MIE CAPSTONE DESIGN PROJECTS

2020 — 2021

Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

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The MIE Design Showcase is a momentous occasion for our students.

This event represents a culmination of their four years of engineering academic studies, as they present their final engineering design solutions in front of their peers, their professors and industry representatives. As 490/491 course coordinators, today is a point of pride for us as well.

Each year, we are privileged to witness our MIE students step up to the challenge and design solutions to complex, real-world industry problems with an impressive degree of engineering acumen and deep collaboration. This year, our students faced the added challenge of collaborating virtually to complete their projects. Students worked in teams to complete 61 projects. The projects are diverse, the results are astounding, and the impact is real.

To our industry partners, we thank you for your commitment to our students and to our mission of providing them with the knowledge and skills to practice engineering design. Their success would not be made possible without your continued, unwavering support of our department and students.

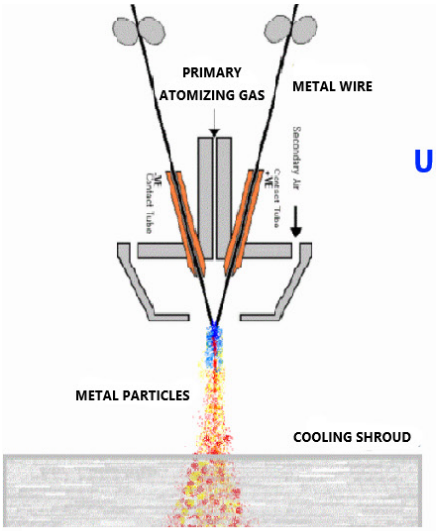
We would also like to thank our faculty supervisors for the guidance and expertise provided to this year's capstone teams, as well as staff who helped coordinate the course and today's event. To our students, we congratulate you on your design achievements and admirable resilience throughout this unprecedented year.

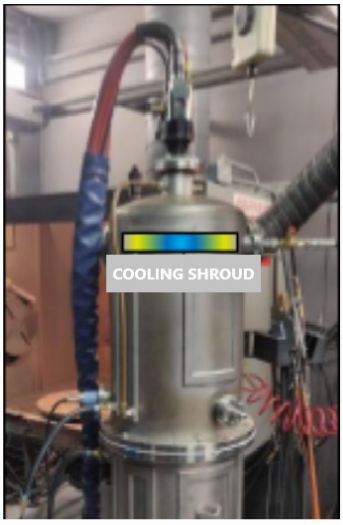
We look forward to another year of academic-industry collaboration, and once again celebrating our students' designs at next year's showcase, which we hope will take place in person.

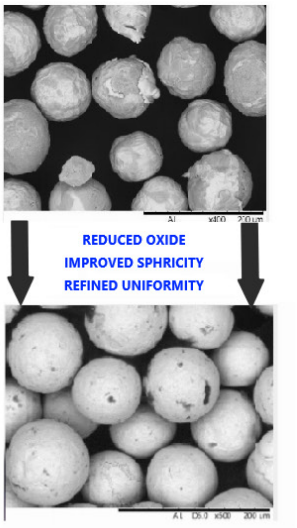
Dionne M. Aleman
Associate Professor

Kamran Behdinan
Professor
NSERC Chair in Multidisciplinary Engineering Design
Director, U of T Institute for Multidisciplinary Design and Innovation (UT-IMDI)

Advanced Industrial Technology







Cooling Shroud for Wire Arc Powder Production

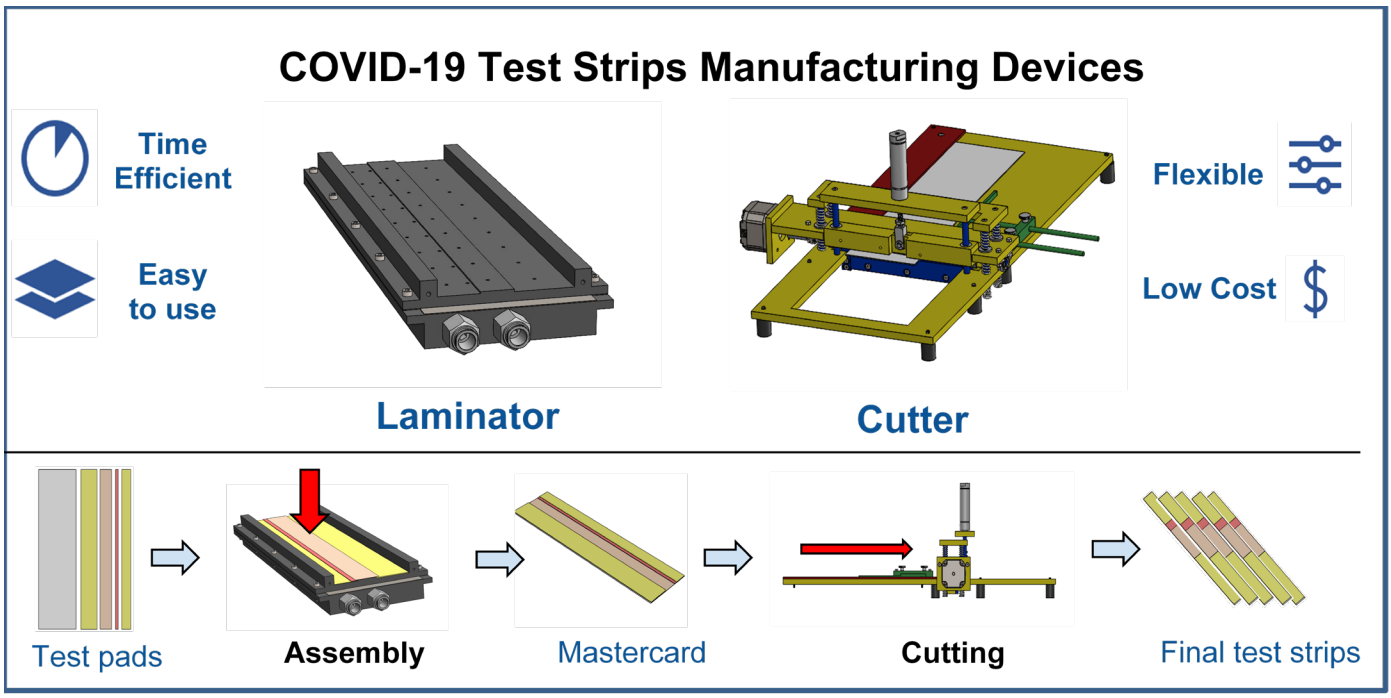
Client: Dr. Larry Pershin
Team Members: Joshua Madero Barba, Yicong Xiao, Mobarrat Shahriar
Supervisor: Professor Javad Mostaghimi

A Cooling Shroud that Yields Perfect Metal Powder

The metal powder industry is lucrative as a material provider as there are many applications for metal powder in the manufacturing industry. The metal 3D printing industry, a subset of all the possibilities with metal powder, is expected to boom from 3 to 12 billion between 2019 and 2027. Our client, The Center for Advanced Coating Technologies (CACT), requires a device retrofitting onto existing equipment to create high quality particles of varying powder sizes to sell to customers using these advanced metal manufacturing technologies. The current capability of the lab to produce metal powder is flawed as the resulting powder has oxidation sites and non-uniform particle size varying from 75mm to 170mm, reducing the quality of the powder. Our design solves this problem by diverting low temperature N2 gas in the direction of the incoming thermal spray of atomized particles. The high-pressure nitrogen buffer will effectively reduce the speed of the incoming atomized particles, providing more time of cooling for molten metal in an inert gas environment. Thus, reducing the oxidation percentage of the formed metal powder. The University of Toronto will benefit directly from this as the lab can sell it directly to metal 3D printing companies or allow for advancement in UofT's very own Additive Manufacturing Lab (TIAM). Increasing accessibility and aiding in the expansion of the industry will lead to cheaper technologies and more intricate designs used in commercial industries. 3D printing can produce virtually any design to a very high surface finish quality with uniform density throughout the part, revolutionizing what we will be capable of building. Products made with 3D metal printing can reduce cycle times, materials and labor cost.

Competitive Industrial Performance at Half the Price

Throughout the design process, we prioritized uniform gas flow and cooling rate maximization. The design allows for variable flow velocity to control the cooling process. To create the strongest nitrogen buffer, the channel wall is angled upwards to the incoming thermal spray, this optimal slant angle is also proved based on multiple fluid simulations. Resulting metal particles show significant improvement compared to previous products with almost 25% less size variation and noticeable less oxide. The design demonstrates competitive performance and has more features than similar products available in the market for over $3,000; the cost of our retrofit is less than half. We achieved this by utilizing off-the-shelf components and minimizing the number of parts. The project implemented the use of a collaborative CAD space, material analysis and then further performing structural analysis and flow simulations to decide on the final design.



Efficient COVID-19 Test Strip Manufacturing Devices

Client: University of Toronto Bio-MEMS Lab
Team Members: Jungho J. Kim, Eason Ong, Jianfei Pan, Qiwei Zhao
Supervisor: Xinyu Liu

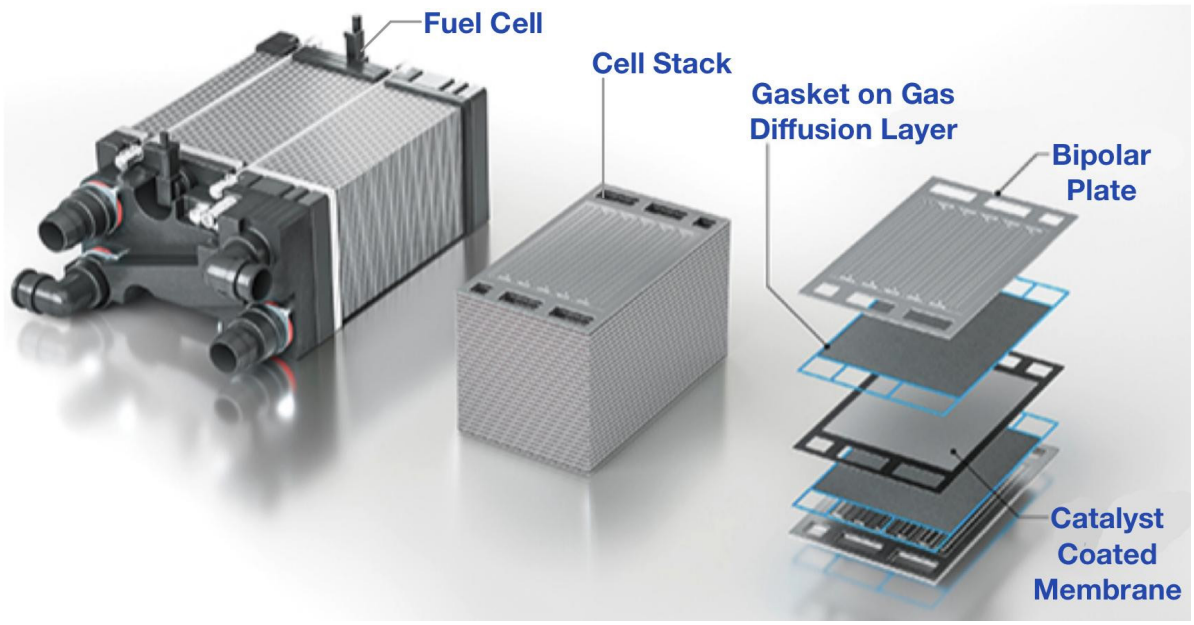
Need of an affordable and efficient machine to manufacture COVID-19 LFT

Lateral flow test strip (LFT) is a simple and economic point of care diagnostic device used to detect the presence of a target analyte in liquid samples. The client requires a continuous supply of LFT to aid their research regarding COVID-19 and other viruses diagnostics. Current LFT laminators and cutters in the market are costly (>10000 CAD combined), complex to operate and are more suited for industrial application. An affordable and efficient table top laminator and cutter would allow the continuous lab-scale production of LFT to facilitate the client's research. Such design could also be deployed in 3rd world countries to aid their COVID-19 mass screening efforts using LFT instead of Polymerase Chain Reaction (PCR) which requires advanced laboratory facilities and highly-trained healthcare workers.

Low cost and efficient laminator and cutter

Laminator: The complementary shape of the engraved top plate is customized to perfectly fit the thickness and width of each test pads for easy alignment. This simple and innovative design reduces operating steps of conventional laminators by half and ensures consistent overlapping between component pads on an adhesive backing card. A vacuum pump will provide suction force on the plate to hold the pads in their respective slots for easy handling of test pads. The overall cost of this design is 6 times cheaper than the market product.

Cutter: The cutter design utilizes a pneumatic cylinder to provide adjustable cutting rates and forces on a variety of materials to guarantee a clean cut across the mastercard. The feeder controlled by stepper motor allows the user to easily and accurately control the final cutting width of LFT strips through a touch screen interface. By utilizing standardized components and designing for manufacturability, the final cost of our design with exact same functionality is 5 times cheaper than the existing design.



Non-Destructive Testing Method Design for Bipolar Plates

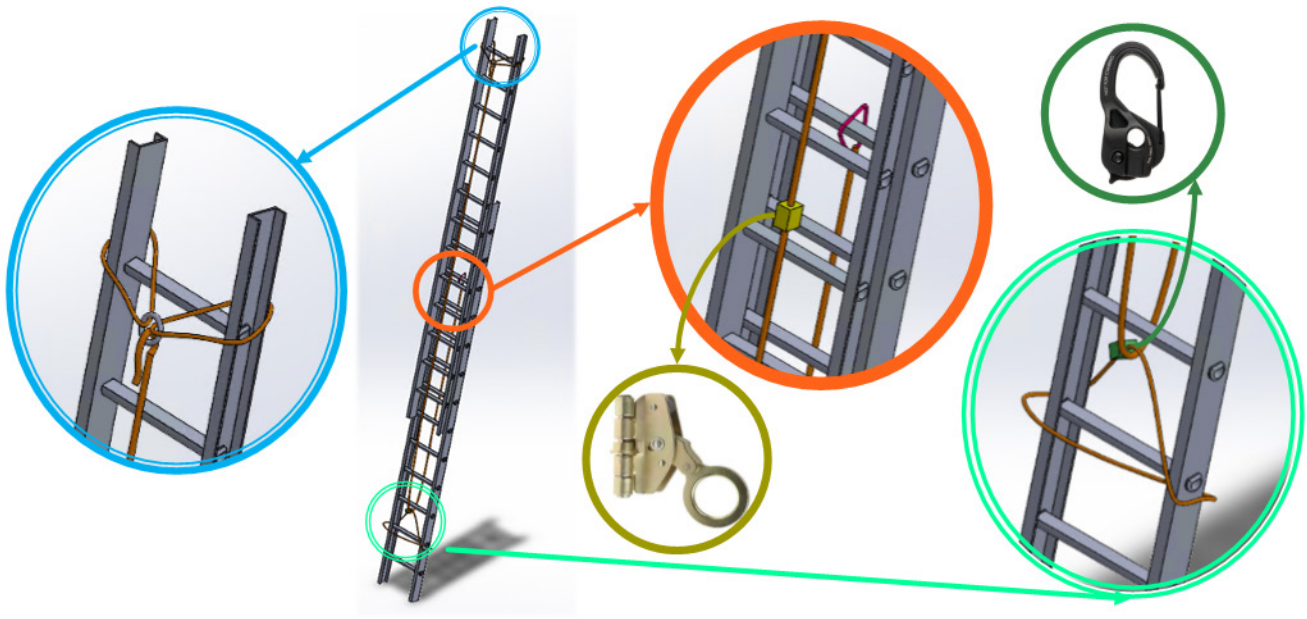
Client: Hydrogenics Corporation
Team Members: Wenhan Jiang, Wei Lin, Roshan Varghese, Yuntian Zhang
Supervisor: Prof. Mohini Sain

Client Need & Impact

Bipolar plates are a key component of the fuel cells as they provide structural rigidity, conduct electrical current, and prevent leakage of gases and coolant. As a result, a bipolar plate can be characterized by 3 key properties: flexural strength, electrical conductivity, and gas permeability. Currently, only gas permeability testing is implemented by our client. To expand their quality control process, additional testing procedures for the other two properties are necessary. The client requires that the testing method should rapidly test the plates in a non-destructive manner. By testing flexural strength, we can predict the likelihood of mechanical failure of these plates. Moreover, by testing electrical conductivity, we can predict its efficiency to conduct current. With a rapidly increasing market for fuel cells, we believe this project will improve the reliability of fuel cells globally.

Overview of design

In order to account for unnecessary complexity in design, gas permeability will be tested independently as our client already does. For electrical conductivity, the design uses a 4-point-probe mechanism to measure the bulk resistivity. Simultaneously, the thermographic camera will be used to observe the inhomogeneity of electrical conductivity. Meanwhile, flexural strength will be tested in two steps: the plates are first heated and applied thermographic imaging to identify defects, then the flexural strength is predicted based on the defect condition. A non-destructive testing method is a new approach since the conventional method damages the plates. Our design is customized to adapt to the bipolar plate dimensions and features. Overall, the design is novel because it incorporates flexural strength and electrical conductivity measurements into one single process.



Revolutionizing Height Access: Construction Ladder Fall Arrest System Lateral Flow Test Manufacturing (LFT-M)

Client: Ministry of Labour, Training and Skills Development (MLTSD)
Team Members: Jae Woo Choi, Keane Daniel Gamao, Ernest Tsun Heen Lau, Sophia Weng
Supervisor: David A. Steinman

A faster and cheaper alternative to conventional work height access solutions

Currently, there are no devices which allow a Type I/Grade 1 extension ladder to be safely used for working at heights. The MLTSD aims to close that gap by implementing a safety device that will enable ladders to be used as anchor points, and prevent workers from falling off them when utilized at an elevated height. This will not only present additional safety options, but also provide confidence for workers to work at heights on ladders.

The design will create flexible work locations for sites where conventional anchor points may not exist. The implementation of this design will help reduce costs and time for small scale construction projects. This design will be validated through simulation in SolidWorks, hopefully inspiring endorsement from ladder manufacturers in the efficacy of the design.

Elevated Safety via Improved Load Distribution on Extension Ladders

The designed safety mechanism aims to effectively distribute loads to multiple points on the ladder. It allows the system to solely rest on a ladder that is set-up and fixed to a location per Ontario regulations. With five points of contact on a ladder, the concern for ladder failure is minimized. The worker is secured to the mechanism through the use of a safety harness and a manual rope grab system on a life line. In the case of a fall event, the rope grab will actuate and secure the worker, immediately arresting their fall.

The safety device's functionality and integrity has been tested using SolidWorks Simulation software. The simulation was able to replicate the research study conducted by Waterloo University, titled "Evaluation of Fiberglass and Aluminum Ladder Stability During a Simulated Ladder Tethered Operator Fall Event." The physical results from this study have been compared to our SolidWorks findings, validating that our modelled scenario is replicating real life occurrences. Our findings also prove that the proposed design is capable of distributing load across the ladder.

Universal Crib Mattress Lift

Client: Lake Harbour Co. Ltd.
Team Members: Michelle Hu, Eleanor Jiang, Seungho Kim, and Shelby Ng
Supervisor: Fae Azhari

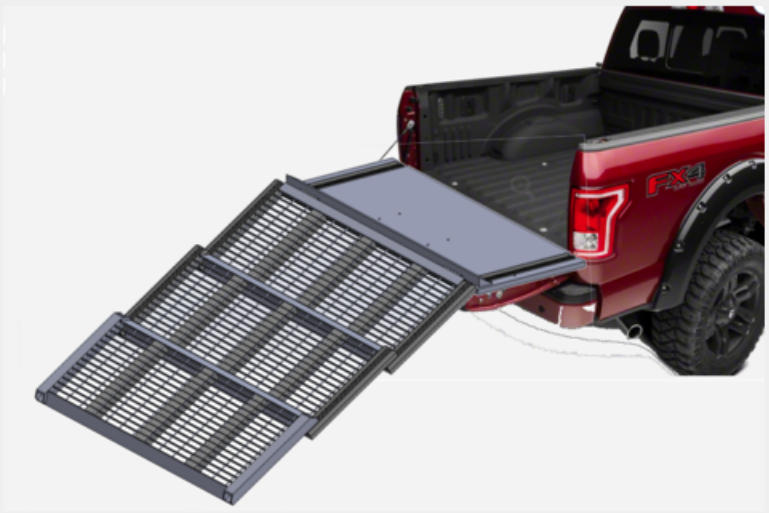
A Solution to Caregiver Back Strain

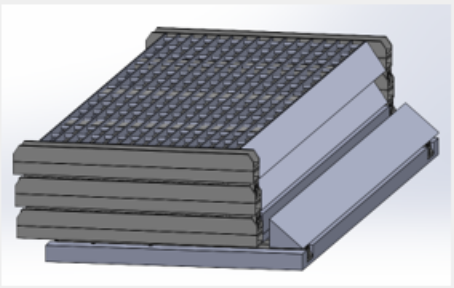
The client requested that the team design and prototype an electronic crib mattress lift to help caregivers lift babies and young children into and out of a crib because drop-side cribs were banned in 2016. As a crib add-on, the device is compatible with existing standard-sized cribs. This mattress lift is designed for parents, grandparents, and other caregivers. Lifting a child into and out of a crib multiple times a day can become physically challenging. This safe and ergonomic mattress lift makes it easy for the caregiver to place the baby in the crib when the mattress is at its highest position, although it can be lowered to various heights so that back strain is reduced. In the long run, the mattress lift eliminates the possibility of cumulative health problems such as chronic back and neck strain in caregivers, and prevents children from falling or climbing out of the crib because the mattress lift is in its lowest position once the child is placed in the crib. As a result, the mattress lift makes caregivers' lives easier and protects babies and young children from accidents.

A Safe, Easy-to-Use Design

Designed for use with conventional cribs, the lift is installed between the mattress and floor. Powered by a linear actuator, the mattress rises to the caregiver's desired height. For safety purposes, the lift automatically returns to the lowest position when the baby or child is inside the crib. The mattress lift has shields over pinch points to prevent the user from pinching his or her hands. The mattress lift is operated with a backlit wall-mounted switch providing accessibility in low light conditions, and well out of reach from children and pets.

Detailed force analyses and simulations were conducted to ensure the design can support and lift the required loads, and functions in a manner appropriate for its purpose. The analyses were also used to determine that the most suitable material is wood which is lightweight, renewable, and inexpensive to use.





Images: Ramp full deployed as shown on Ford-F150 truck tailgate (left), Ramp folded into storage position (right)

User-Oriented Loading Ramp for Ford F-150 Truck

Client: Lake Harbour Co.
Team Members: Zoha Khan, Hafsa Amer, Deshani Sritharan, Pooja Perinpanathan
Supervisor: Alison Olechowski

Aftermarket ATV Loading Ramp with User-Centred Features

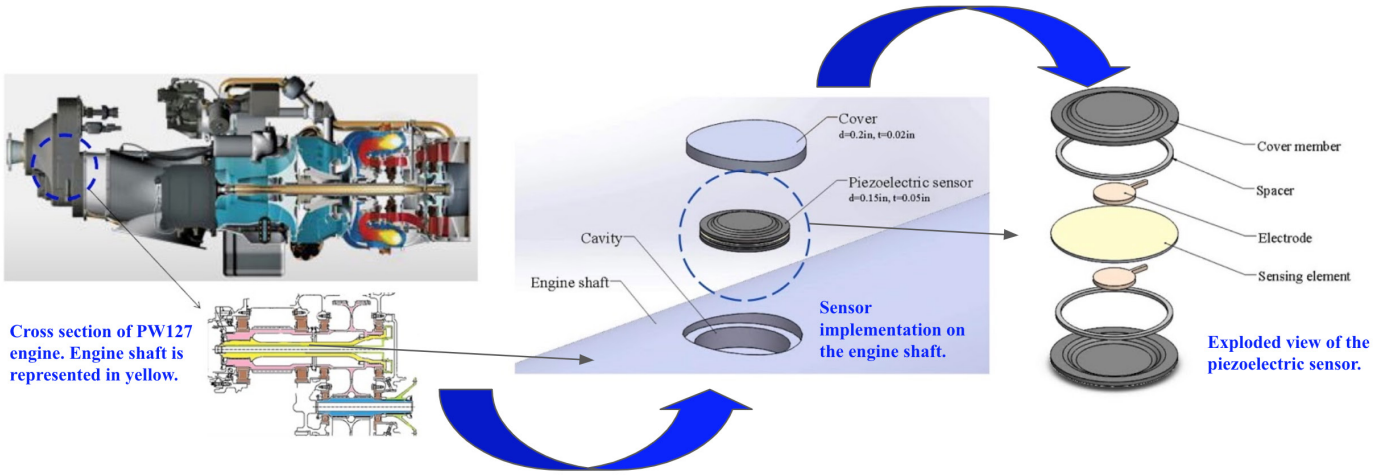
Aftermarket ramps are a popular option to drive ATVs and other wheeled vehicles onto the Ford F-150 truck bed. Current aftermarket options include various trade-offs with size, strength, safety, cost and ease of operation. A successful design will be one that achieves these trade-offs the best and is patentable. The design itself should be a self-sufficient mechanism, that is easily deployed by one individual without requiring additional equipment. It should require minimal operational effort, use minimal storage space and be integratable with the truck in a way that only requires one-time installation. A long-term goal is to scale this product to extend beyond use on a Ford F-150 truck and be usable on different truck models.

Compact, Integrated, User-Oriented, Ramp Design

A sliding 3-piece loading ramp was designed by the team, focused around improving the user experience. The ramp is integrated within the tailgate of the truck. A very ergonomically friendly design, the user would simply unlock the mechanism, grab the handles and pull the telescopic ramp out to deploy it. The novelty of the design lies in the combination of the easy to use sliding mechanism with a very compactly designed rail system. This means that when folded in the truck bed, the ramp occupies less than 17 cm in storage space. This unique feature was achieved by incorporating a sunken pathway for the mounting plate rail, as well as ensuring no hinge interference. Additionally, the use of aluminum only achieves a lighter design, and is therefore easier to deploy than other options on the market. Due to the distinctive design choices including sliding mechanism, storage and material, the ramp successfully achieves the following goals:

- Easy deployment
- Safe
- Unique (patentable)
- Easy maintenance
- Low-cost
- Compact

Aerospace



A Novel Piezoelectric Torque Measuring System for Pratt & Whitney Canada Turboprop Gas Turbine Engines

Client: Pratt & Whitney Canada - Ian MacFarlane
Team Members: Kayenaat Khan, Xin Di Zhang, Alan Peng, Yunong Gao, Yifan Qu
Supervisor: Professor Ridha B.Mrad

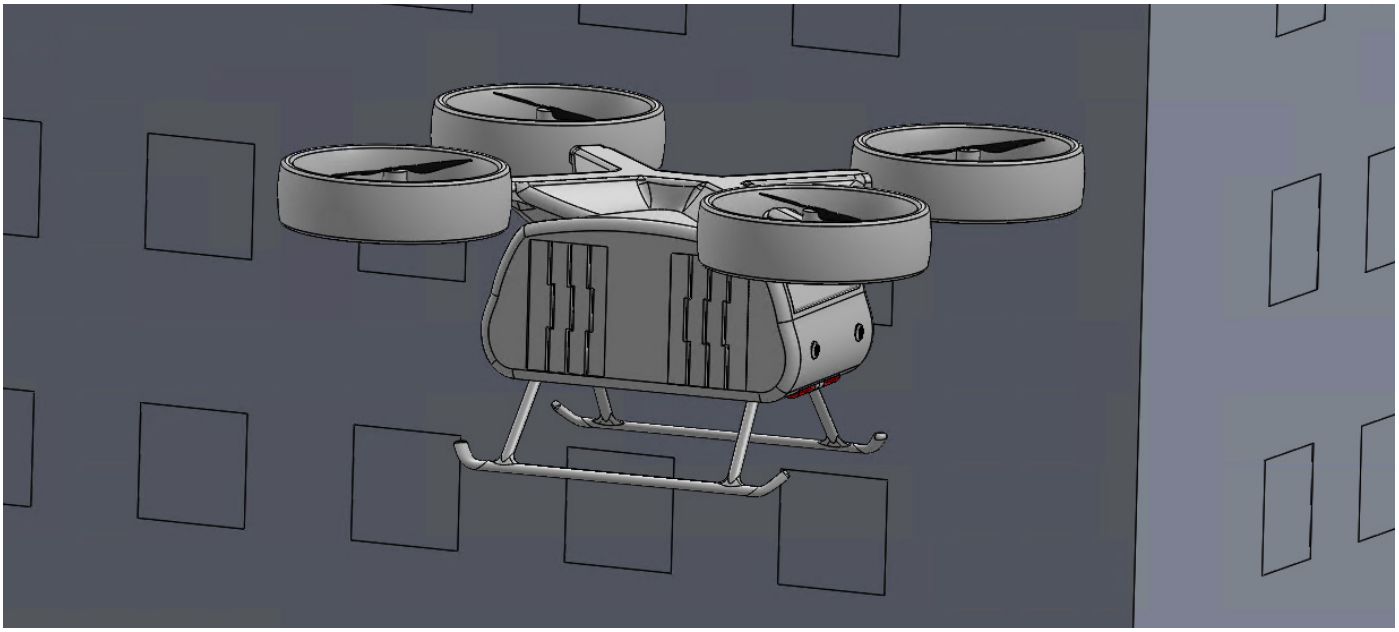
A novel system to measure the torque of turboprop gas turbine engines

To introduce a new torque measuring system that is both reliable and accurate, we have investigated existing and novel torque measuring methods to design a robust system for Pratt & Whitney Canada (PW&C) - Turboprop Gas Turbine Engine (PW127). Trade and feasibility studies were conducted to highlight strengths and weaknesses of multiple proposed solutions. The team focused on key characteristics such as: accuracy, measurement range, reliability, cost, weight, and bandwidth to research and design the optimal solution.

