# 2016 POLYTECHNIQUE MONTRÉAL WINTER RESEARCH INTERNSHIP

POLYTECHNIQUE MONTRÉAL

LE GÉNIE EN PREMIÈRE CLASSE

## Polytechnique Montréal

Founded in 1873, Polytechnique Montréal is a leading Canadian university for the scope and intensity of its engineering research and industrial partnerships. It is ranked #1 for the number of Canada Research Chairs in Engineering, the most prestigious research funding in the country, and is also first in Québec for the size of its student body and the scope of its research activities. Polytechnique Montréal has laboratories at the cutting edge of technology thanks to funding of nearly a quarter of a billion dollars from the Canada Foundation for Innovation over the past 10 years.

## Research Internship Program

A research internship is a research activity that is an integral part of a visiting student's academic program at the home institution. Each year, Polytechnique's research units welcome more than 250 students as research interns from other universities wishing to put into practice the technical and scientific knowledge acquired in their studies. The research conducted is supervised by a professor of Polytechnique and is always related to needs expressed by society or companies, and can be made in laboratories or *in situ*.

## Duration

The recommended duration of the internship is a minimum of 4 months, usually taking place between January and May 2016. Other duration or period can be negotiated to suit your university schedule.

## Financial Arrangement

- Tuition fee waiver for the duration of the internship;
- Free transportation from the airport to your place of residence upon your arrival;
- A minimum scholarship of $500 CAD per month for a maximum of four (4) months;
- Employer Compliance Fee of $230 CAD covered by Polytechnique Montréal (once the internship is confirmed, the work permit applicant must pay the requested immigration fee).

## Eligibility Criteria

- Being enrolled in one of Polytechnique Montréal's partner universities;
- Having completed at least two years of an engineering undergraduate program or one year of a Ph.D. program according to projects' requirements as described in the following pages;
- Meeting the specific skills required by the supervisor if any;
- Being fluent in French or in English (no language proficiency test is required).

## Required Documents for Application

**(in French or in English)**

- Letter of motivation including the following information:
  - your selected project (see list of projects next page)
  - explanations of your interest in working in this project
  - your skills in respect to the project
  - starting and ending dates of your internship;
- Curriculum vitae (CV);
- Copy of your most recent academic transcript;
- Proof of a full-time enrollment from your home institution (the letter must confirm that you are currently enrolled in a full-time program and will continue to be enrolled upon your return);
- Section 1 of the attached specification sheet must be completed;
- If possible, a copy of an internship report made in the past.

## Application Deadline

All documents [illegible] 2015 to [illegible] éal: *brin* [illegible] rch Inte[illegible] ference call may be orga[illegible] ection.

**Deadline: 2nd August 2015**

**IMPORTANT: Application MUST be submitted through UTM International Office.**

## Announcement

The results will be announced in September 2015 to each candidate. Selected candidates will receive an "Offer of Employment to a Foreign National Exempt from a Labour Market Impact Assessment (LMIA)" and will have to apply for a Work Permit at the Canadian Visa office that serves the area they live in.

## Additional Information

You can count on the support of the International Relations Office to make your stay most enjoyable. You can also get further information on Montreal: *www.tourisme-montreal.org/MontrealTV*

Come and experience the pleasures of a true winter in Québec where there is no time to freeze but only fun activities to enjoy!

**For any questions regarding your application, please contact:**
International Relations Office ■ *brin@polymtl.ca*

## LIST OF RESEARCH PROJECTS

Click on numbers to access project description

### Aerospace Engineering

1 Biomimetic Design of a Passively Adaptable Flexible Wing (undergraduate)

2 Numerical Study of the Out-of-Autoclave Repair Technology for Stiffened Composite Panels Used in Aeronautic Structures (undergraduate or Ph.D.)

