THE UNIVERSITY OF BRITISH COLUMBIA

Mechanical Engineering

2020 CREATE-U Projects

Augmented Reality (Hololens) for Intra-Operative Fluoroscopy

Laboratory Name: Surgical Technologies Lab (VGH)
Faculty Supervisor: Antony Hodgson
Graduate Student Mentor: Matthew Hickey (PhD student)

General Area of Research:

Biomedical Engineering (medical device design)

The Project:

In many orthopedic surgeries, the surgeon relies on a C-arm fluoroscopy machine with the images usually displayed on a bedside monitor. The mental effort that surgeons expend transferring information from the imaging display back to the surgical site can lead to distraction causing errors that could directly influence quality of surgery.

We have developed a Depth Camera Augmented Fluoroscopy (DeCAF) device which uses an Intel RealSense depth camera to provide real-time visualization of the surgical site by overlaying x-ray images from the C-arm onto live video of the patient's surface anatomy. Using geometric data acquired via the depth camera, the device transforms a real-time video feed aligned with the camera coordinate system to a perspective aligned with the x-ray source. In effect, we give the surgeon 'x-ray vision'.

Our lab has also developed a machine learning technique that uses intraoperative x-rays to determine a C-arm fluoroscope's orientation in the OR relative to a preoperative CT. This technique can then prescribe the translational and rotational changes needed to acquire a desired x-ray. Using a calibration object placed in the surgical space, DeCAF can determine changes to the real-time orientation of the C-arm intraoperatively. This orientation tracking coupled with our labs machine learning algorithms could be a means of reducing surgical time and the number of unnecessary x-ray shots during surgery.

We now need a means to display this information to the C-arm operator.

What You Will Do:

Your task will be to develop a means of visually communicating the transformations required to acquire the desired x-ray shot to the radiology technologist (radtech) so that they are able to quickly and easily manipulate the C-arm to the desired position. This could be done using visual displays in the operating room or using augmented reality technology such as the HoloLens or a new free-standing technology called The Looking Glass. There will likely be some prototyping and mechanical design aspects associated with this project.

Supervision Received:

You will do this work in the Surgical Technologies Lab at the Centre for Hip Health and Mobility at VGH. Our group of about 10-12 graduate students has regular weekly meetings and most students will be working regularly at the lab throughout the summer. Dr. Hodgson works at the lab most days during the summer and maintains an open-door policy. The graduate student, Matthew Hickey, is a PhD candidate and has experience in related projects – he will be available for consultation on a near-daily basis.

Skills for Success:

Students should be generally familiar with solid modeling tools (eg, Solidworks or similar) and typical engineering programming languages (eg, Matlab or C/C++ or Python or similar). Any experience in user interface design or visualization or 3D displays would be an asset

Complex Fluids Experimental and Computational Simulation of Oil & Gas Wells

Laboratory Name: Complex Fluids
Faculty Supervisor: Ian Frigaard
Graduate Student Mentor: Alondra Renteria

General Area of Research:

Experimental & Computational Fluid Dynamics

The Project:

By 2013 more than 550,000 oil & gas wells had been drilled in Canada. Before hydrocarbons can be produced every well undergoes primary cementing. This operation consists of sealing the annular section between the steel pipe that stabilizes the well (the *casing*), and the rock formation. The seal should increase production and prevent subsurface fluids from percolating to surface. Nevertheless, gas leakage to surface is common. Roughly 10-20% of wellbores leak, which reduces productivity, has health & safety consequences and environmental/ecological impact. This project will study this process from a fluid mechanics perspective.

In the field, after the well is drilled, the casing is lowered into the open well. In this point, the space inside and outside the casing is occupied by the drilling mud that keeps the hydrostatic balance between the hole and the formation. Then, cement slurry is pumped downwards inside the casing, reaches the casing's bottom, and flows up into the annular section displacing the drilling mud upwards. A good seal will not leave residual mud anywhere.

In the lab, we use two flow loops to simulate the field process. We have carefully designed and built the loops to achieve dynamic similarity. We can control the key parameters of the process, such as flow rate, eccentricity, rheology, and fluid's densities. The data acquisition is through imaging with high sensitivity cameras and automated instrumentation. The objective is to capture experimental data relevant to theoretical predictions of the fluid-fluid displacement flows under a wide variety of scenarios.

What You Will Do:

The student will perform some combination of experimental work and associated computations, depending partly on interest and partly on needs of the team. Experimentally, the student will assist in all operations related with the experiment: fluid preparation, running experiment, image processing of the data, rheometry measurements of the fluids and data analysis. The student will learn the physical background to the experiments and may help in design of new components, undertake bits of machining/manufacturing, and implement changes to the current apparatus. Computationally, the student will run and analyse simulations for parameters selected to match with the experiments.

Supervision Received:

The graduate student mentor will support the student on a daily basis, as will another PhD student involved in the project. Professor Ian Frigaard will facilitate a number of group meetings.

Skills for Success:

Active listening, communication, creative thinking, critical thinking, problem solving. Basic programming and machining skills. Interest in fluid mechanics.