Torque measurement is crucial to the aerospace industry as it ensures that engines meet all conformance qualities. An accurate and reliable torque measuring system will ensure high aircraft mechanical performance in both the commercial and private aviation sectors. The aerospace industry can greatly benefit from our novel design as our design performs better in all the aforementioned key characteristics compared to existing technologies. Furthermore, due to its simple, low-cost and light-weight characteristics, the design has minimal impact on the environment and ensures sustainable development.

An accurate, reliable and low-cost approach

The design is a novel torque measuring system with an embedded piezoelectric sensor that is rigidly attached to the engine shaft. The piezoelectric sensor functions alongside the supporting circuitry for signal transmission and processing. Torque values are deduced according to the signal changes. The working mechanism of piezoelectric materials as a sensing element was demonstrated with underlying physics. The performance of the piezoelectric torque sensor was tested with a comprehensive robustness evaluation with Finite Element Analysis (FEA). A baseline assessment was also conducted to highlight its improvement by 66% in accuracy and 33% in cost over the existing solution, while meeting the maximum reliability target.



Autonomous Rescue Air Vehicle for Emergency Evacuation

Client: Shaker A. Meguid
Team Members: Peter Blaszczyk, Maxwell Hadley, Ibath Rahman, Zinan Cen
Supervisor: Shaker A. Meguid

A Versatile Vehicle That Can Save The Unsavable

Between 2009 and 2013, there were a reported 14,500 high-rise structural fires in the United States. This led to approximately 200 deaths and 2500 serious injuries. Many of these deaths occurred because current firefighting and evacuation methods are simply not suitable for high-rise structures. The sheer heights of many modern structures render these methods useless, as they are not able to reach and rescue individuals in the highest levels of these structures. This poses a severe problem for the future – as cities become more densely populated, as structures become taller and taller, and as climate change continues to accelerate and cause major problems, it is expected that this death toll will only increase in the future. Thus, the team was tasked with designing an autonomous rescue air vehicle that capable of saving individuals in the world's tallest structures. The design is operable in urban spaces and can reach the tallest floors of city structures. Furthermore, a rigorous evacuation system is set in place to ensure that the individuals at risk can evacuate quickly. This design can drastically improve the safety of urban spaces worldwide.

A Safe & Effective Evacuation Procedure

The final design is an autonomous 6-seater, multi-rotor aircraft that is designed to begin evacuating individuals within 10 minutes of the alarm of the fire. The aircraft is controlled remotely from a central hub, reducing the payload, and allowing for more passengers to be rescued simultaneously. The product implements state of the art avionics and control systems, an innovative approach to powering the aircraft, and uses advanced materials to reduce weight and costs. Furthermore, the team designed with inclusivity in mind – and allows for the vehicle to effectively transport injured individuals, those with accessibility needs, and people of all shapes and sizes. The design's quick and proven evacuation method will drastically improve the safety of urban living and working.

Medical Delivery Drone – A Move in the Flight Direction

Client: Aerlift, Inc.
Team Members: Shawn Arya, Shivam Maharaj, Stephanie McDonald, Chloe Oriotis
Supervisor: Amy Bilton

Urgent Need for Novel Medical Delivery Solution in Rural Rwanda

Rwanda's healthcare system consists of district hospitals which provide supplies like vaccinations, test samples, and blood for emergency transfusions to a series of rural clinics. Supply chains between clinics and district hospitals are highly contingent on the navigation of often impassable roads due to intense local weather. These clinics service 80% of Rwanda's population. As such, disruptions to medical supply chains can leave millions critically underserved. Transportation of supplies and test samples between clinics and hospitals is critical to high-quality care, and in emergency situations can be the difference between life and death. Aerlift, Inc. has requested the development of an aerial drone capable of bypassing difficult terrain and weather to deliver lifesaving medical supplies.

Solution for Efficient Dual Directional Delivery

This Team's primary achievement is the development and optimization of this drone's aerodynamic planform, capable of delivering blood for transfusions from hospitals to rural clinics. The design was validated by electro-mechanical component sizing and structural analysis at critical points.

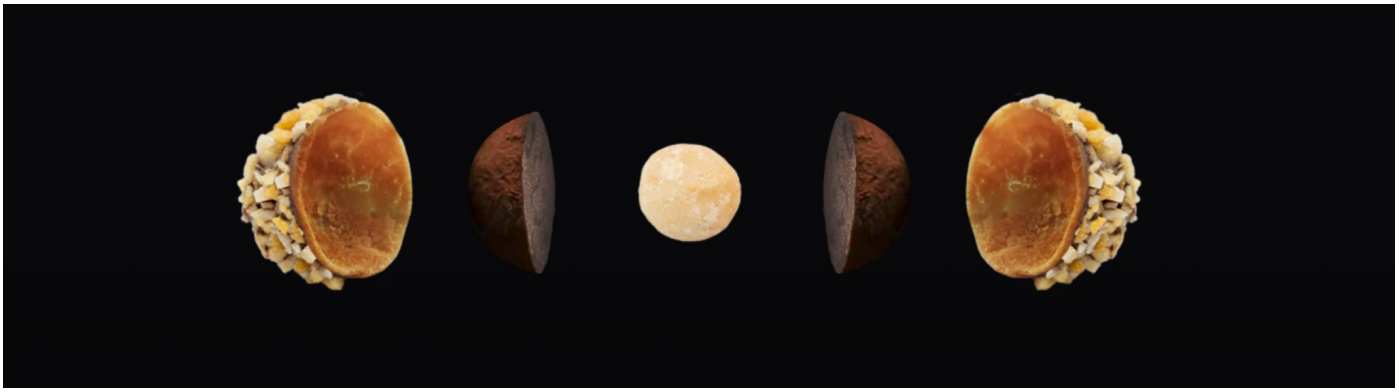
Aerodynamic efficiency was optimized for each of the key lift and drag-inducing components.

- The main wing maximizes lift/drag ratio through both the selected airfoil and the designed wing geometry while also providing stability to the aircraft in high winds.
- The fuselage efficiently packs components with minimal material thereby reducing drag.
- The raised tail provides a counterbalance for forward flight stability while avoiding air flow interference from the forward propeller.

With efficient aerodynamics on a lean and robust planform, the drone excels by:

- Delivering a large payload with a 3.4 kg mass within 6.5 L of volume, while maintaining a small drone size with a wingspan of 1.8 m, a length of 1.2 m and a dry mass of 12 kg.
- Operating at high speeds of 100 km/hr, able to service locations 50 km away within 30 minutes.
- Eliminating the need for infrastructure at start or end points through the use of vertical take-off and landing, facilitating two-way delivery.

For optimal transportation ability and cost-effective implementation, the drone can be disassembled and packed in a standard transport case.



Space Food: Manufacturing Technology

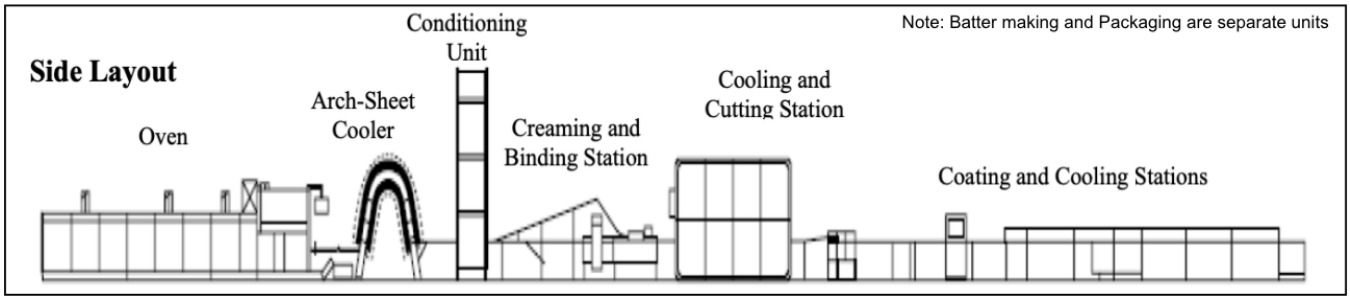
Client: Mission: Space Food
Team Members: Simar Virk, Shivam Mittal, Muhammad Omar Sawal, Parisa Aziz
Supervisor: Matthew Mackay

Balance, Enhance, Taste - Bridging the Gap in Space Food

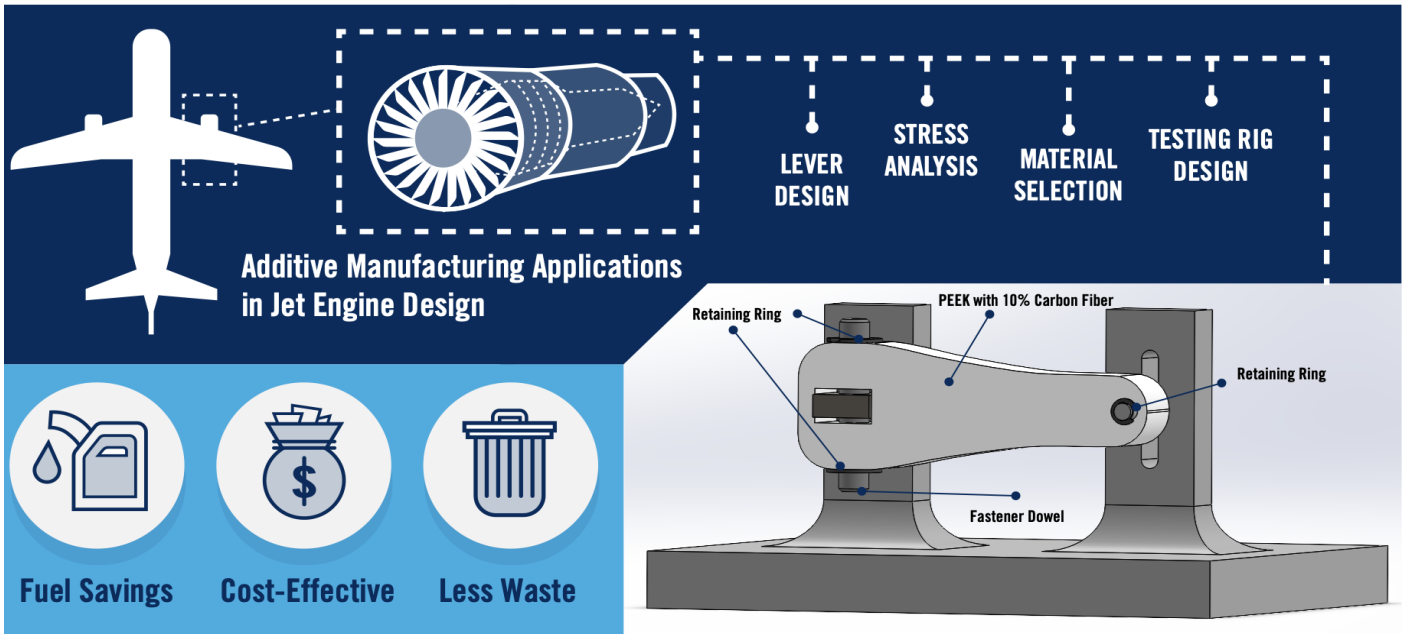
Food options for astronauts generally comprise pre-processed, rehydratable, thermostabilized, and natural-form products. As a result, space food can be unappetizing as improving nutritional value, portability, and shelf-life is prioritized over taste. To address this gap, Mission: Space food has developed Astreas, a delicious, gluten-free, hand-made snack that balances elements of taste and nutrition. Furthermore, Astreas is packed with a balanced nutritious fortification that provides key micronutrients such as Vitamin D3, Vitamin B12, and Vitamin K2 in a single serving and replaces supplements. At the consumer level, mass-producing this snack will promote healthy eating habits amongst both astronauts and young adults without compromising taste.

Industrial Scale Manufacturing Technology for Astreas

Our approach applied engineering design principles to assess existing concepts within the industry. Challenges were encountered to identify an optimal solution while meeting constraints on product specifications, resource availability, and financial limitations of a start-up. To address this, the team consulted multiple leading wafer manufacturing line suppliers, analyzed their product offerings using engineering principles, and concluded a line supplied by Wanshunda Foodstuff Machinery would be the optimal choice.



There are 10 stages to consider in the manufacturing process: batter mixing, baking, cooling, conditioning, filling, nut depositing, cutting, coating, cooling and packaging. A viable solution had to encompass all of these steps. The recommended candidate, Wanshunda, successfully allows the client to increase their production capacity 600x with improved product quality and minimal waste. Beyond technical considerations, the team assessed suppliers based on customer support, maintenance, and after-sales service to ensure client satisfaction over the long-run and provide the support necessary for a startup.



Variable Vane Actuation Lever for Gas Turbine Engines

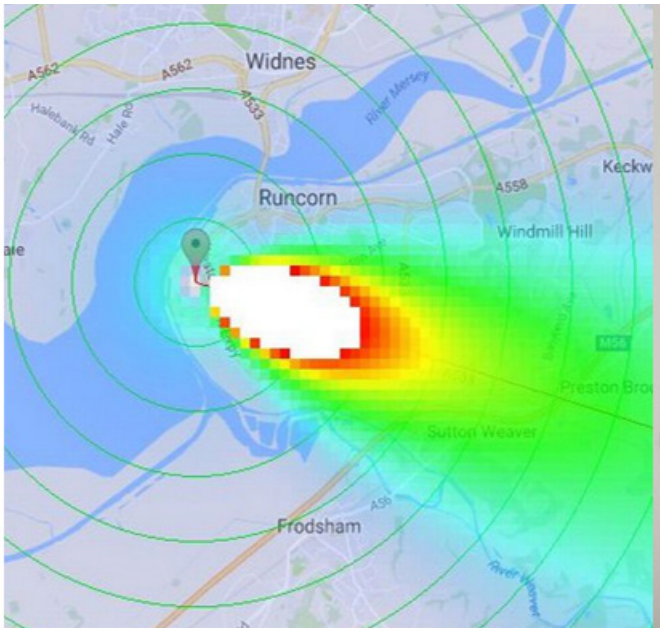
Client: Pratt and Whitney Canada
Team Members: Keith Sebastian, Yaakob Bendayan, Sophia Kurtz, Ifaz Uddin
Supervisor: Kamran Behdinan

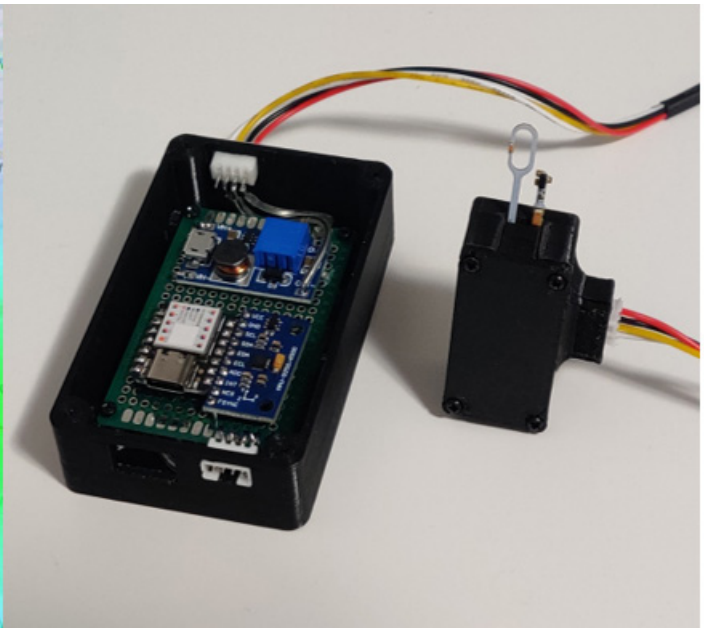
Sustainably-Minded Redesign of a Traditional Aerospace Component

Variable vane actuation levers have been extensively used in gas turbine engines to transfer and transform the linear motion of an actuator into the rotational motion of a vane stem and attached inlet guide vane. The rotation of this vane adjusts the incoming air's angle of incidence into the engine compressor, allowing for optimal performance in off-design conditions. Typically, these levers are made of metallic materials manufactured through traditional subtractive methods. However, as the use of composite materials and additive manufacturing continue to rise in the aerospace industry, Pratt and Whitney Canada is seeking to investigate the feasibility of a non-metallic, additively manufactured vane actuation lever. Given the global push for a more environmentally sustainable future for commercial aviation, weight-saving redesigns of such components could have immense benefits in the long-term future of aircraft efficiency.

A Fully Encompassed Solution

The proposed design for the lever is as shown above, whose features were rigorously optimized using both finite element analysis and various solid mechanics design theories. A fastening solution was developed to secure the lever to its existing interfacial components through aerospace-grade retaining rings and dowels. The material of choice, ten percent carbon fiber reinforced polyetheretherketone (PEEK) filament, with an appropriate additive printer, was chosen through weighted decision matrices. A custom-designed pass/fail type load testing rig was also created to allow the clients to verify the airworthiness of each lever pre-installation. The 83.1% mass reduction associated with the recommended PEEK material can save up to nearly 14,000 gallons of fuel per retrofitted engine per year. The applicable additive manufacturing method can also reduce material waste by 34% and betters carbon emissions targets by 15%, proving the environmental sustainability of the design for future use.





Wind Velocity Estimation Device for Quadcopters

Client: Scentroid
Team Members: Darie Roman, Ali Kaan Duranyildiz, Brij Patel, Sebastian Gri
Supervisor: Beno Benhabib

Impacts and obstacles to dynamically mapping pollution plumes

Our client has designed a drone-mounted air quality analyzer called the DR2000, and would like to improve the precision with which their customers can map out a polluted area. By having access to this information, companies can more easily localize pollution sources and address potential risks to local communities and the general environment. To achieve this greater goal, it is first necessary to know the wind velocity at all times so that air movements can be monitored during the drone's flight. We have been tasked to develop such a system that can be integrated into our client's air quality analyzer. The challenge is that turbulent airflow from quadcopter propellers can interfere with many wind sensors, and it may not be ideal to mount a relatively heavy device far from the drone's body.

A simple, effective wind measurement device for drones

Our design splits the task of obtaining wind velocity into two subtasks: estimating the direction, and measuring the magnitude. An Inertial Measurement Unit (IMU) measures linear accelerations and tilt in all three axes. We were able to derive a drone-independent equation for the wind angle using the ratio of drag forces along X and Y. The wind magnitude is measured using a Hot Wire Anemometer (HWA) which functions by measuring the power dissipated through convection. This device is small and light enough to be mounted on the air quality analyzer's existing sampling tube, away from any propeller downwash. A built-in microcontroller communicates the resulting wind velocity back to the analyzer, which uses this information to correct its readings. By subdividing the problem, our design is able to creatively circumvent key obstacles in accurately measuring wind velocity from a quadrotor drone.

Automotive and Transportation

Custom High Voltage Inverter for a Formula SAE Vehicle

Client: University of Toronto Formula Racing Team
Team Members: Ally Fraser, Andrew Rogers, Areg Armavil, Ben Sprenger, Jonathan Lee
Supervisor: Anthony Sinclair

Client Need

University of Toronto Formula Racing (UTFR) is a student team that designs, manufactures, and races a small Formula-style vehicle at international competitions in North America and Europe. Due to growing industry interest in vehicle electrification, UTFR has decided to switch to an all-electric powertrain to compete in the upcoming 2022 season. UTFR requires a team to design an inverter and motor controller to convert power from a 600V battery to supply a pre-selected motor.

Overview of Design and Key Results

The project is broken down into two main design aspects:

1.Mechanical design, including
   a. A lightweight, waterproof structural casing
   b. Thermal management of high-power components
2. Electrical design, including:
   a. Inverter bridge consisting of gate drivers and the IGBT module which switches on and off to produce 3 phase AC
   b. Microcontroller responsible for supplying efficient PWM signals to the inverter bridge and for monitoring the safety of the overall system

Each electrical sub-system was designed with a focus on modularity, allowing for ease of repairability, customizability and design optimization. The inverter uses off-the-shelf software integration to allow UTFR to focus on vehicle integration and tuning. As well, an integrated passive cooling concept reduces complexity and eliminates the need for a liquid cooling circuit.

Impact

This design provides an inexpensive, reliable inverter solution that allows UTFR to compete with an electric vehicle. This custom design opens the door to developing in-house software that may provide customizability for future iterations of the UTFR vehicle, such as traction control and regenerative braking.

Driverless Vehicle Design for Toronto's Winter

Client: Shaker A. Meguid
Team Members: Haoyang Guo, Zhuolun Song, Yuqing Li, Yuan Zhang
Supervisor: Shaker A. Meguid

Client Need & Impact — Safe Autonomous Vehicle in Winter Condition

Our client is seeking for an autonomous driving system which can safely drive a vehicle to the desired destination on public roads without any human interaction. Moreover, the autonomous vehicle shall be more adaptive to Toronto's extreme winter conditions. Autonomous vehicles are projected to reduce deaths and injuries due to car crashes by 90%.

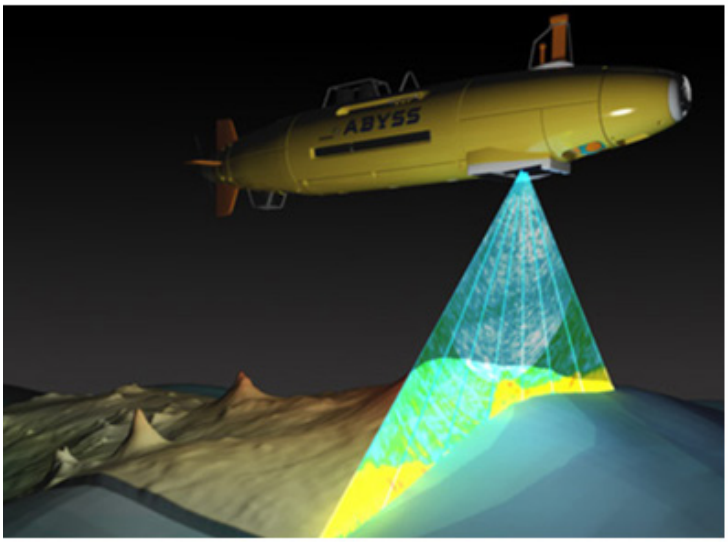
This design targets drivers living in normal or extreme weather regions. The stakeholders of this design include regulators, legislators, automotive manufacturers and environmental organizations. Users struggling with extreme weather driving will be greatly benefited by the high precipitation / snow protection vehicle design. The widespread adoption of autonomous vehicles will lower CO2 emissions, reduce traffic congestions and provide drivers with greater convenience and saved time.

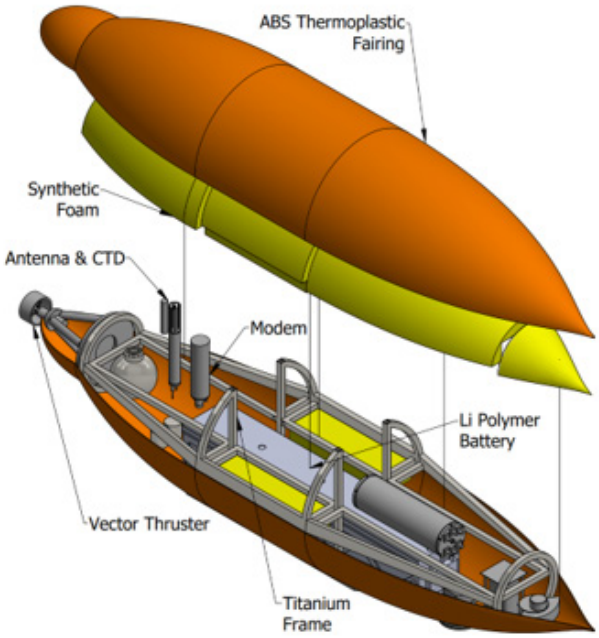
Overview of design/key results — Sensing, Perception and Decision Making

The autonomous driving system is divided into three main processes: sensing, perception and decision making. In our design, a Lidar is used to measure distances from the vehicle to obstacles in the surrounding; a set of eight sCMOS cameras and twelve ultrasound sensors are used for lane line, traffic sign, and blind spot detection. The comprehensive combination of sensors enables 360° detection and mapping of the vehicle's surrounding. The consolidated sCMOS-Lidar platform features durability under harsh weather.

The sensory data is then passed onto the perception module, where SLAM technique is utilized for vehicle perception alone with several performance improvements for operation under snowy conditions. Lastly, the vehicle's navigation information is passed by existing Google APIs, and lane-level driving commands were issued by end-to-end machine-learning based models. Icephobic Coating, UV Filter, and Heating Units are featured to ensure usual operation of all sensory components in extreme weathers.

For the engineering showcase, the design process, final design prototype and the machine learning performance will be displayed in graphics/videos and explained in detail. The Solidworks prototype, Python simulation results, and detailed FEA on the modified vehicle in winter conditions will be included in the final report.





Low-power, Bionic Penguin-shaped Autonomous Underwater Vehicle

Client:Shaker A. Meguid
Team Members: Ge Lin, Jianyao Sun, Yu Zhang, Zitian Wu
Supervisor: Shaker A. Meguid

Project Background & Requirements

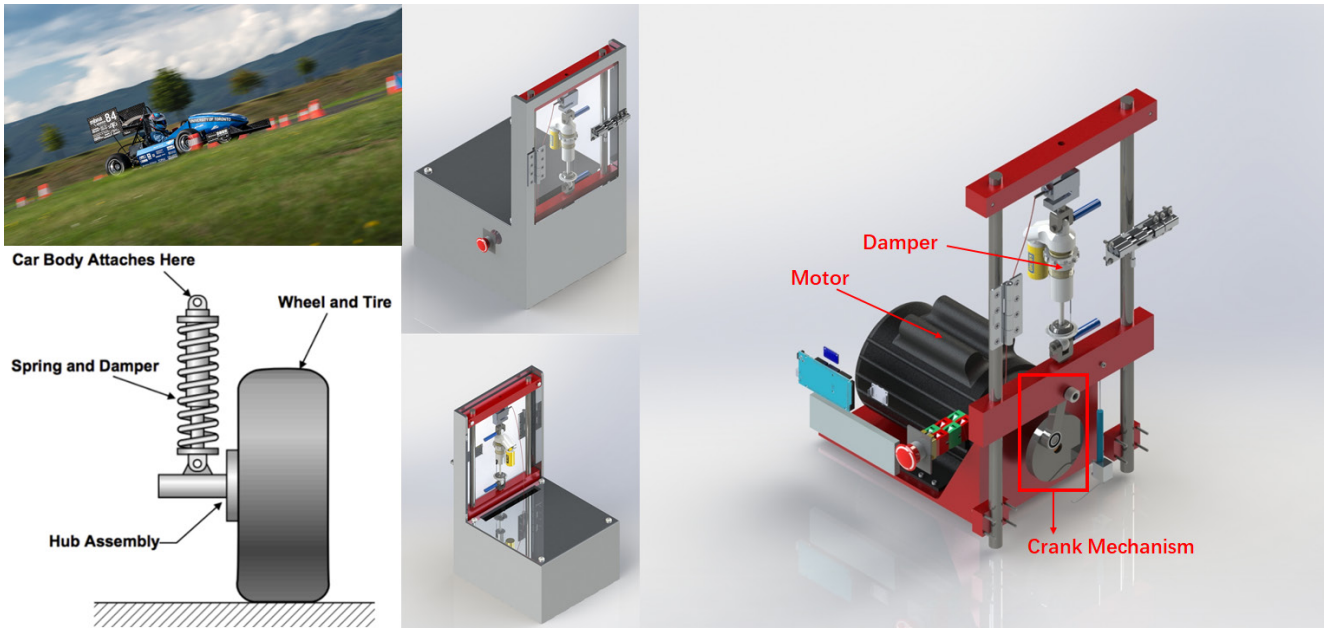
An autonomous underwater vehicle (AUV) is a self-driving vehicle that is the primary device for discovering the deep-sea environment. The client is seeking a solution to utilize autonomous underwater vehicles(AUVs) to explore the underwater world, including tasks of seafloor mapping, hotspot detection on the seabed and real-time data transmission. The major requirements for AUVs are multi-functional, energy-efficient, and long endurance.

Final Design & Features

Our proposed design is a penguin-shaped pressure tolerant AUV with a fin-less, single thruster propulsion system. The goal is to develop a more power-efficient AUV design based on the current state of the arts. Throughout the design process, the hull design is optimized through ANSYS simulation to minimize the fluid drag force. To further refine the energy efficiency, the design's weight is minimized by using a combination of ABS fairing and synthetic buoyancy foam instead of the pressure hull system. All functional components are encapsulated to withstand a 60MPa pressure which offers our AUV a depth rating of 6000 meters; unlike the traditional AUV, our design implemented the vector thruster, which could further advance the energy efficiency by reducing the degree of freedom. It is controlled by a Proportional Integral and Derivative(PID) controller to generate thrust force in different directions to maintain desired posture and velocity. The design is capable of navigating autonomously by following the obstacle-free path generated by the rapidly exploring random tree (RRT) planner based on the sensor input.

