as an effective sealing in repositories with good heat dissipating properties.

## Assessing the Digestibility of Methanotrophic Biological Sludge by Anaerobic Digestion

Researcher(s): Pranav Menon
Dept. of Civil Engineering
Researcher Program: Mitacs
Supervisor(s): Ahmed Eldyasti

The objective of the project was to investigate the digestibility of methanotrophic biological sludge, using anaerobic digestion (AD). Sludge produced at the end of biological treatment in conventional waste-water purification plants, is typically digested using AD to produce methane rich biogas. Methanotrophic bacteria offer a novel approach for utilizing this methane for the production of value adding products. The use of methanotrophic bacteria for nitrogen removal from waste water is one such application. My research specifically focused on determining the digestibility of the sludge produced at the end of this process by AD bacteria. The biological methane potential (BMP) of the methanotrophic sludge, was determined by running batch assays. The test was run for a period of 30 days during which the amount of methane being produced was monitored. In addition to this, tests were run on the reaction liquid to determine the concentration and composition of volatile fatty acids being produced, which helped monitor the progression of the anaerobic digestion process. The level of ammonium and well as other inhibitors to the AD process being produced, was also determined. The test was run in 4 separate batches in order to provide a suitable control, and to understand the BMP of the bacterial seed itself. In addition to this, one of the batches was run at thermophilic conditions (55 C), while another was run at mesophilic conditions (30 C). The results obtained from the project will help provide a better understanding of the amount of methane that can be produced from spent methanotrophic sludge, which will help determine the feasibility of using it for biogas production to help improve the process economics, in a novel biological waste water treatment facility.

## Enzyme Cocktails to Trap Heavy Metals from Municipal Wastewater

Researcher(s): Ruben Del Rosario
Dept. of Civil Engineering
Researcher Program: RAY
Supervisor(s): Satinder Brar, Ahmed Eldyasti

The presence of heavy metals in municipal wastewater has increased with urbanization. Heavy metal contamination negatively affects the environment as these metals can bioaccumulate and in higher doses, have toxic effects on humans and wildlife. Currently, heavy metals are removed by precipitation using chemical coagulants such as aluminum sulfate (alum), aluminum chloride, and ferric sulfate. However, the current methods used to remove heavy metals require acidic pH levels to operate which consequently brings toxicity and safety concerns. Additionally, acidic pH conditions may corrode pipelines thus hindering the efficiency of the heavy metal removal process. The purpose of this study is to investigate the effectiveness of a more environmentally friendly method to remove heavy metals from municipal waste water. By producing glycosly hydrolases from specific fungal strains Aspergillus niger (A.niger) and Aspergillus oryzae (A.oryzae), extracting crude enzymes from the fungal strains, and applying these enzymes to the municipal wastewater, the current study aims to precipitate heavy metals. Wastewater prior to the first primary clarifier will be targeted in this study. The process would operate at a neutral pH level without added acidity or bases occurring in the effluent streams. Furthermore, overall reduction in solid waste and cost of operations are expected to be more advantageous in comparison to current methods. If results demonstrate similar heavy metal removal efficiency as chemical coagulants, this study can provide a more sustainable practice that is applicable in wastewater treatment plants for the removal of heavy metals and may be extended to bio-recovery of precious metals.

## Sorption of hydrogen sulfide through a bentonite barrier

Researcher(s): Rahmha Khalid, Talha Irshad
Dept. of Civil Engineering
Researcher Program: LURA
Supervisor(s): Magdalena Krol

Diffusion of hydrogen sulphide through an engineered barrier system in a deep geological repository. Canada has devised a plan for the long-term storage of used nuclear fuel in a deep geological repository (DGR). A DGR is a network of tunnels and placement rooms that will be placed 500m below ground and used to store used nuclear fuel containers (UFCs) within a multi-barrier system. The current multi barrier system design includes a copper coated steel container surrounded by layer of highly compacted bentonite (HCB). The copper coating acts as a corrosion barrier and the HCB surrounding the container suppresses the movement of corrosive agents to UFC and therefore prevents corrosion of the canister. Corrosion of copper canister is a special concern in DGR design as it may threaten the canister integrity. Given that the DGR is planned to have an operational life span that is in excess of a million years, the depletion of oxygen and therefore existence of anaerobic conditions will prevail during the functional lifetime. Under such anerobic conditions a UFC may corrode by microbiologically influenced corrosion (MIC) where sulfate is converted to hydrogen sulfide and transported, via diffusion, to the UFC. There are various factors that can affect the diffusion rate of sulphide through bentonite including temperature, saturation, bentonite density, and ionic concentration. Therefore, the goal of this research was to examine the effect of these parameters on hydrogen sulphide diffusion.

## Using 3D printed materials to understand the behaviour of heterogeneous rock specimens

Researcher(s): Xinrui Xiong
Dept. of Civil Engineering
Researcher Program: Mitacs
Supervisor(s): Matthew Perras

The objective of the project is to use 3D printed materials to understand the behaviour of heterogeneous rock specimens. 3D printing has been applied to print of a variety of materials including polymers, metals, ceramics, sand, and gypsum. This project revolves around using sand or gypsum as 3D printed materials. Since one specimen is never exactly the same in nature, these printed materials have the potential to be able to replicate natural structures and therefore natural behaviours of rocks under compressive and tensile loading in a repeatable manner. Based on the previous experiments, this project focuses on refining 3D printed materials to replicate natural rock behaviours better.

## Experimental investigations of the optical properties of CO2 ice in a simulated martian environment

**Researcher(s): Adrianna Van Brenen**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: NSERC USRA**
**Supervisor(s): Isaac Smith**

Mars' south polar cap has a permanent reservoir of carbon dioxide ice. This ice persists even though surface temperatures should theoretically exceed the ~150 K sublimation point of CO2 ice. Literature suggests that CO2 ice recrystallizes in the warmer seasons in order to increase albedo. The purpose of this project is to obtain more data on the reflectance spectra of CO2 ice as well as the effects of light on the ice. Currently, there is no experimental data for the UV optical constants between 127 and 172 nm (Hendrix et al., 2010). The majority of existing data across all bands has largely been measured in transmittance, while the reflectance spectra of CO2 ice remains lacking. The dependence of the ice's crystalline structure on light is also under-explored (Portyankina et al., 2018). As most data has also been obtained in a terrestrial environment, this experiment will be conducted under martian conditions. My primary tasks have been to source parts and assemble the equipment needed to seal an inherited vacuum chamber and conduct experiments. After pumping down, the chamber is filled with CO2 gas to a pressure of 5.4 Torr—to parallel Mars. From this point, liquid nitrogen flows through a cold plate inside the chamber to lower the temperature below the condensation point of CO2. The CO2 then freezes onto the plate in different crystalline structures depending on experimental conditions. The primary goal of this summer project is to produce CO2 ice, and my efforts have enabled that. Future experiments will measure spectral properties of the ice. The results will allow for a better understanding of remote sensing data from planetary surfaces with abundant CO2, and in turn largely contribute to our knowledge of climatic processes on Mars and other planetary bodies.

## Illumination Models of Martian Craters to Support Space Exploration

**Researcher(s): Ariella Kantorowitz - Sapers**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: RAY**
**Supervisor(s): John Moores**

Formation of valley networks during the Noachian Era has suggested that there was liquid water at the surface of Mars and a warmer and thicker ancient Martian atmosphere. This research will investigate the glaciation and see the expected retreat of low altitude ice as the obliquity of Mars changes, particularly for the Gale crater. An existing illumination model created by Kloos et al. (2019) is utilized to assess the geographic variation of solar flux within impact craters known for harbouring water ice. The illumination model is altered for the Martian surface starting with the Korolev crater. Other craters with evidence of ice will be identified and orbital imaging will be used to identify the geographic dispersion of ice on the crater floor. High-resolution topographic data from the Mars Orbiter Laser Altimeter (MOLA) instrument on board the Mars Global Surveyor (MGS) spacecraft is used with the aim to see how geographic variation in solar flux received by each crater correlates with ice distribution detected from orbital data. A map of radiation received by the base of craters at different locations will be compared to a map of craters with ice on Mars. For the Martian surface, this incoming radiation from the sky will primarily come from the Sun. With successful codes running for the Korolev, Gale and Louth crater, we are able to see the craters Horizon and how much sun is visible at certain locations in and around the crater. Doing this will allow for a better understanding of Martian history as well as trying to make sense of the impacts of Mars' odd obliquity.

## Developing a Deep Neural Network for Bridge Maintenance

**Researcher(s): Brian Diep**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: LURA**
**Supervisor(s): Gunho Sohn**

As our infrastructure become further developed and expanded, new systems are required for the maintenance of this complex and intertwined network. One facet of this problem is the identification and inspection of bridges for physical damage (i.e., cracks, corrosion). Standard practice for inspections require humans to be directly on the ground. This is a time-consuming, expensive, and often infeasible due to the sheer scale or safety concerns. The next step, and the project objective, is to streamline this process through the automation of the bridge inspection process with deep learning for computer vision. A convolutional neural network (CNN) architecture like U-Net is used to complete this semantic segmentation task. Despite lacking a large dataset of images for bridges, knowledge transfer is employed by training the network with similar data from roads. The network will be trained on a large dataset of partially labelled images of major provincial highways provided by the Ministry of Transportation Ontario (MTO). To solve the issue of the incompletely annotated data, semi-supervised learning techniques will be used to bridge the gap between the labelled and unlabeled data with the goal of outputting more accurate ground truth predictions. Furthermore, a generative adversarial network (GAN) will help to augment the amount of available training data available for the CNN. The end goal will be to allow the network to take images of various surfaces and perform a semantic segmentation task to identify and label instances of damage according to its severity. Using the method outlined will potentially cut the monetary and time costs of inspections and create a safer and more efficient transport network, while remaining compliant with MTO inspection regulations.