Cytoskeletal mechanics of cancer cells

Micro & Nano Mechanics Lab
Faculty Supervisor: Mattia Bacca
Graduate Student Mentor: Alessia Pallaoro and Albert Kong

General Area of Research:

Cytoskeletal Mechanics

The Project:

Project description

This project *focuses on* the mechanical characterization of the active behavior of cancer cells using fluorescence imaging and physiological perturbations of ATP (adenosine triphosphate, the fuel that helps drive cell motion) suppressing drugs. The in vitro aspects of the project will be carried out at the BC Cancer Research Center. It will involve the preparation of samples for in-vitro cell imaging and image data processing in order to extract important determinants on cell motility. The project will also involve the use of liquid and solid extracellular matrices (ECM, the medium in which the cells are embedded), which will need to be mechanically characterized with a custom-built testing apparatus. Cell-membrane motion and tracking the trajectory of nanoparticles included in the ECM and "digested" by the cell will be captured using fluorescence imaging techniques. The student will also image and quantify mitochondrial membrane potentials to assess ATP levels in the cell. The image data will be processed to extract the average change in cell shape and position corresponding to different levels of ATP. Finally, the results will be compared against theoretical predictions formulated by the research group with the ultimate goal of understanding the mechanical efficiency of the cytoskeleton in producing mechanical work via biochemical processes like ATP hydrolysis.

Impact and significance of the project

The human body is made of roughly 30-40 trillions of cells. Cells in fact control most of the functions of our body and their life and death has a significant impact on our health and on the potential of the development of a disease. Of particular importance is cancer, one of the main causes of death worldwide. Cancer is the uncontrolled proliferation of cells, which escape the physiologically controlled life-and-death cycle of regular (immune) cells. The proliferation of cancer has shown experimentally to be affected by the stiffness of the surrounding, where stiffer ECM could slow cancer proliferation and even make cancer cells dormant. This suggests the importance of Cell Mechanics as a fundamental parameter in understanding cancer progression, and designing novel anti-tumour therapeutics. In order to describe and model cell mechanics, it is necessary to quantitatively characterize the energetics of cell motility (energy conversion from ATP hydrolysis to mechanical motion) in relation to the cells' environments. The proposed studies in this project will therefore help to unravel some basic understanding on cytoskeletal mechanics of cancer cells.

What You Will Do:

The student will prepare hydrogel samples modified with selected peptide sequences to mimic aspects of the ECM and utilize a custom-built testing machine to mechanically characterize them under the guidance of the graduate student mentors (GSM) and other members of the Micro & Nano Mechanics

Lab. The student will also help the GSM to load the hydrogels with brain glioma cells, stain the cells and prepare the cells/gel samples for high content analysis fluorescence microscopy. The student will also help the GSM capture and process high quality images of the cells' motion. Finally, basic image analysis will be carried out on post-processed images to extract important determinants describing cell motility with respect to ATP levels in the cells. Imaging will be carried out with an automated high-content analysis fluorescence microscope (InCell). Data analysis will be performed with the use of the software Image-J and will potentially involve some Matlab coding and/or the use of MS Excell to generate some data plots.

Supervision Received:

The Micro & Nano Mechanics Lab schedules a group meeting every month, on average. The faculty supervisor (FS) schedules a meeting with every student once a week, on average. The student will meet with the GSM individually every day or every 2-3 days initially, based on the necessity and on the progress. Once the testing protocol is in place these meetings can be set to be 1-2 times a week based on the necessity. The student will also meet with the FS roughly 2-3 times a month, or more often than that based on the necessity.

Skills for Success:

The student should have some basic knowledge of mechanics of materials, thermodynamics and chemistry. The student should have a good foundation in mathematics and physics and have some basics of programming in Matlab. Prior experience working on a wet lab and in mechanical testing is an asset for this project. Experience in tissue culture or microscopy is an asset, but not an absolute requirement. Training in cell culture techniques, gel synthesis, and cell staining will be provided. The student will also be trained in the use and disposal of biohazards and cytotoxic materials. Directions on the transformation from imaging data to numerical descriptors of cell motion and energetics will be provided as well.

Aside from the aforementioned technical skills, a strong interest in the physical sciences, motivation and enthusiasm for the project and its impact and scientific insight is an important asset for the success of the student.

Data driven modelling of materials and structures.

Laboratory Name: Modelling and Simulation Laboratory
Faculty Supervisor: Mauricio Ponga.
Graduate Student Mentor: Lucas Casparini.

General Area of Research:

Solid Mechanics, Mechanics of Materials, Data-driven modelling.

The Project:

Data science is the extraction of information from large volumes of unstructured data. Nowadays, data science plays an important role in the determination of decisions in many fields such as advertisement, politics, finance, social sciences, security, policy, medical informatics, etc. This has drastically changed the way we interpreter things and many fields are now making decisions based on data-analysis and machine learning. In engineering and physics, however, there is an extra layer of complexity since the physical phenomena are ruled by universal laws that need to satisfy rigorous mathematical balances. For instance, in mechanics, equilibrium and balance of linear moment should be satisfied. This raises new challenges in data science and therefore, the full potential of data science as it relates to high-performance scientific computing is yet to be realized. In this project, we seek to develop a data-driven modelling of materials and structures. The project will focus on developing data-based models to understand complex behavior of materials ranging from metallic materials to biomaterials. The expected outcome is the implementation of data-driven framework to predict energies and interactions that can be easily used by other users.