Impacts

AUVs are implemented for various applications, including scientific research, military and inspections. A multi-functional and energy-efficient AUV is desired for exploration efficiency. These features would facilitate further discoveries to the ocean. AUV is cost-effective compared to other human-dependent technologies implemented. The undercovered resources could stimulate further research in the oil and gas industries. Oceanographical, and geological oceanography will also be benefited from practical AUV applications.



The Dynamite - Damper Dynamometer for Formula SAE Vehicle

Client: University of Toronto Formula Racing Team
Team Members: Han Yuan, Krista Magnone, Zeenat Habibiy, Zhiwei Qian
Supervisor: Anthony Sinclair

Characterizing a Critical Suspension Component of FSAE Vehicles

Automobiles have many inputs that affect performance and driver comfort. The damper is a critical suspension component that controls a vehicle's dynamic properties, ensuring that the vehicle's tires remain in contact with the road surface at all times. The University of Toronto Formula Racing (UTFR) team requires an in-house damper dynamometer to test and record damper characteristics under all possible setting combinations. Currently, the UTFR team outsources adjustable dampers which allow for a variety of adjustment options, but have incomplete and invalidated data. With only commercial rigs available at a high price for much larger systems, a device to characterize these adjustable dampers is needed. The information and characterization of the damper will allow FSAE teams, such as UTFR, to make useful adjustments to ensure safety, advance vehicle performance, and improve ride comfort.

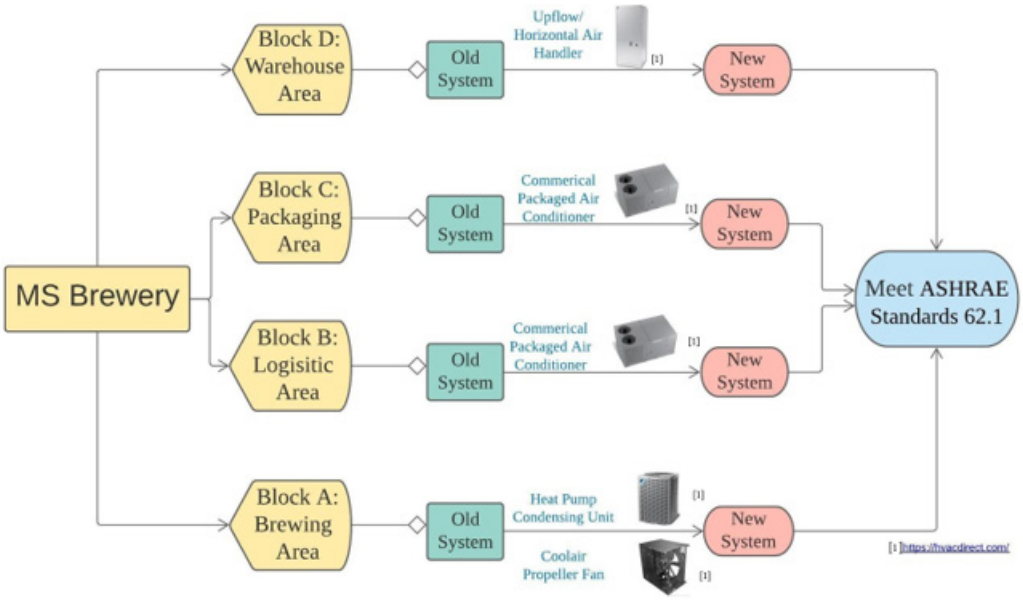
A Simple and Effective Crank-Driven Solution

The proposed damper dynamometer, "The Dynamite" follows the subsequent process:

- The user's deflection speed is registered and input into the controller.
- A signal is sent to the motor to actuate the crank mechanism displacing the damper at the given speed.
- The damper force is measured by the load cell.
- The force, displacement and temperature sensors send the information back to the controller and to a computer through a post-processing tool which outputs a plot of the force vs. velocity and temperature results.

The design approach optimizes all aspects of the design by combining the best solution to each elementary component of the system. The proposed solution is distinct from commercial damper dynamometers in that it provides a cheaper and safer alternative to testing a smaller damper system. A complete CAD model consisting of all mechanical and electrical components are to be showcased along with simulations to prove the feasibility of the design.

Energy and Environment



Cost-Efficient HVAC Design for a Brewery

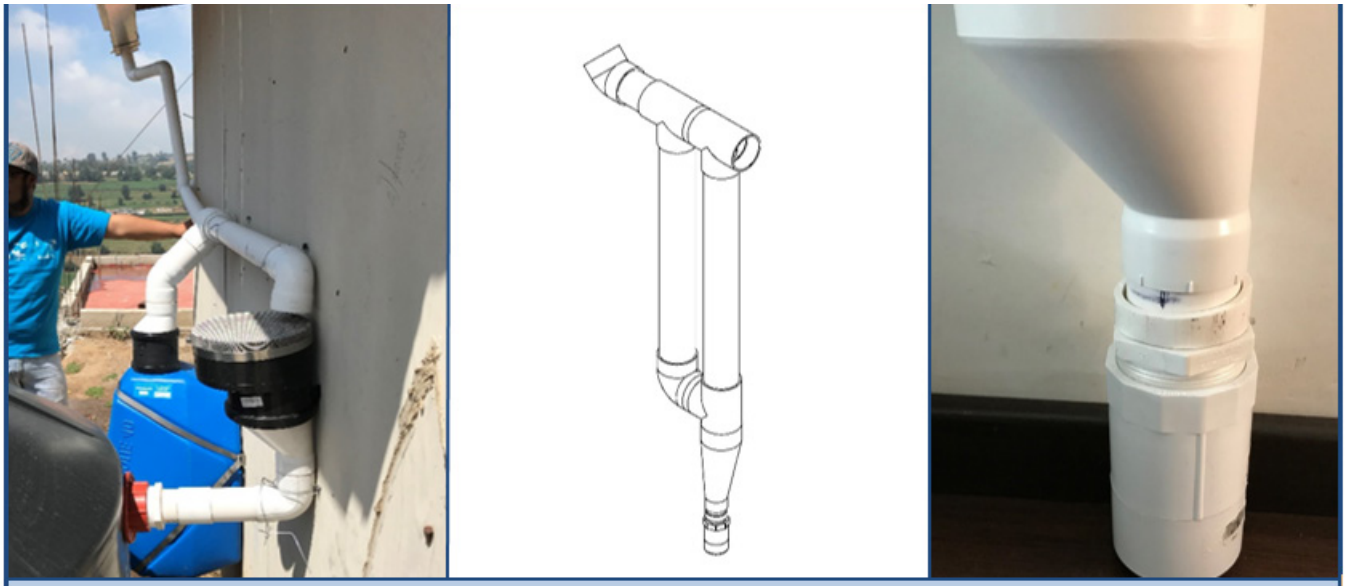
Client: Mill Street Brewery
Team Members: Deepti Madanagopalan, Jiaxiang Li, Minyang Feng, Yan Wu
Supervisor: Marianne Touchie

Designing an HVAC system to provide a comfortable and safe working environment

HVAC(Heating, Ventilation and Air Conditioning) systems control the environment of the building. They are used to control the airflow into and out of the building, the temperature of the space and ensure that the environment is comfortable. HVAC systems are also used to ensure the air in the building is clean. Our client, Mill Street Brewery, has asked us to evaluate the performance of their existing HVAC systems and make recommendations to improve the existing design. Improving the performance will greatly increase the efficiency of the brewery and ensure that the facility is compliant with the required codes and regulations. The new design can benefit the owners, managers and workers in Mill Street Brewery as it provides them with a more comfortable and safe working environment. It also meets the requirements of the government and relevant departments.

Ensuring the system meets the industry standards

The performance of the existing HVAC system is compared to the industry standard, ASHRAE 62.1 to determine the gap. Our design integrates new equipment with the existing HVAC system to fulfil this gap. The performance of the new system is determined by calculating the heating capacity, cooling capacity, air intake rate and air exhaust rate using different factors such as infiltration, solar radiation and air leakage. The new equipments are selected based on the existing duct layout and the gap. Our design meets all the objectives and costs $98,000 less than the proposed budget which is proven to be the most cost-efficient for our client. Our design also provides optimized thermal comfort for workers and it complies with ASHRAE Standard 55. Ultimately, by fulfilling the gap, the efficiency of the HVAC system will be increased.



Left: Original - intense load concentrations and expensive, Middle: New Design - reduces load concentrations, Right: Draining Prototype – automatic

Improving Water Quality Through the Use of a First Flush Diverter for Rainwater Harvesting in Peri-Urban Mexican Communities

Client: Manuel Mosqueda, TECHO
Team Members:Kally Van Mulligen, Kathleen Sheppard, Marya Kemp, Cameron Lewis
Supervisor: Amy Bilton

Improving Community Adoption of Rainwater Harvesting Systems

TECHO, a Latin-American non-profit, requested a first flush diverter redesign for their rainwater harvesting systems to improve community adoption by reducing maintenance requirements and issues with structural integrity.

TECHO's water security project targets poverty-stricken Mexican neighbourhoods, increasing the adoption of rainwater harvesting systems, which are a source of potable water in a city where water is an expensive, inaccessible, and rapidly diminishing commodity.

The design is a crucial part of TECHO's mission to provide water security and independence to hundreds of families in Mexico City, while also contributing to the conservation of the city's depleting aquifer.

Appropriate Technology Focused on Improving User Experience and Reducing Maintenance

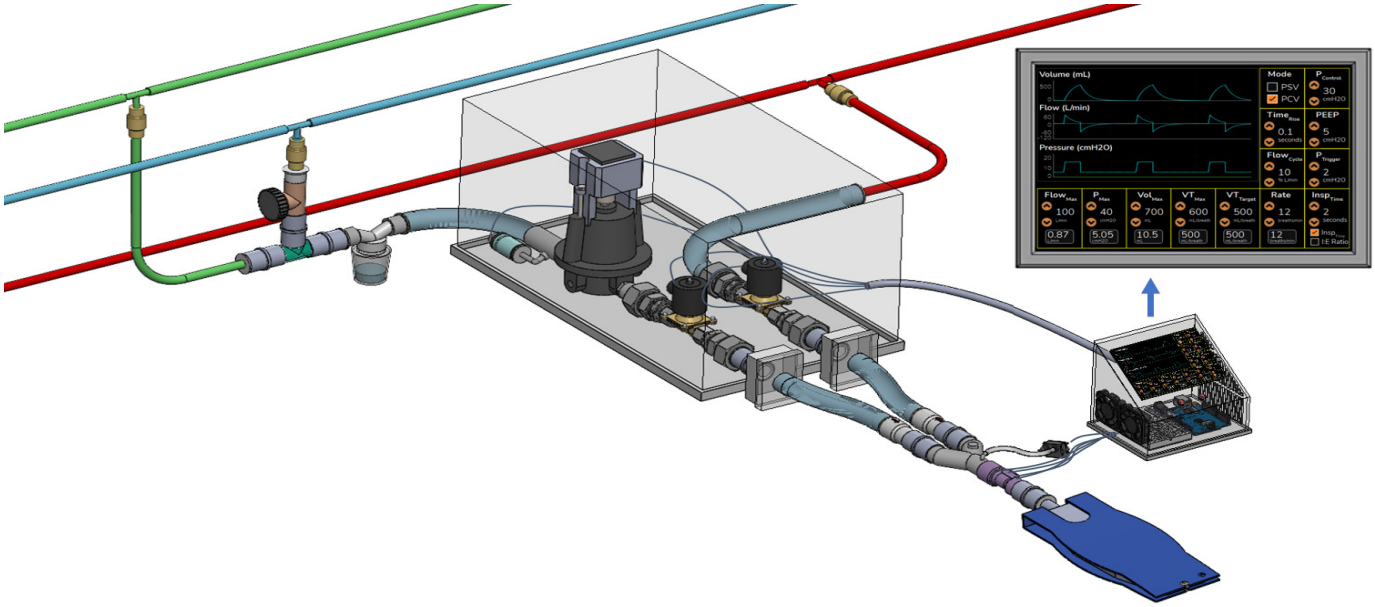
The design will divert the first 20-40 L of rainwater, which contains built-up debris from the roof. This will prevent contaminants from entering the water storage, ensuring the system can produce potable water.

This design utilizes a slow drip draining mechanism, which automatically drains diverted water before the next rain event. This reduces user input and decreases the likelihood of debris from subsequent rainfalls bypassing the diverter and contaminating the stored water supply.

The system was designed with a focus on appropriate technology and user experience above all else. While not flashy or complex, the system will be inexpensive and easy to use, providing a tangible impact on access to clean water in target communities.

The new design reduces the cost of the diverter by 55% for the families.

Using exclusively local materials, the team has ensured that TECHO has autonomy, flexibility, and easy access to all necessary supplies when building the system. The feasibility of using all local materials was validated by prototyping in Mexico.



Multi-Patient Ventilator

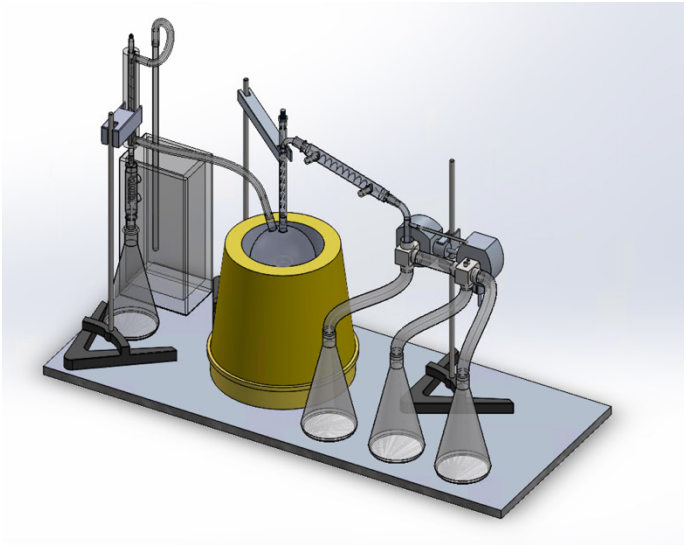
Client: HH Angus Ltd., Sinton Lab
Team Members: Fanny Lin, Chris Cardoza, Vasant Batta, Alice Ko
Supervisor: David Sinton

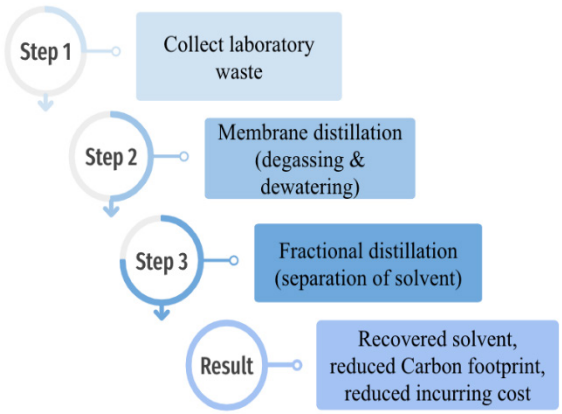
The Need for 100-PV and its Global Impact

In response to the ventilator shortages due to the COVID-19 pandemic, we were inspired to design a multi-patient ventilator that can provide mechanical ventilation to multiple respiratory illness patients through a single centralized gas processing system. Further, we challenged existing multi-patient ventilators' inability to provide per-patient tunability, and aimed to deliver a product whose output is individualized to meet the needs of each patient. The success of the 100-PV will mean that ICUs can alternatively operate at a lower cost by replacing the premium $25,000 ventilators with the new $1500 (per-patient) multi-patient design. This implies economical savings on the scale of roughly $23,500 or more per-patient in hospitals worldwide. These savings may even continue post-pandemic.

The Novelty Behind 100-PV and its Potential

100-PV employs pressure control with a pressure-regulator, pressure-sensor and flow-sensor (all per-patient). To meet affordability, conventions of modern ventilators were broken; 1) replace sophisticated components (electronic regulators & valves) with manual counterparts and motor actuators, 2) replace the electronic oxygen-blender with a manual oxygen-valve, 3) replace the standard per-patient humidifier with a humidifier scaled to supply upto 10 patients. Yet, this design is still versatile, providing all the minimally required ventilation modes for the full treatment. A typical treatment starts with pressure control (ventilator controlled breath rate with some patient triggers) and ends with pressure support (breath rate controlled by patient with ventilator preset pressure assistance). All functions are controlled per-patient through a bedside interface connected to an Arduino. Test results validated that ventilation modes and delivered breath rates match the operator inputs. The design also demonstrated the ability to synchronize with the patient's breath rate. Overall, the 100-PV meets the primary objective of affordability while achieving what existing multi-patient ventilators couldn't: per-patient tunability.





SoluSave Recyling Device: Smart way to Reduce Waste

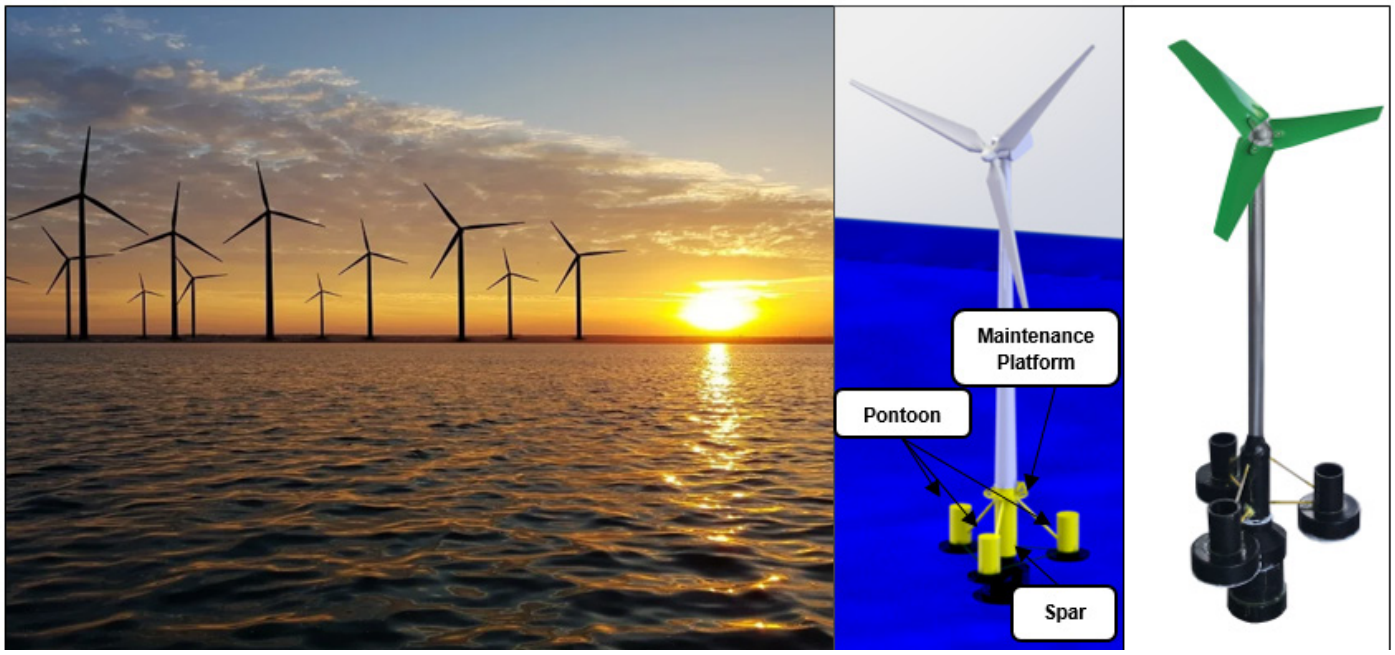
Client: SoluSave
Team Members: Amna Sakurai, Domenica Aquin, Ryuji Mori, Zicheng Liu
Supervisor: Sanjeev Chandra

Environmentally Sustainable Laboratory

SoluSave aims to reduce chemical waste by recycling commonly used laboratory solvents and therefore reduce the overall carbon footprint. At present, 43% of aqueous wastes are organic solvents that can be recycled using distillation methods available, however, due to space and cost constraint, labs are forced to dispose of these wastes. The collection of these hazardous chemicals in landfills pose a threat to both humans and the environment. As a result, research facilities will benefit most from the development of a cheap, compact distillation operating system as it helps to reduce the incurring cost of solvent purchase and disposal, which will indirectly benefit the environmental organization imposing waste treatment regulations. The recovery of solvents will also reduce energy intensive production of these commonly used chemicals.

Solvent Recycling, Collection Technology

The SoluSave distillation device not only recovers solvents from miscible mixtures but also combats non-homogenous solutions (e.g. Azeotropes - constant boiling mixtures). The device uses equipment readily available in the laboratory such as conical flasks, cooling condensers, etc., while integrating the control system to adhere by the fractional and membrane distillation operating conditions to collect the desired solvent with a 90% percentage recovery and 98% purity level. These goals were identified based on testing results of an acetone and oil mixture which achieved 74% acetone recovery with fractional distillation which has a highest achievable purity level of 80% based on research. An analog system for the multiple sensors and circuit connections are identified, along with an Arduino programming code to control the input and outputs of the system. A user interface is also developed to provide substantial support to the control system, by allowing the user to select two desired solvents for recovery.



Supporting Wind Energy Generation in Deepwater Environments

Client: Mechanics and Aerospace Design Lab
Team Members: Ali Khan, Benson Lau, Saif Beiruty, Shahzeb Mahmood
Supervisor: Shaker Meguid

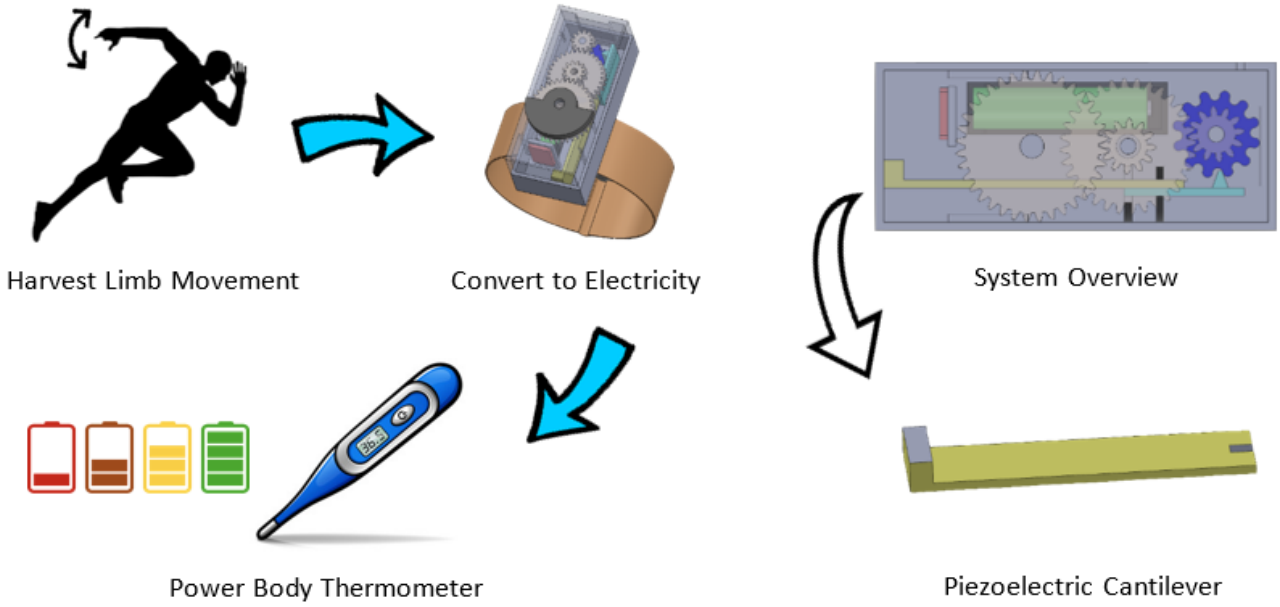
Striving to Achieve Stability and Structural Integrity

Most wind turbines today are operated on land, which introduce noise and visual pollution, endanger local wildlife, and have high land costs; wind speeds on land are also inadequate for energy generation. Offshore wind turbines are a great alternative but methods of stabilizing them in deep-water environments are limited. The Mechanics and Aerospace Design Lab has identified this and tasked our team with developing a state-of-the-art floating platform to support wind turbines in energy generation. The project can extend the locations in which wind turbines are implemented; it has promising potential as sustainability and environmental awareness become more relevant. This can benefit coastal communities by offering a source of cost-effective, clean, and renewable energy.

A Novel Design Providing a Stable Platform for Energy Generation

The design consists of a central spar column, connected to three pontoons through a bracing with the central column having a ballast of concrete and water. Slack mooring lines are attached from the spar column to the seabed to keep the structure in place. This design utilizes the finest elements and leading features from multiple state of the art designs, combining the hydrodynamic stability of the spar-buoy and the wind endurance of a semi-submersible platform. The platform also features a fully active, high-precision stabilizing control system that delivers water to the pontoons to counteract the rolling and pitching motion of the structure during operation. This ensures that the wind turbine remains upright at all times, allowing it to harness maximum energy. 3D CAD software was used to optimize the geometry of the platform, and finite element analysis was employed to validate its structural integrity. The design impeccably merges engineering innovation with business ingenuity, having an expected electrical cost of 11 ¢/kWh.

A scaled-down physical prototype was constructed to verify the form and function of the design. Scaled loading conditions were applied on the prototype and it was determined that the full-scale design will be able to resist winds greater than 100 km/h.



ZnO Piezoelectric Energy Harvester: Wearable Tech Powered by Human Movement

Client: The Advanced Research Laboratory for Multifunctional Lightweight Structures
Team Members: Mark Meschino, Lingyun Wang, Haitong Xu
Supervisor: Kamran Behdinan

Finding Sustainable Low-Cost Alternative to Brittle Piezoceramics in PEH Design

Piezoelectric energy harvesters (PEH) are devices which make use of the piezoelectric effect to extract electrical energy from externally induced mechanical stresses. The current standard in high performance piezoelectric materials, known as piezoceramics, are brittle and require additional substrate layers for structural support. Mitigation of these mechanical limitations provides the opportunity for microscale vibrational energy capture and the removal of large energy storage components found in many common electronic devices.

The Advanced Research Lab for Multifunctional Lightweight Structures at the University of Toronto approached the capstone team for a PEH design, and an accompanying manufacturing and testing plan, incorporating robust, sustainable, and low-cost alternatives to piezoceramics. In consultation with the client, the team selected an application for the PEH design and decided on a wearable device used to measure human body temperature.

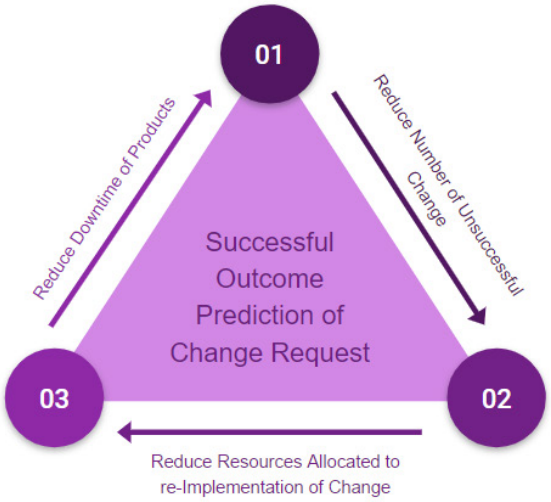
Optimizing Low Frequency Energy Capture with High-Performance Rectangular Cantilever Beam

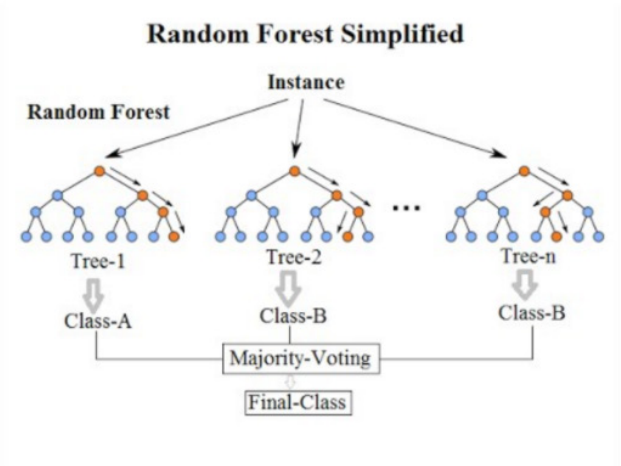
The proposed PEH design consists of a layered ZnO composite cantilever beam which is housed in a comfortable band attached to the upper arm of the user. Extracted electrical energy passes through a circuit used to power a thermometer which measures the user's body temperature at the touch of a button. The chosen design was selected after extensive iteration, validation and modelling with COMSOL to predict its electromechanical performance. These COMSOL models were used to optimize the output power and reduce the resonant frequency to values typically generated by human movement. The resulting design has the following key characteristics:

- Low resonant frequency: 25.8 Hz
- Produces about 7.5 V at only 1.01 mm tip deflection
- High output power: 4.16 μW
- Uses only biocompatible piezoelectric materials: ZnO and PDMS

Finance and Risk Management

Project Overview - Outcome Prediction by Random Forest





Change Request Prediction

Client: Alexandra Jackson
Team Members: Ninghao Wang, Haolin Wu, Yiwen Ding
Supervisor: Michael Gruninger

Exploring Impacts on Change management & Product downtime

Change managers need to keep track of change requests because they are required to follow up post-Change activities. It's critical to minimize the downtime of products as soon as possible because once Changes are being implemented, the product will be out of service for all clients. Prioritizing uptime by improving the success rate of Changes and the business process of submitting Change requests has captured Finastra's attention. Our project can help XXX reduce the downtime caused by the Change process, thus reducing the losses caused by the downtime of its customers' products. Our project will benefit both the Change Management Team and XXX's clients, as less downtime will help XXX improve the quality of their software and help clients operate their products more efficiently. Our project may in the future help Change Management Team to automate the processing of change requests in the most efficient way.