## Numerical prediction of sea fogs over Grand Banks

**Researcher(s): Diana Laura Díaz García**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: Mitacs**
**Supervisor(s): Yongsheng Chen**

Canadian East Coast waters, especially Grand Banks, is one of the foggiest place in the world with 50% occurrence rate during the summer months. It often impose dangers to traffic and off shore oil industry operations. The objective of this project is to improve numerical prediction of sea fogs in this region. An ensemble forecasting system using the Weather Research and Forecasting (WRF) model will be implemented to achieve a better fog forecasting. Fog prediction is a challenging task due to the complexity in the physical processes in the atmospheric boundary layer. As consequence there has been slow progress in the operational fog forecasting. Nowadays fog is still not a direct model guidance product, it is diagnosed by local forecasters based on statistical methods and indirect model output variables. There had been growing efforts to numerically predict fog but most of the efforts had been deterministic forecasts. Recent studies in East China suggest ensemble forecasts outperform deterministic forecasts of fogs. We will first evaluate the performance of the official deterministic forecast by comparing the Rapid Refresh (RAP) product and the observations during the summer months in 2018. Then the ensemble system will be developed considering the uncertainties in the initial conditions and the physics. The ensemble forecast will be compared to single deterministic forecast. The reduced visibility due to fog is one of the most significant meteorological-oceanical problems. Fog needs to be better predicted to avoid accidents, so this project would help to have a better understanding of fog and to try to provide a better fog forecast to determine more precisely visibility in the area of study."

## Design and Development of Attitude Detection and Control Subsystem for ManitobaSAT-1

**Researcher(s): Fuat Diriker**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: LURA**
**Supervisor(s): Regina Lee**

The ManitobaSAT CubeSat aims to explore the physics of the space environment of the Low-Earth Orbit by studying how the space weather affects different materials, along with the Moon and asteroid composition. It does so by exposing meteorites and other materials to the space environment and studying their effects. York University team is responsible for designing, manufacturing and testing the Attitude Detection and Control Subsystem (ADCS). The ADCS is a critical subsystem on a spacecraft, responsible for correcting and maintaining the attitude of the satellite while in orbit. ADCS prevents undesired tumbling and minimizes orbital perturbation effects for maximum data acquisition and power production. Development and implementation of the ADCS is particularly challenging in CubeSats, as volume and mass constraints significantly limit design freedom. This forces for research in ways of using smaller and lower-power components in the space environment. The ADCS consists of magnetorquers, digital custom sun-sensor, two magnetometers and two gyroscopes. The sun-sensor, an original design by our research team, and is awaiting flight qualification for deployment on another CubeSat mission, DESCENT. The sensor is comprised of two perpendicular photodiode arrays, covered with a custom aperture mask to detect the Sun angle. This design is significantly cheaper and easier to implement than the commercial products, while offering the same accuracy. The magnetorquers are also custom designed and fabricated by our team and provide non-thruster attitude control mechanism. The electronic circuitry, including for the torque rods and the sun-sensor are currently under development their interface to the other ManitobaSAT subsystems are examined along with the control algorithms.

## Calibration of Panoramic Camera for Atmospheric Monitoring on Mars

**Researcher(s): Heather Stone**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: LURA**
**Supervisor(s): John Moores, Kim Strong**

The objective of this project was to calibrate an optical panoramic camera for atmospheric monitoring. This camera is one component of a prototype designed to observe cloud activity, optical depth, and atmospheric aerosols from the surface of Mars. Radiometric calibration was done to obtain spectral radiance from pixel intensity, and images were dark current, bias, and flat-field corrected. Two main techniques of acquiring images where investigated. With the mean frame subtraction (MFS) technique, a series of images is taken and averaged together to create a mean frame which is then subtracted from each individual image. This reveals subtle differences between images, allowing for observation of hard to see clouds such as those seen on Mars. The high dynamic range (HDR) technique uses a series of images taken at varying exposures which are combined into a single image. This reduces the amount of over- and under-exposed pixels to increase the amount of usable data. Using MFS, cloud images were successfully obtained with the sun both in and out of the field of view. However, HDR did not contribute to the overall quality of image data. A light weight, compact, and efficient meteorological instrument such as this could be deployed to multiple locations on the surface of Mars, improving our understanding of the Martian atmosphere. This instrument could also be utilized on other planetary bodies, including Earth. Greater study of the Martian atmosphere, and the atmospheres of other planetary bodies, will contribute to our understanding of global climate models and atmospheres in general, including that of Earth.

## Navigation and Control Algorithm Development for Customized Self-driving Vehicles

**Researcher(s): James Le**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: LURA**
**Supervisor(s): Jinjun Shan**

**Researcher(s): Hunter Schofield**
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**Researcher Program: NSERC USRA**
**Supervisor(s): Jinjun Shan**

**Researcher(s): Harry Zou**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: NSERC USRA**
**Supervisor(s): Jinjun Shan**

We deployed an array of autonomous ground vehicles and constructed an environment to test autonomous driving algorithms. This project was inspired by the need to test self-driving control on multiple types of ground vehicles (cars, busses, drones). During our tests, multiple vehicles coordinated together to simulate real world driving conditions in our lab environment. We performed initial testing on the Qbot 4e with a mounted Kinect camera. Subsequently we constructed our own RC cars using a Raspberry Pi system to model real-world vehicles. Our process involved implementing visual lane tracking and object detection via image analysis and mapping techniques. We began by researching and developing possible algorithms on Python and MATLAB. Using our motion capture system, we record positional data of the vehicles during the tests, and compared it with the desired path to obtain the tracking error for control purposes. The result was a precise and consistent simple self-driving algorithm. Through this, the vehicles were able to successfully compute and navigate around a closed track while simultaneously performing collision avoidance maneuvers and traffic sign detection. The results from this testbed give insight on how to implement similar visual processing algorithms on larger autonomous ground vehicles that have the potential to navigate on the real-world roads.

## Improving Navigation Satellite-based Positioning Software through Signal Simulations

**Researcher(s): Ivan Mishev**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: LURA**
**Supervisor(s): Sunil Bisnath**

The objective of this project is to develop accurate satellite range measurement files from a Global Navigation Satellite System (GNSS) signal simulator, that can then be used with York University's Precise Point Positioning (PPP) software for cm-level positioning. As navigation by GNSS becomes more prominent, the need for better accuracy using single- and dual-frequency receiver chipsets becomes more important. The goal of this research project is to achieve file generation using a GNSS signal simulator that is accurate, repeatable, and highly adjustable. The research initially focused on becoming familiar with all aspects of the GNSS signal simulator and its software package, SimGEN. This work was followed by developing a novel program in MATLAB that creates input files for SimGEN based on the satellite orbits of both GPS and GLONASS satellite systems. The program ensures that the simulated scenarios are as realistic as possible, and also enables the York GNSS Lab to recreate simulated scenarios using actual, field gathered data. The capability to execute accurate simulations and produce output files for York's PPP algorithm allows for testing of the algorithm. By being able to simulate the measurement errors that are applied, errors can be more accurately modelled, and therefore eliminated. The final aspect of the project is to simulate triple frequency GPS signals. Using three frequencies will increase the accuracy of the user position and reduce solution initialization and convergence to the desired level. The aim of this research is to improve accuracy from tens of metres to the centimetre-level in low cost GNSS chips. This work is globally leading-edge, and applications for such performance include vehicle navigation, augmented reality, and precision agriculture.

## Constraining phase function for ice and liquid clouds with DSCOVR's Earth Polychromatic Imaging Camera

**Researcher(s): Noah Stanton**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: NSERC USRA**
**Supervisor(s): John Moores**

The purpose of this analysis was to determine the phase functions for liquid and water ice clouds on Earth using data from the Earth Polychromatic Imaging Camera (EPIC) on NASA's Deep Space Climate Observatory (DSCOVR) captured between June 2015 and March 2019. EPIC consists of a 10 channel 2048x2048 resolution camera with 4 UV channels, 4 visible channels, and 2 near infrared channels. Images from DSCOVR are taken from a distance ranging from 1.4 to 1.6 million km away, in the L1 Lagrangian point. In L1, DSCOVR stays fixed between the Earth and the Sun, always observing the sunlit side of Earth. The phase function is a dimensionless parameter that is dependent on both the scattering angle and orientation of the scattering. Observationally derived phase functions can be used to infer microphysical properties of the clouds such as ice crystal size and shape. The almost constant scattering angle observed by DSCOVR ranges between 168.5° and 175.5° giving a unique perspective near the backscatter peak at 180°. Using Level 2 cloud products, the most likely cloud particulate phase was identified for each pixel, and cloud opacity and phase function were derived using radiometrically corrected reflectance from the 680nm data. Pixels with an opacity greater than 2.2 were chosen to ensure the clouds were sufficiently thick. The data was first separated by particulate phase and then phase functions were determined for each. The initial results show differences in the shape of the phase functions, and a larger range of scattering angles from the dataset is currently being processed. The phase function observations from Earth's atmosphere can be a proxy for exoplanetary atmospheres, providing insight into the microphysical properties of clouds in exoplanetary atmospheres.

## Reinforcement Learning Based Navigation, and Environment Mapping Using LiDAR

**Researcher(s): Peter Caruana**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: Direct employment**
**Supervisor(s): Jinjun Shan**

My objective with this project was to integrate SLAM (Simultaneous Localization and Mapping) with Reinforcement learning to have an autonomous robot navigate through an environment while it creates and updates a map of its surroundings. The development of autonomous vehicles is a quickly advancing field. The ability for robots to control themselves in unknown environments replaces the need to have human operators. Applications include self driving cars, mining, space exploration etc. where a robot may be able to react faster and more appropriately than a human operator. In particular, autonomous vehicles will greatly impact the efficiency of commerce, trading and many other small everyday tasks done by humans. A robot's ability to see its environment is a crucial element of autonomy, and as such, the primary sensor used is a VLP-16 LiDAR. This allows for point-depth measurements to be made in 360 degrees, giving the robot the ability to see all around it. The base of the robot is a Turtlebot2, powered by an Nvidia Jetson Tx2 computer. The navigation, mapping, and control is run using Robot Operating System (ROS), running on the Jetson. Laserscan data is collected from the LiDAR and combined with odometry data to map the environment and localize the robot within it. Given this information, Reinforcement learning is employed to train the robot to navigate the environment. I use an  -greedy algorithm to implement reinforcement learning and train on a simulated environment using the Gazebo simulator. This allows more expansive training to be done in a shorter time. In order to avoid biasing, multiple environments were used to train the algorithm. This method can speed up the development and implementation of autonomous vehicles to be used in real world applications.