What You Will Do:

The successful candidate will develop a data-driven model to predict free-energy using data obtained from accurate models such as molecular dynamics and ab-initio calculations. The student will create/handle big data sets of information and use part of this information to develop a machine-learned potential that can accurately predict the collective behavior of materials.

Supervision Received:

The project will be carried out under the supervision of Prof. Mauricio Ponga and M.A.Sc. student Lucas Casparini. The supervision will be on daily basis as the project requires a well-defined time line. The student will meet weekly with the PI, and daily matters will be discussed with Mr. Casparini. The student will also have a mid-project presentation to report the progress of the project to the group, and a final presentation towards the end of the internship.

Skills for Success:

Intermediate C/C++ programming, Intermediate/Advance Python and Matlab (Machine Learning Toolbox). Good knowledge of coding techniques and data-compression skills will be an asset for the project.

Development of a Directional Backlight Device for Use in Augmented Reality Head-up Displays

Laboratory Name Stoeber Lab
Faculty Supervisor: Dr. Boris Stoeber
Graduate Student Mentor: Hongbae Sam Park

General Area of Research:

Augmented reality, Optics, Microfabrication

The Project:

We are developing a thin transparent sheet with a holographic or microstructured surface that produces a directional emission of light that enters the sheet through one of its edges. This device will be used as a light source in a head-up display for augmented reality applications.

What You Will Do:

The student will characterize the performance of the light emission device: the intensity of the emitted light as a function of emission direction, the transparency of the device, and the image quality looking through the light emission device are to be measured. Multiple light emission devices will be fabricated by a graduate student. The device that meets the performance criteria will be assembled with the head-up display prototype, and the quality of the resulting head-up display image will also be evaluated by the student by capturing the displayed image with a camera and applying image processing.

Supervision Received:

Sam, a Ph.D. student in Dr. Stoeber's group, will be the student's day-to-day mentor. We will have a group meeting with Dr. Stoeber on a weekly basis.

Skills for Success:

We would like to see someone who has an interest in Augmented Reality, some knowledge of basic Optics (i.e. knows the lens equation, refractive and diffractive properties of light), and a good mathematical background to begin with. Some scripting will be involved so an exposure to programming languages such as Python, Matlab, or C would be a good asset. If the student likes photography, it would be a bonus.

Development of a Pressure Bar for understanding high-strain rate behaviour of materials.

Laboratory Name: Modelling and Simulation Research Group

Faculty Supervisor: Mauricio Ponga.
Graduate Student Mentor: Mohamed Hendy.

General Area of Research:

Solid Mechanics, Mechanics of Materials.

The Project:

The project is focuses on designing an apparatus to understand the high strain rate behavior of materials. Usually, high strain rate behaviour of materials differ from quasi-static properties because loads are applied very quickly and the material deforms differently in these conditions. This is important in many fields of engineering such as machining, impact applications and collisions of vehicles. The project focuses on developing a Pressure Bar to test materials, from the conceptual design to manufacturing and calibration of the device with amplifiers and strain gauges involving many areas of Mechanical Engineering. The device will be combined with high rate video cameras available in the Department to understand the failure of materials.

What You Will Do:

The successful candidate will design, manufacture and calibrate the device from scratch. Due to the constrained timeline, the candidate should have a good background in machining of metals and use of strain gauge if possible. Selection of materials and profiles is required (for instance be familiar with McMaster Car Catalogue). Once the device is built, the student will perform several tests on specimens made of steel, aluminum and magnesium, which are widely used in aerospace industry.

Supervision Received:

The project will be carried out under the supervision of Prof. Mauricio Ponga and Ph.D. student Mohamed Hendy. The supervision will be on daily basis as the project requires a well-defined time line. The student will meet weekly with the PI, and daily matters will be discussed with Mr. Hendy. The student will also have a mid-project presentation to report the progress of the project to the group, and a final presentation towards the end of the internship.

Skills for Success:

3D CAD design (SolidWorks or similar). Intermediate/Advance Machining of Metals (MECH training and proven machining skills). Good hands-on experience in machines and design. Analytical skills on mechanics of materials. Good use of electronics (amplifiers, strain gauges, welding, etc.) and instrumentation.

Experimental Study of Liquid Jet Impingement on a Moving Wall

Laboratory Name: Applied Fluid Mechanics Laboratory
Faculty Supervisor: Dr. Sheldon Green
Graduate Student Mentor: Athena (Xiaohe) Liu

General Area of Research:

Experimental Fluid Dynamics

The Project:

Liquid jet impingement on a moving wall is related to a variety of industrial applications, such as surface coating, cleaning, and cooling. A recent application in the rail industry involves coating of the rail surface by impinging specially made lubricants as jets from a moving train in order to reduce rail-wheel wear and improve fuel economy. Studying the physics of jet impingement will help engineers avoid splashing of the liquids and maximize deposition[1], hence optimize the aforementioned applications.