Preventing Failed Change Requests by Prediction and Forecasting

The Capstone team intends to design a machine learning tool to accurately predict the potential sub-state given a change request submitted by a user. By comparing all models aforementioned, the team decides to apply a random forest model. The team also applies the feature-importance method to evaluate the importance of features on the final Random Forest model. It helps the team better understand the solved problem and sometimes lead to model improvements by employing the feature selection. The team developed a user interface for the design that allows importing new change request data to be trained or tested instead of using Python scripts for future reusability at XXX. The Capstone team will also assist the Change Management Team at XXX in understanding the model's usage and limitations and finally implementing and utilizing the design solution.

Note: All company name is replaced with XXX to protect customer privacy.

1. Problem

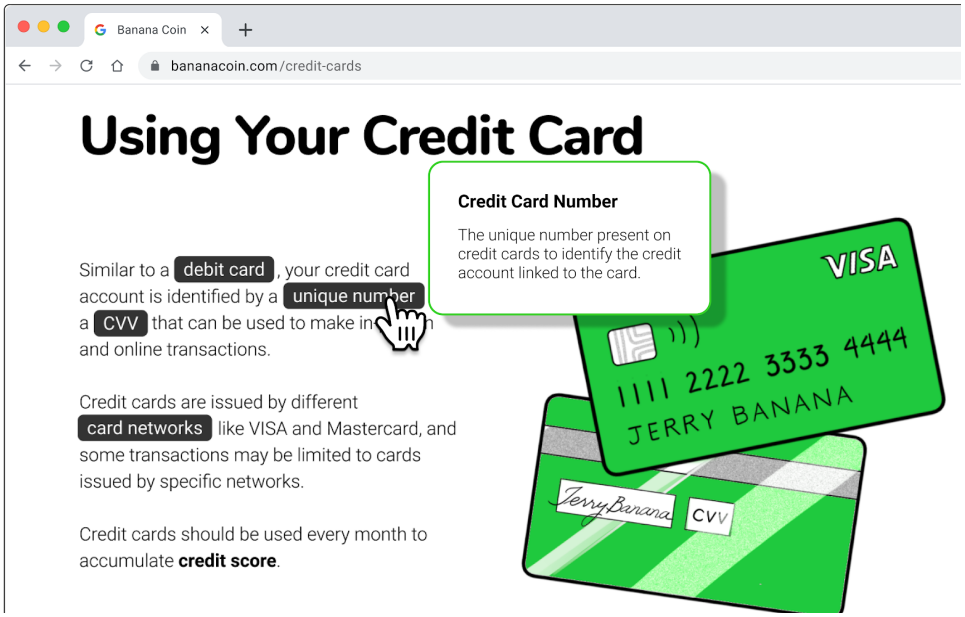
Young adults lack essential financial literacy

2. Our Design

An interactive website to make financial learning fun

3. Impact

Empowering a new generation to make confident decisions



Designing a Financial Literacy Education Tool to Empower the Next Generation of Young Adults

Client: Square - Dessa
Team members: Michael Jia, Matthew Kwan, Ellen Lau, Yueling Lu
Supervisor: Mark Chignell

Problem and Project Scope: Young Adults Lack Essential Financial Literacy

Canadian young adults lack essential financial literacy. They are under equipped to navigate the ever-increasing market of financial products and make informed financial decisions that may significantly alter the course of their lives.
We designed an accessible, digital solution to improve financial literacy in Canadian young adults. Our solution will provide secondary students, post-secondary students, and working young adults with a foundational and actionable financial literacy education that will aid them in future financial decisions. Ultimately, by providing accessible and engaging education, we will contribute to Square's mission of building a future where everyone can participate and thrive in the economy.

Using Human Centered Design to Create a New Financial Literacy Education Tool

The solution was developed using the user-centered Design Thinking methodology. It was discovered from primary user research that current solutions lack visual interest and fail to keep the users actively engaged. After creating prototypes and assessing methods of engagement such as gameplay and storytelling, our final design addresses these issues by providing an interactive website for young adults to learn about credit cards and other financial topics. Various techniques to promote retention and engagement were employed:

- Storytelling and Relatable Characters
- Journaling and Commitment to Action
- Situational and Simulation Games
- Modular In-line Quizzes

Our prototype focuses on credit card utilization but will be extended to additional topics such as mortgages, budgeting, and investing in future iterations. Ultimately, our solution will equip young adults with practical and actionable financial knowledge for their day-to-day and long-term decision making.

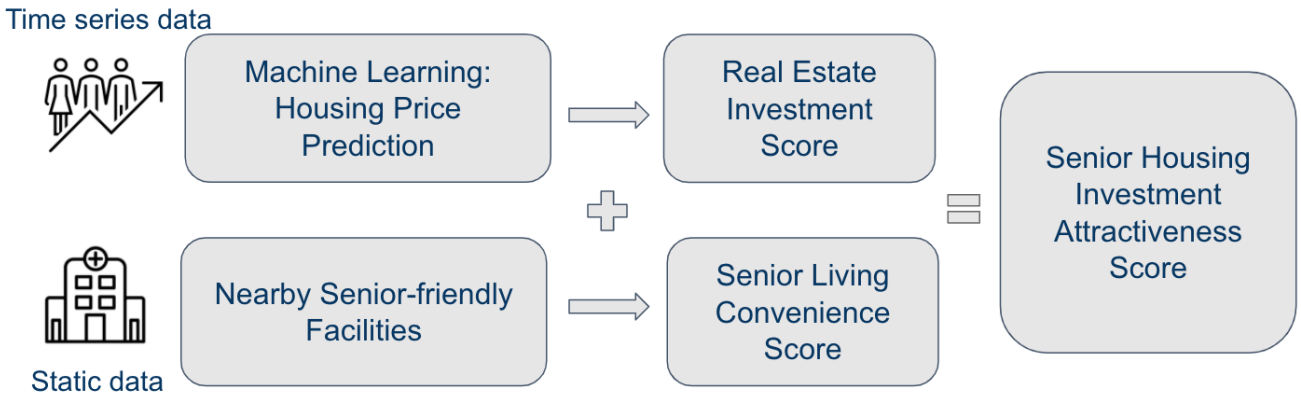


Figure 1: Architecture of a Weighted Quantitative Model: A two-component, multi-faceted data driven solution measuring a senior housing investment attractiveness score.

European Senior Housing Investment Attractiveness Analysis

Client: Signal Capital Partners (SCP)
Team Members: Renjie Li, Jiayi Li, Caroline Ming, Yuqin Sun
Supervisor: Mark S. Fox

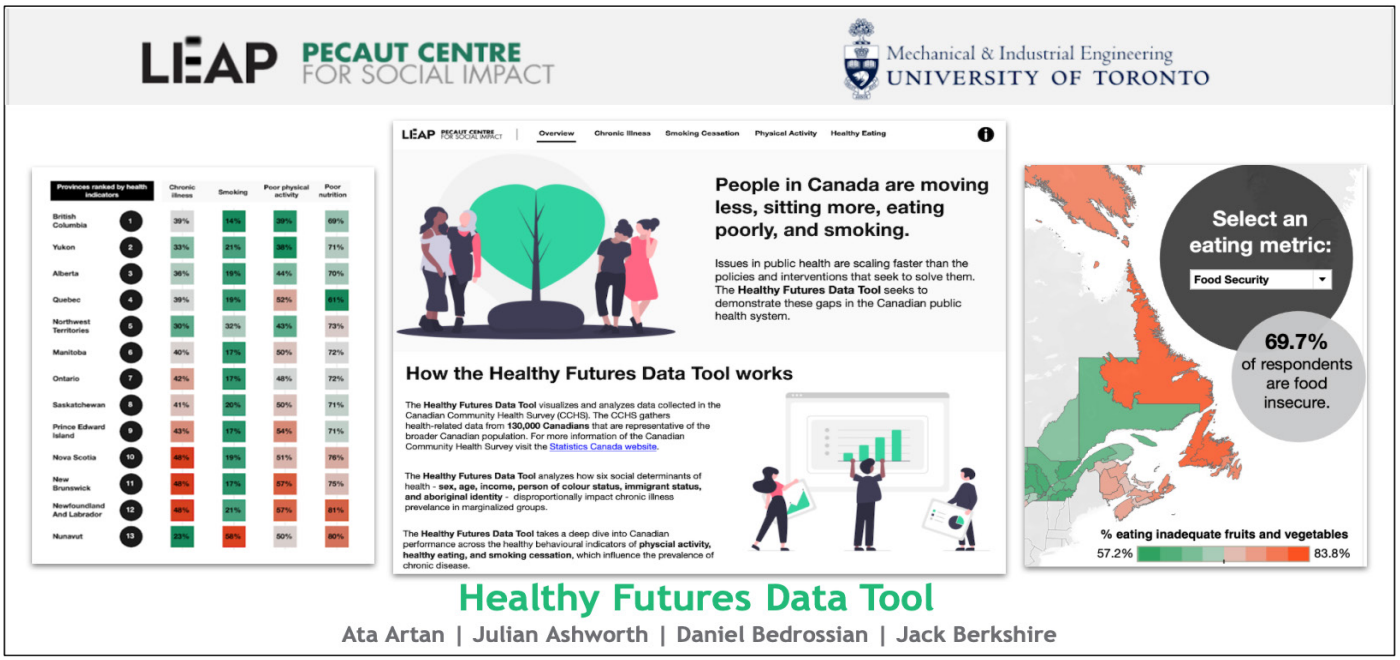
Investment Attractiveness of Senior Housing in Europe

The changing age demographics in Europe led to an increase in elder care housing. Signal Capital Partners (SCP), a UK-based private asset management firm foresees a promising return on investment opportunities in senior housing investment. As a result, SCP tasked the project team to evaluate investment opportunities in senior housing across Europe. This project offers SCP a data-driven solution to make better senior housing investment decisions based on thematic trends (i.e. demographics, economics, social changes, etc.). The investment analytics user interface presents and visualizes a ranking score for each target community demonstrating potential investment attractiveness. The solution investigates both the UK and France as initial potential opportunities; It can be applied to other countries across Europe immediately and with existing demographic data the rest of the world. The project directly benefits SCP and its client and indirectly benefits senior communities worldwide since it contributes to the development of senior housing.

Multi-faceted Data Driven Senior Housing Solution

Our solution is a weighted quantitative model (Figure 1) that outputs a ranking score consisting of two components. For the first component, two variants of the decision tree model generate a prediction of the general housing price and the second component, which reflects the senior living quality of a community is generated by calculating the distance between a community and nearby senior-oriented facilities. An overall ranking score is calculated by standardizing and combining the two scores together. Existing studies evaluate senior housing investment attractiveness in many different ways but most analyze this topic from a single perspective, limiting the investment insight. We are the first team that addresses this problem in a multi-faceted data driven way. There are no existing solutions that quantitatively address the problem by combining the prediction of general housing price with senior living quality related information.

Healthcare/Social Services



Analyzing Inequalities in the Canadian Public Health System

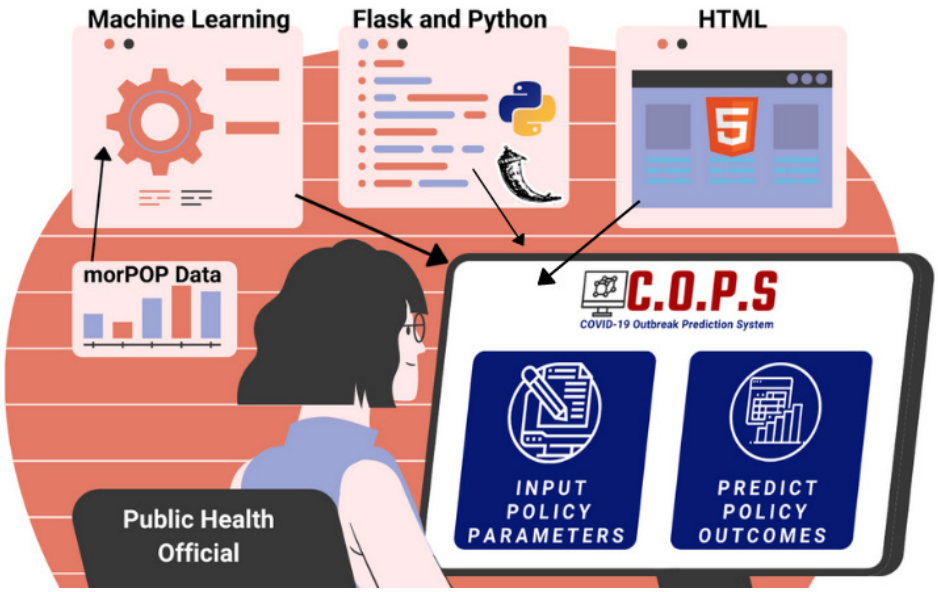
Client: LEAP: Pecaut Centre for Social Impact
Team Members: Ata Artan, Julian Ashworth, Daniel Bedrossian, Jack Berkshire
Supervisor: Merve Bodur

Moving the needle on public health data accessibility to enable data-driven decisions

The LEAP Pecaut Centre for Social Impact catalyzes large-scale social impact by scaling social ventures. Healthy Futures is LEAP's venture accelerator that funds, mentors and scales early-stage startups that are committed to preventing chronic illness in Canadians. The Healthy Futures accelerator focuses on helping startups that promote three healthy behaviours: (1) Physical Activity (2) Smoking Cessation and (3) Healthy Eating. To demonstrate the societal need for the Healthy Futures accelerator startups, LEAP requested a deep, comprehensive analysis of public health data that highlights the inequalities in Canadian Public Health. This tool would also allow LEAP to strengthen its position in the non-profit space by contributing a novel and comprehensive Canadian public health data visualization dashboard, which currently does not exist. The subsequent task was to build a public health data tool that demonstrates the intersectionality of sociodemographic and geographic factors with the three healthy behaviours of interest.

Tableau based interactive data tool

The Healthy Futures data tool is built in Tableau to enable a high level of user interaction and customized user experience. An overview page motivates the need for action in the public health space, and four subsequent dashboards identify Canadian chronic illness prevalence and performance in the three healthy behaviours. The tool allows users to explore relationships between social determinants, geographic regions and health metrics from data collected from two Canadian Community Health Surveys. Additionally, the tool identifies the economic impacts of healthy behaviours and chronic illness on public health spending. Choosing Tableau, instead of building a custom webapp like existing government public health data tools, allows the team to meet solution requirements while upholding scalability and maintainability, ensuring the longevity of the design solution upon handover to a non-technical team.



C.O.P.S: COVID-19 Outcome Prediction System

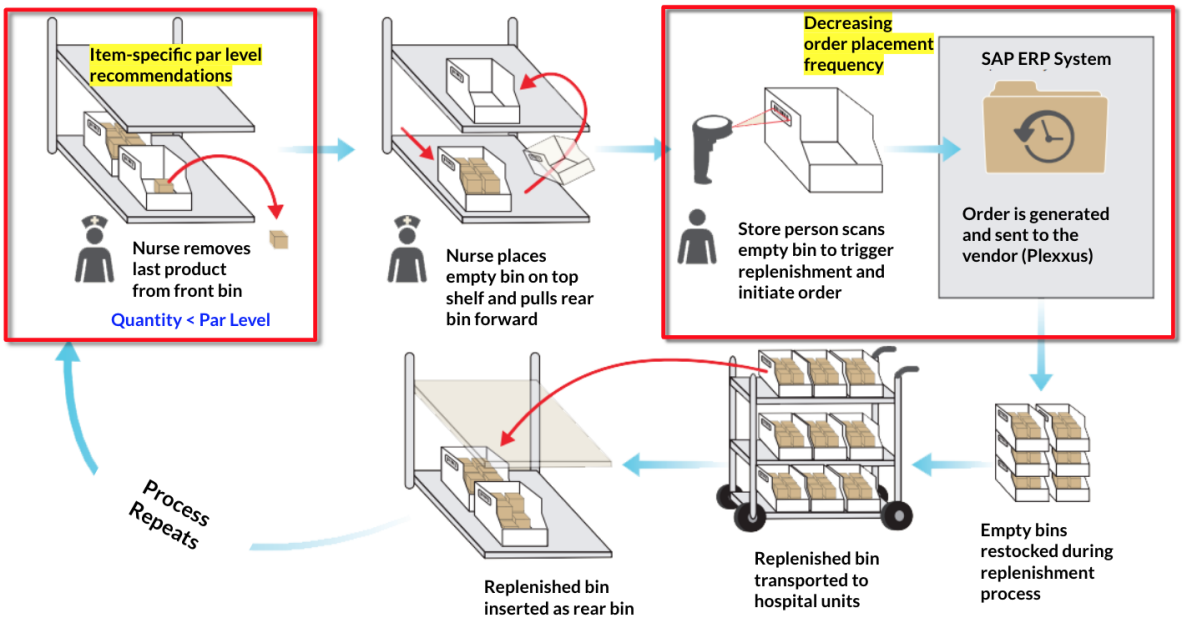
Client: Medical Operations Research Laboratory, University of Toronto
Team Members: Golbarg Eslami, Hanin Afzal, Min Jue Kim, Parastou Hadizadehmoghaddam
Supervisor: Dionne Aleman

Machine Learning Prediction of COVID-19 public policy outcomes

The COVID-19 pandemic emphasizes the need for time-sensitive and evidence-based public health policy decisions. Due to the novelty of this virus, data to support such decisions are scarce and simulations are crucial to fill this gap. The Medical Operations Research Lab (morLAB) uses a large-scale agent-based simulation tool called morPOP (morLAB Pandemic Outbreak Planner) to inform public health decisions around a Canadian province's COVID-19 response. However, running simulations and analyzing the results is time-consuming, and requires niche expertise. Therefore, there is a need for a faster method to assess simulation outcomes without relying on model experts. This project makes accurate policy outcome predictions available for ad-hoc analyses through a machine learning system easily utilized by public health officials and other intended users. The tool helps public health officials to estimate the outcomes of specific policies as it relates to the spread of the virus and forecast requirements for essential supplies in response to the COVID-19 pandemic. The quick, accurate results provided allow faster implementation of effective policies, which will help ensure the health and safety of the general population. The system has the potential to be utilized for a wide variety of public health crises, from pandemic management to vaccine rollout.

The COVID-19 policy outcome prediction web application

The COVID-19 Outcome Prediction System (C.O.P.S) is the first to leverage morPOP data to construct machine learning models for COVID-19 predictions. The results from a subset of all possible morPOP simulations constructed a robust and meaningful dataset which was utilized to train a series of machine learning algorithms. The chosen classification algorithms yielded 95.7%, 96.8%, 97.5% and 95.6% classification accuracy on test datasets of Pandemic Days, Infections, Deaths and Hospitalizations respectively. Flask, a web framework written in Python and equipped with the tools, libraries, and technologies necessary to build a web application, connects the user interface to the machine learning models, making C.O.P.S web-ready for public health officials. The webpages within the application are coded in HTML, enabling Flask to render interface functionalities on a web browser. Thus, the system allows users to input their desired policies for testing and obtain predictions on outcomes from trained Machine Learning models through a web-based user interface. The predictions relate to public health metrics such as the length of the pandemic, the total number of deaths, hospitalizations and infections and can be saved and downloaded by users for future reference.



Operating Cost Analysis and Inventory Planning Redesign at North York General Hospital

Client: North York General Hospital
Team Members: Mohamed Abdellah, Eric Chan, Chengyun Yang, Sahar Karimiabdolrezaee
Supervisor: Michael Carter

Understanding Monetary Benefits of 6S Project and Diagnosing Kanban Process

In 2017, NYGH undertook a 6S project to optimize space utilization of supply carts and reduce operating costs by clearing out redundant supplies. Although 550 items were eliminated, no follow-up analysis was conducted to understand the financial impact and to convince management to take on future inventory optimization initiatives. Quantifying cost savings provides management with a directive as to how much money can be reinvested into research and targeted activities for improving patient care. Additionally, the logistics manager at NYGH voiced concerns regarding item-level ordering patterns. The hospital currently utilizes a Kanban system, which maintains a blanket 4-day par level across all items. Despite this, some items have been observed to be ordered more than twice a week. Thus, the hospital needs to understand if adjustments to the par level would be necessary or if a different approach to inventory management should be adopted. Proposing item-specific policies for inventory management can alleviate strain on the vendor's warehousing operations associated with the frequent placement of orders.

Conducting a Pre-and-Post Financial Analysis and Utilizing Data Segmentation to Assign Inventory Management Policies

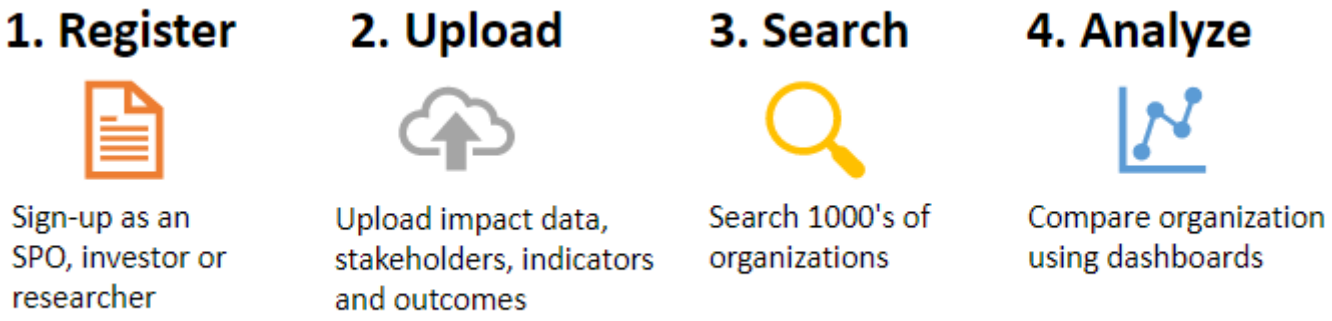
Solutions were split into two sections to address the two gaps identified.

In the first section, the team created an interactive tool that:

- Provides periodic summaries of operating costs and deep dives into the supply usage in each hospital unit
- Categorizes items to allow users to quickly pinpoint significant cost drivers contributing to overages

In the second section, ABC classification was first used to identify 90% of dollar usage contributors, followed by a variability and seasonality analysis to categorize items based on ordering patterns. Based on items' usage contributions and ordering patterns:

- Each item was assigned to one of the following policies: automatic reorder point planning with adjusted fixed lot size or forecast-based planning with economic order quantity
- A set of KPIs were recommended to monitor the performance of the proposed policies



Rethinking Social Purpose Organizations: A Common Approach Repository

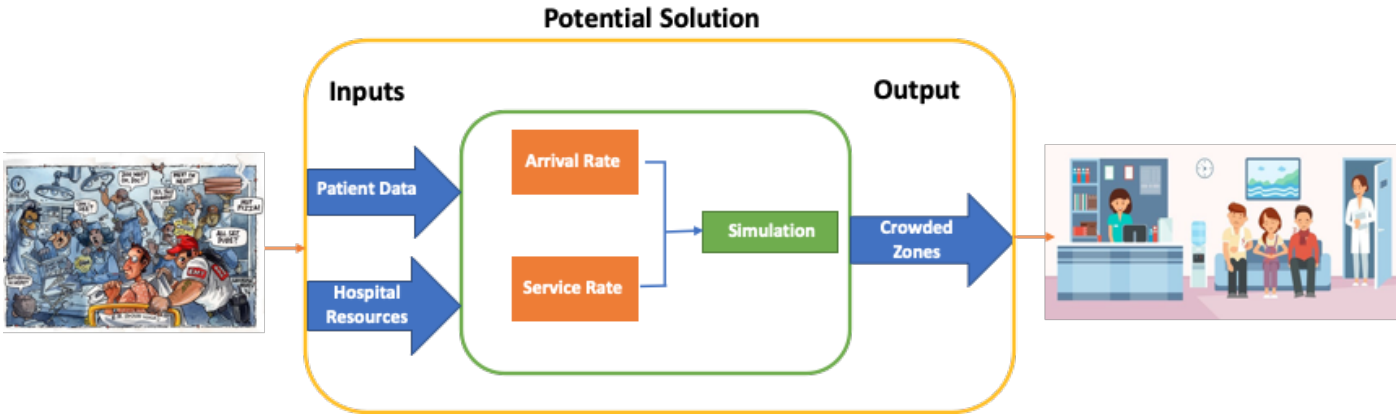
Client: Mark S Fox
Team Members: Diego Simon, Amro Buhloul Jifi, Dennis Kiprono, Dorsa Saebi
Supervisor: Mark S Fox

Towards Transparency, Data Standardization and Centralized Access

There are currently around 10,000 Social Purpose Organizations (SPOs) in Ontario with a revenue of 489 million CAD. These are enterprises looking to create a positive outcome through their revenue generating activities. However, there is no common repository to enable easy sharing of information across SPOs, investors and researchers. The Centre for Social Services Engineering (CSSE) has proposed a user friendly repository interface to cater to the needs of different stakeholders. Having a common approach to measure and report impact data allows SPOs to track their performance and draw comparisons among SPOs with similar Sustainable Development Goals (SDGs) such as no poverty and zero hunger. The increased data accessibility will also guide investors with decision making and attract more funding to the sector. Furthermore, aggregation of data from the repository will enable governments and policy makers to assess the performance of the industry as a whole.

The Multi-Purpose Repository: New Tool for Impact Reporting

The common repository website supports a variety of functionalities including but not limited to account creation, upload of SPO information, search, and data analysis of indicator descriptions. In terms of the design process, we started by researching different web development stacks and selected one based on the project timeline. A database in SQL Light was created and a Flask/Python framework was used to integrate the backend. The team designed the interface using Figma and implemented it in HTML along with Bootstrap CSS. After the completion of all functionalities, the website will be hosted using Amazon's Web Services (EC2 server). Ultimately, this web application will allow the efforts of Ontario's SPOs to be measured and acknowledged nationally.



St.Michael's Emergency Department Simulation for Zone Overcrowding

Client: Unity Health Toronto - Data Science and Advanced Analytics
Team Members: Alissar Hamie, Burak Böcügöz, Hamzah Nasser and Natalie Milevsky
Supervisor: Michael Carter

"To improve patient outcomes and hospital efficiency"

Problem: The system in place at St.Michael's hospital ED only allows the employees to view forecasted patients arrivals (based on acuity level?), without explicitly identifying crowded zones, Therefore, it does not accurately reflect the potential state of the ED and causes prolonged wait time, with an average of 1.6 hours per patient. There must be a dynamic aspect that can receive real-time data and forecast occupancy and wait times based on the zones rather than the acuity level.

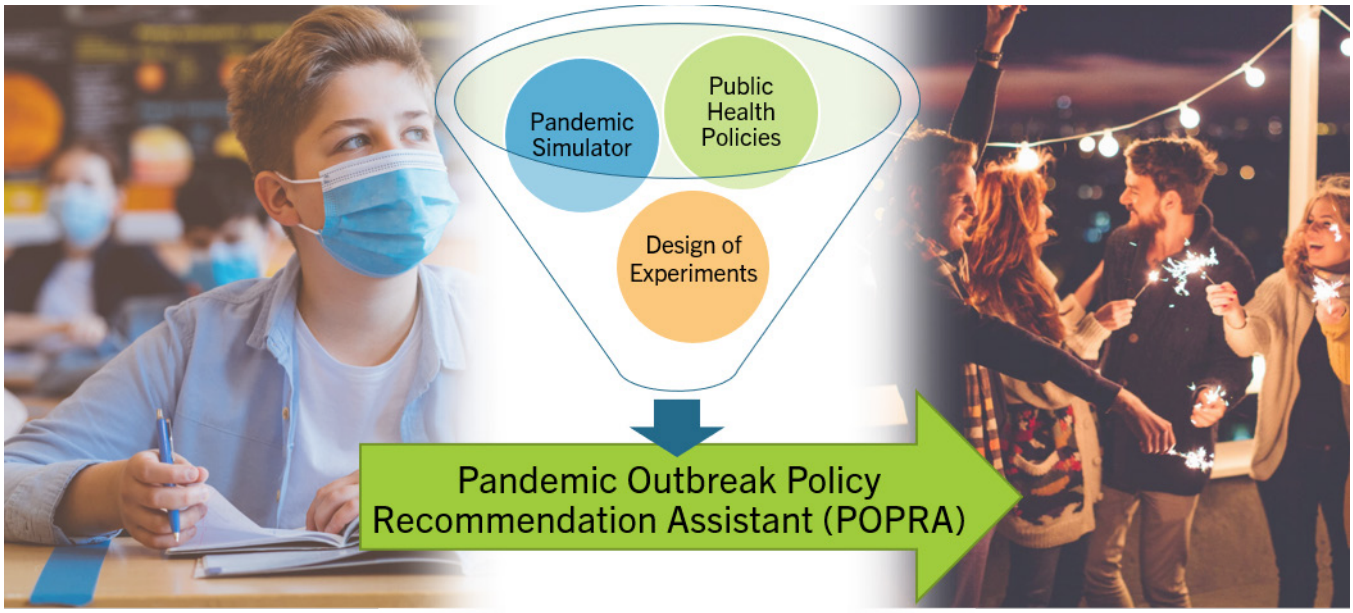
Real-world impact: The project's functional basis is to identify the overcrowded zones in the ED. It will surpass the current system in both accuracy and agility, allowing for a correct representation of the ED zone's crowdedness.