## Observations of Atmospheric-Surface interaction for various Mars Years using THEMIS and MARCI observationsObservations of Atmospheric-Surface interaction for various Mars Years using THEMIS and MARCI observations

**Researcher(s): Pruthvi Acharya**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: Work-Study**
**Supervisor(s): Isaac Smith**

This project focused on observing atmosphere-surface interaction the north polar region of Mars. Interactions such as CO2 sublimation and wind transport were observed using the Thermal Emission Imaging System (THEMIS) and the Mar Color Imager (MARCI). The interactions can be explained by the evolution of the temperature and katabatic winds, thin fast-moving winds moving 200m above the surface. Clouds created by the katabatic winds exhibit movement of material across specific regions on the north polar ice cap and can constrain mass flux. I analyzed seasonal THEMIS images for several Mars years. THEMIS has a narrow field of view, 1 km scale, allowing us to fully resolve near-surface clouds. The cloud images were sorted by their date and statistically studied their seasonal variability in frequency. I then analyzed daily MARCI videos across seasons of the same Mars Years. MARCI has a much larger field of view so large-scale events on scales of 10s-100s of km are visible. The two data sets and modeled wind maps were compared for any correlation and used to explain the seasonal processes that occur. In my summer research experience, I discovered many correlations between THEMIS cloud images and the MARCI videos. For example, I observed how cloud presence can be explained by large-scale wind activity and constrained the origin of large-scale dust activity using cloud images. Following on the work of my advisor, I refined the correlation between the evolution of the surface ice and the katabatic winds. In this presentation, I will explain how the polar region of Mars evolves with time and the correlation between the small-scale and the large-scale events. Going forward, we will use these results to refine the knowledge of Mars polar processes and present-day climate.

## Development of a GNSS-R Sensor for Soil Moisture Determination

**Researcher(s): Sogand Talebi**
**Dept. of Earth & Space Science & Engineering**
**Researcher Program: LURA**
**Supervisor(s): Sunil Bisnath, Regina Lee**

The object of the project is to retrieve soil moisture using Global Navigation Satellite System- Reflectometry (GNSS-R). The measurement system consists of the receiver and two antennas: one zenith facing antenna to receive direct signal emitted from GNSS satellite, and the nadir facing one to receive reflected signals from the Earth's surface. Characteristics of the reflected surface, such as its dielectric constant, can be found by comparing the two signals. Since there is a relationship between water content of a surface and its dielectric constant, algorithms can be developed to retrieve soil moisture. The primary objective is to develop and improve the existing FPGA software, used in York developed GNSS-R receiver, to record the raw satellite signals from the antennas. The main challenge with the current design is the limited data that the hardware supports (approx.100 milliseconds). This amount is not sufficient to make quality correlations necessary to estimate soil moisture parameters. The problem lies within the Direct Memory Access portion of the software, which can be solved by gathering data in a cyclic manner for at least an hour. Currently, the preferred solution is to use a cyclic function in the DMA section of the software to achieve longer data collection periods. The secondary objective of this project is to design an enclosure for the GNSS-R receiver, to make the system mobile, and weather proof to enable effortless data collection. The NX software was used to design the enclosure and to laser cut the acrylic, which is now finished and functional. It is expected that GNSS-R will enable the study of soil moisture remotely, and it will help to increase the understanding of climate change and to provide this valuable information to various industries.

## Oral Neutrophils and Artificial Intelligence: an Interdisciplinary Approach to Portable Early Detection of Chronic Diseases

**Researcher(s): Alessia Sacco, Alessia Sacco, Jenny Kim, Eren Yigit, Morteza Ghafar-Zadeh**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: Summer Undergraduate Research Assistant**
**Supervisor(s): Ebrahim Ghafar-Zadeh**

According to the American Academy of Periodontology, there are 64.7 million adults in the US alone that suffer from Periodontitis. This number represents nearly half of the adult American population. In most cases, Periodontitis goes undetected until severe life-threatening symptoms appear, at which point consequences are irreversible and may lead to death. Our body already has the means to detect this disease: specifically made leukocytes called neutrophils. Based on recent studies, elevated levels of polymorphonuclear neutrophil in saliva, are able to identify and engulf various diseases such as Periodontitis. This research is aimed at exploiting the behaviour of neutrophil when in presence of a disease, specifically Periodontitis, to detect it in its early developmental stages. This project focuses on developing a low complexity method and tool to isolate the cells from saliva and count the number of cells using image processing methods. In this isolation method, the adhesion properties of neutrophils on a hydrophilic surface are used. In order to increase this property, Oxygen Plasma is applied. As a result, the creation of an Artificial Intelligence (AI) based on research data, can be easily implemented in portable devices for home monitoring and testing. The proposed method is noninvasive, diminishes the risk of infection and leads to early detection of diseases. This will improve accessibility and availability of screening tools for patients. High neutrophil counts have also been associated with Neurodegenerative and Cardiovascular diseases. Thus, the AI can be applicable to the early onset detection for a plethora of diseases, such as Cancer and Lateral Sclerosis. This method can potentially revolutionize the screening and diagnosis processes on a global scale.

## Instrument for Real Time Acquisition and Transmission of Ballistocardiogram Signals

**Researcher(s): Ashar Latif**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Peter Lian**

The objective of the project was to develop a wearable data acquisition system for ballistocardiogram (BCG) signals that would subsequently wirelessly transfer the captured data to a nearby computer for deeper analysis. With the recent rise in the prowess of machine learning algorithms, we can capture data in increasingly non-invasive ways and then let the algorithms sift through the sea of data to sniff out patterns that can indicate potential health problems. The BCG measures the force of blood ejection during cardiac cycle. It can be acquired in a non-invasive way that the skin requires no contact with electrode. This project aims to design a highly integrated wearable amplification and transmission circuits for real-time BCG monitoring. An analog front-end (AFE) with gain of 2.0 and a 24-bit analog-to-digital converter (ADC) from the Texas Instruments ADS1292 with SPI readout protocol is adopted for the BCG amplification. Then the amplified BCG is read by a Bluetooth module based on the Nordic Semiconductor NRF52810 for wireless transmission. The designed board measures 32mmx24mm, and it is estimated that it will draw only 250 µA of current. With this design we hope to create a device that people with heart conditions will not have to think about, non-invasive and small enough with a long enough battery life that the adoption rate, which is ultimately the determining factor for the efficacy of any health monitoring device, will increase and provide a wealth of data to health care professionals.

## Object Detection in Nursing Homes for Autonomous Wheelchair Software

**Researcher(s): Brittany Danishevsky**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: NSERC USRA**
**Supervisor(s): John Tsotsos**

When creating autonomous robots for indoor health-care environments, common technologies such as LIDAR, GPS, and RFID chips can be unreliable, and interfere with medical electronics. Thus, computer vision is proposed as a less invasive and more reliable technique. This project, which is divided into two parts, aims to develop software for an autonomous wheelchair, which will use vision to navigate around a nursing home. The first part of this project is building a data set of items encountered in a nursing home (e.g., wheelchairs, walkers, canes, etc.). This dataset will be trained on an existing object detection algorithm (e.g., YOLO9000) and tested in a nursing home setting. The second part of the project is to determine what features of the nursing home can be used to localize the wheelchair, allowing it to autonomously navigate within a pre-mapped space reliably. The strategy for localization is a combination of an existing global pose refinement framework, as well as object classification using the dataset put together in the first part of the project. Successful classification of objects will inform the current location of the wheelchair (i.e., answer "where am I right now?"); global pose refinement, which is guided by wheel odometry and feature detection of wall edges, will allow the wheelchair to localize as it moves through nursing home corridors. Such autonomy will relieve some of the burden on elder care professionals, while also providing independence to nursing home residents. In addition, this project will contribute a novel dataset to the growing body of computer vision research, as well as a unique application of computer vision and robotics to elder care.

## Survey of Interpretability in Machine Learning and Data Generation Analysis for Model Extraction

**Researcher(s): Chester Wyke**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Ruth Urner**

The increasing use of Machine Learning (ML) for decision support in industry and administration has lead to ML having a growing impact on individuals' lives. As a result, there has been growing societal concern regarding understanding how ML models work (Interpretability). For example, EU regulators have taken note and required that explanations be provided when there is substantial impact on people's lives. As the first part of this research internship, an extensive literature survey was conducted and a categorization of current methods designed to provide interpretability in ML was compiled. On a high level, there are three approaches to addressing interpretability in ML. Firstly, develop an intrinsically interpretable model. Secondly, provide an explanation for a particular prediction from a black box model (local explanation). And finally, explain the model behaviour in general (global explanation). State of the art techniques for each of these three approaches were reviewed.

The second part of the internship focuses on a particular framework ("Interpretability via Model Extraction") for developing a global explanation of a blackbox ML model. In this framework, an interpretable "student model" is learned to mimic the global behaviour of the black box "teacher model". The goal of internship research is to analyze how the quality of the student model depends on the type of unlabeled data that is used for its training. For this, the explanatory value and the approximation to the teacher model under different data generation methods are empirically compared.