What You Will Do:

The CREATE-U student will design and conduct experiments to study the outcomes of liquid jet impingement on a moving wall under different testing conditions. They will develop their experiments based on an existing piece of equipment called the "Spinning Disk", which allows them to test jet impingement of different jet speeds, wall speeds, nozzle configurations and liquid properties. They will use high-speed camera to capture the impingement outcomes, and use image-processing techniques to analyze the results. Their studies will be integrated to theoretical and numerical studies of the group, to form a more complete understanding of the jet impingement phenomena.

Supervision Received:

The PhD Student Mentor, Athena Liu, will provide day-to-day supervision of the student. The student will be working in the same office and laboratory with her, and she will be available to answer quick questions in the workdays. Group meetings will be conducted once per week, where the student will present their work to the faculty supervisor and discuss any questions or challenges that they have.

Skills for Success:

- Undergraduate level fluid mechanics (e.g. knowing what Reynolds number means)
- Experimental methods (how to design and conduct experiments, analysis results and do uncertainty analysis)
- Basic mechanical design skills (e.g. designing simple parts in SolidWorks and manufacturing using Machine Shop tools)

---

[1] (Splash refers to the case where the jet disintegrates into smaller droplets upon impingement, while deposition refers to the case where the jet spreads smoothly over the substrate.)

Exploring the Effect of Hand Dominance on Data Quality for Robot Learning from Demonstration

Laboratory Name CARIS
Faculty Supervisor: Machiel Van der Loos
Graduate Student Mentor: Maram Sakr

General Area of Research:

Robotics

The Project:

Robots are increasingly being used in many areas in our daily life, from industrial and social robots to robots used in medicine and space. Thus, it is crucial to have effective methodologies for robot programming and customization. Robot Learning from Demonstration (LfD) is the branch of robotics research that is concerned with programming robots to perform tasks by observing demonstrations from humans without the need for any robot programming experience. It has been shown that robot learning efficiency is significantly affected by the quality of the demonstration data. By having high quality demonstration data, we accelerate a robot's learning process. In addition, allowing robots to share their knowledge with other robots contributes to the ultimate goal of fast deployment of robotic resources.

Many factors affect the quality of robot teaching, such as the demonstrator's handedness. In this project, we will study how much hand dominance affects the demonstration quality and how to eliminate this effect. Toward achieving this goal, we will study knowledge transfer between robots. Specifically, we will study how to transfer the skills from one arm to the other in bimanual robots. This will allow the human to use the most appropriate hand for task demonstration to guarantee data quality. Afterwards, the acquired skills can be transferred to the other arm and hand, a process that is not trivial since the situation (geometry, relationship with objects, environmental considerations) are different. This will contribute to improving the robot's performance by having two hands able to perform a task that was taught to only one of them. We will use the PR2 robot as our test platform throughout this project.

What You Will Do:

The student will write code for mapping the taught trajectory from one arm to the other. Afterwards, an experimental protocol will be designed with the mentor's help to study the effect of the handedness on demonstration data and how skill transfer between robot's arms will tackle this problem. Then, data collection will start from different participants who differ in hand dominance to study the effect of handedness on the demonstration data.

Supervision Received:

This project will be carried out under the supervision of Prof. Mike Van der Loos and a PhD student, Maram Sakr. The supervision will be on a daily basis with the mentor while the student will meet the supervisor on a weekly basis. In addition, we have a weekly group meeting at which we discuss and present our work, allowing the student to learn more about other work in the lab and seeking help from other lab members if needed.

Skills for Success:

Student should be generally familiar with robot kinematics and programming. Specifically, our system uses ROS. A knowledge of C/C++ or Python will be required. Basic knowledge with Machine Learning will be an asset.

Eye-Tracked VR Head Set

Microelectromechanical Systems Laboratory
Faculty Supervisor: Dr. Mu Chiao
Graduate Student Mentor: Hiroshan Gunawardane

General Area of Research:

Electronics (design and fabrication), Human Machine Interactions, Eye Tracking, Game programming

The Project:

This project is focused to implement a new virtual reality (VR) head set compensating eye fatigue in VR gaming. The off-the-shelves Eye-Tracked VR Head Set (E-RVHS) currently being implemented in the MEMS laboratory will be used in this project. The primary goal of this project is packaging, fine tuning and testing of the E-RVHS. This technology is focused to be helpful in VR gaming, augmented reality platforms and dizziness diagnosing.

What You Will Do:

The CREATE-U student will fine-tune the E-RVHS and will do necessary packaging. Then E-RVHS will be interfacing with computers or VR platforms. This project will implement a program to read the electrode signals and head movement signals (accelerometers/gyroscopes). These signals will be combined in a program and will be used in the VR game to accommodate real-time control of camera coordinates. The CREATE-U student will also implement a small game using UNITY or Blender game engines to demonstrate the function of E-RVHS.

Supervision Received:

The day-to-day supervision will be carried out by the graduate student at the MEMS laboratory and the student will be meeting the faculty supervisor weekly basis. In case of unavailability, skype discussions will be arranged to clarify any issues related to the project. The student will gain hands-on experience in packaging, fine tuning, interfacing and VR related game programming.