Project Impact: The simulation's results will allow the ED's management to allocate resources in the predicted crowded zones, reducing prolonged wait time and overcrowding As a result, this leads to a lower mortality rate and improves patient outcomes which meets St. Michael's vision "To improve patient outcomes and hospital efficiency".

Overview of the Simulation Model Design

Throughout the project, the team utilized data analysis to create a simulation model of the emergency department to assist the ED management in health care system operations. The team came up with a model to simulate the patient flow through the ED. The model's primary function is to identify the overcrowded zones by (1) identifying patient pathways with the highest probabilistic symptom, (2) identifying the service rates for each station, (3) simulating each pathway and patient flow, and (4) outputting the crowded zones.

Validation Process: In order to validate the operation of the proposed model, the team will use the same data inputs to compare the outputted patients' length of stay (LoS) from the proposed simulation to the LoS from St. Michael's ED historical data.



Stop the Spread: COVID-19 Public Health Policy Decision Support

Client: Medical Operations Research Lab, University of Toronto
Team Members: Olivia Bierman-Dyk, Clara Birch, Jean Carlos Cedeno Bravo, Catherine Grace Lloyd
Supervisor: Dionne Aleman

From Simulation Model to Public Health Policy

The Medical Operations Research Lab (morLAB) at the University of Toronto has been engaged by a provincial public health department to assist in making informed decisions about COVID-19 policies. Together, they integrated real public health data provided by the province into the morLAB Pandemic Outbreak Planner (morPOP). To bridge the gap between Public Health's expertise and the complex simulation model output, the design team created a decision support system (DSS) consisting of a statistical analysis to determine the most effective policies and a user interface to display the results. The DSS enables Public Health to investigate the morPOP simulation outcomes self-sufficiently. Knowing the significant relationships between policy parameters and their impacts on model outcomes guides Public Health on the types of policies that have the most influence on controlling the spread of COVID-19.

Building an Informative and Dynamic Decision Support System

The Pandemic Outbreak Policy Recommendation Assistant (POPRA) DSS gives Public Health access to key results for the statistical analysis. Using Design of Experiments, the team designed and ran 428 policy scenarios on the morPOP model. These scenarios compared seven parameters representing policies and their impact on three metrics: peak number of infections, total number of infections, and peak number of hospitalizations. Analysis of Variance was used to determine the parameters with a significant impact on the outcome metrics. At the 95% confidence level, the significant parameters include the following:

Unrestricted Policies	Household Bubble Size Fixed to Current Guideline
Household bubble size	Maximum number of daily community contacts
Maximum number of daily community contacts	Physical distancing and mask usage
Physical distancing and mask usage	Quarantine duration

The Excel user interface contains the analysis data, a summary of significant parameters, and a tool to independently analyze parameter combinations. The DSS can be updated with new simulation parameters and outputs, and the UI refreshes automatically when updated for ease of use.

User-Friendly & Informative Dashboard to Improve Clinical Decision-Making on Patient Safety

Client: North York General Hospital (NYGH)
Team Members: Jenny Graydon, Teresiah Muiru, Samin Parsa, Alisha Vohora, Nathan Ling
Supervisor: Michael Carter

Current Gaps in HACs Dashboard & Medication Administration Compliance

North York General Hospital (NYGH) has policies guiding the medication administration process to promote patient safety. Deviations from the set process puts patients at risk. Currently, NYGH has no way of tracking compliance with medication administration processes and how this influences adverse medication events.

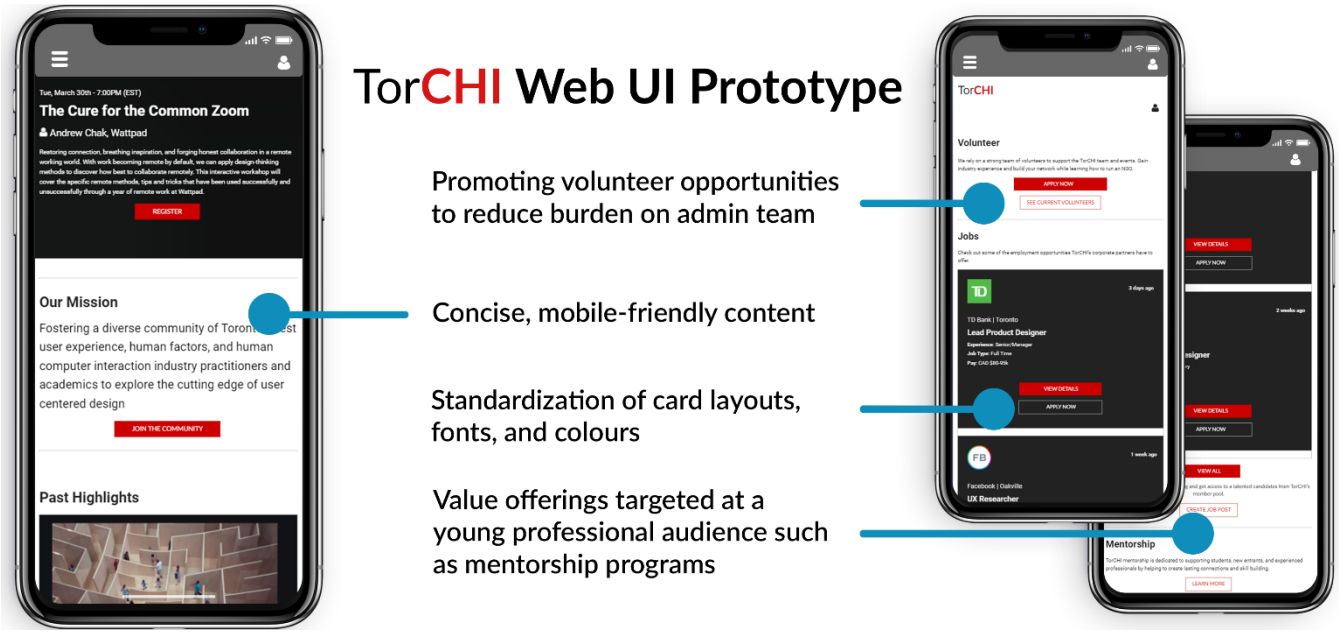
Moreover, NYGH has a dashboard that tracks several indicators, among them falls and pressure injuries. These are known as Hospital Acquired Conditions (HACs) and generally affect patients negatively by threatening their overall health. The current dashboard is rarely utilized by decision-makers as it is difficult to use and provides impractical insights, based on user accounts.
The project's aim is to develop a future dashboard that increases patient safety by providing hospital staff the necessary insights to make effective decisions that provide quality care by preventing HACs. This will also lead to improved patient outcomes and quality of care while encouraging a safety culture throughout NYGH.

Applying Data Visualization & User-Centred Design to Support Clinical Decision-Making

The project design integrates Human Factors principles into a redesign of the current NYGH dashboard to be more readable, interactive, and informative. The design incorporates visual representations of HAC incident/occurrence data for falls, pressure injuries, medication incidents, and medication administration non-compliance in various graphical forms based on metrics determined by the team. The demonstration of actionable data helps Clinical Team Managers (CTMs), the primary users, make decisions within their department to further prevent the recurrence of HACs.

The redesign transforms the existing dashboard into more dynamic representations of useful metrics. Through Heuristic Evaluations, user interviews, and usability testing conducted throughout the design process, the team has created a final prototype that is easy to use and provides the necessary insights to make informed clinical decisions that uphold patient safety. The intended impact of the final design is to promote higher quality of care at NYGH by reducing HAC occurrences.

Information Systems, Data Visualization, and User Interfaces



Applying User Centered Design to Revive a Professional Community

Client: TorCHI (Toronto Chapter of SIGCHI)
Team Members: Anthony Tang, Sarika Goel, Kailyn Henderson
Supervisor: Mark Chignell

Impact of Analyzing Dynamic User Needs in Organization Design

TorCHI is the Toronto chapter of the Special Interest Group on Computer Human Interaction (SIGCHI), a professional association of practitioners of User Experience (UX), Human Computer Interaction (HCI), and User-Centered Design (UCD). TorCHI has fostered a community of both academics and industry practitioners in the aforementioned fields for over 30 years. In recent years however, TorCHI has seen dwindling community engagement and membership, a rising burden on its admin team, and a lack of new volunteers.

The client seeks to revive the organization through an evaluation and redesign of TorCHI's business model and digital presence by applying principles of user centered design to visualize, prototype, and test innovative user experiences. TorCHI's revival targets UX, human factors engineering, and HCI industry practitioners and academics with an emphasis on students in these fields to reestablish a cohort of student members and volunteers. Utilizing core user-centered design principles to deliver superior experiences for TorCHI is a validation of the academic and industry knowledge endorsed.

Meeting All Users' Needs

The website delivered incorporates new learnings derived from user interviews and includes a redesigned web UI that showcases the community-facing results of the organization redesign and substantially improves overall usability. Special care is taken to address both executive needs for managing the new organization and community needs from both current and prospective members. Design methodology leans heavily on user interviews, usability testing, and heuristic analysis, all of which are well-documented user-centered research tools to utilize. Key UX features include standardizing page components, mobile focused user interface, and better highlighting areas of member value.

COVID19 TravelSafe Navigation Tool

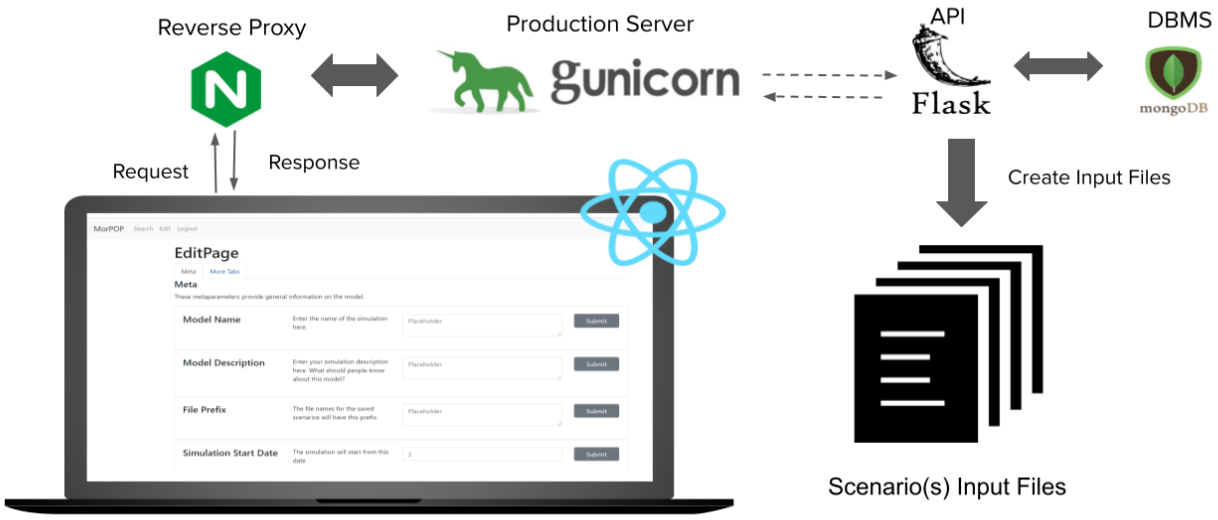
Client: Mott MacDonald Canada Limited (MM)
Team Members: Dingyuhan Wang , Yingzhi Liang, Yixin Sun, Qiaoyi Yan
Supervisor: Scott Sanner

The Urgent Need for a COVID TravelSafe Navigation Planner

During the COVID-19 pandemic, pedestrians are more circumspect when traveling within the Greater Toronto Area. Similar situations are present around the world. Among the existing navigation tools, little has been done to incorporate the risk of exposure to the COVID-19 virus in the route planning phase. As a result, pedestrians need a practical way to reduce their traveling risk. Our client MM is looking for a solution that integrates COVID-19 related data, geographical information systems (GIS), and machine learning techniques to provide an interactive navigation tool for pedestrians and public transit riders to travel safely in the urban environment. The development of such tools can better inform pedestrians about the infection risks of different routes, assist them to make travel decisions, and protect the community. The tool was developed in a modular structure which enables the inputs of different geological traffic information and hence it can potentially be applied in other cities to prevent any respiratory virus spread in transportation.

The Innovative Approach Using Computer Vision and Machine Learning Techniques to Reduce Travellers' COVID Infection Risk

This COVID-19 TravelSafe navigation tool is a web-based application that customizes routes based on user preferences on travel time and risk and so, interactively assists decision making in pedestrian and public transit travel. The user can adjust the tradeoff between time and risk, and the particular locations to avoid, and the mode of transportation any time while using the tool. Furthermore, in order to measure COVID-19 risk based on open-source data, the team uses object detection algorithms to crawl real-time pedestrian density data from Toronto's traffic surveillance camera images. The extracted data is then interpolated and evaluated through machine learning solutions. In particular, the A* search algorithm is leveraged to find a set of fast and sparsely-populated routes for the users. Through iterative user studies and design processes, the tool is developed to provide a user-friendly interface so that minimal knowledge is required to use the app. Besides providing a timely solution in response to the ongoing pandemic situation, the team strived to obtain the best available data possible given the resources available.



Web-based scenario creation interface for a pandemic simulator

Client: Medical Operations Research Lab, University of Toronto
Team Members: Ciel Emond, Emir Hermanto, Nojhat Hrishti
Supervisor: Dionne Aleman

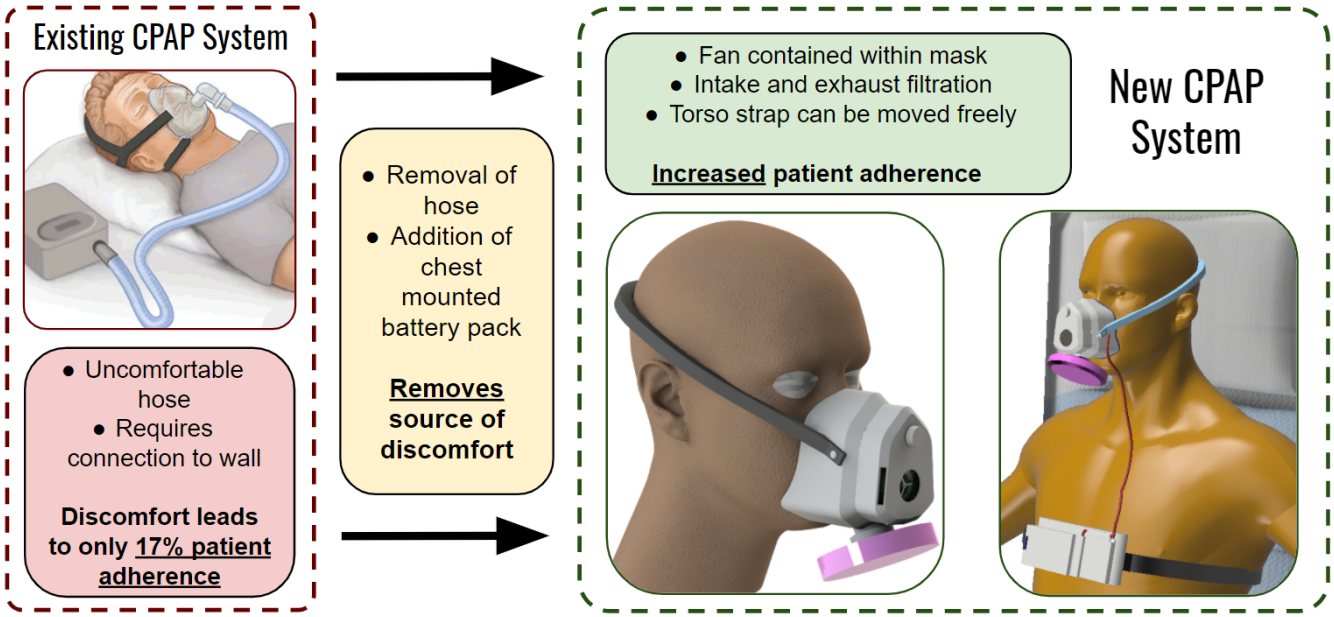
Problem Context: Simulating COVID-19 in a Canadian Province

The morPOP simulator, created by Professor Aleman's morLAB team, predicts the spread of a pandemic disease amongst a complex population. It is currently being used to model the spread of COVID-19 in a Canadian province under different public policy options. The simulator accepts text files that contain information about provincial demographics, pandemic disease characteristics, and public policy information. Editing these text files is very tedious and prone to human error. A model scenario is a collection of these input text files. The lab requires a platform that would make it easier to build and edit these model scenarios. The simulator results are important in helping public health officials create policies that mitigate the population's risk of exposure.

Solution: A Web Application for Scenario Creation and Modification

The team designed a web application to create, save, and edit scenarios. With this web application, a user can search for their scenario and edit parameters that are relevant to: communities; population demographics and health; hospitals and health centers; workplaces and schools. Users can specify ranges of parameter values to create batches of scenarios for sensitivity analysis. To create a highly flexible, scalable, and responsive website, the team employed state-of-the art web development tools. Our testing shows that our design leads to a 19% improvement in time for task completion. In addition, participants gave an average 4.5 rating on a 5-point Likert scale for satisfaction when completing tasks on the web application.

Medical Equipment/ Health Care Technology



A Hoseless CPAP System for Improved Quality of Life

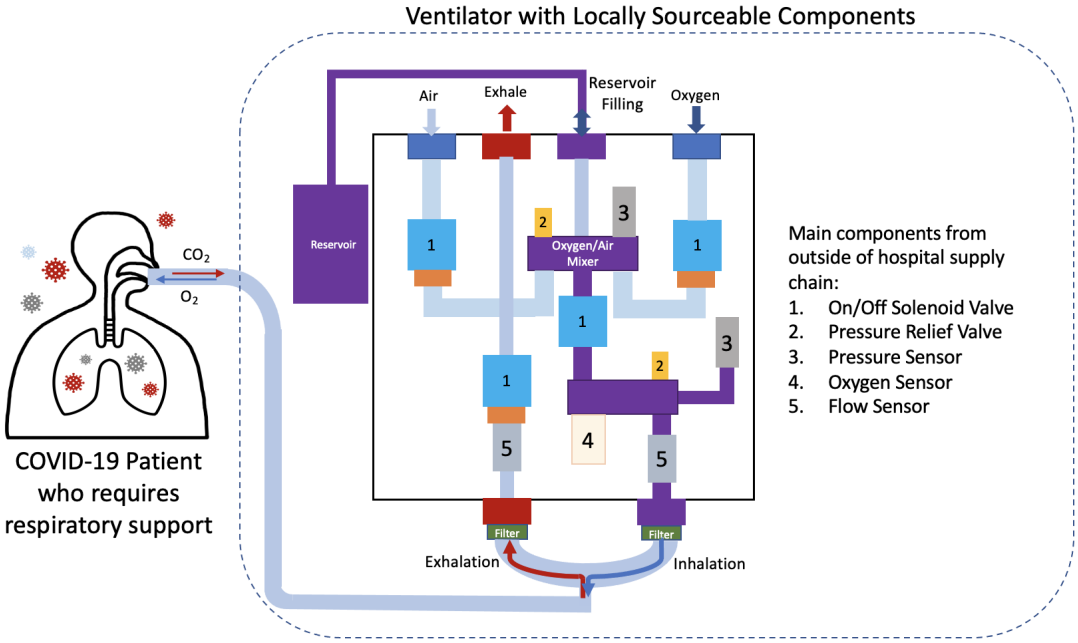
Client: Saeed Zaiee, Intelligent Engineering Solutions (IES)
Team Members: Adam Koa, Sarah Toukan, Jacob Sinopoli, Danylo Varshavsky
Supervisor: James K. Mills

An Uncomfortable and Restrictive Solution

Continuous Positive Airway Pressure (CPAP) systems are commonly used to treat obstructive sleep apnea (OSA), a condition where the airway collapses during sleep; in the United States, approximately 20% of the adults suffer from OSA. Regular CPAP usage can improve a patient's emotional stability and daytime alertness, with some research linking these factors to reduced rates of motor vehicle accidents. CPAP usage can also reduce the risk of heart disease, strokes and diabetes, thereby providing better general health and lower medical expenses. Despite these radical quality-of-life improvements, it has been estimated that less than 17% of OSA patients regularly adhere to their prescribed CPAP treatment. Existing CPAP systems can be uncomfortable to use, largely due to the restrictive connection hose that interferes with the user's sleep. Intelligent Engineering Solutions (IES) is looking to design a novel CPAP system that improves user comfort during sleep by eliminating the need for a hose; due to the widespread prevalence of OSA, even minor increases in CPAP adherence could have far-ranging benefits.

Unplugging for a Deeper Sleep

The new design operates similarly to existing CPAP systems: a fan provides a continuous stream of air to the lungs, pressurizing the airway and preventing the throat from collapsing. The key innovation in this design is the removal of the hose; rather than connecting the mask and the fan with a hose, this design includes a fan mounted directly inside the mask. Additionally, the design offers the ability to be powered from a chest-mounted battery pack, allowing the user to remain untethered during sleep and provides the ability to use the CPAP without a wall outlet. The battery pack is placed in a soft pouch that can either be worn across the user's torso or placed nearby for the utmost freedom during sleep. During the design process, comfort was prioritized as the primary objective; as such a combination of experimental validation via physical prototyping and computer simulations was used to confirm the system's functionality and its improvements in user comfort. Finally, the mask was designed to reduce the possible spread of infectious diseases, and is compatible with common 3M respirator filters.



Battle Against COVID-19 and Ventilator Components Shortage

Client: Toronto General Hospital (TGH)
Team Members: Mariem Ahmed, Youna Jung, Hakyung Lee, Hyeon Jun Noh
Supervisor: Kamran Behdinan

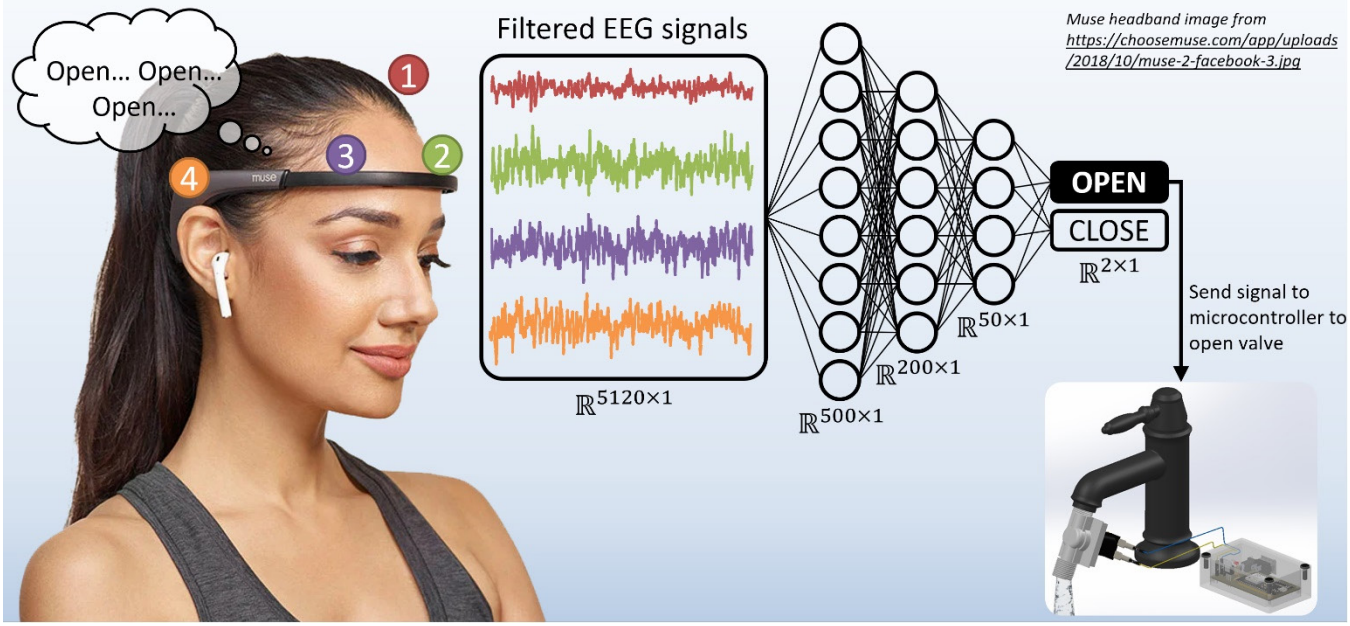
Standalone Ventilator that can be Built Anywhere in Canada

Existing standalone ventilators rely on the global supply chain to source hundreds of subcomponents. The demand for ventilators increased rapidly worldwide due to the COVID-19 illness. However, many countries, including Canada, have stopped exporting medical equipment, resulting in equipment shortages. TGH requires an open-source ventilator that provides the necessary amount of oxygen to and eliminates carbon dioxide from patients' lungs. With the help of a sustained global design effort, the team designed an open-source invasive standalone ventilator with locally sourceable components to fulfill the TGH's needs. The design directly contributes to COVID-19 patients who require immediate respiratory support and hospitals that have experienced, and may continue to experience, a ventilator shortage.

Sophisticated Ventilator Design with Locally Sourceable Components

The design supports the Pressure Regulated Volume Control mode delivering a desired tidal volume to the patient at the lowest possible airway pressure. The design employs three main phases per respiratory cycle during ventilation: inhalation, reservoir filling, and exhalation. These phases are fulfilled by utilizing the following critical components from outside of the hospital supply chain: two pressure transducers, four direct-acting solenoid valves, an oxygen sensor, a two-litre container as a reservoir, and two flow sensors. The team also utilized a logic module, DAQ, and Raspberry Pi instead of a customized printed circuit board and simple on/off solenoid valve to not interfere with existing ventilator supply chain and to rely on alternative sourcing of components.

The control of these components was mainly designed analytically and mathematically applying fluid mechanics principles such as Reynolds Transport Theorem, ideal gas law, and subcritical/supercritical flows. The analytical and mathematical model was validated by simulating ISO-80601-2-12:2020 test cases on a process simulator. Unlike current standalone ventilator designs, the team designed a ventilator that is easy to assemble, is open-source, and can be implemented using standard and locally sourceable components.



Brain Computer Interface for Industrial Fluid Flow Control

Client:Nasser Ashgriz
Team Members: Amaani Zuberi, Farhan Wadia, Justin Park, Mrinal Jha, Stephanie DiNunzio
Supervisor: Nasser Ashgriz

Disrupting the process control and machine operator industry

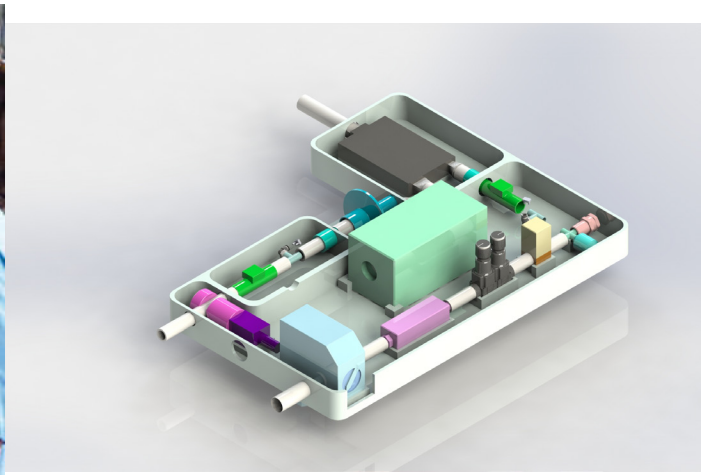
As a mechanical engineering professor interested in brain computer interfaces (BCIs) and their potential usage in emerging industrial applications, Prof. Ashgriz requested our team to develop a proof-of-concept system to show that solenoid valves can be controlled using a BCI. In other words, a user's thoughts, which can be characterized by recording their electroencephalogram (EEG) signals, would control the opening or closing of a solenoid valve. With further refinement of this proof-of-concept, the idea could be applied to several industries involving flow control as a way to potentially increase productivity or provide new opportunities for disabled people to work as process control and machine operators. Specifically, we believe that a more refined version of our design would be well suited for adoption by process control and machine operators in the food and beverage processing industries.

Developing the proof-of-concept BCI for controlling a solenoid valve

After benchmarking commercially available EEG headsets, our team decided to use Prof. Ashgriz's existing Muse 2 in order to limit costs, but with the tradeoff of having fewer EEG channels and limited software support compared to alternatives like the OpenBCI or Emotiv Insight.

Our team considered multiple approaches for the BCI design, such as trying to classify between staring at flashing lights of different frequencies, classifying between imagined hand movements, and classifying between repeatedly thinking 'open' or 'close' without vocalizing as ways to control the valve's movement. After training preliminary models for each, which all had similar accuracies, we chose the latter due to it being most similar to the original vision to simply think open or close and have the valve move. We then collected more training data to improve the model, worked on implementing it in real-time, and programmed an Arduino and developed a control circuit to actuate the valve.