## The World's Largest Dynamic Scenes Video Database

**Researcher(s): Haider Al-Tahan**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: NSERC USRA**
**Supervisor(s): Richard Wildes**

Scene classification is a fundamental challenge to the goal of automated visual perception. Here, scene classification refers to assigning a viewed scene to a known category, e.g., beach vs. city vs. forest. Although humans are proficient at perceiving and understanding scenes, making computers do the same poses a challenge due to the wide range of variations in scene appearance. Currently, there are a variety of algorithms available to attack this problem; however, algorithmic advances in this area are being held back by the lack of adequate video databases on which to train and test. Moreover, data are available in a wide range of formats, from various sources, and often they are not stored in a format that is ready to feed into a computer vision or machine learning pipeline, hence, the process of creating a dataset is expensive and time-consuming but necessary. This project directly addresses this shortcoming by building a video database to support the training and testing of dynamic scene recognition algorithms. The main goal of this project involves developing a large dataset with videos of a variety of dynamic scenes. This task can be categorized into the formulation of scene categories, design, implementation and deployment of tools for video collection, annotation of collected videos and testing of scene recognition algorithms on the constructed video database. By the end of summer, this project will yield a new database for release to the computer vision community that can serve as a novel benchmark to help researchers from around the world and thereby contribute to the advance of computer vision and, more generally, artificial intelligence.

## Neural Networks for Heart Rate Detection in Ballistocardiogram (BCG) Signals

**Researcher(s): Jabavu Adams**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Peter Lian**

**Researcher(s): Fasil Cheema**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: NSERC USRA**
**Supervisor(s): Peter Lian**

The project goal is to use machine learning to do real-time and robust detection of heart rate in a potentially noisy and distorted ballistocardiogram (BCG) signal. Ballistocardiography measures the repetitive motion of body tissues in response to blood pumped by each heartbeat. BCG sensors are cheaper, more rugged, and less invasive than electrocardiogram (ECG) sensors, and can be integrated into seating, bedding, or wearable devices. Thus, having reliable BCG heart rate detection could reach a larger number of people who might benefit from heart rate monitoring, as well as broaden the environments in which monitoring is possible. This could lead to better patient care, to earlier identification of potential cardiac problems, and also to novel consumer devices. Our goal is to train neural networks to detect heartbeats in BCG signals, and to deploy these algorithms to mobile devices. To use supervised-learning training techniques, we need labeled (annotated) training data consisting of input signals, and the corresponding outputs. We are not aware of labeled datasets of BCG data. However, there are good industry-standard datasets of labeled ECG data, such as the MIT-BIH ECG dataset. To generate labeled BCG data to train on, we use simultaneously recorded ECG and BCG signals. ECG measures electrical activity in the heart, while BCG measures motion, so the ECG heartbeat peak occurs before the BCG peak, with a relatively consistent time lag.

We expect that by developing very accurate ECG heartbeat detection, and exploiting this predictable time lag, we will be able to use supervised-learning to train neural networks to detect the heartbeat in BCG signals. We expect this approach to cope with noise and distortion due to subject motion better than simpler techniques.

## Application of Machine Learning Algorithms in Real-Time Access Control

**Researcher(s): Jia Ying Ou**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Amir Chinaei**

Password-based authentication is one of the most commonly used access control techniques to secure computers against intrusions. Yet, this technique is not reliable unless it is complemented by other techniques such as using security questions. The problem is that the authentication is no longer in real-time, and a more robust approach is necessary. The objective of this research is to apply machine learning algorithms in password-based authentication to make it more real-time. The basis of this research is to exploit patterns that users demonstrate during typing—such as keystroke latency—in order to automatically add them to access control rules, thus to bring the reliability of password-based authentication to a higher level. During the study, we have found that by training data using logistic regression in a multi-layer neural network, we can improve upon false positive and false negative rates. In particular, during the training steps, the network learns new access control rules that are based on user's typing patterns. As a result, the trained network can detect typing abnormalities of the user by comparing them to the added access control rules and minimize false inferences without applying non-real time approaches such as using security questions. There are several directions to continue this research in future, including using probabilistic neural network to increase the classification accuracy of typing patterns, applying other typing dynamics such as the amount of time a key is pressed, and comparing the results using k-nearest neighbour algorithm.

## Visualizing Structure Health Monitoring of Carbon Fiber Composite Through Electroluminescence

**Researcher(s): Jiefeng Qiu**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: RAY**
**Supervisor(s): Gerd Grau, Garret Melenka**

Conventional damage inspection methods and characterization of carbon fiber (CF) composites are typically destructive, expensive, and do not provide spatial resolution. In this work, non-destructive monitoring of CF composites is presented with an integrated intrinsic alternating current electroluminescent (ACEL) thin-film epoxy resin-phosphor membrane sandwiched between semi-transparent CF mesh and woven CF fabric lamina. Different damage states in the CF composite cause EL luminance gradients which allows for visual inspection and damage detection of the CF composite at specified locations. The objective of this research is categorized into three steps: fabrication, characterization, and performance. The project imitates with fabrication of the device with conventional material and processes. As the proposed structure is simplified as parallel RC electrical model, it is then characterized with analyzing the mathematical relation among fabrication, electrical, and output EL parameters, and to obtain the optimal settings for mechanical performance test. The characterization apparatus is composed of power and acquisition module to obtained digital data of EL luminance on specimen with different combination of fabrication parameters through camera and DC-AC inverter power supply. ASMT D2344 three-point bending test on short beam specimen is selected to perform damage and strain response with respect to EL luminance gradient. The mechanical test apparatus is a modification on the basis of characterization apparatus to obtain the relation between stress, strain, and EL luminance gradient. The proposed methodology offers simple and effective structural health monitoring to any product constructed from CF ranging from aerospace to high performance sporting goods.

## Recovery of a Reference Architecture for Computer Vision Projects

**Researcher(s): Jovan Hovey**
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**Researcher Program: Mitacs**
**Supervisor(s): Jack Jiang**

As the machine learning industry is ever moving faster, reuse of established architectures are a simple way to keep speed and quality concerns up while reducing costs at the same time. In the past, reference architectures such as the Web Server Reference Architecture (Hassan & Holt, 2000) have been used to better understand the challenges software systems for specialized domains are facing, as well as provide a template on how to overcome these challenges. The objective of this project is to recover an architecture beneficial for Computer Vision (CV) projects by performing an empirical investigation of open sourced CV frameworks. The architectures of selected projects were reverse engineered following the example of Tran and Holt (Tran & Holt, 1999), visualized, and compared to discover recurring elements and subsystems. To increase the detectability of commonalities, the focus was on CV projects written in Python and using the TensorFlow framework. The initial part of my research was to write a tool based on Python's ast module that would perform static analysis of internal and external module dependencies. The subsystems' dependencies of different frameworks were then manually visualized and compared. The result of the research will enable software engineers to reuse both the experience in design, as well as code of components such as deployment or checkpointing.

## Learning Interactions of Moving Objects Using Variational Auto-encoders

**Researcher(s): Ken Tjhia**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: NSERC USRA**
**Supervisor(s): Manos Papagelis**

Advances in location acquisition and tracking devices have given rise to the generation of enormous trajectory data consisting of spatial and temporal information of moving objects, such as persons, vehicles or animals. Mining interaction patterns of moving objects, based on spatiotemporal proximity of their trajectories in Euclidean space, is of increased research interest due to a broad range of useful applications, including analysis of transportation systems and location-based social networks. However, conventional approaches to address this problem heavily rely on expensive Euclidean similarity computations of a large number of pair-wise trajectories. In this research we present a deep learning approach to learn latent interactions of moving objects. The model is based on a variational graph auto-encoder and is able to accurately discover pair-wise relationships (interactions) among moving objects over time. The model is able to learn these interactions using an unsupervised learning approach operating on individual trajectories and without relying on Euclidean distance metrics that involve expensive pair-wise computations. By extension, we are able to learn the whole interaction graph, where nodes represent moving objects and edges represent that two objects have interacted with each other. In addition, for each edge we learn a weight that represents a latent metric of proximity according to the total time two objects were close to each other. We demonstrate the effectiveness of the model on several synthetic and real world data-sets, comparing the results against the ground truth provided by deterministic algorithms.

## PROMISE: The world's largest benchmark suite for probabilistic model checking

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**Researcher Program: LURA**
**Supervisor(s): Franck van Breugel**

Software bugs cost the worldwide economy hundreds of billions of dollars annually. Our research, focusing on finding bugs in software that relies on randomness, will be a stepping stone towards fixing this astronomical problem. Randomness is pervasive in the hottest fields including machine learning, games and AI, due to the fact that randomized algorithms, in which the outcome is not always the same, allow previously unsolvable problems to be solved and can be drastically more efficient than ordinary deterministic algorithms. Testing is most commonly used to find bugs in software, however running a test on software with randomness does not guarantee that all possible executions are checked. Enter probabilistic model checking, a formal technique for analyzing systems that exhibit probabilistic behavior. However, the field is severely lacking good benchmarks, which would allow for rapid progress. State of the art tools either consider less than a handful of realistic models, providing little confidence in the results, or use randomly generated models, which is not useful as they tend not to have the same properties as models encountered in practice. The goal of our research is to obtain a large database of realistic probabilistic models. This is done by collecting all existing examples and converting them into the same format, as well as implementing randomized algorithms in Java and extracting models from them. Currently, the largest benchmark suite contains 36 models. We have already collected 85 models and plan to reach over 150. Our results will be made open source, providing much-needed benchmarks for probabilistic model checking; further, this will serve the larger research community as it impacts some of the most important areas within computer science research.