Skills for Success:

The knowledge in basic programming such as C and Python will be required. Mechatronics specialization will be preferred. Previous experience in game development engines such as UNITY or Blender will be advantageous.

Injection experiments through hollow microneedles

Laboratory Name: Stoeber Lab
Faculty Supervisor: Prof. Boris Stoeber
Graduate Student Mentor: Pranav Shrestha

General Area of Research:

Fluid dynamics, tissue biomechanics, microfluidics, biomedical imaging

The Project:

Hollow microneedles provide a promising alternative to conventional drug delivery techniques, by precisely delivering drug-containing fluid into the skin (intradermally). Intradermal delivery of drugs, especially vaccines, has been considered beneficial in the past, but its use has been limited due to the challenges related to injection with long hypodermic needles. Microneedles solve most of the challenges of conventional intradermal drug delivery, and have the potential of injecting drugs more reliably. This study aims to explore the effect of injection parameters, such as fluid viscosity and pressure, on flow into the skin through a hollow microneedle. The experiments will be performed while recording fluid properties using microfluidic sensors, and controlling different injection parameters. During the injection, the skin will be imaged in real-time using optical coherence tomography (OCT). The data generated during these experiments can help us better understand how fluid flows into biological tissue, which can eventually help improve microneedle injection systems.

What You Will Do:

- Prepare injection fluid, skin tissue sample and experimental setup for injection experiments
- Conduct injection experiments on excised porcine skin tissue using existing experimental setup with microfluidic sensors/controllers
- Design and 3D print any required modifications to the experimental setup to test new samples
- Analyze and process sensor/actuator data
- Conduct literature review to relate experimental findings to theoretical models

Supervision Received:

The day-to-day supervision of the student will be performed by the graduate student mentor. The student will be provided with initial references for literature review, and will be trained on using the experimental setup and the imaging modality. The student will get access to the lab and a student office space in Kaiser, which is shared by members of the Stoeber Lab and other research groups. The student will attend group meetings for the Stoeber Lab, which occur approximately once every week.

Skills for Success:

- Interest in fluid mechanics and/or biomechanics
- Interest in working in a laboratory setting
- Ability to work under minimal supervision
- Curiosity to learn new things
- Willing to handle biological materials

Investigating the human brain's response to mechanical trauma

Laboratory Name: Sensing in Biomechanical Processes Lab (SimPL)
Faculty Supervisor: Lyndia Wu
Graduate Student Mentor: Calvin (Zhuhan) Qiao

General Area of Research:

Biomechanical Engineering, Injury Biomechanics

The Project:

Mild traumatic brain injury, commonly known as concussion, is a major public health concern. In sports, falls, and car accidents, blunt impacts on the head can result in brain trauma. It is thought that stresses and strains in the brain are the direct mechanical factors causing brain dysfunction. However, the exact mechanism is still poorly understood. In this project, we will use experimental and computational methods to determine mechanical inputs to the brain, and correlate with injury outcomes such as common concussion symptoms. A better understanding of this mechanism can lead to more timely diagnosis of injury and design of more effective protective equipment (e.g. helmets).

What You Will Do:

This is a flexible project where, based on the experience level and interests of the student, one or more of the following activities could be discussed:

- *Building/applying physical brain models and acceleration devices to simulate brain mechanical deformations.*
- *Developing or applying computational brain models to simulate brain deformations.*
- *Instrumenting human participants with biomechanical and physiological sensors to measure the input head accelerations and output brain changes.*
- *Analysis of human participant data from sports and other head impacts scenarios.*

Supervision Received:

1. *Weekly meetings with Dr. Wu (additional ad hoc meetings can be scheduled as needed); 2. More frequent interactions/consultations with grad student mentor as well as other graduate/undergraduate students in the lab; 3. Weekly lab meetings to communicate research with all members of the group.*

Skills for Success:

- *Basic understanding of solid mechanics, materials, and dynamics (MECH2 level) required*
- *Experience with Matlab, computational modeling software, inertial sensors, and Arduino-type circuits could be assets*

Machine Learning for Cell Detection

Laboratory Name: Multi-scale Design Laboratory
Faculty Supervisor: Hongshen Ma
Graduate Student Mentor: Samuel Berryman

General Area of Research:

Biomedical Engineering / Machine Learning

The Project:

Cytometry is the quantitative assessment of biological cells based on characteristics such as cell size, shape, morphology (internal structure), as well as the presence or absence of certain elements identified using fluorescence labels. Advances in microscopy imaging has been steadily improving the quality of images that could be acquired on single cells. While advances in machine learning is beginning to make it possible analyze and assign meaning to vast quantities of image data. My group is looking for a capable student to develop machine learning approaches for analyzing microscopy data to detect the presence of specific cells.

What You Will Do:

Students will acquire images of cellular samples and develop machine learning algorithms analyze microscopy data for specific applications in biomedical and health research.

Supervision Received:

The student will receive day-to-day supervision from graduate students or research associate. The student will meet with the supervisor weekly during group meetings.

Skills for Success:

The student should be organized and able to work in a team. The student should be comfortable with working in a biological wet lab. The students should have previous software experience. Exposure to machine learning would also be an asset.