Our final model is an artificial neural network with three hidden layers of sizes 500, 200, and 50. The input is of size 5120 (4 EEG channels × 5s recordings × 256 Hz sampling frequency) and the output is of size 2 (open, close). It was developed using 350 files for training and 75 files for validation, with an additional 75 files were held-out for testing. On this test set, the model achieved an accuracy of 87%. As the state of research in covert speech based BCIs progresses, we hope that our model can benefit from new advances in order to reach an accuracy level where it can be relied upon for industrial applications.



Design of a Easy-to-manufacture and Operator-friendly Ventilator

Client: ARL-MLS and UHN/TGH
Team Members: Jie Mao, Shijie Liu, Yuanshang Ding, Yufeng Zhou
Supervisor: Kamran Behdinan

Statement of Impact

Patients and the global health care system will be the primary beneficiaries of this engineering project. In the short term, the design will mitigate the ventilator shortage during COVID-19 or similar pandemic surges in the future. Moreover, the project's long-term goal is to reduce the overall cost of medical devices and make medical services more available and affordable to the general public.

Overview of Design

The ventilator design mainly consists of four sub-systems: gas mixing chamber, inspiratory path, innovative safety design, and expiratory path. The system components are either off-the-shelf products that can be mass-produced or designed to have a quick production turnaround.

The design has a few outstanding features compared to the existing products. An innovative safety design concept is adopted from the 1968 US Army Emergency Respirator proposal that allows the patient to initiate inspiration and expiration. Optimization is made to improve performance and reliability.

The ventilator utilizes both single and dual setpoint controller strategies to control the parameters selected by the operators, such as inspiratory flow, pressure waveform, peak value, or inspiratory time. A convolutional neural network-based deep learning model is also introduced to detect and synchronize the ventilator's and the patient's breathing cycles.

Key Results

The proposed design has been theoretically validated through various engineering tools, such as Solidworks, Simscape, CFD simulation, testing sets for the machine learning model and analytical calculations. Cost analysis and benchmarking are also conducted to prove its market viability. A prototype testing plan is prepared to validate the safety and performance of the proposed design physically.

Mapping the Progression of Onset Dental Caries

Client: Quantum Dental Laboratories
Team members: Wonyoung Na, Eric Seeram, Raheel Amjad
Supervisor: Andreas Mandelis

Current Issues with Dental Caries Diagnosis

Current dental caries are only identifiable at relatively late stages of development using x-rays, and thus progress can be made in caries diagnosis. The possibilities being looked into with this project include diagnosing caries development at significantly earlier stages, leading to easier prevention and treatment for patients globally. This would not only benefit patients' quality of care, but also the general effectiveness of dental treatment.

Photothermal Radiometry (PTR) Frequency Results and Enhanced Truncated Correlation Photothermal Coherence Tomography (eTC-PCT) Image Analysis

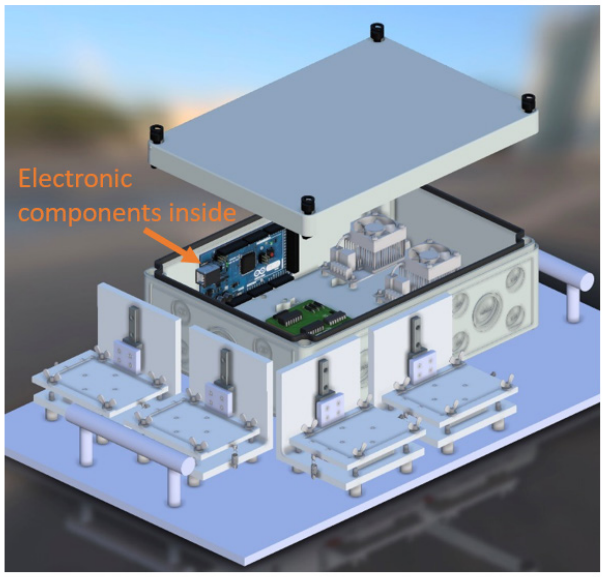
The rig to be used in the imaging process was designed to have freedom of movement in the X, Y, and Z axes, with a rotational stage on top to allow for side profiles to be imaged.

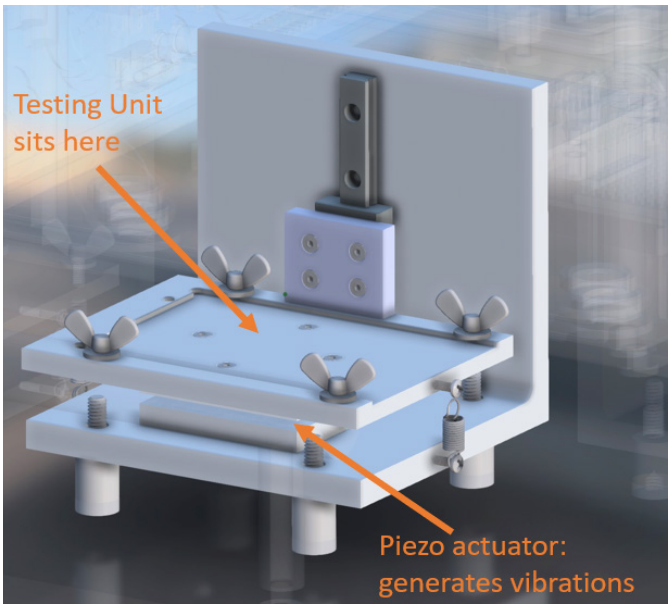
PTR is a technique that is based on the modulated thermal infrared response of a medium. When optical energy from a source is absorbed by a medium, there is an optical-to-thermal energy conversion that takes place, with minimal radiation emission. This results in a modulated temperature, and an infrared detector can be used to monitor the thermal photon emissions. The PTR signals carry information about whatever is beneath the surface of a medium, such as a tooth, as the temperature accurately shows the geometry and thermophysical properties of the medium.

After receiving the data from the eTC-PCT imaging, image filtering algorithms are used to analyze the severity of the dental caries. Common imaging techniques include a simple median filter or a total variation filter, which is used to decrease the integral of the absolute gradient of the image. These filters help to make caries more detectable by improving the visibility of edges as well as edge depth.

The designs in this project build on existing techniques. The PTR method developed by Professor Andreas Mandelis remains unchanged. The image filtering algorithm is based on common algorithms used in dental imaging adjusted to this process.

The goal of this project is to propose techniques for future use in the dental field.





Mechanobiology Testing Platform

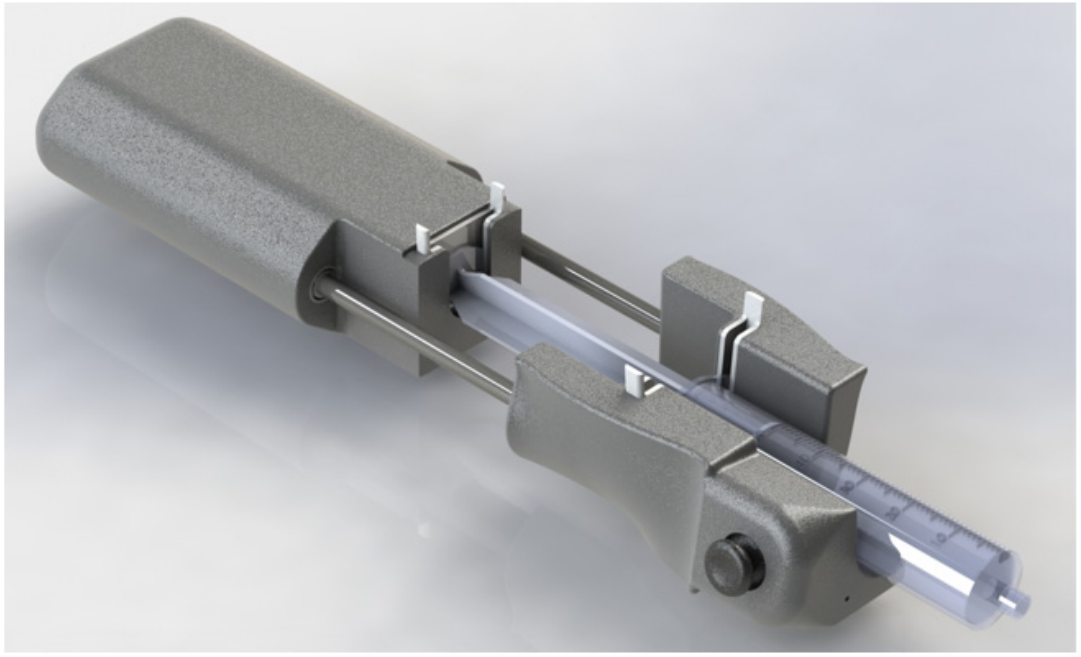
Client: The Cellular Biomechanics Laboratory (CBL)
Team members: Siqi Chen, Hanzhen Shi, Yuhang Song
Supervisor: Lidan You

Mechanical loading study on bone cells using vibrators

The CBL is studying about the mechanical loadings' effect on the bone cancer metastasis. The lab requests for a system which can vibrate a set of MFDs together but separately. The vibration needs to follow user instruction with amplitude ranging from 0.1 to 0.3g (g=Gravitational acceleration constant), and frequency ranging from 20 to 90 Hz. With the assistance of our design, the lab will be able to get accurate results on how bone cells behave under different vibrations. The professionals may then develop therapies to eliminate cancerous bone cells with the understanding of osteocytes' response. Therefore, our design can help the university/lab researchers and medical professionals studying in this area, which in a bigger picture, will be beneficial to all bone cancer patients.

Humidity-resistant system providing desired vibrations

The design consists of four vibration platforms secured on a base plate. It will receive values of amplitudes and frequencies from the user via the laptop interface and generate vibrations accordingly. The design is humidity resistant and will work in the lab incubator.
We would like to showcase the design of the Printed Circuit Board (PCB) which has made the design more concise and improved the ease of maintenance. Also, we learnt from the metal anti-rust methods and applied hydrophobic coating to protect the electric components against the moisture in the working environment (i.e., the incubator). The addition of humidity resistant enclosure acts as a secondary protection, which isolates the Arduino, PCB and piezo drivers from the moisture. It is to be highlighted that this design combines the use of Arduino (for programming) and piezo actuator (for vibration), which completes the conversion from user inputs to accurate vibrator outputs and allows the control of four platforms at the same time.



Minimizing Injuries when Preparing Medication

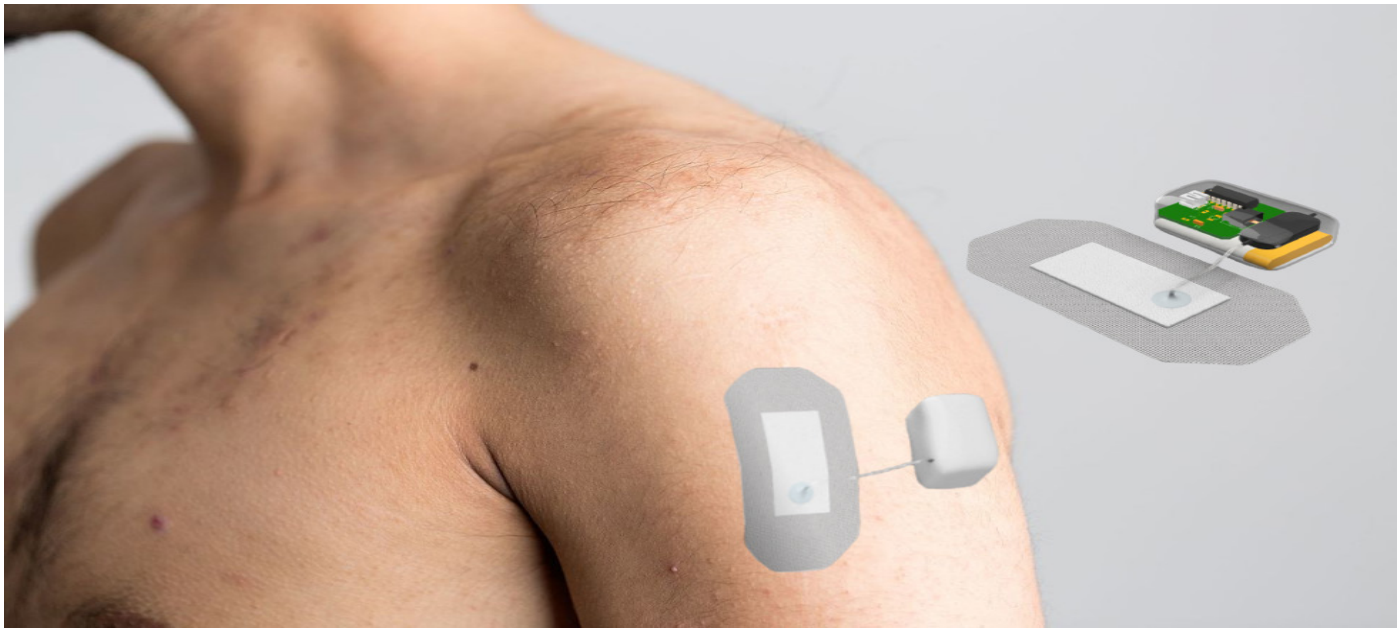
Client: North York General Hospital (NYGH)
Team members: Abdullah Gulab, David Rolko, Eshan Gokhale, Thomas Rolko
Supervisor: Craig Simmons

Reducing Musculoskeletal Injuries when Compounding with Medical Syringes

North York General Hospital has presented the task to improve the process of pharmaceutical compounding with syringes. When using a syringe to prepare medications, technicians often experience musculoskeletal injuries (MSI). Traditional compounding methods create high stress in the technician's hand due to the repetition of applying a high force to push and pull a syringe. The team designed and prototyped an innovative device allowing the technician to expend little to no force when compounding. The solution reduces the possibility of MSIs, thus, improving technician's physical health. Another advantage is that the chance of lost productivity and downtime due to these injuries is reduced.
This innovative design could offer many benefits by reducing occupational injury across the pharmaceutical industry. Any hospital or organization that performs compounding with syringes can incorporate this technology into their daily procedures.

The Pencil Design - Rethinking Medication Preparation

The Pencil Design uses a lead screw that converts rotational movement of a lightweight brushless motor to linear movement of the syringe. It was designed to accommodate syringe sizes between 20 ml to 50 ml. This handheld device is plugged into a wall outlet to power the motor and required controllers.
The Pencil Design is innovative because of its mobility and ergonomic features. The technician can comfortably hold the entire device with one hand using its sleek handle. Since it is portable, it can be maneuvered within a laminar flow hood without having awkward manipulations. All these factors contribute to the functionality requirement, which was to reduce musculoskeletal injuries.



Negative Pressure Wound Therapy for Small-Scale Wounds

Client: Nasser Ashgriz
Team members: Alex Dolmaya, Christopher Calogero, Deepak Lakha, Gobind Vasir
Supervisor: Nasser Ashgriz

"Negative Pressure Wound Therapy (NPWT) is a therapeutic technique using a suction pump, tubing, and a dressing that accelerates healing in acute or chronic wounds and burns."

Negative Pressure Wound Therapy is Limited by Size

- Conventional technologies are bulky and limited to clinical settings.
- The goal of this project is to develop a portable NPWT solution that makes treatment unobtrusive and accessible in mobile use cases.
- The prototype design implements existing principles of NPWT at a scale equivalent to modern wearable technologies.

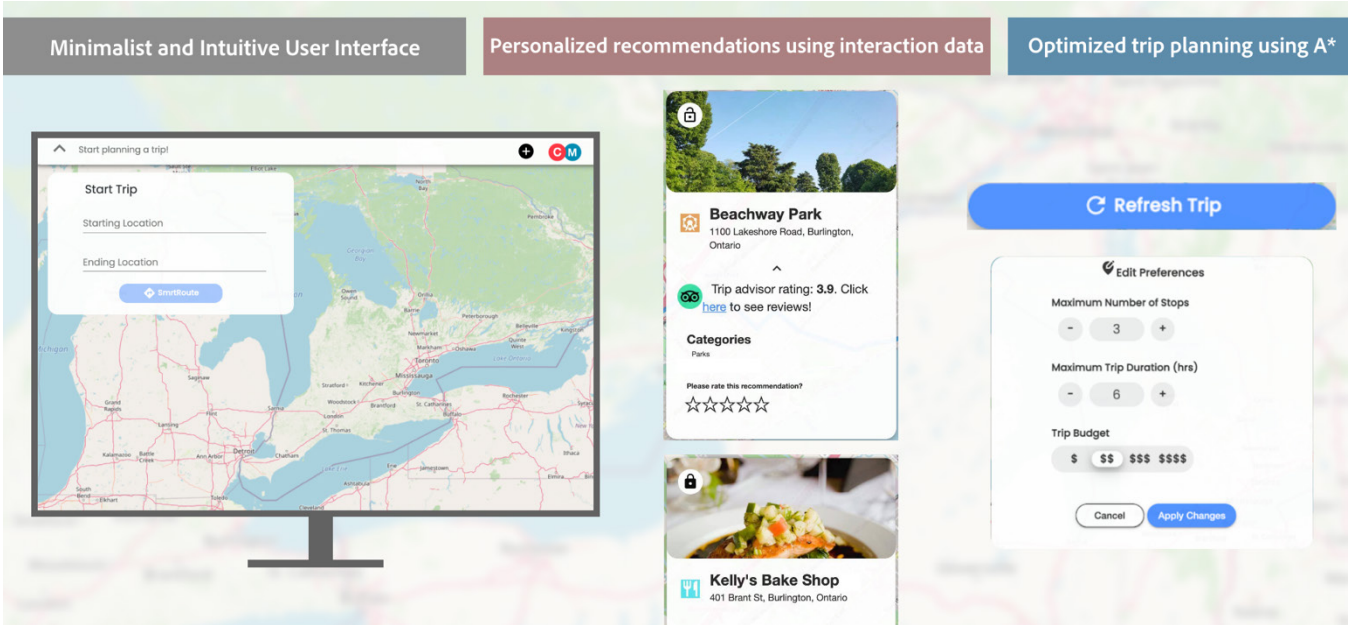
Concealable Microscale Technologies Completely Transforms Day-To-Day Treatment

Value
- Advanced wound care at an affordable cost
- Modular patch that adheres to skin
- Rechargeable Lithium Polymer Battery with micro usb cable

Small
- Coin-sized piezoelectric micropump provides 100 mbar of suction pressure
- Easy to wear underneath loose clothing

Easy-to-use
- Apply dressing and begin negative pressure treatment at the press of a button
- Device supports mobility during daily activities

Predictive analytics: Machine learning and forecasting



A Road-Trip Planner Personalized for Your Interests

Client: Ron Di Carlantonio, iNAGO
Team Members: Bassam Bibi, Christopher Palumbo, Merih Atasoy, Matteo Ciserani
Supervisor: Scott Sanner

iNAGO's Need and Project Impact

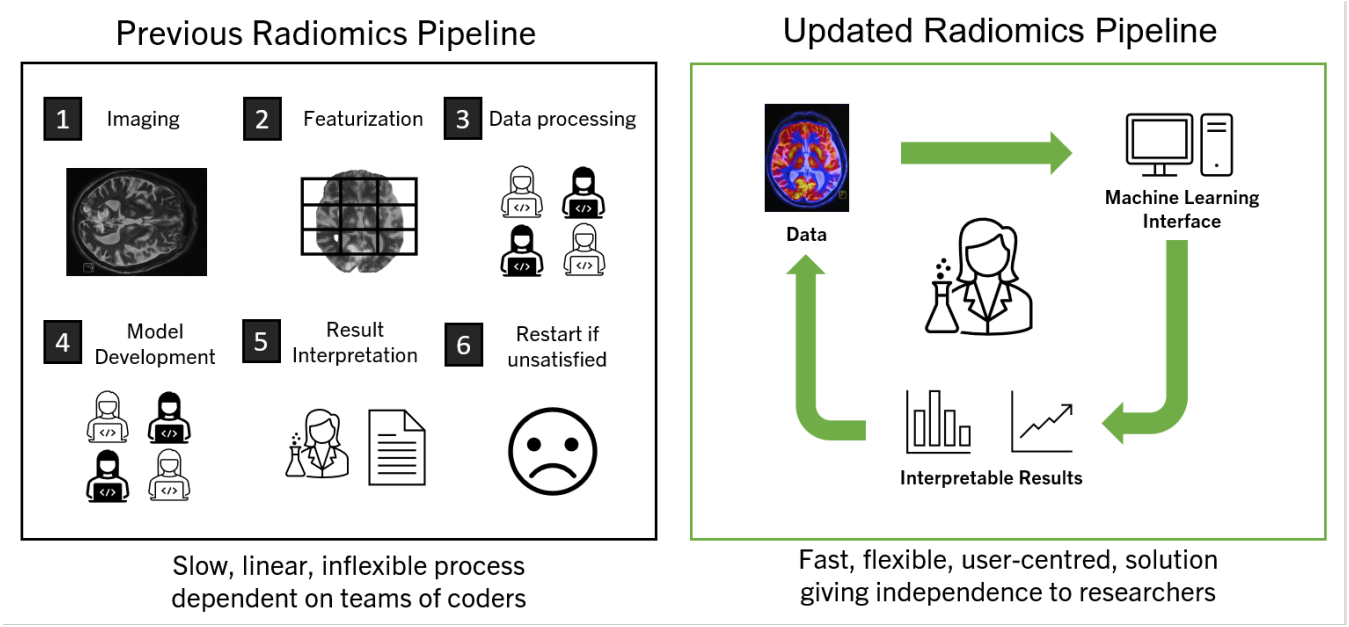
iNAGO's on-route assistance technology is equipped to suggest attractions and points of interest (POIs) to drivers during any road trip: commute to work, short vacation, or long journey. However, the recommendation system used to suggest POIs to drivers does not assist users in creating start-to-end itineraries and does not consider groups of users with varying interests. The ability to understand each group members' interests increases the percentage of customers using the recommendations and affects iNAGO's product leadership by creating competitive advantage. In the bigger picture, effective route-based recommendations act to increase local tourism within communities, leading to increased small/medium sized business revenue and encouraging community connectivity.

Design overview and analysis

The team developed a website intended for user(s) to input their starting and ending road-trip locations and be suggested a modified route with several touristic stops on the way. User(s) can interact with the system by saving or refreshing individual stops and editing routing options (number of stops, trip duration, budget).

The novelty of the design is emphasized by automatically generating a complete itinerary to the user and allowing users to add other members (family, friends, etc.) to the trip, making use of group recommendation algorithms. The design is intended to showcase a personalized Point of Interest (POI) recommendation system which learns about each user's interests by encouraging them to rate POIs. Finally, innovation and engineering expertise was applied in calculating similarities between POIs using 180'000 TripAdvisor reviews, and finding optimal trip paths by modifying the A* algorithm to include POI stops.

The final web interface was deployed to iNAGO's servers for their development and testing teams to analyze. Following modifications and a full cycle of regression & user testing, the application can be implemented as a tool in the dashboard of iNAGO's worldwide clientele.



Advancing Radiology with User-Friendly Machine Learning

Client: Ernest Namdar
Team Members: Ines Gomes, Samuel McCulloch, Gabriella Tolnai, Lora Tyufekchieva
Supervisor: Farzad Khalvati

Making Machine Learning Accessible for Radiology Research

The Hospital for Sick Children required a new Graphical User Interface (GUI) for creating machine learning models to analyze diagnostic images. The previous pipeline required radiology researchers to consult with teams of programmers to perform data processing, model development, and result interpretation. This process was iterative as user needs would change frequently and, as a result, was a time intensive process.

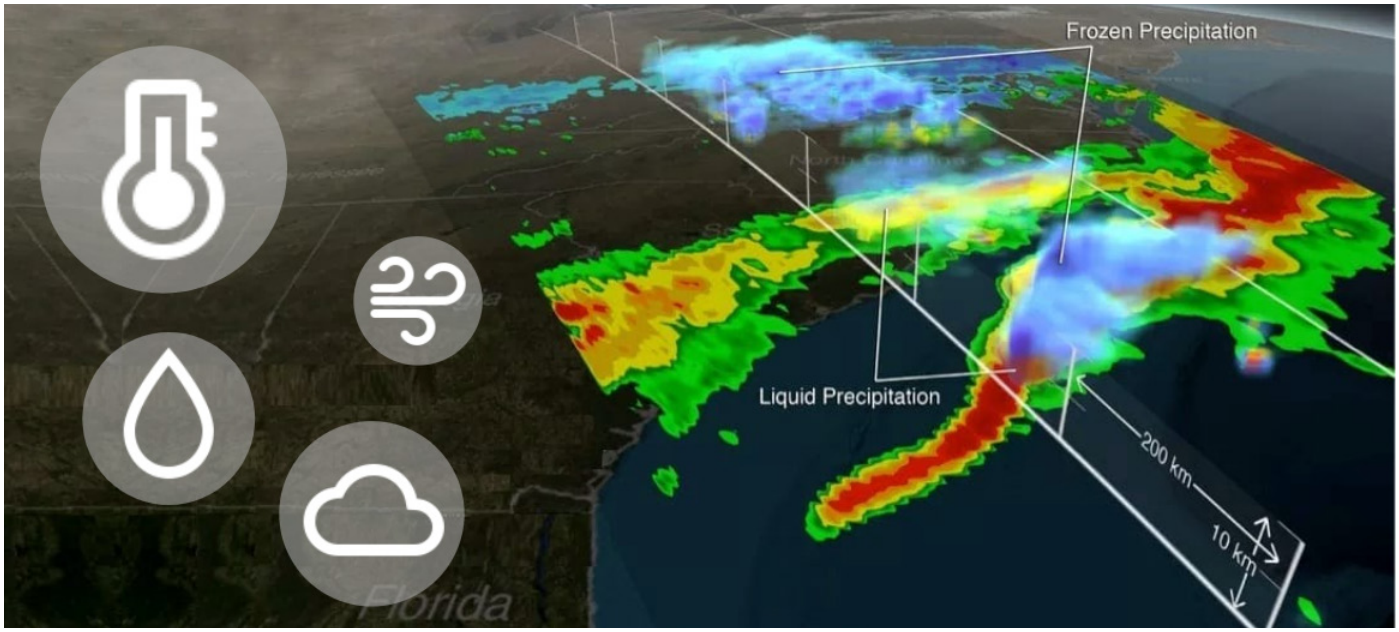
The new GUI gives radiology researchers a tool to independently perform the tasks needed to create machine learning models and interpret their results. This means less dependence on programmer teams, faster turnaround for model changes, and the ability to replicate models from academic literature. The updated pipeline enables more research into radiomics (the combination of radiology and machine learning) and could eventually lead to radiomics moving from a research field into a clinical one.

Simplified Radiomics with a User-Centric Interface for Machine Learning

The GUI's first two pages guide users through data processing and model selection with easy-to-understand headings and options. After filling out the required fields, users can then run their model. The results are displayed on the evaluation page containing all model specifications and key metrics, such as AUC, accuracy, and precision. This evaluation page makes result interpretation easy for radiology researchers.

Human-centered design was the highest priority in the GUI's conception. Design heuristics and human factors principles were incorporated in each stage of ideation. A low-fidelity prototype was created and used for preliminary user testing by the target end-user group. This feedback was then incorporated into a high-fidelity prototype and evaluated in a second round of user testing with a new set of target end-users.

The final product is a combination of Human Factors Engineering and Artificial Intelligence Engineering. The successful execution of both disciplines by a team of four industrial engineers shows the value of a broad-based education.



Automation of Weather Forecast Data Summarization

Client: Environmental and Climate Change of Canada
Team Members: Khaled Khalil, Omar Khan, Suri Xiang
Supervisor: Mark Fox

Creating Flexibility and Granularity to Improve Efficiency in Summarizing Forecasted Weather Data

Meteorologists at the Meteorological Services of Canada (MSC) issue weather forecasts to protect life, property, and economic interests across Canada. Over the past three decades, the existing weather forecasting system prioritizes satisfying business rules for economic policy, flawed design, and bureaucracy, over providing detailed and accurate weather forecasts. As such, the project team was tasked with providing an innovative solution to streamline the generation of weather forecasts and address the shortcomings of the current design.

Our solution envisions reducing meteorologists' workload, diminishing the MSC's operational waste, providing more control to operating meteorologists, and producing more granular forecasts. This will result in more detailed weather forecast summaries that will benefit the interests of downstream audiences like the general public, aviation program, marine program, and the military.