## Phrase Graphs for Multi-Modal Embeddings

**Researcher(s): Kevin Joseph**
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**Researcher Program: NSERC USRA**
**Supervisor(s): Hui Jiang**

Scene understanding attempts to analyze objects within an image with respect to their spatial, functional, and semantic relationships. This information is typically expressed as a graph. Unfortunately current Scene Graph creation methods concentrate on the 50 most frequent relations, resulting in repetitive, or unspecific graphs. In order to express a potentially unlimited amount of relations, one could embed these objects and relationships. In this work we propose a contextualized multimodal embedding frame work via annotating caption, image pairs that share common objects. Our hope is that these embeddings can be used for a plethora of downstream tasks such as image retrieval, image captioning, and visual relation detection. In this work we focus on image retrieval. Given the correct pairs of shared between an image and it's caption, our embeddings can produce competitive image retrieval results.

## Distributed Sweep-line Algorithm for Scalable Geometric Object Intersection Analytics

**Researcher(s): Mahmoud Alsaeed**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Manos Papagelis**

The objective of my research was to design and develop a scalable distributed algorithm for identifying and quantifying the size of multiple intersections among a large number of axis-aligned geometric objects. Currently, the state-of-the-art approach for addressing such intersection problems in Euclidean space is collectively known as the sweep-line or plane sweep algorithm, a key technique in computational geometry. The idea behind sweep line is to employ a conceptual line that is swept or moved across the plane, stopping at some points. However, to report all K intersections among any N objects, the main sweep line algorithm (based on the Bentley–Ottmann algorithm) has a time complexity of O((N + K)log N), therefore cannot scale to very large number of objects and cases where there are many intersections. The objective of the research was to design and develop a distributed version of the sweep line algorithm using the MapReduce programming paradigm. Towards that end, we designed a novel and fast method that uniformly at random partitions the data to workers and computes the model in a distributed manner. The main idea of the distribution follows the divide-and- conquer principle for solving problems. Furthermore, we designed a distributed method to construct an intersection graph, where nodes represent geometric objects and edges represent that two nodes are intersecting. This graph serves as an auxiliary data structure and can effectively be used to provide connectivity properties among multiple intersecting objects. As such, it can inform exploratory ad hoc intersection queries. The proposed algorithm can inform many data mining and machine learning methods and can be utilized in a variety of application domains, including gaming and transportation, to name a few.

## Seizure Detection Using Brain EEG Signal Processing

**Researcher(s): Mohammadreza Karimi**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: NSERC USRA**
**Supervisor(s): Hossein Kassiri**

Approximately 360,000 Canadians live with epilepsy. For 20% of these patients who are refractory to drugs, a medical device capable of early detection of an upcoming seizure could significantly improve their quality of life by either alerting the patient and/or triggering an intervention mechanism such as electrical stimulation. Over the past decade, recording and processing brain's electrical activity has been used as a promising method for detecting epilepsy seizures. However, the success has been very limited due to (a) the large patient-to-patient variations in terms of seizure manifestation, and (b) limited computational resources available in an implantable device. Recently, machine learning algorithms have been investigated, with some success, to realize a patient-specific algorithm to overcome the first challenge. However, the majority of reported algorithms are too computationally-expensive for an implantable device. In this project, we have designed, implemented, and optimized a machine learning algorithm with both detection accuracy and computational efficiency in mind. To achieve high detection sensitivity with minimal false alarm rate, we have extracted various features of the recorded signals such as signal frequency band energy and phase synchronization, and fed them to a trained support vector machine (SVM) classifier known for its reliability and efficiency. Different modules of the implemented algorithm (e.g., data acquisition, feature extraction, and classification) are individually optimized for hardware implementation. The algorithm is tested on a 916-hour 24-patient labelled MIT EEG Database and can detect 90% of seizures with only a 10 false alarms per day (commercial devices have 200 to 600 daily false alarms (Bergey, et al, Neurology, 2015)).

## Detecting and preventing impact concussions in real time.

**Researcher(s): Olga Klushina**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Peter Lian, Yang Zhao**

This work develops a backend system to be used in a "smart helmet" for contact sports. The system senses and triggers countermeasures to prevent brain concussions in real-time. The data acquisition system is designed on a printed circuit board (PCB), mainly consisting of an accelerometer and Bluetooth module. The PCB is designed, programmed and tested in-house to ensure reliability. The accelerometer provides the raw data, which is analyzed for potential concussion events and onboard calculation activates the airbag when safety threshold is breached. The data is also transmitted wirelessly via Bluetooth and is stored on an external device for further study and analysis. Bluetooth low energy (BLE) technology is used to maximize operational time and reduce drain on batteries.
Before deploying the safety system to the athletes, the PCB will be tested using a simulation of real world conditions. If successful, the project will be a great advancement in sports science and ensuring the safety of the sportsman.

## Automatic labeling of lung tumors in CT scans

**Researcher(s): Ori Wiegner**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Suprakash Datta**

Currently, lung cancer is the leading cause of cancer death in Canada. Lung cancer accounts for 26.1% of cancer deaths in males and 26.2% in females. The standard method of lung cancer detection is through computed tomography scan (CT) which utilizes X-rays and specialized algorithms to recreate detailed pictures of organs and structures within a patient's body. Unlike traditional X-rays which produce a single image, CT scans produce multiple cross-sectional images. Due to the number of images in a single CT scan, interpretation requires time, which could be reduced using a computer-aided diagnosis system (CAD). This project will create a CAD system that automatically process a patient's CT scan to determine if there a lung tumor present. This system will be validated on two real CT scan data sets (n=65 and n=10) containing a combination of malignant and benign tumors which were previously diagnosed by a radiologist. Initially a noise reduction filter and segmentation algorithms are applied to each image in a CT scan to remove all soft tissue surrounding the lungs. The system then distinguishes between tumors and any other soft tissue structures within the lungs based on 3D shape (e.g., Haralick features) of putative tumors and traditional machine learning classifiers (e.g., Support Vector Machines). Some of the challenges for designing such a system include detection of chest wall tumors (i.e. tumors attached to the lung walls) and detecting small tumors. CAD systems for the interpretation of CT scans has the potential to impact the way diagnosis of lung cancer is made, by simplifying the process of both reading and interpreting CT scans, as well as reducing the number of interpretation errors.

## Minimally-invasive Subdermal Implantable Wireless EEG Recording Device

**Researcher(s): Petr Roganov**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: Volunteer**
**Supervisor(s): Hossein Kassiri**

Electroencephalography (EEG) is a method for recording the electrical activity of the brain. With current methods of EEG the patient must either be bound to the recording hardware with physical wires or has to wear bulky headsets, none suitable for patients who need long-term EEG monitoring (e.g., epilepsy patients). Our project aims to create a minimally-invasive subdermal (i.e., under the skin) implantable wireless device. My focus specifically is the design of a test-bench circuit board that hosts the custom-designed EEG recording and wireless communication integrated circuits required for such a medical device. The board receives signals from 8 recording channels. Following signal amplification and digitization, the on-board FPGA serializes the data from all 8 channels into a single stream. That stream of data is then sent over a low-energy Bluetooth interface to the computer for processing. In order to allow for future miniaturization emphasis is made throughout the design process on using low-power components and optimally placing them relative to each other for the purpose of noise reduction which becomes critical in low-power high-throughput circuits. During the testing process we are hoping to get data rates in the range of hundreds of Kbit/s while the overall current consumption stays in the range of a few milliamps. Reducing the power consumption of the electronics while maintaining the necessary data throughput rates will allow for the design of a highly-compact implantable recording device capable of long-term brain signal monitoring without causing discomfort to the patient.

## User Pairing Schemes for Aerial and Terrestrial networks using NOMA

**Researcher(s): Ramein Zahedi**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: RAY**
**Supervisor(s): Hina Tabassum**

Non-orthogonal multiple access (NOMA) is considered as a promising multiple access technique for B5G/6G cellular wireless networks where several users can be served on a single resource block using the concepts of superposition coding at the transmitter and self-interference cancellation at the receiver. The achievable gains of NOMA over traditional orthogonal multiple access (OMA) are well-known for terrestrial cellular networks. However, the performance gains of deploying NOMA in aerial networks are unknown as compared to the terrestrial network.

In this work, we investigate the gains of NOMA-enabled unmanned aerial vehicles (UAV) networks and, based on our conclusions, we aim to investigate the feasibility of NOMA for integrated terrestrial-aerial networks. For both the uplink and downlink NOMA in aerial networks, first we theoretically derive the conditions under which the spectral efficiency gains of NOMA can be guaranteed for all users served on a single resource block. We demonstrate the performance of a two-user NOMA cluster served by a UAV for three different user pairing mechanisms, i.e., max-min pairing, random pairing, and threshold pairing which is based on the conditions derived. Numerical results show the significance of the derived conditions for user pairing in uplink and downlink NOMA and provide a comparison between all three pairing schemes. Finally, we outline the critical research challenges in integrated aerial-terrestrial networks and provide insights on opportunistically selecting a correct multiple access mechanism to optimize the performance gains.

## Development of Pipeline for Evaluating HDR Compression Standards

**Researcher(s): Richard Robinson**
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**Researcher Program: LURA**
**Supervisor(s): Robert Allison**

To support the development and evaluation of state-of-the-art image compression codecs we are developing workflows to process and present high-dynamic range (HDR) test images 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 images are capable of representing a much broader dynamic range of brightness. For testing, dozens of carefully chosen images were rendered by Unity, Unreal, and Blender, the requisites for such images including having sufficient detail, a wide range of brightness, and being rendered in stereo, HDR, 4K resolution using the BT2020 color space. These master images were then exported and processed via the OpenEXR library and MATLAB. The OpenEXR image format is an HDR format using the IEEE 754 16 bit half-precision floating-point format. For compression we convert the image to a 10 bit HDR format (PPM). To fit in this 10-bit range we tone map the luminance values beyond the maximum range of the display and convert the color data to the P3 color space. The compression algorithm then compresses the image using various bit rates per pixel, ranging from 10 to 4. The quality of the compression is measured by evaluating a flicker test done with each image displayed in a stereoscope. This compression standard could decrease image stream bandwidth requirements by a wide margin. As such, having a compression standard like this one will be useful in greatly decreasing the bandwidth requirements for cables and other links while maintaining the 10-bit necessity of HDR files.