Machine Tool Motion Simulation

Laboratory Name: CAD/CAM/CAI Research Laboratory
Faculty Supervisor: Steve Feng
Graduate Student Mentor: Mr. Minsi Sung (MASc) and Dr. Jack Chen (Research Engineer)

General Area of Research:

Computer-Aided Manufacturing

The Project:

This project is part of a core development in our research group in recent years. The overall objective is to simulate Computer Numerical Control (CNC) machining operations accurately and efficiently. The worldwide CNC machining industry is huge and keeps growing. Machining simulation serves this massive industry by validating planned machining processes before actual physical machining. Our research group has developed a novel, patent-pending geometric modeling method to compute the changing in-process workpiece geometry during machining with both accuracy and efficiency. The development has been coded into a software engine for in-process workpiece model update. The CREATE-U project will contribute to the development of a machine tool motion simulation software module that drives the cutting tool to remove the unwanted materials from the in-process workpiece model. It will involve the development and utilization of geometric and kinematic models of a machine tool. With the machine tool motion accurately simulated, the highly undesirable machining collisions can be detected reliably prior to actual machining on a physical machine tool.

What You Will Do:

The CREATE-U student will write a section of computer codes to enable motion simulation of CNC machine tools.

Supervision Received:

The CREATE-U student will be part of a team on machine tool motion simulation. The team consists of an MASc student (Mr. Minsi Sung) and a Research Engineer (Dr. Jack Chen). The student will work closely with Mr. Sung and I will meet with the team on a weekly basis.

Skills for Success:

- Basic knowledge on and a keen interest in machine tool structure and kinematic motion
- Intermediate object-oriented programming

Microscale Soft Pneumatic Actuator

Microelectromechanical Systems Laboratory
Faculty Supervisor: Dr. Mu Chiao
Graduate Student Mentor: Hiroshan Gunawardane

General Area of Research:

Soft Robotics, MEMS

The Project:

This project is focused on developing a new soft material-based microscale actuator. The soft actuators are primarily used to perform various tasks such as gripping, surgical operations and locomotion. Most of these actuators have a single degree of freedom (either it can only bend or stretch) and a uniform force distribution along the contact surface. This is a disadvantage in many applications especially when handling complex shaped objects. Therefore, this project will investigate new designs that are capable of generating complex movements and non-uniform force distribution. Furthermore, this project will characterize the fabricated actuator and its input vs. performance relation.

What You Will Do:

The CREATE-U student will design and fabricate microscale pneumatic actuators. The student will validate the conceptual actuator (a sketch will be given) using SOLIDWORKS and COMSOL. Then a mold will be designed and fabricated (either using 3D printing or MEMS lithography). The final mold will be used in soft-lithographic techniques to fabricate the soft actuator. Finally, input vs. performance characteristics will be studied and different complex motions will be demonstrated.

Supervision Received:

The day-to-day supervision will be carried out by the graduate student at the MEMS laboratory and the student will be meeting the faculty supervisor weekly. In case of unavailability, skype discussions will be arranged and clarify any issues related to the project. The student will gain the hands-on experience in designing, validating and fabricating of microscale soft actuators.

Skills for Success:

The experience in SOLIDWORKS and finite element analysis packages (not mandatory) will be advantageous.

Residual Stress Identification of Double Yield Points in Mild Steel

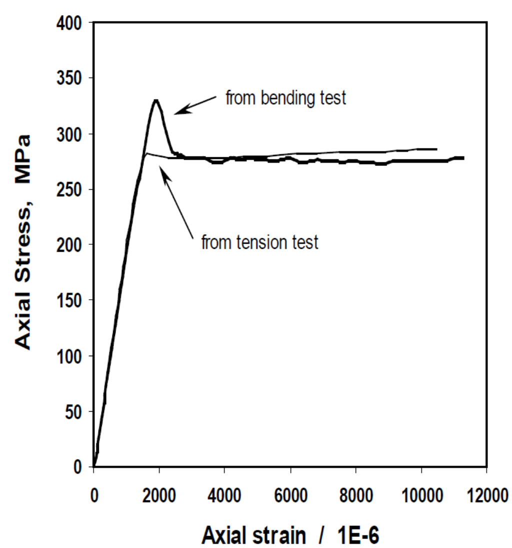
Laboratory Name Renewable Resources Lab. www.rrl.mech.ubc.ca
Faculty Supervisor: Prof. G. S. Schajer
Graduate Student Mentor: Juuso Heikkinen

General Area of Research:

Mechanics of Materials, Residual Stress Measurements, Optical Metrology

The Project:

Mild steel is unusual in that it can have a double yield point. During a tensile test, the stress rises linearly according to Hooke's Law until an "upper yield point" is reached. The stress then rapidly falls 5-10% to a "lower yield point", from which ductile yielding at approximately constant stress continues. The effect is not easy to observe and can easily be missed if the testing machine is not sufficiently stiff. The effect can be more consistently observed during bending testing, where the through-height linear strain distribution that occurs during loading causes the double yield point behaviour to be reproduced within the beam cross-section. On unloading, remnants of these stresses become imprinted in the form of residual stresses.