### Biomedical Engineering

3 Evolving Mathematical Expressions Using Genetic Algorithms for Modeling of VO2 Kinetics (undergraduate or Ph.D.)

4 Artificial Vision for Rotobic Control in a Rehabilitation/ Adaptation Context (undergraduate or Ph.D.)

5 Intelligent Evaluation of AIS Severities during GAIT (undergraduate or Ph.D.)

6 Development of Innovative MRI System for Compensating Respiratory-Related Artifacts (undergraduate or Ph.D.)

7 Synthesis of Compliant Mechanisms for a Walking Application (Ph.D.)

8 Twisting Wire Actuation in Self-Adaptive Fingers (Ph.D.)

### Chemical Engineering

9 Photochemical Surface Engineering of Polymer Substrates (undergraduate or Ph.D.)

### Electrical Engineering

10 Path Planning for High-Precision 3D Mapping with Mobile Robots (undergraduate)

11 Accelerators for 5th-Generation Wireless Networks (undergraduate or Ph.D.)

12 Analysis and Design of Emerging Monitoring and Control Networks (Ph.D.)

### Mechanical Engineering

13 Designing and Prototyping a Planar Differentially Driven Cable Robot (undergraduate)

14 Designing and Prototyping of Tactile Sensors for Mechatronics Hands (undergraduate)

15 Design and Fabrication of a Legged Robot Prototype (undergraduate)

16 3D Printing of Mechanical Microsystems (undergraduate)

17 3D Printing of Advanced Materials for Mechanical Microsystems (Ph.D.)

### Physics Engineering and/or Materials Science

18 Biomimetic of Spider Silk: Instability-assisted Microfabrication of Tough Fibers (Ph.D.)

19 Characterization of Thermal and Electrical Transport Properties and Thermoelectric Alloys (Ph.D.)

### Computer and Software Engineering

20 Identifying Bottlenecks in Build System Performance (undergraduate and Ph.D.)

## ADDITIONAL AREAS OF EXPERTISE

### You didn't find what you were looking for?

- Browse our professors' directory by area of expertise: ***www.polymtl.ca/recherche/rc/en/expertises/***
- Submit the area of expertise you would like to work on and provide the names of 2-3 professors working in this field.
- Explain in your letter of motivation why you would like to do a research internship in this area.
- The International Relations Office will try to find the appropriate match for you!

### Here are some ideas:

- Applied Mathematics
- Artificial Intelligence
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer and Software Engineering
- Design and Manufacturing
- Electric and Electronic Engineering
- Environmental Engineering
- Fluid Mechanics
- Fuel and Energy Technology
- Geophysics
- Hydrology
- Industrial Engineering
- Information Technology
- Materials Science and Technology
- Mechanical Engineering
- Mining and Mineral Processing
- Nuclear Engineering
- Polymers Chemistry
- Robotics
- Structural Engineering

## #1: Area of Expertise: Aerospace Engineering

**Research Project Title**
Biomimetic Design of a Passively Adaptable Flexible Wing

**University Cycle**
1st cycle (undergraduate)

**Background Information**
In most engineering applications, structures are designed to be stiff so that the loads they carry do not deform them significantly. In nature, structures are usually compliant; that is especially true for terrestrial and aquatic plants. Because they seek to maximise their surface and height in order to capture the most sunlight, plants rely on their flexibility to change form and reduce their drag when subjected to fluid flow, whether water current or wind. We say that they reconfigure. By studying how flexible structures reconfigure when subjected to flow, we can learn more about the adaptation of plants to their environment and also inspire biomimetic applications of passive reconfiguration to aerodynamic loads. With wind tunnel tests and fluid-structure interaction models, we seek to understand how flexible structures deform with great amplitude and how this affects their drag and lift. Because they seek to maximise their surface and height in order to capture the most sunlight, plants must rely on their flexibility to change form and reduce their drag when subjected to wind. We say that they reconfigure. This behavior is highly interesting for biomimetics because plants rely on passive reconfiguration and lack complex control systems. From what we have learned from studying plant reconfiguration, we seek to apply this bioinspiration to design a passively morphing wing.

The goal of the project will be to design, fabricate and test a wing that will reconfigure passively when subjected to flow. This will allow the wing to maximize its lift at low flow velocity and minimize its drag at high flow velocity. This morphing wing could have applications in miniature unmanned aerial vehicles, wind turbines or even Formula 1 racing.

**Main Tasks during the Internship**
To do this the student will design the wing structure, perform calculations to evaluate its reconfiguration when subjected to flow, fabricate the wing with soft polymers and test the wing in a closed loop wind tunnel we have at Polytechnique. The student will be involved in all stages of the project: design, calculations, fabrication and testing. He can expect to spend some time in front of a computer to design the wing and simulate its deformation. He will have to mold his flexible wing from soft polymers and test it in the wind tunnel. He will be supervised by a professor and a PhD student.