## Non-invasive Micro-Electrode Array Electrophysiological Recordings

**Researcher(s): Ryan Karaba**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Ebrahim Ghafar-Zadeh**

Zebrafish are a growing model for neurophysiological research specifically in drug application, neurological disorders, and development studies due to their close relation with the human brain. Previous electrophysiological recording methods trend towards the use of invasive micro-pipette electrodes whereas this project establishes the use of a non-invasive system provided by Multichannel Systems. The focus of this research project is to expand the current zebrafish larvae experimental epilepsy models through the use of microelectrode arrays (MEA). This method has the ability to record electrical activity from 60 simultaneous locations spread evenly across the microarray. The basis of the project was to discover and implement the best placement of the zebrafish within the MEA to receive consistent electrical activity that portrays electroencephalographic (EEG) signals. Initially my research focused on familiarization and hardware testing of the system provided, followed by the recording of baseline activity from the zebrafish for later analysis using the MATLAB Signal Processing Toolbox to filter electrophysiological signals. To achieve optimal mounting of the fish within the MEA, a 3D structure was designed using 123D design then printed for use. For this stage, the recordings should resemble proper baseline EEG signals confirming the system can be used for specimens of such minimal size. Additional viability tests were done using Neuro-2A (N2A) cells. The gathered information will be built upon by analyzing the effects that seizure inducing drugs have on the zebrafish. With an emerging interest towards zebrafish studies, insight into high-throughput system designs would prove valuable in recording from multiple zebrafish which could lead to a multitude of discoveries.

## Static Volumetric Neutrino Display (IceCube Experiment)

**Researcher(s): Saadia Riaz**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: RAY**
**Supervisor(s): Robert Allison**

The 'Static Volumetric Neutrino Display' research project aims to compare 2D and 3D volumetric neutrino displays in their ability to support users to interact, utilize, and obtain accurate display results. The volumetric neutrino display is a scale model of the actual IceCube neutrino observatory that is located in Antarctica. The 2D display is a computer graphics animation of the same observatory. Participants can use the displays to observe and describe various neutrino patterns. The experiment will quantify the benefit of a volumetric display in learning complex spatiotemporal patterns. The experimental data and the participants' feedback will be collected, organized, and analyzed using statistical software (ex. SPSS) and charts as a way to reach significant conclusions. The hypothesis is that users will learn to recognize the patterns more effectively in the 3D display than the 2D display. However, if the experimental results suggest the 2D display to be similar to or better than the 3D display, then this project would argue against the need to invest in 3D display technologies. This would save cost, time, and energy. In general, the results will evaluate the benefits of volumetric displays on the precision and effectiveness of pattern recognition tasks, which could be used to improve various research activities, processes, and virtual reality equipment. In addition, this project can be strongly applied in my field of health informatics as a successful display would contribute to greater efficiencies with medical and health economic visualizations, which would lead to better health services, analyses, and an improved population health across Canada.

## Assessment of Dynamic Forces in High-Voltage Substations for Distributed Generations Connection

**Researcher(s): Samy Elias**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Afshin Rezaei-Zare**

Due to the ever increasing the number of conventional and renewable distributed generations (DGs), there has been an increase in short-circuit faults levels of the power system/s. High short-circuit level poses several concerns which should be addressed during the planning and operation stages. These concerns include the adequacy of the system equipment to handle the fault levels, power system stability, and of course, safety. In the context of the distributed generation connection to the main power system, many researches have been devoted to the assessment of the system operating conditions from the electrical standpoint. However, the substation to which the generations are connected should be assessed to ensure that their structures provide sufficient mechanical strength when subjected to the elevated fault levels experienced due to the DG connection. The research at hand aims to address that need by calculating the forces which are generated, and therefore experienced by the substation structures during the short-circuit faults in the power system. The goal of this research is to produce a plot of the reactionary forces at the connections with respect to time. To that end, a representation of the cables is established to facilitate examining their relative position which - along with the current - determines the electromagnetic force. That electromagnetic force – along with the gravitational force – in turn determines the new position, and so on. A suitable model is proposed, and then the calculations is done using Matlab. The final result, as expected, will be subject to review and, if approved, can then be used to determine the strength which the substation structures should possess in order to afford a safe level of operation.

## Development of a thermal analytical model for predicting the reliability and accuracy of photovoltaic micro-converters

**Researcher(s): Theresa Nguyen**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): John Lam**

Energy is one of the main contributors to climate change – the current global electricity generation exceeds 26,700 TWh with a large corresponding CO2 emission footprint of 13 giga-tonnes. To reduce these drastic changes to our climate, alternate sources of energy should be considered. Photovoltaic (PV) solar energy is the fastest growing renewable energy resource with a global capacity increase from 5.1GW to 402GW from 2005 to 2017. Leading PV panel manufacturers estimate a PV panel to have a lifetime of over 20 years, but on average, the micro-converter is replaced every 5 years due to failure of semiconductor components in the circuit, increasing cost. This micro-converter is essential to collect the maximal amount of solar energy under different atmospheric conditions. This research project is to develop an accurate analytical thermal model that can: (1) determining the thermal power loss of components in the micro-converter and (2) predicting the reliability of the micro-converter. The thermal models are developed in Powersim, an advanced power electronics simulation software. A hardware prototype of the micro-converter is developed with the thermal performance studied with a thermal camera. Mathematical relations are then used to analyze and compare results to hardware models. Testing results demonstrate an accuracy close to 93% is achieved in the developed thermal models. This research has been used to optimize the design of commercial micro-converters in order to maximize energy cost and minimize consumer cost. The ultimate goal of this project is to accurately predict and optimize the lifespan of the entire solar energy conversion system, so that highly reliable and affordable clean energy can be widely utilized for a more sustainable future.

## Precision Matrix Estimation in Highly Correlated Models

**Researcher(s): Wes Eardley**
**Dept. of Electrical Engineering & Computer Science**
**Researcher Program: LURA**
**Supervisor(s): Gene Cheung**

Graph signal processing (GSP) is the study of signals that reside on irregular data kernels described by graphs. One key challenge in GSP is to identify the most suitable underlying data kernel given limited signal observations—one that captures pairwise data similarity / correlation. Assuming a stationary signal generation model, this is equivalent to the Maximum A Posteriori (MAP) estimation of a precision matrix (also called the inverse covariance matrix) given some data. The state-of-the-art method for doing so is the Graphical Least Absolute Shrinkage and Selection Operator (GLASSO), which is known to have several desirable properties in terms of computation complexity and consistency of the estimator. Where GLASSO tends to fail, however, is in signals with strong correlation throughout the data, when a so-called “incoherence condition” fails. A reasonable alternative to the GLASSO is the Constrained L-1 Minimization for Inverse Matrix Estimation (CLIME). The researchers will use both real-world and simulated data sets to evaluate the performance of the CLIME estimator in highly correlated models. They will demonstrate that in these settings, the CLIME estimator demonstrates better accuracy over the GLASSO. Additionally, the authors will extend CLIME to allow for certain graph Laplacian constraints concerning e.g. graph connectivity or sparsity level that are desirable in many applications of graph learning. The goal of this research is to promote to both academics and practitioners the usage of CLIME to estimate a highly connected dependence structure that is both accurate and adaptable to different applications in GSP.

## Fan-assisted Trombe Wall

Researcher(s): Abdallah Alshantaf
Dept. of Mechanical Engineering
Researcher Program: LURA
Supervisor(s): Paul O'Brien

The present work focuses on developing a Trombe Wall equipped with smart booster fans. A Trombe Wall is a passive solar technology which uses thermal energy storage (TES) for spatial heating. TES materials are categorized into latent, sensible, and thermochemical. The stored heat can be used for heating, cooling, or power generation. This aims to reduce the heating loads of buildings using renewable energy. In the AM-SET-LAB, a scaled Trombe Wall was developed to experimentally test the effectiveness of different materials, as well as monitor air flow, temperature, humidity, and pressure. The experimental setup consists of a solar simulator, a scaled Trombe Wall with vents, and Smart Cocoon's smart booster fans in the wall's vents. The booster fans work concurrently with smart homes, to improve the air quality indoors. In this experiment, the Solar simulator heats up the TES material. An air channel resides between the TES material and a window that transmits the incident solar energy. Using dampers and the smart booster fan, the airflow through the ventilation channel can be controlled, such that stored heat energy can be delivered from the TES material. Experiments will be performed to investigate the TES material selection, thickness of the ventilation channel, and airflow on the performance of the Trombe wall. Optimizing these parameters will lead to much more effective Trombe Walls. Implementing this technology in residential and commercial buildings will reduce running and maintenance costs, improve air quality and comfort, and reduce carbon footprint.

## The Design and Fabrication of a Towing Tank

Researcher(s): Amanda Capacchione
Dept. of Mechanical Engineering
Researcher Program: RAY
Supervisor(s): Ronald Hanson

The aim of this project was to design and manufacture a towing tank that can be used to conduct various fluid dynamic experiments. The manufactured towing tank will be approximately 6m in length, 0.7m in width, and 1.2m in height, and will facilitate test velocities of up to 4m/s in water. Unlike a water tunnel where water flows through the test section over a stationary object, a towing tank contains a carriage located at the top of the tank which is used to tow an object along the surface or submerged within the working fluid. An advantage of a towing tank resides in the stationary fluid, such that low turbulence levels are encountered. Furthermore, boundary layers occurring at the wall of the water tunnels are reduced in a towing tank making such a facility desirable to simulate conditions relevant to an extensive range of applications. A requirement of the towing tank is full optical access for instrumentation such as time-resolved particle image velocimetry (TR-PIV) system. Such a system will allow interrogation of the flow physics occurring in the towing tank over large two-dimensional planes. Utilizing this approach will enable the study of critical flow mechanisms, such as flow separation, or vortex dynamics. This acts as a step toward developing advanced drag reduction technologies which aid in characterizing the understanding of complex flow fields. The effects of drag are important in a broad range of applications from automotive, aeronautical, to even speed-based sports, such as cycling, Paralympic wheelchair racing, and speed skating. The added capability of a towing tank at Lassonde will not only support new research opportunities but also benefit future undergraduate teaching and experiences in fluid and aerodynamics.