The Slitting Method is an effective modern method for evaluating residual stresses. It involves measuring the deformations that occur during the progressive cutting of a slit through the material thickness. The residual stresses can then be evaluated from the deformation measurements. The research interest here has three main aspects:

1. confirmation that the double yield point phenomenon leaves its imprint within the loaded beam cross-section

2. demonstration of the capability of the slitting method to observe the double yield point phenomenon. This case is interesting because the effect is very localized, so the

ability to observe it would give a good demonstration of the ability of the Slitting Method to resolve fine spatial details.

3. the measurements for the Slitting Method are typically done using strain gauges, and this approach will initially be used here. Subsequently, a new measurement approach is planned using Electronic Speckle Pattern Interferometry (ESPI). This is a full-field optical method and can give a much richer and potentially more informative data set. This use of ESPI is novel and would represent a substantial advance in the application of the Slitting Method.

What You Will Do:

1. Strain gauge a bending specimen, load it into the plastic region while measuring surface strains. Use an inverse calculation to infer the uniaxial stress-strain curve (hopefully demonstrating the double yield point).

2. Build an apparatus for doing slitting (using a three-axis motorized stage and motorized cutter). Write custom control software, likely in Matlab.

3. Use apparatus to do a Slitting Method measurement using strain gauges.

4. Use an inverse calculation to infer the residual stress cross-section (again hopefully demonstrating the double yield point).

5. If making really good progress, build an ESPI system for in-plane measurements on the Slitting Method specimen.

6. Use the apparatus to do a Slitting Method measurement using ESPI measurements. Do an inverse calculation to infer the residual stress cross-section (once again hopefully demonstrating the double yield point).

7. If all goes well, write a rather nice research paper.

Supervision Received:

The student(s) will work in a lab with professor and senior PhD student in a lab full of optics equipment and mechanical tools. The computational parts of the project will be very challenging and help will be available for this part. Guidance will be available for all other parts as well, although it is hoped that student will display substantial initiative and will work largely independently.

Skills for Success:

#1 is personal initiative and motivation. Working in a research lab is very much like working on a student team. You join the team because you want to be there and are really interested in what they do. You get on with the job without waiting to be told what to do. Success in this project will require good hand and brain skills, ability to write rather sophisticated Matlab code and to be able to think independently.

Self-Localizing Tools for Spinal Reconstruction

Laboratory Name: Surgical Technologies Lab (VGH)
Faculty Supervisor: Antony Hodgson
Graduate Student Mentor: Luke MacLean (MD/PhD student)

General Area of Research:

Biomedical Engineering (medical device design and surgical navigation)

The Project:

Approximately 600 000 spinal surgeries occur in the US every year, and most of these will include the insertion of pedicle screws to reconstruct and support the spine. Hence, this is one of the highest volume procedures, but screw placement can fail at rates 5-40% on depending on the technique and study.

We are proposing a novel navigation approach whereby ultrasound integrated into the pedicle drill will offer the surgeon accurate and dynamic guidance of the placement. This concept leverages a new ultrasound technology recently developed at UBC.

To date, a few protype designs have been conceptualized and a simulation model has been used to verify the concept of ultrasound localization. A current prototype is being developed and will require a unique localization algorithm for efficient navigation. The tool and navigation approach will then be verified on surgical phantoms and cadaveric specimens.

What You Will Do:

Your task will be to assist in conducting ultrasound simulations aimed at tracking the pedicle screw drill. This will include adjusting the simulation for new iterations of the hardware design and investigating alternative approaches to achieve real-time localization of the drill's position. You would also assist in validating the tool on phantom, animal or cadaveric specimens. You would be attending regular lab meetings with the rest of the Surgical Technologies Lab and have the potential to attend a spinal procedure in order to better understand the clinical application.

Supervision Received:

You will do this work in the Surgical Technologies Lab (STL) at the Centre for Hip Health and Mobility (CHHM) at VGH. Our group of about 10-12 graduate students has regular weekly meetings and most students will be working regularly at the lab throughout the summer. Dr. Hodgson works at the lab most days during the summer and maintains an open-door policy. The graduate student, Luke MacLean, is an MD/PhD student with a background in mechanical engineering and related projects. He will be working fulltime on his related PhD work and will be available for daily consultation.

Skills for Success:

Students should be generally familiar with solid modeling tools (eg, Solidworks or similar) and typical engineering programming languages (eg, Matlab or C/C++ or Python or similar). They should also have an interest medical devices and navigation.

The mechanics of puncture

Micro & Nano Mechanics Lab
Faculty Supervisor: Mattia Bacca
Graduate Student Mentor: Stefano Fregonese

General Area of Research:

Mechanics of Soft Materials

The Project:

Project description

This project involves the mechanical characterization of soft polymeric materials like rubbers and gels via compression, indentation and *puncture tests*. The tests will be performed in the Multiscale Mechanics of Materials Laboratory located in CEME 1052. The student will first characterize the viscoelastic behavior of the material with compression tests. Next, the student will explore the behavior of the material when subject to indentation with various indenter and sample size. This part is important to inform in-vivo and in-situ tests performed on soft biomaterials. Finally, the student will perform puncture tests on the same materials, *i.e.* using small diameter indenters and needles of various geometry and size. After these tests, the student will perform post-mortem analysis of them via microscopy to investigate on the failure mechanism that created surface rupture at puncture initiation. All the above experimental observations will be compared against the theoretical findings of the group in order to obtain a comprehensive description of the relation between indenter and needle shape and size with the physical parameters of the material to determine the force-displacement behavior and the critical puncture force.