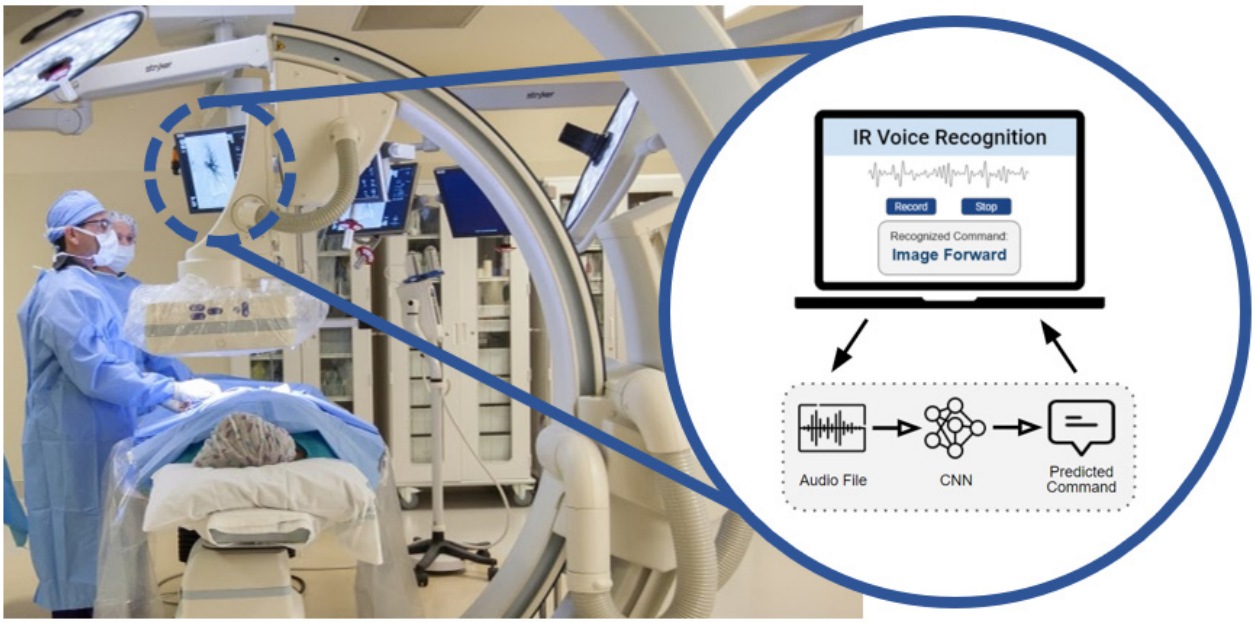
A New Operating Model to Capture Human Expertise in Automated Summary Production

The team approached the opportunity from a systematic perspective, and designed a new operating model to maximize the scale of process automation while ensuring meteorologists' knowledge is still retained. Our design includes:

- An automated forecast summarization process powered by a machine learning model that considers multiple weather elements and identifies data patterns
- An interface that records meteorologists' interactions with the model, and captures their subject matter expertise for sustainable model training and improvement
- An advanced text generator that translates output data into forecast messages to downstream audiences

The team prioritized the project and implemented a Machine Learning model which detects and aggregates spatial and temporal weather patterns regarding temperature, cloud coverage, precipitation, wind speed and direction, with adjustable sensitivity settings. The modular nature of the solution along with the novel operational model lays a strong foundation for future developments of an entirely autonomous weather forecasting system.

Image source: Weather. (2021). Retrieved 20 March 2021, from https://www.nasa.gov/centers/ames/earthscience/programs/researchandanalysis/weather



Creating a Voice Recognition System for Image Guided Brain Surgery at SickKids Hospital

Client: Dr. Prakash Muthusami, SickKids Hospital
Team Members: Bayaan Shalaby, Christina Seo, Litong Zheng, Sheree Zhang
Supervisor: Farzad Khalvati

An Interventional Radiology System that Minimizes Communication Errors in Image Guided Surgery

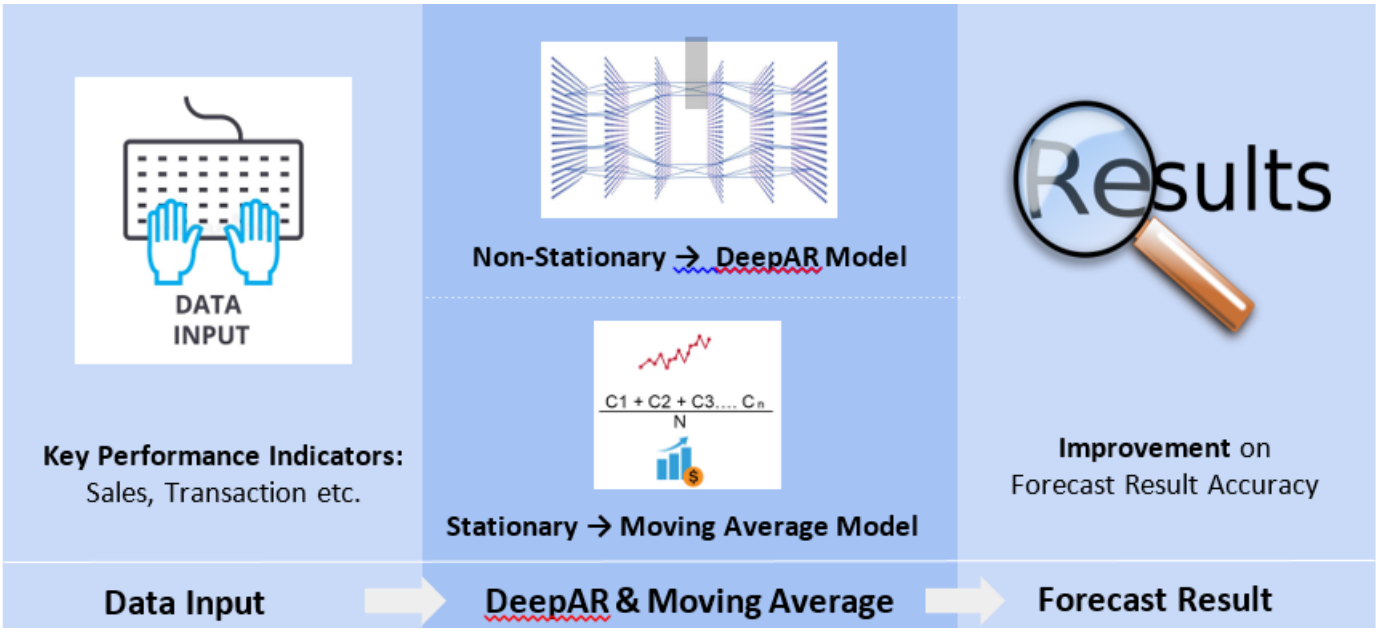
In image guided brain surgery, neurointerventionists rely on a variety of computerized imaging systems to guide them through performing procedures. To maintain sterility, they verbally communicate several commands to assistants for them to control the machines or images. The presented problem was that an operator for pediatric patients needed to communicate in suboptimal conditions including:

- Through a mask
- Over background noise
- To a rotating set of technologists and nurses

These conditions can lead to communication errors causing delays in execution. The client needed an interventional radiology (IR) system that can accurately deliver the operator's commands and minimize the risk of error, ultimately allowing for more successful procedures. The objectives of the design were that: it should be intuitive to use, inexpensive, robust and durable, and requires minimal upkeep.

A Machine Learning System that Accurately Recognizes Operator Commands

A voice recognition system utilizing a machine learning model, namely a Convolutional Neural Network (CNN), was developed as it would maintain sterility and minimize the likelihood of communication errors. The system includes a simple web interface, which allows the user to verbalize a command into a microphone and feeds the audio into a pre-trained CNN, whose predicted output will then be displayed on the user interface. The model achieved an accuracy of 95.8%. The proposed solution overcomes certain communication issues in neurointerventional surgery by leveraging machine learning techniques to accurately identify verbal commands. Future work includes integrating the above design into the hospital's IR system and testing in the live environment to execute the commands.



Improve the Forecasting Accuracy of Multiple Time Series

Client: Ceridian Inc.
Team Members: Zhuoru Pan, Jiahui Yu, Weiyue Zhou, YiLing Wang i
Supervisor: Merve Bodur

Background

Ceridian, a global software company that is dedicated to providing Human Capital Management (HCM) solutions to make fast and intelligent decisions regarding workforce management. The need of the project is to improve the prediction accuracy of their current forecasting key product DayForce. The team investigates the current state of the art of forecasting methods to compare with the classical forecasting methods. Throughout the exploration of classical forecasting methods and feature learning-based algorithms, the team decides on a simple moving average as the representation of classical forecasting methods and DeepAR as the representation of a deep-learning-based algorithm. The final suggestion on forecasting algorithm selection will be based on the data behaviour that is captured by both algorithms with further statistical support by comparing the quality metrics - RMSE and MAPE.

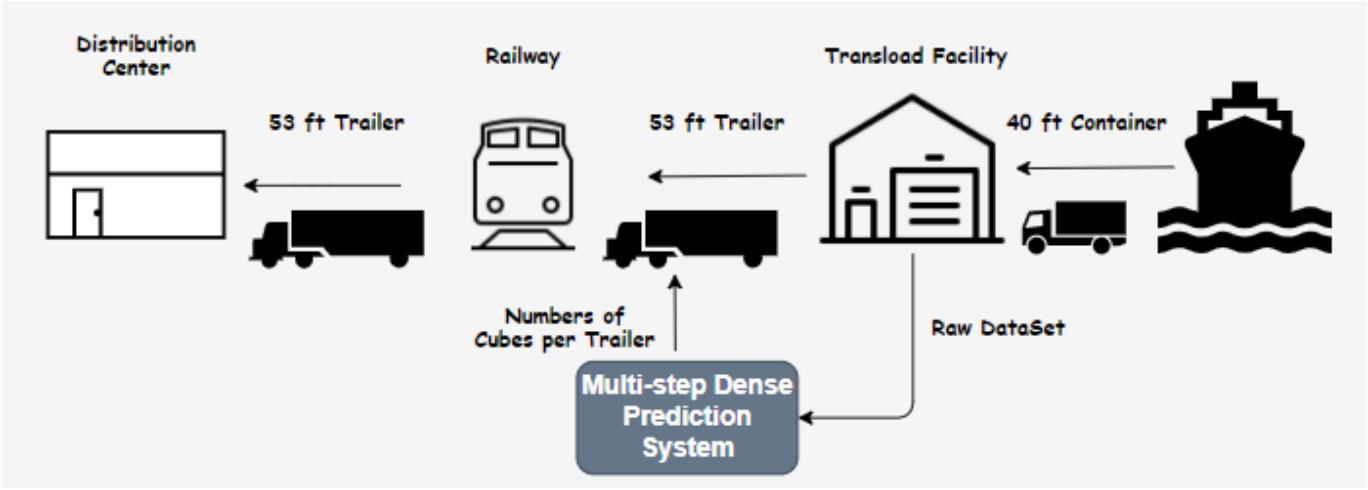
Business Impact

Demand forecasting plays a significant role in impacting a company's business strategies and performance regarding labour scheduling decisions. The design suggests a suitable forecast method to Ceridian's clients for the purpose of a better alignment on human resources.

DeepAR and Moving Average as the Forecasting Methods

DeepAR utilizes the neural network from training all the time series to predict results for each time series whereas moving average predicts single time series by taking a moving window mean. The forecast result from DeepAR is in the form of the probability distribution meaning the user can customize the percentage of the confidence interval of the forecast value while moving average provides a point estimator. The moving average forecast algorithm can be implemented easily while more time is required to compile DeepAR.

Retail/Supply Chain Management



A Machine Learning Approach to Predict Transload Performance via Cubes per Load

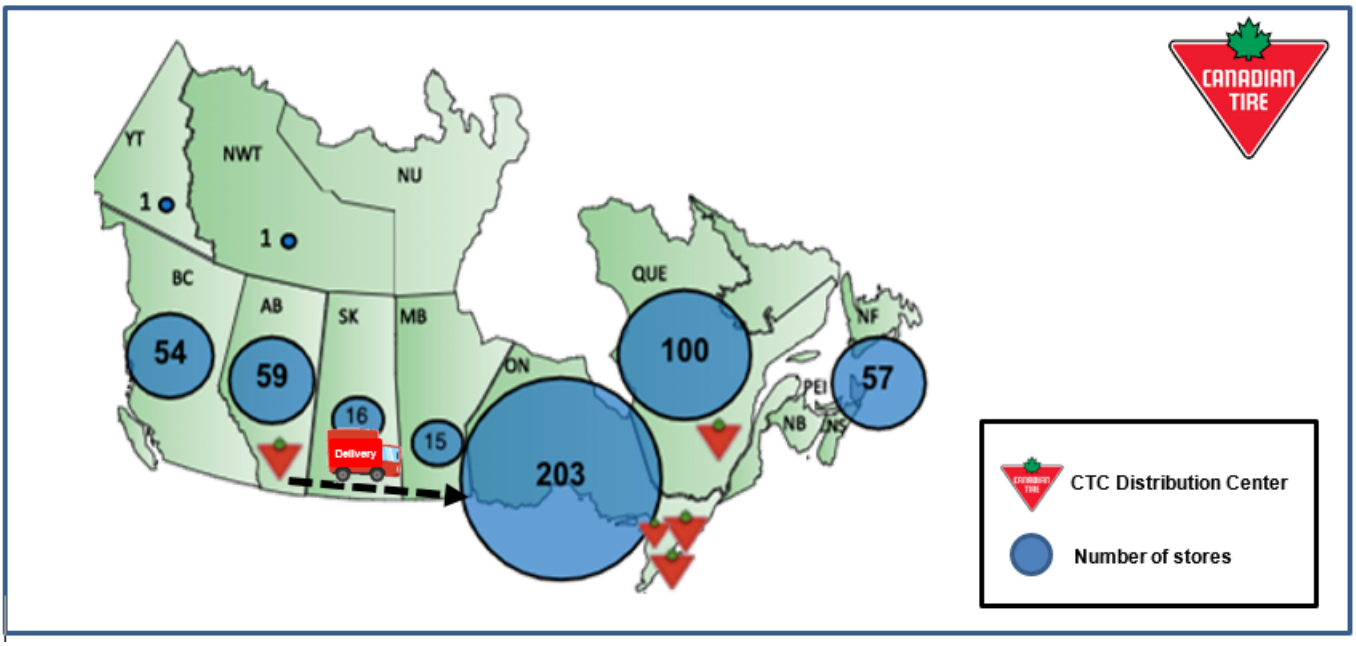
Client: Canadian Tire Corporation
Team Members: Cheng Chi, Ying Chen, Hao Zhou, Junyuan Ou, Yupei Feng
Supervisor: Prof. Chi-Guhn Lee

Project Description & Impact

Canadian Tire Corporation operates a distribution network that connects international suppliers to every Canadian Tire Retail store. One of the most important factors is to deliver goods from transload facilities to local distribution center. In order to minimize the transportation cost, CTC wants the team to predict the performance of the transload facility, which is measured in outbound cubic meters of goods per trailer. A predicting system that encoded using machine learning algorithm is constructed to predict this metric. With the success of the project, the predicting system can be easily integrated to the transload process of other supply chains. The significant improvement of prediction accuracy can increase the efficiency of supply chain planning and ultimately decrease the cost of bringing every Canadians' favourite import products to the store near them.

Design Overview & Key Results

The system designed to use historical raw stock keeping data entries as input. The raw data is used to train in Multi-step Dense Model. The model generates outbound cubes per load prediction metric in the future. Multi-step Dense is an advanced version of machine learning model named Single-time-step Model. For the first time ever, Single-time-step Model has been used to predict the performance of transload facilities. The team conducted preliminary testing on one of the transload facility and have found that comparing to the existing method used by CTC, the Multi-step Dense Model has reduced the mean absolute error of cubes per load prediction by around 40%.



Delivery Optimization Model for Canadian Tire Corporation

Client: Canadian Tire Corporation
Team Members: Kimia Taghvaei Ganjali, Fereshteh Navabzadeh, Mina Akman
Supervisor: Chris Beck

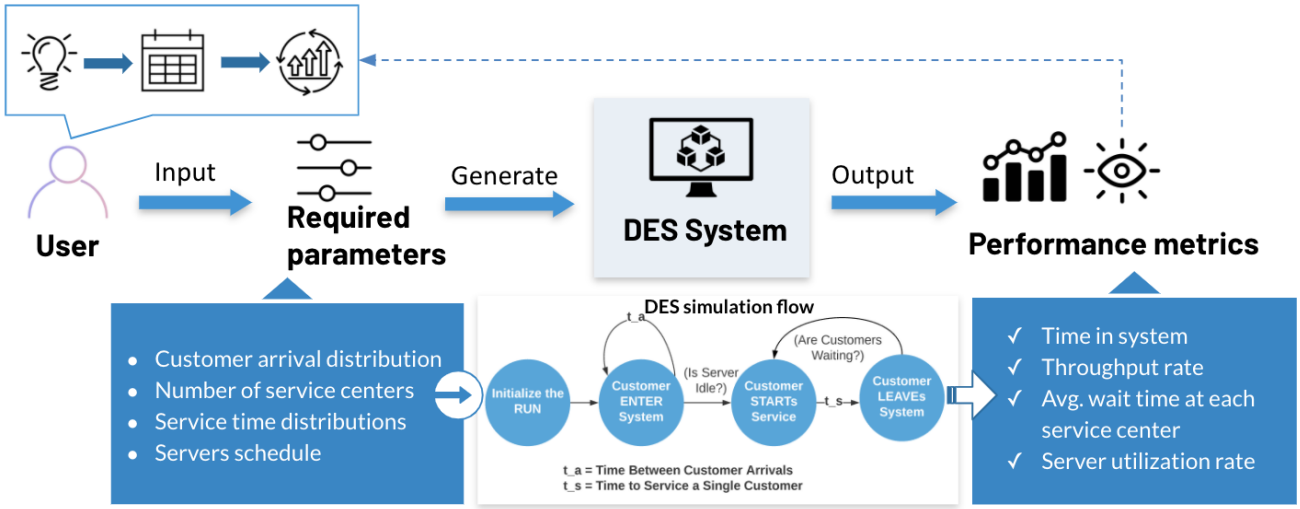
Client Need & Impact

Canadian Tire Corporation's (CTC) supply chain needs a master template that schedules load deliveries from each distribution center (DC) to every store. An optimization model is currently being used at CTC to create this template. However, there are some new transportation rules that need to be integrated into the model to provide a more practical template. The engineering team is asked to add the new rules and design an innovative optimization model to create the template. The design solution fills the current gap in the CTC's optimization model and creates a template for the entire distribution network of CTC.

Millions of dollars are spent on transportation every year at CTC. Improving the process using the newly developed optimization model could save a portion of this cost. The master template derived from the optimization model will be used every day by DC's, stores, and the transportation team. While the design is tailored to satisfy the rules presented by CTC, similar approaches can be used for other supply chain scheduling problems.

Overview of Design

The model takes the store/DC weekly demand volume and transit lead times for each load and uses decision optimization (CPLEX) to create a template that respects transit lead times and store delivery preferences. The template has the set of stores, DC's, and their corresponding deliveries for the weekly demand. The engineering team is exploring two designs: 1) a model with creative approaches and designs without the bias of CTC's current model, and 2) an extension of the current CTC model by adding the non-existing transportation rules. The two designs are compared based on some metrics suggested by the client to showcase a proof of concept.



Evaluating Retail & Hospitality Workforce Schedules with Discrete Event Simulation

Client: Ceridian
Team Members: Erica Li, Helen Zhang, Jessica Li
Supervisor: J. Christopher Beck

Bringing Discrete Event Simulation to Workforce Schedules Evaluation

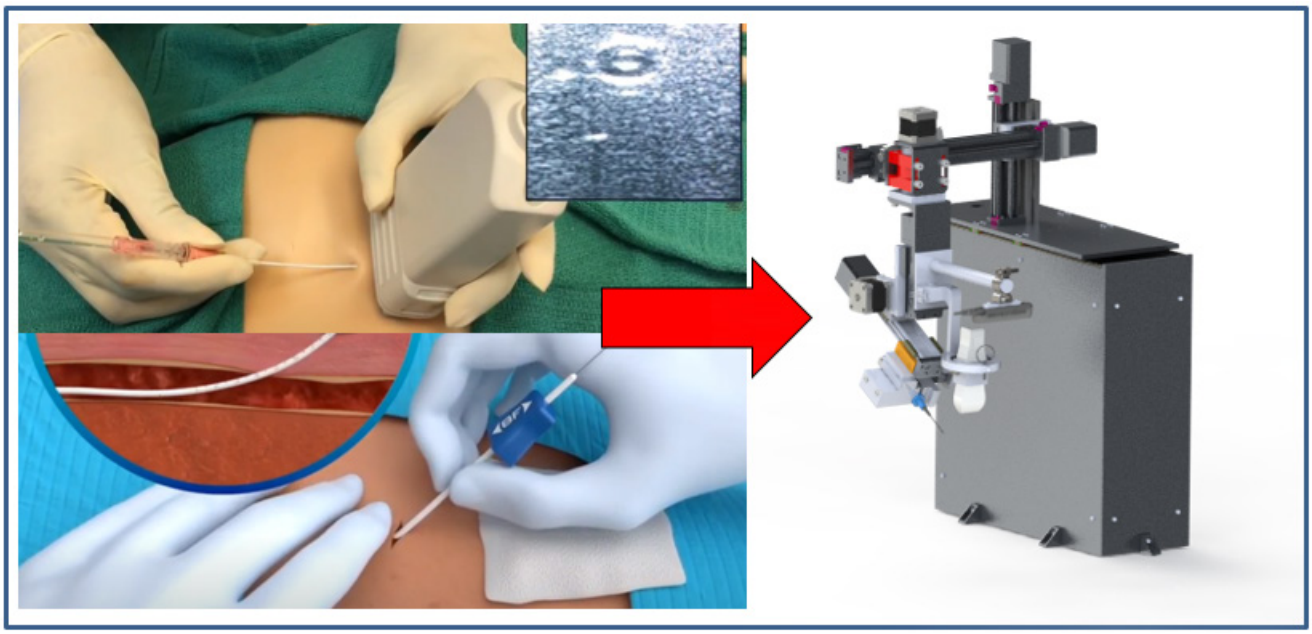
Ceridian is a global Human Capital Management (HCM) software company. Its flagship product Dayforce is a cloud HCM platform that combines Human Resources, payroll, workforce management in a single application. Ceridian wishes to investigate whether simulation could be used for Dayforce's workforce management module to provide useful insights about workforce schedules to its enterprise users. The team was tasked to build a simulation-based application which could project performance metrics such as time in system.

The team's primary challenge was to assess the viability of the simulation application and develop a customizable prototype. In general, the prototype can be efficiently utilized in numerous real-world scenarios by inputting parameters such as arrival distributions, service time distributions. A case study was conducted on the Whitbread PLC restaurants, one of Ceridian's clients, to demonstrate the benefits from the projected performance metrics by exploring their staffing solutions and customer arrival policies, to reduce customer waiting times and enhance customer arrivals.

Java Simulation Application Development for Retail & Hospitality Schedules

The team simulated the restaurant scenario as a queuing network. Simulating such a queuing network requires the knowledge of customers' arrival distribution, service time distributions of servers and the routing mechanism. The team utilized event-driven simulation as the framework to model the operation of a system as a sequence of events in time. Each event occurs at a particular instant in time and marks a change of state in the system. To initialize the simulation, the application invokes the user to input parameters including employee schedules, customer arrivals, and service time distribution to construct the simulation model. The application will project key performance indicators, which will help the user to better design the staffing level of each service center and customer queuing for improved performance and customer service.

Robotics/Mechatronics/ Electrical Technology



Autonomous Femoral Artery Needle Insertion for Patients in Rural Areas

Client: Yu Sun
Team Members: Daniel Murcia, Rachel Haigh, Brianna Bredin, Anqi Li
Supervisor: Yu Sun

Challenges With Current Femoral Artery Needle Insertion Process

Stroke patients require timely intervention to prevent permanent brain damage. In many rural areas there is a lack of trained physicians who can perform femoral artery needle insertion, which is the first step in stroke treatment.

This project aims at developing a fully automated needle insertion robot meant to help treat and remove brain clots which cause strokes and can lead to irreversible brain damage.

This device would benefit people in rural areas, like the 20% of Canadians[1] , who may not have access to trained professionals to perform these treatments. With more readily available treatment options the chances of irreversible damage or death from a stroke greatly reduces.

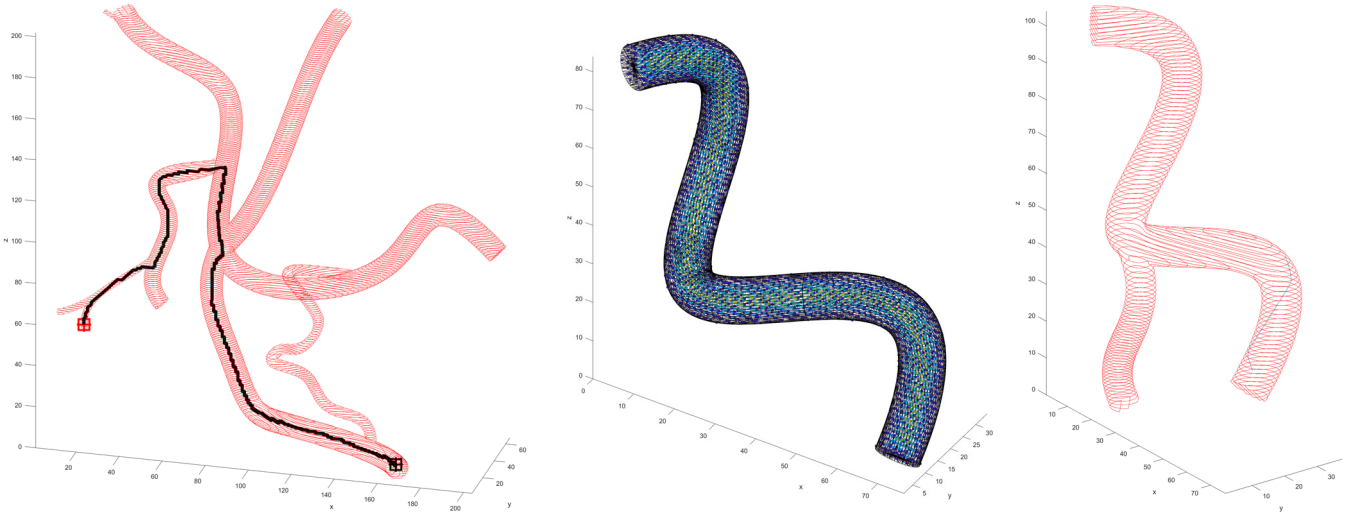
Benefits of High Performance Automated Robotic Needle Insertion Device

The product has several key objectives. It utilizes a total of 10 degrees of freedom to give the robot the same range of motion that a physician would possess. To be able to find the femoral artery it uses a combination of near infrared cameras and live ultrasound feedback to locate and keep track of the artery, and plan for any future motion. For safety concerns, a force sensor and emergency release are incorporated as well.

This is a novel robot as similar designs have been used for venipuncture and taking blood samples, but this device focuses on the femoral artery and has more degrees of complexity as more degrees of freedom are required for guiding the needle into the femoral artery.

The team would like to demonstrate the complexity of the overall mechanical design and the analysis which was conducted to ensure safety and reliability for automated needle insertion.

1 R. Fleet, S. Bussières, F. K. Tounkara, S. Turcotte, F. Légaré, J. Plant, J. Poitras, P. M. Archambault, and G. Dupuis, “Rural versus urban academic hospital mortality following stroke in Canada,” Plos One, vol. 13, no. 1, 2018. [Accessed: 25-Sep-2020].



Design of a Guidewire Simulation to Analyze Damage to Arterial Walls

Client: Advanced Micro and Nanosystems Lab (AMNL), University of Toronto
Team Members: Maximilian Glidden, Catherine Kucaba, Savo Bajic
Supervisor: Yu Sun

Client Need & Impact

The client requires a method to quantify the damage caused to arterial walls as a guidewire navigates a blood vessel. The guidewire is oriented using a magnetic field, which influences magnets attached to the wire, and is mechanically 'fed' to travel further into the blood vessel. With this simulation, the client will be able to objectively compare different navigation methods and guidewire configurations to minimize damage to vessel walls during operations that use guidewires. The main impact of this project is the subsequent research enabled by it. It will allow for the theoretical testing of different guidewire designs and guidance methods to see if they are less harmful to patients than current existing methods.

Overview of Design/Key Results

The simulation used in this project was designed entirely in MATLAB, a commercial programming and numeric computing platform. The guidewire is modelled as a string of rod segments with the vessel geometry provided as a standard .STL file. The damage to the surfaces of the vessel is determined as the wear parallel to and normal to the walls.

The simulation of the guidewire was achieved using a quasi-static finite element analysis of its model, where the wire was simulated as stationary at regular steps through its movement in the vessel. The tip was treated as a controlled point to simulate the behaviour of a magnetic-based system and followed a prescribed path that the system determined without human intervention (other than declaring a start and end point). At each step, the normal forces experienced by the guidewire's segments are recorded to determine damage.

Due to COVID-19 restrictrictions, the simulation results have not been physically verified at the present time.