## Mechanical and structural properties of boiler grade steel

Researcher(s): Cezary Kirczuk
Dept. of Mechanical Engineering
Researcher Program: LURA
Supervisor(s): Aleksander Czekanski

Boiler grade steel containing high amount of chromium, nickel and molybdenum is proposed as material with good mechanical properties combining high temperature strength and creep resistance. Additionally, it has a good thermal conductivity and corrosion resistance. The major challenge is that boiler steel and others parts of energy plants are exposure to high temperature and pressure for the extended period of time. Moreover, presence of inorganic compounds released during fuel combustion generates the corrosion environment. The combustion of solid fuels produces solid, liquid and gaseous compounds that can accelerate corrosion of heat-transfer surfaces of boiler. Coal and biomass can contain significant amount of sulphur or chlorine which can accelerate steel corrosion leading to important operating problems because of the degradation of metallic material. Thus, the strength of boiler steel decreases with the time under high temperature and corrosion environment. In this project, two kinds of X10 and X10CrMo boiler steel materials were tested (both from the P91 grade). They are classified as a martensitic steel, high-alloy and heat-resistant. The main aim of this project was to study the mechanical and structural properties of materials. The samples were first heat treated (reaching 60HRC hardness), and then annealed in an oven at 400, 600, 800 and 1000°C for 2 hours. The mechanical properties were tested for studied to determine the effect of the exposure to high temperature. The analysis of the steel structure was carried out using a scanning electron microscope with an EDS detector and an optical microscope to determine the microstructure. This study aims to characterize several boiler steel materials that can be used in energy sector industry applications.

## Manufacture and Analysis of Braided Composite Structures

**Researcher(s): Dhruvikumari Desai**
**Dept. of Mechanical Engineering**
**Researcher Program: LURA**
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**Supervisor(s): Garrett Melenka**

Braided composites are a type of material characterized by a woven structure saturated with resin. These materials have been identified as being more stronger, tougher and more damage tolerant compared to conventional materials of the same structure. Due to this, they have several applications in the aerospace, medical, and automotive industries. However,the properties of these types of materials can be quite variable and complex to study compared to conventional materials, which has prevented braided composites from being more widely adapted until recently. Furthermore, braiding machines, the machine capable of manufacturing composites, are typically large scale and commercially unavailable. As a result, to increase the accessibility of braided composites, the focus of this project is to manufacture a small-scale maypole braiding machine capable of producing braided composite samples.Overall, the focus of this research is to produce braided composites and to subsequently study the mechanical properties of this type of material. The braiding machine, in the lab, was fabricated using desktop manufacturing techniques including laser cutting and 3D printing, as well as was automated using a Raspberry Pi, a type micro-computer. The automation and design of the braiding machine enables the production of various configurations; (materials, geometries) of braids which can then be subjected to further study. This research is significant as the testing and studying of braided composites enables the properties of this material to be more predictable, which in turn may result in this material being more widely adapted. Additionally, the research on these materials will also help to create new materials with revised mechanical properties within various industries.

## On-demand Electric Field Induced Egg Laying of Caenorhabditis Elegans

**Researcher(s): Daphne-Eleni Archonta**
**Dept. of Mechanical Engineering**
**Researcher Program: NSERC USRA**
**Supervisor(s): Pouya Rezai, Khaled Youssef**

C. elegans is a model organism offering a well-mapped and accessible neuronal system for disease studies. Egg-laying is a behavior of interest in neurobehavioral studies, governed by a sensorimotor circuit regulated by different neuronal and muscle cells. Optogenetics, the main method used to stimulate neurons to study the egg-laying sensorimotor pathway, is restricted to genetically-modified worms, calling for a simple, on-demand and inclusive egg-laying stimulation technique applicable to non-mutant worms. We report a novel microfluidic technique which exploits electric field (EF) stimulation to induce and investigate egg-laying of C. elegans on-demand, without the need for genetic modification required in optogenetics. A setup was developed to investigate the effect of direct-current EF on stimulating egg-laying in C. elegans partially-trapped in a microfluidic device. The effects of worm age (64-136hr) and EF direction, strength (2-6V/cm) and pulse duration (5-40s) on the number of eggs released within 10min were investigated. The EF direction and strength were investigated under controlled conditions of the trap, leading to significantly more egg-laying events when 64hr-old worms faced the anode. Moreover, EF exposure time had no significant effect on the total number of eggs laid over 10min by 64hr-old worms. Age had a significant effect on EF-induced egg-laying with 136hr-old worms laying 76% fewer eggs than 64hr-old worms. C. elegans EF-induced egg-laying is a novel contribution that provides a simple and on-demand technique to stimulate and investigate egg deposition behaviour and sensorimotor processes in wild-type, and potentially mutant, worms; while not being restricted to genetically-modified strains.

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

**Researcher(s): Constantinos Kandias**
**Dept. of Mechanical Engineering**
**Researcher Program: LURA**
**Supervisor(s): Ronald Hanson**

The goal of this project is to research, design and fabricate components of a subsonic, closed loop wind tunnel - mainly the contraction, and corner sections. The components are designed to accommodate a test section having a 1m by 0.675m cross section, while other geometric parameters are constrained by the available laboratory space. Computational Fluid Dynamics simulations were used to optimize the shape of the contraction and turning vanes. The results of these simulations are being validated against experimental data of similar designs found in the literature. A parametric study is used to develop an understanding of the effect of various geometric parameters on the flow quality, such as contraction length, inflection point location on the polynomial curves defining the contraction wall shapes, and the spacing/chord-length ratio of the turning vane array. A contraction with a minimized footprint and suitable flow quality is selected, and is being manufactured. The structure of the contraction is formed from a lattice of precision cut rib sections that define the polynomial surface of the contraction, over which a flexible material will be laid to form the flow surfaces. The turning vanes are being further optimized, in order to improve the flow quality within the wind tunnel, and reduce the overall pressure losses in the tunnel loop. Given that preliminary results show that the vanes will increase efficiency, and therefore reduce power consumption of the wind tunnel. Wind tunnels are valuable tools, allowing for collection of empirical data on aerodynamic phenomena in a controlled environment. Once completed, the wind tunnel will allow for future work in experimental aerodynamics to be conducted on site, eliminating the need to use equipment in external facilities.

## Drug Screening of Zebrafish Larvae Using Microfluidics

**Researcher(s): Ellen van Wijngaarden**
**Dept. of Mechanical Engineering**
**Researcher Program: NSERC USRA**
**Supervisor(s): Pouya Rezai, Arezoo Khalili**

Drug screening using an accepted model organism is a critical stage for developing treatments to combat illnesses such as Parkinson's disease (PD). The use of Zebrafish (Danio rerio) due to their high genetic homology with humans can provide rapid data on the neuronal and behavioral affects of PD drug candidates. The objective of this project was to create a microfluidic device for simultaneous lateral and top microscopy of semi-mobile zebrafish larvae for cardiovascular and movement monitoring assays. The microfluidic device allows for precise stimulation, control and high-speed imaging of zebrafish larvae to test their sensitivity to various chemicals and drugs. Three-dimensional printing was used to create a mold to fabricate the polydimethylsiloxane (PDMS) microfluidic device. The device consists of two PDMS microchannel layers, a PDMS valving membrane and a 5mm right-angle prism positioned beside a larva trap for lateral microscopy. The microchannels and valve facilitate loading and head immobilization of a zebrafish larva while allowing the tail to move freely. Larvae were exposed to various chemicals and tested in the device with a 3µA electric current at 6 days-post-fertilization to stimulate movement, which was quantified as Response Duration (RD) and Tail Beat Frequency (TBF). Exposure to 3% ethanol significantly decreased the heart rate acting as a proof of concept for the device. The effects of levodopa, a common treatment for PD, on heart activity and tail movement were studied. Exposure to 0.5-2mM levodopa had no significant effect on heart rate or TBF while 0.5mM levodopa reduced the RD significantly.
The results demonstrate the device's potential to screen new chemicals and examine behaviour important for drug screening and toxicology.

## Contactless Solar Evaporation Structures (CSES) for the Purposes of Water Distillation and Purification

**Researcher(s): Kourosh Toghrol**
**Dept. of Mechanical Engineering**
**Researcher Program: Contract**
**Supervisor(s): Thomas Cooper**

This project investigates the modeling, fabrication, and experimental demonstration of a floatable and portable solar water distiller that is impervious to fouling when deployed in areas of saltwater and high mineral content. As the race for clean drinking water increases, the creation of a novel and rapidly deployable system becomes both useful and vital in emergency and aid situations. This Contactless Solar Evaporation Structure (CSES) structure operates on the premise of converting short wavelength light into long wave thermal radiation to heat the surface of a water body efficiently and optimally. As a result of this conversion to the longwave spectrum, thermal radiation penetrates only up to 20 µm into the surface allowing for quicker and more effective steam generation. Following the recent proof-of-principle study (Nature Communications 9, Article 5086, 2018) this research focused on scaling up the system into an operational prototype. This started off by creating a 3-D model of the structure and applying finite element thermal studies to create a baseline target of efficiency and a model for fabrication. The research then transformed to the physical prototyping of the CSES that is 16 times larger than the previous prototype. The expected performance of this prototype is to provide the user with 2.5 litres of clean distilled water, per day, per square meter, under one sun illumination. Upon successful construction of the prototype, outdoor performance testing will be conducted to determine performance under real world conditions. Following this, optimization of the design to maximize thermal efficiency and to reduce the cost will be carried out.