Impact and significance of the project

Mechanical characterization of soft biological materials via indentation and puncture has broad impact in engineering, medicine and biology for applications such as sensing, drug delivery (injections) and robotic surgery. Quantitative analysis of the mechanical testing described above can improve the design of existing engineering tools and foster the development of new technology.

What You Will Do:

The student will calibrate the load cell of a custom-built indentation machine and prepare material samples for testing, all under the supervision of the graduate student mentor (GSM). The materials to be tested are silicone rubbers; agar gels and, based on the progress of the project, other more complex hydrogels. Next, the student will help collecting and/or fabricating the indenter and needles used for the testing described above. During the mechanical testing, the student will record the force and the displacement of the indenter and will then post-process the data to obtain dimensionless force-displacement graphs. This will involve the use of MS Excell and Matlab. After puncture, the sample will be removed from the machine with the needle inside (paying careful attention to not move the needle). The sample will then be positioned under a microscope equipped with a camera, which will then create a top-view of the rupture site. From the image a comparison between the size of the crack created to allow for needle penetration and the size of the needle will provide useful information to validate a theoretical model produced by the GSM.

Based on the technical challenges potentially encountered, some design modification to the custom-made machine might be needed. This will potentially involve the need for the student to perform fabrication and assembly of new components and Arduino assembly and programming. However, the GSM and other members of the group, who designed the machine, will provide detailed guidance in every step of the process.

Supervision Received:

The Micro & Nano Mechanics Lab schedules a group meeting every month, on average. The faculty supervisor (FS) schedules a meeting with every student once a week, on average. The student will meet with the GSM individually every day or every 2-3 days initially, based on the necessity and on the progress. Once the testing protocol is in place, these meetings can be set to be 1-2 times a week based on the necessity. The student will also meet with the FS roughly 2-3 times a month, or more often than that based on the necessity.

Skills for Success:

The student should have some basic knowledge of mechanics of materials. The student should have good foundation in mathematics and physics and have some basics of programming, in particular with Matlab. Some basics of mechatronics and instrumentation, *e.g.* basic knowledge of Arduino assembly and programming, are an asset for this project since they will help the student operating the machine and modifying the testing protocol more effectively and efficiently if needed. Prior experience in mechanical testing is also warmly welcomed.

Aside from the aforementioned technical skills, a strong interest and motivation in the project and its impact and scientific insight is an important asset for the success of the student.

Wrist Fracture Fixation Device

Laboratory Name: Surgical Technologies Lab (VGH)
Faculty Supervisor: Antony Hodgson
Graduate Student Mentor: Prash Pandey (PhD candidate)

General Area of Research:

Biomedical Engineering (medical device design)

The Project:

Broken wrists are a very common problem – several hundred thousand people each year fracture their wrist in North America alone. The conventional approach of applying a cast has reasonably good success rates, but the patient loses the use of their wrist for a couple of months and, because of the immobilization, has to go through an extensive period of physiotherapy afterwards. Frequently, they never regain their pre-injury range of motion.

A better alternative is surgery, in which the surgeon places a screw across the fracture plane of the bone. This has a high success rate and patients can resume activities within days. Because there is no immobilization, they have little need for physiotherapy and have minimal loss of range of motion. However, the surgery is tricky, and therefore not done nearly as often as many surgeons think it should be.

We have developed a concept for a new surgical technique aimed at making it much easier to accomplish the primary surgical goal. It relies on a semi-disposable device that is used during surgery. X-ray images are taken with the device in place, and a targeting adjustment is made to ensure that the screw goes in the right location.

To date, we have developed a couple of generations of the design and have verified that it can meet our accuracy goals. We now need to refine the design so that it can be tested first on cadavers and then on humans. We also need to refine it so that it could conceivably be manufactured in a cost-effective manner.

What You Will Do:

Your task will be to iterate on the design and carry out the next round of testing – initially on a plastic model and subsequently on an animal and a cadaver specimen. Prototyping will likely be done using a combination of plastic and metal 3D printing. Ideally, you would also work with some software (largely pre-existing) to process the x-ray images and generate the device adjustment instructions.

Supervision Received:

You will do this work in the Surgical Technologies Lab at the Centre for Hip Health and Mobility at VGH. Our group of about 10-12 graduate students has regular weekly meetings and most students will be working regularly at the lab throughout the summer. Dr. Hodgson works at the lab most days during the summer and maintains an open-door policy. The graduate student, Prash Pandey, is a PhD candidate and has extensive experience in related projects – he will be available for consultation on a near-daily basis.

Skills for Success:

Students should be generally familiar with solid modeling tools (eg, Solidworks or similar) and typical engineering programming languages (eg, Matlab or C/C++ or Python or similar).