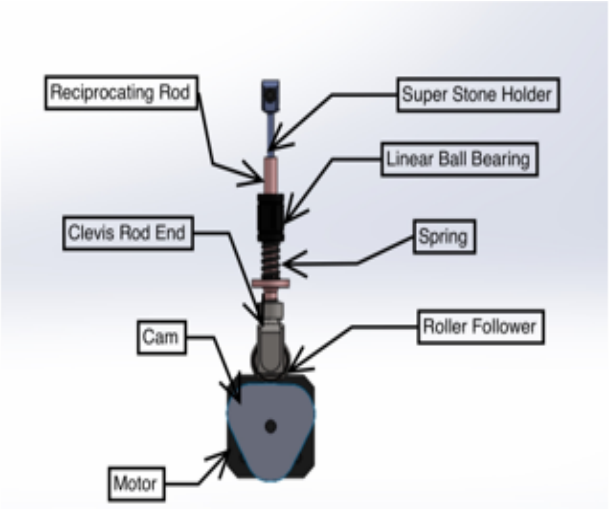


Figure 1. Reciprocating Mechanism

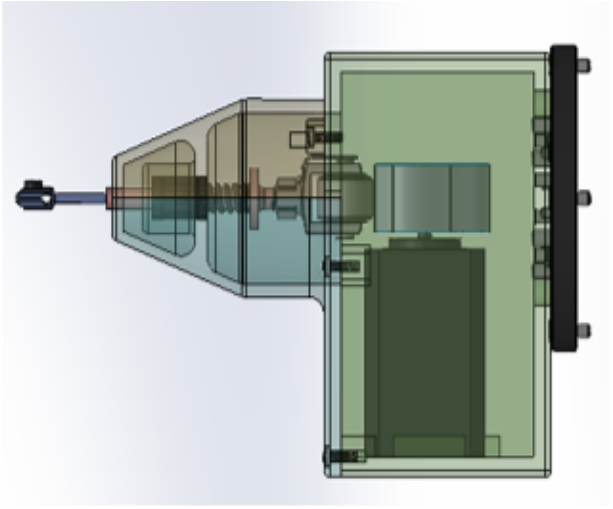


Figure 2. Side-view in Casing

Design of a Reciprocating End-effector for Robotic Polishing System

Client: Concours Technologies
Team Members: Katrina Cecco; Yiwen Qian; Qianqian Wan; Leting Xue; Xueming Zhao
Supervisor: Mohini Sain

Industry Needs in Automating Handheld Mold Polishing

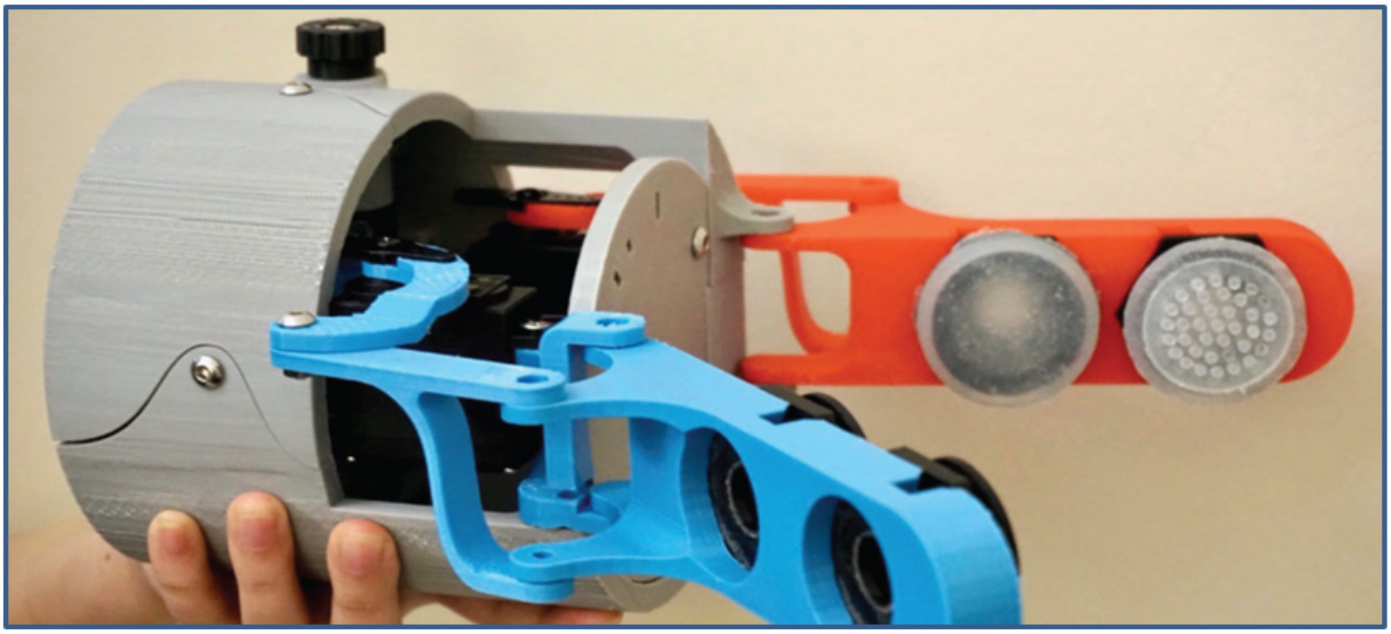
Concours Technologies is seeking an end effector for a mold-polishing robotic arm that moves the ceramic polishing stone in a reciprocating profile. The main objective is to automate reciprocating polishing processes to reduce labour time and associated costs, which is also the main challenge in this design problem. This end effector benefits mold manufacturers who are looking to produce high-quality molds in reduced time; it can also benefit technicians by reducing the risk of strain injury associated with the use of hand polishing tools.

Cam Mechanism for Precise Motion Profile and Contact Force

Our reciprocating end effector uses a cam-follower mechanism to achieve the desired 12,000 strokes/minute and 5mm stroke. Reciprocating motion requires that the ceramic stone bit changes direction several times a second, resulting in very high acceleration. This problem was mitigated by selecting a cycloidal cam profile. Furthermore, to reduce the required motor speed, the cam has 3 repeating rise-and-fall profile to achieve 3 strokes per revolution, which expands the motor selection range to improve design flexibility. However, the cam system with required frequency and force output leads to very high motor power, and motors with enough power output greatly exceed the dimensional and weight limitations.

Future Direction

Based on the benchmarking of the air-powered filing machine and pneumatic reciprocating saw, a pneumatic mechanism with single-acting pneumatic cylinders may potentially satisfy the frequency, stroke-length and dimensional requirements of this project. However, it is still uncertain if the pneumatic solution can output required frequency and stroke length simultaneously. Moreover, the output force of a single-acting pneumatic cylinder through full stroke is inconsistent. If the constant 36N contact force remains a design constraint, a compensator is needed to actively compensate the force exerted by the pneumatic cylinder.



How Adjustable Adhesion Improves Mechanical Gripping

Client: The Hatton Lab
Team Members: Chloe Shao, Claire Gledhill, Liina Sadul, Michelle Ji
Supervisor: Matthew Mackay

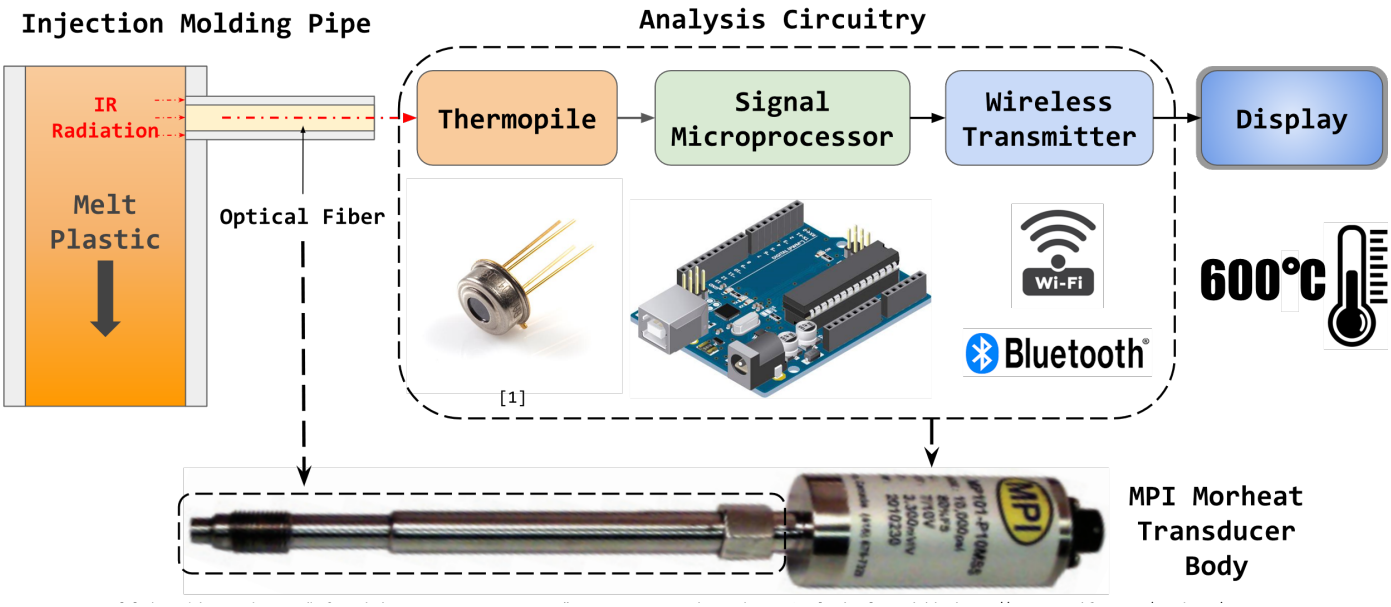
Can't Get a Grip?

The Hatton Lab has developed adjustable-adhesion surfaces made of silicone that can vary the frictional force exerted on an object. A mechanical gripper design was requested by the client in order to evaluate the effectiveness of the adjustable-adhesion surfaces and to demonstrate their functionality in a practical device. Upon further refinement of the design, the gripper could be incorporated into prosthetic hand end-effectors, as existing designs lack methods for fine-tuned grip control and slippage prevention.

Improved Gripping Ability Through Material Science and Mechatronics Integration

The team designed and built a prototype to serve as a testing platform to demonstrate the practical use of the gripping surfaces. Servo motors are used to move the fingers of the gripper into a position that allows the gripping surfaces to engage with an object. Air pressure is then used to deflect the silicone gripping surfaces into a concave (negative pressure) or convex shape (positive pressure) to allow for the fine tuning of the applied frictional force on the object's surface. This allows the gripper to grip objects without requiring that the object have surface features that the gripper can mechanically lock around or enclose. To enhance the testing capabilities, the angle between the planes-of-motion of the fingers can be adjusted to be between 90° (perpendicular) and 180° (parallel). To better demonstrate and quantify this ability, the team designed a testing plan that incorporates changing the test object's weight, size, and surface finish.

Due to the limited resources available to the team, the gripping surfaces were scaled-up to remove the requirement for unavailable facilities. However, the test results of this gripper can direct future iterations by outlining the strengths, weaknesses, and limitations of using pneumatics with silicone surfaces for gripping.



Inline Optical Temperature Measurement for Industrial Production Lines

Client: MPI Morheat
Team Members: Yuming Lei, Damilola Olaiya, Kevin Han, Anh Kiet Nguyen
Supervisor: Pierre Sullivan

The Challenge with Temperature Monitoring in Extreme Industrial Environments

Temperature monitoring is a crucial part of the plastic molding industrial process. During this process, the temperature profiles, pressure requirements, and flow rates of the melt plastic are critical to the quality of the overall product. Failure to properly account for these factors can lead to warping, sink marks, surface bubbles and other defects in the finished article. Our client presented the problem of developing a sensor that can measure the temperature of a melt plastic flow in real-time. We aimed to produce a durable design with a sufficiently long service life and meeting the following requirements while minimizing the cost:

- High temperatures (300°cto 600°c)
- High pressure (up to 1000 psi)
- High accuracy (+/- 10°c)

Designing a Contactless and Wireless Infrared Radiation Thermometer

Traditional conduction-based measurement systems are not suitable for the operating conditions in the plastic injection system. Our solution is an infrared thermometer modelled after MPI's existing pressure transducer. The thermometer head heats to the temperature of the melt plastic as it flows by. This heat is then released to the inside of the thermometer as infrared radiation. A thermopile captures the radiation and converts the thermal energy into an electrical signal. Next, the electrical component of the solution consists of a circuit that can amplify and process the signal, returning a temperature reading to an attached display or sending it wirelessly to a desktop-based monitoring software.

The team also used ANSYS to model the temperatures and heat fluxes at various points in the melt plastic and temperature sensing system. This information was used to inform component placement in the design as well as estimate the error from conductive and convective heat transfer. Error due to non-radiative heat transfer is significant due to high operating temperature. However, due to size limitations, active cooling methods like water or air jackets are not suitable. Instead, heat sinks are incorporated in the design to reduce the internal temperature.

Portable Droplet Image Analyzer

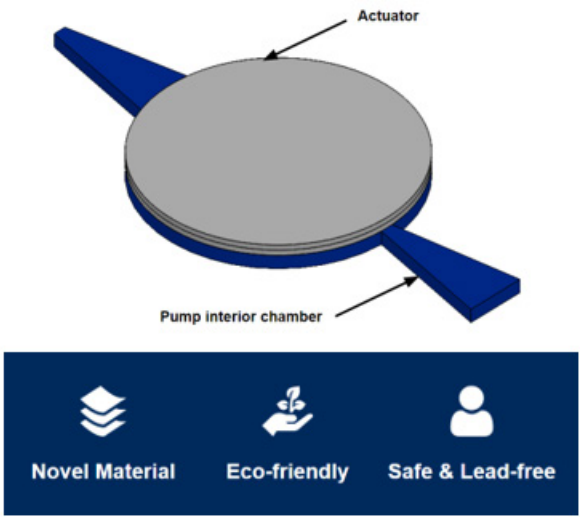
Client: Multiphase Flow and Spray Systems Lab
Team Members: Andrew Seki, Francis Gomes, Imaan Singh, Subhang Nanduri
Supervisor: Nasser Ashgriz

A Low-Cost Droplet Imaging Device

Multiphase Flow and Spray Systems Lab (MFSSL) requested a consumer-grade device to detect disease-carrying respiratory droplets in the air, which can contribute to the spread of viruses such as COVID-19. By allowing people to detect these droplets, they can avoid areas where respiratory diseases are most likely to be transmitted. MFSSL required a device which can image and quantify droplets in ambient air to identify areas of highest concern for disease transmission. By creating such a device, the world-altering impacts of pandemics such as COVID-19 can be reduced, and individuals can be prepared for any similar pandemics in the future. This device is intended to be low-cost and therefore accessible to a wide range of communities and consumers.

Ambient Air Image Capture and Analysis

The design consists of a physical device to image droplets with an internal analysis software and a mobile application to communicate with the device. The physical device captures high quality images of moving microscopic droplets. The device operates by channelling ambient air into an imaging chamber, where the particles are illuminated and imaged by a camera. These images are then processed by an algorithm, which determines the number and size of droplets present in the nearby environment. The results from the algorithm are sent via Bluetooth Low Energy to the mobile app. The app allows the user to initiate the test with one interaction, and then displays the result, allowing the user to see how safe their current environment is in real time. In our testing, we found that the device detected droplets with diameters as small as 11.14 µm.



The Future of Diabetes Treatment: Lead-Free Insulin Micropumps

Client: Advanced Research Lab for Multifunctional Lightweight Structures
Team Members:Alexandra Angelou, Stefan Albers, Courtney Norman, Nicolas Miran
Supervisor: Kamran Behdinan

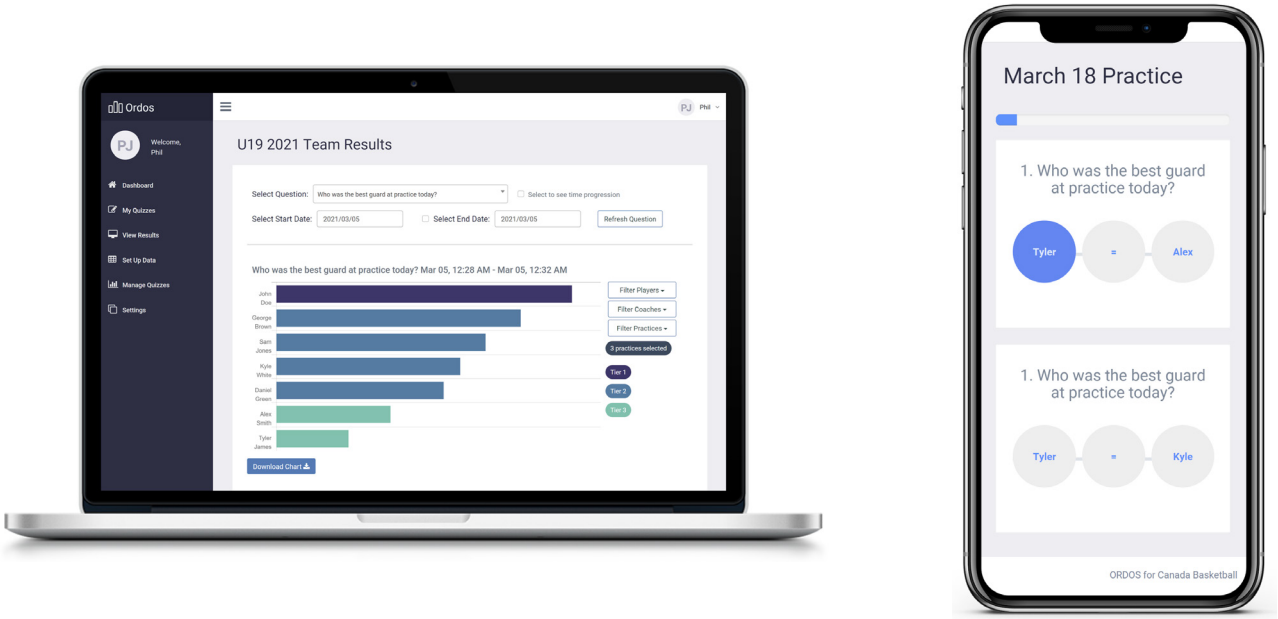
Insulin Pumps are Not Lead-Free

About 400 000 Americans were using insulin pumps to regulate their diabetes in 2018 - a 14% increase from 2016. More of the 463 million people with diabetes worldwide are looking to use pumps instead of traditional treatments to increase their quality of life. All piezoelectric insulin pumps currently use lead, which is toxic to both humans and the environment. Exposure to lead may cause anemia, kidney damage and brain damage, among other conditions. Health and environmental effects are so severe that European regulations require medical devices to be lead-free. However, insulin pumps are a major exception in this regulation, since there are currently no viable alternatives.

The Solution: A Novel Advanced Composite Material

An insulin pump has been designed using a novel, lead-free Barium Titanate ($BaTiO_3$) and Polyvinylidene fluoride (PVDF) composite. Insulin is pumped into the body using this piezoelectric material - which deforms when exposed to electricity. The new material is non-toxic, environmentally friendly, and entirely lead-free, while exhibiting comparable properties to lead-based piezoelectrics. It also produced results 50x better than another popular lead-free alternative, a Zinc Oxide (ZnO) and epoxy composite. The design is small and lightweight so it can be easily carried by the user. The performance of this new micropump was optimized using a specialized analysis software, COMSOL Multiphysics, with validation done using Computational Fluid Dynamics in ANSYS Fluent. An ideal geometry was selected for the application so that the pump can successfully deliver insulin into the body while being easy to manufacture. By using advanced piezoelectrics, the future of insulin micropumps can be lead-free.

Sports Analytics



A Decision Support System for Canada Basketball Roster Selection

Client: Canada Basketballl
Team Members: Jamal Chu, Malak Mostafa, Ita Zaporozhets
Supervisor: Roy Kwon

Modernizing roster selection by highlighting performance trends

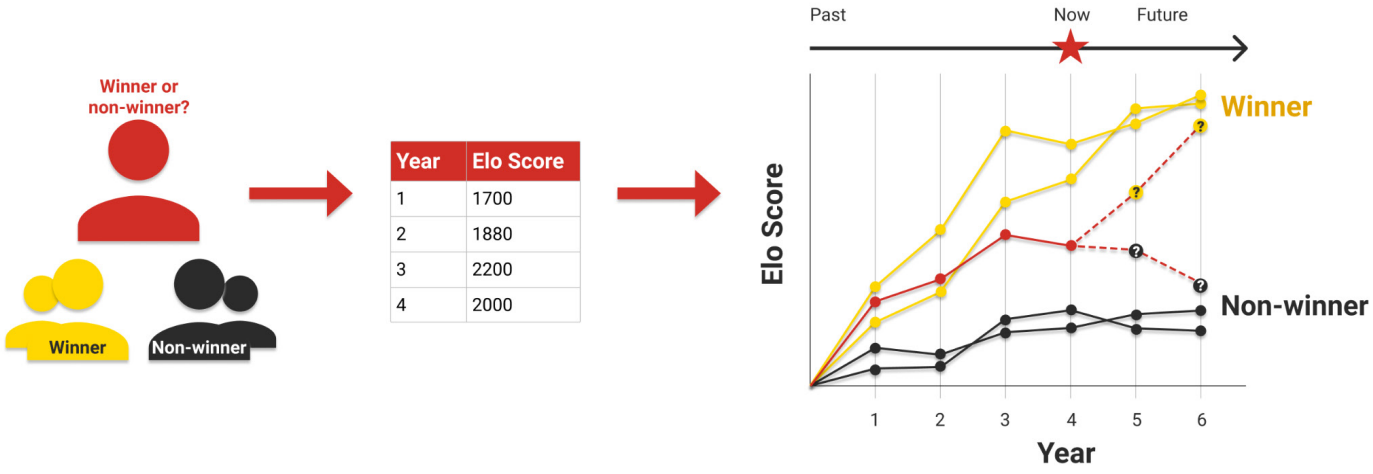
As the governing body for basketball in Canada, one of Canada Basketball's responsibilities is to evaluate players for their youth national teams and finalize roster selections during a fast-paced training camp. They were looking for a modern decision support system that could collect, aggregate, and visualize player evaluations from all coaches in an efficient and user-friendly manner. The goals of such a system were to save valuable time for coaches at training camp, structure the collection and analysis of player evaluations to reduce bias and inform roster decisions, and to keep record of historical player evaluations for future analysis.

A user-centered approach to leverage analytics for improved decision-making

A multi-platform web application was developed that collects, analyzes, and visualizes coach player evaluations using an intuitive design to communicate analytical insights to Canada Basketball decision makers. The application allows administrators to create and distribute customizable quizzes for coaches to respond to from any device, enabling efficient and organized data collection. Responses can be collected in a variety of formats, but emphasis was placed on pairwise comparisons to reduce bias. Statistical methodologies are used to produce informative and interactive charts to support roster decision making. The design of the application interface was centered on usability heuristics with iterative user testing and task analysis conducted to ensure a seamless user interface.

Behind the scenes of usability: Customized algorithmic design

To increase efficiency of data collection, an algorithm was designed to intelligently order questions and impute responses to reduce the length of the quiz. Analysis is done with a novel statistical methodology to convert pairwise comparison data into tiered rankings, improving the interpretability of results.



Improved Ranking Methods to Evaluate and Predict Athlete Performance

Client: Canadian Sport Institute Pacific
Team members: Hannah Fletcher, Jingkai Xu, Lamia Anjum, Siyuan (Ethan) Wang, Shine Ko
Supervisor: Vahid Sarhangian

The Need for Better Ranking Systems and the Ability to Predict Future Athlete Performance

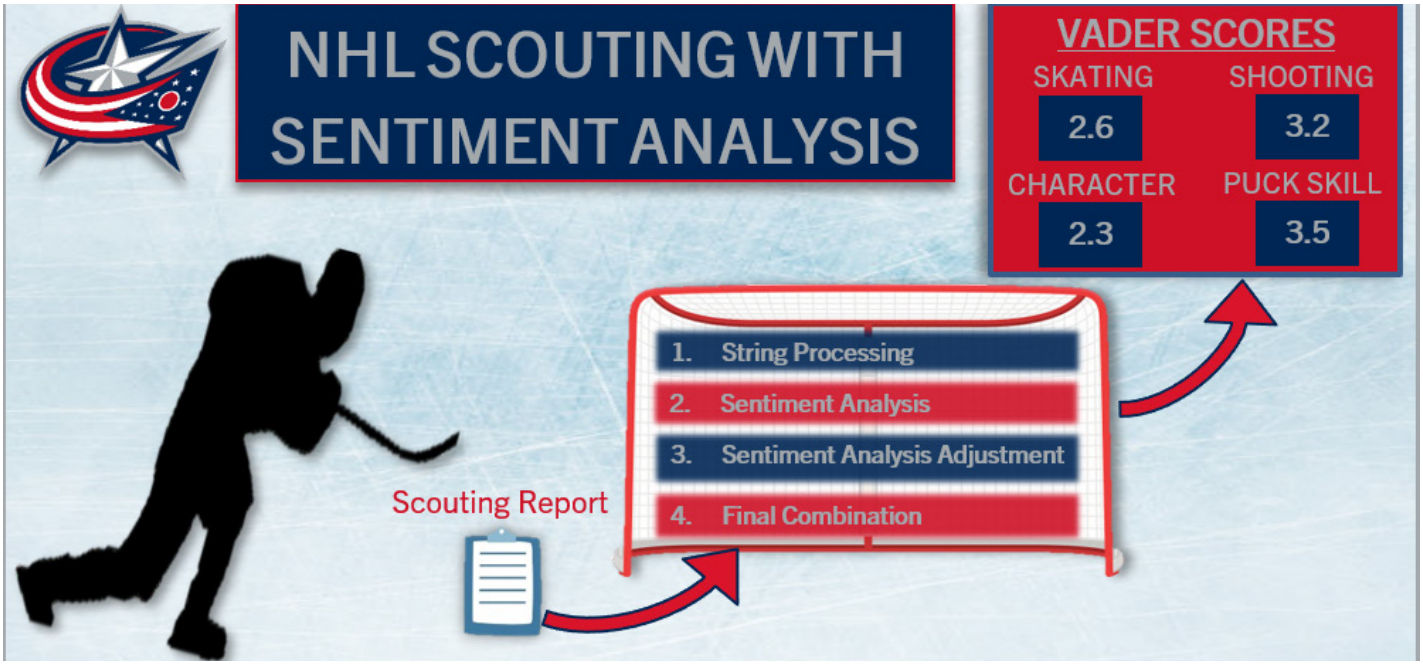
The World Snowboarding Points Lists (WSPL) rank athletes in all three snowboarding event types: Slopestyle, Halfpipe, and Big Air. The current official ranking system uses past competition data but fails to take into account important characteristics of the competitions (e.g., number and competency of the participants) leading to rankings that are often not reflective of the true performance and potential of the athletes.

The Canadian Sport Institute Pacific needed an improved ranking system to ensure that athletes' true capabilities are reflected in their ranks against other athletes. Improved rankings would help identify athletes with a high potential for winning medals early in their career and allow for allocation of the appropriate training resources to cultivate their potential. Medal winners attract new sponsors to the Canadian Sport Institute Pacific, which ultimately benefits Team Canada.

The Improved Elo Rank System and Classification of Athletes

The team identified three ranking systems, originally proposed for other settings (Elo, Glicko, and Microsoft TrueSkill) and adapted them for Halfpipe through data-driven calibration of their parameters. All three methods outperformed the current ranking system, but the team ultimately recommended a new version of the Elo system adapted for multiplayer competitions due to its interpretability. The recommended ranking system achieved an average accuracy of 75% across all athletes compared to the 55% accuracy of the official rankings.

The team also proposed a k-nearest neighbors algorithm (k-NN) to leverage the improved rankings and predict medal winning athletes based on their past rankings. The classification algorithm achieved an average accuracy of 80%, providing a highly accurate analytical method in identifying medal winners for Team Canada.



What Does the Scout Say? NHL Scouting with Sentiment Analysis

Client: Zac Urback - Hockey Analyst, Columbus Blue Jackets
Team Members: Deniz Nalbantoglu, Yicheng Pan, Keaton Smith
Supervisor: Timothy Chan

Transforming Qualitative Scouting Reports into Quantifiable Metrics

Analytics and scouting reports provide a diverse set of insights for National Hockey League (NHL) player evaluation departments. However, they are treated as mutually exclusive analyses which need to be manually combined to create comprehensive player evaluations.

The Columbus Blue Jackets requested an efficient methodology to assess the performance of players from a combined analytical and scouting report perspective. The team sought to create quantifiable scouting reports metrics which could be seamlessly integrated into analytical models without compromising report integrity. This would create a massive competitive advantage for Columbus and can be adapted to any competitive sports industry around the world!

The Solution: Valence Aware Dictionary for Sentiment Reasoning (VADER) Scores

VADER scores considers the polarity and intensity of emotion within a group of text to quantify them into a compound score. The model is comprised of four sections:

1. String Processing: Scraping textual scouting reports into phrases and categorizing them based on four main skills (Character, Skating, Shooting, and Puck Skill).
2. Sentiment Analysis: Applying VADER scores on the phrases.
3. Sentiment Analysis Adjustment: Adjust VADER scores based on player archetypes and report source.
4. Final Quantitative and Qualitative Combination: Outputting finalized metric which can be combined with quantitative models and metrics.

The design process focused on modularity and a high level of user control. Modularity allows for easy reconfiguration of the model to generate diverse insights. User control allows manual adjustment of the scores to reflect team philosophies and trust in each scouting source. This allows for the scores to reflect the genuine sentiment of the scouting process by valuing the knowledge and expertise of scouts.

THANK YOU

The Department of Mechanical & Industrial Engineering would like to thank our Capstone clients. Through your support, our MIE students have gained an invaluable experience that will serve as a solid foundation for their future.

Advanced Micro and Nanosystems Lab

Advanced Research Lab for Multifunctional Lightweight Structures

Aerlift

Canada Basketball

Canadian Sport Institute Pacific

Canadian Tire Corporation

Cellular Biomechanics Laboratory

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Ceridian

Columbus Blue Jackets

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North York General Hospital

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