## The Effects of Electrospinning on Triboelectric Nanogenerators for Power Generation and Smart Sensing Applications

**Researcher(s): Matteo Timpano**
**Dept. of Mechanical Engineering**
**Researcher Program: NSERC USRA**
**Supervisor(s): Sunny Leung**

As the worldwide energy demand increases exponentially, solutions for green energy are becoming imperative. Mechanical energy in the form of friction is universally present but often converted into low quality energy such as heat. Triboelectric nanogenerators (TENGs) provide an avenue for converting this wasted potential into electrical energy. The energy can then be stored or used immediately in self-powered sensors. In this research, we explore the effects of electrospinning to increase the electroactive phase content and surface area in the negative friction layer of the TENG and test their harvesting and sensing capabilities in a small-scale wind turbine. A solution consisting of PVDF, DMF, and chitin is first loaded into a syringe pump and a high voltage source establishes an electric field between the needle tip and an aluminum substrate. The electrical force generated overcomes the surface tension of the solution causing PVDF nanofibers to deposit on the substrate as the negative friction layer. The friction layers are then lined on the rotor and stator of a wind turbine. As the rotor rotates, the surfaces periodically contact each other generating tens of volts and micro-scale current. Additionally, the voltage peaks generated are extracted using a Python code so that the TENG doubles as a self-powered tachometer. A calibration curve was created to relate the time difference between peaks to the known speed of an encoder. The empirical relation developed yielded an R2 value of 0.9983 and a sensitivity of 3 rpm. This research has demonstrated the ability for TENGs to recover some of the wasted energy that is universally available. Additionally, we have shown how TENGs will insert themselves into the future of electronics as high-sensitivity, self-powered sensors.

## Improvement of Pool Boiling Heat Transfer Using Micro-Structures Manufactured by Selective Laser Melting

**Researcher(s): Mohamed Karam**
**Dept. of Mechanical Engineering**
**Researcher Program: Mitacs**
**Supervisor(s): Roger kempers**

Over the previous decades, pool boiling has been identified as one of the most effective cooling methods for high-power electronic devices and has been utilized in several systems including thermosyphons and heat pipes. Surface modification was extensively applied through literature to enhance the pool boiling heat transfer coefficient (HTC) and critical heat flux (CHF) using several methods, such as surface coating, machining, wettability, metal or graphite foam and selective laser melting etc., The objective of the current work is to exploit the selective laser melting (SLM) additive manufacturing technique to build micro-structured surface swirlers which resemble twisted micro-structured blades and are not possible to fabricate using conventional machining. The working principle relies on generating multiple eddies in the pool that can help in wicking the liquid to the surface decreasing the wall superheat even near the critical heat flux. Three different geometrical parameters were tested namely number of blades, blade length and density of surface swirlers. These tests are conducted using deionized water at the atmospheric pressure. The SLM process produces small surface topologies having a small length scales which can work as stable nucleation locations and helping in the liquid replenishment as well. The measured HTC and CHF are compared to boiling on flat surfaces and design guide and understanding of the improvement offered by swirler design parameters is presented.

## Design and construction of a tabletop PIV experiment

**Researcher(s): Nilotpal Chakraborty**
**Dept. of Mechanical Engineering**
**Researcher Program: Mitacs**
**Supervisor(s): Ronald Hanson**

The aim of my project is to develop a novel, time-resolved PIV experiment to estimate the effect of dynamic yaw of an object immersed in a fluid on the drag experienced by it. The importance of PIV lies in the fact that it shows us the actual dynamics of flow, for the first time in the history of mankind. It shows a broader picture than what even simulations on superfast computers would do. Having said that, the average cost of a PIV system is USD 100000, which has limited such systems to be within the walls of a limited number of research labs. After getting PIV images, it is very easy to derive information using well established software packages. The design of a proper experiment is the challenge, and we are developing a highly efficient and affordable system. I would break down my research into milestones. I spent the initial time digging deep into papers to find out what has not been done yet. I found out that we could use a polygon mirror, the ones used in laser printers, to make a laser sheet, instead of expensive optics. I had taken it out from a printer, so had to figure out how to make it spin. After that, I designed the setup for the mirror, the laser and the camera in CATIA. The challenge was reducing the system's weight, while maintaining structural integrity. Once that was decided, I built the actual setup. There were challenges here too. For example, we were getting two sheets of light inside the glass tank, because the laser was getting reflected from the bottom of the tank. I solved the problem by placing black nuts on the bottom of the tank, so they would absorb the light. Currently I am trying to develop a synchronizer so that we get one image per laser sheet.
This system will be a gift to York University for research and teaching.

## Characterization of Thermal Properties for 3D Printed Continuous Carbon Fiber Composites

**Researcher(s): Sinan Olcun**
**Dept. of Mechanical Engineering**
**Researcher Program: LURA**
**Supervisor(s): Roger Kempers**

The objective of this research project is to experimentally characterize the thermal conductivity of 3D printed continuous carbon fibre composites using pitch carbon fibre and use this information to further improve the continuous carbon fibre printing process recently developed at the TF-LAB. Both the mechanical and thermal properties of carbon fibers are anisotropic. The most popular method of 3D printing carbon fibre composites, where chopped fibres are mixed into common polymer, do not take advantage of the directional properties of carbon fibre. By printing continuous fibres, an alternative to the lay-up process is created which takes advantage of the very favourable properties of continuous and aligned carbon fibres and can also allow for more complex geometries. The thermal conductivity of these samples was characterized by measuring 3 different grades of carbon fiber at 3 different volume fractions for each grade. K13D2U (Mitsubishi Materials) is the most significant of the grades as it has the highest thermal conductivity at almost 5 times that of Aluminum alloys used in heat transfer applications. However, the biggest failure mode in the printing process is the question of if during the process, the fibres are breaking, as the K13D2U grade of carbon fibre is exceedingly brittle, which may necessitate further modification of the process. Thermal conductivity of each sample is measured using a high-accuracy guarded heat flow meter. The measured values will be compared to theoretical models to ascertain whether the printing process used is consistent in printing carbon fibres. The results of this work will inform improvement to the process, and soon, enable fibre printing using a robotic arm to be able to print geometries more

## Investigation of fabric pattern and seam location on the drag characteristics for cycling speed suits.

**Researcher(s): Affan Behzad**
**Dept. of Mechanical Engineering**
**Researcher Program: LURA**
**Supervisor(s): Ronald Hanson**

The objective of my project is to design and develop equipment to be utilized in the full-scale wind tunnel testing for speed suits. These experiments were conducted to determine the effects of different fabric materials such as hexagonal dimples, vertical stripes, horizontal stripes etc. Another prominent feature on these suits was the placement of seams in different locations. In these experiments the sleeve was selected as a starting point for the investigation. The geometry of the arm was approximated as a cylinder to allow fair comparisons between different fabrics. From our knowledge of trip wires on cylinders, we know that seam locations on the fabric will have a significant effect on the total drag. The cylinder was rotated a complete revolution so that the effect of different seam locations can be documented for the sake of thoroughness. The test was conducted at five, ten and fifteen meters per second to replicate slow hill climbing, steady cruising speed and sprinting which are a part of a typical Tour de France race. The cylinder was rotated fifteen degrees each iteration with a total of twenty-four iterations to reach a full revolution. This data will help us understand the features that are desirable and develop guidelines for speed suit manufacturers. These guidelines will help them to develop better products in the future.

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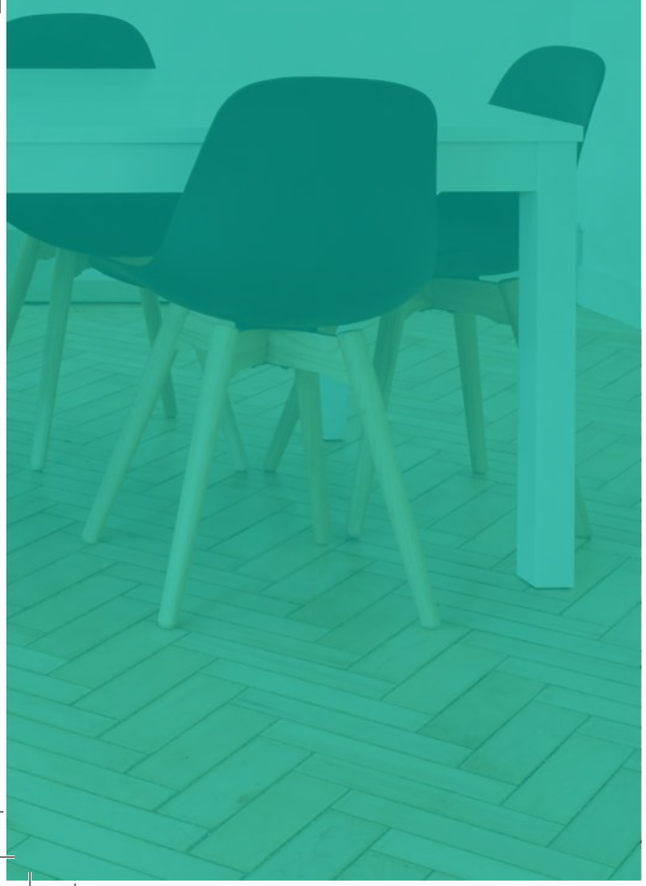

Congratulations to all undergraduate researchers working with Lassonde professors this summer whose research is highlighted in this booklet.

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We would like to express gratitude to the professors who hosted and supervised your research experience. We want to thank any graduate students, postdoctoral fellows and technicians from York who played a mentorship role and otherwise supported your efforts. We would also like to express our appreciation to the York University staff members who manage the USRA program. The time and attention that you have invested in training the next generation of researchers in Canada are invaluable.

Sincerely,

***Serge Villemure***
Director, Scholarships and Fellowships, NSERC

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