**Required Skills for the Internship**
The interested student should have basic knowledge of aerodynamics, solid mechanics, numerical methods and strain gauge measurements. The student should be at ease with Matlab and some CAD software. Knowledge of finite elements is a plus.

**Supervisor**
Mr Frederick GOSSELIN, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=542&Langue=A
Website: http://www.fgosselin.com

## #2: Area of Expertise: Aerospace and/or Mechanical Engineering

**Research Project Title**

Numerical Study of the Out-of-Autoclave Repair Technology for Stiffened Composite Panels Used in Aeronautic Structures

**University Cycle**

1st cycle (undergraduate) or 3rd cycle (Ph.D.)

**Background Information**

The maintenance and repair of the aircraft composite structures are always of main concern to the end-users as well as the manufactures. The need to repair a component can arise from physical damage due to accidental impact (bird, strike, etc.) or from deterioration caused by absorption (moisture, hydraulic fluid, etc.). The repair solution is to replace the parent damaged area by an adhesively bonded patch. Reliability and durability of bonded patch is linked to its ability to resist mechanical loading and successfully to transmit stresses.

The internship subject concerns the numerical optimization of bonded patch to effectively fulfill its role. The work is part of a multidisciplinary project involving major actors of aerospace industry of Montréal region as well as other students from two other universities. Different aspects of design and manufacturing of out-of autoclave repair technologies for composite panels are studied.

**Main Tasks during the Internship**

Finite Element Analysis (ANSYS® or Alatir Hyperworks) will be employed to conduct parametric studies in order to define the influence of different parameters on the repaired panel behavior under complex loading:

1. Model a scarf-repaired composite panel with T-stiffeners in ANSYS®.
2. Define and develop of elasto-plastic modelling for bonded area using Cohesive Zone Modelling
3. Define the appropriate failure criteria and predict the type of failure under different types of loadings.
4. Conduct an optimization study considering geometrical, thermal and mechanical properties as parameters.
5. Develop an optimized repair in order to retrieve the most of the original performance of the panel.

**Required Skills for the Internship**

- Experience with composite materials and finite element analysis
- Knowledge of finite elements method and design of experiments
- Interested in design optimization using the finite element methods or meshfree methods

**Supervisor**

Mr Aurelian VADEAN, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=288&Langue=A

## #3: Area of Expertise: Biomedical Engineering

**Research Project Title**
Evolving Mathematical Expressions Using Genetic Algorithms for Modeling of $VO_2$ Kinetics

**University Cycle**
1st cycle (undergraduate) or 3rd cycle (Ph.D.)

**Background Information**
The oxidative mechanism is the main source of energy on which humans depend to maintain life and work capacity (JONES; POOLE, 2005). The rate at which an individual extracts, transports and uses oxygen is called oxygen consumption, or oxygen uptake (V̇O2) (BASSET; HOWLEY, 2000), whereas the "V̇O2 kinetics" is the study of the dynamic response of V̇O2 to variations in exercise intensity

V̇O2 kinetics data analysis can provide valuable information on the metabolic function of an individual, such as his fitness level or the possible presence of cardiovascular and respiratory dysfunctions (JONES ; POOLE , 2005). The use of an accurate modeling is thus essential to the proper interpretation of the results provided by exercise test protocols applied to in humans, commonly performed in treadmills or cycle ergometers.

Several works simplify this task by fitting the experimental data as a combination of first order dynamic systems spread over very specific time series ranges. However, inconsistencies between the current model and recent data have shown some failures in the currently adopted model.

In this project, we expect the student to apply genetic algorithm/programming methods to already existing experimental data in order to automatically evolve mathematical formulas without prior knowledge of any possible trends. The goal is to obtain the best fitting formula describing the V̇O2 kinetics.

**Main Tasks during the Internship**
- Get familiarised with V̇O2 kinetics testing protocols.
- Get familiarised with V̇O2 kinetics data and existing mathematical models.
- Learn the use of genetic programming for formula generation, already existing tools can be used such as MEXE or FPEG.
- Propose options to mathematically describe the V̇O2 kinetics.
- Write a report on the results.

**Required Skills for the Internship**
- Coding skills in C++ OR MATLAB or any equivalent scientific language
- Analytic mind
- Good level of English or French
- Autonomy

**Supervisor**
Supervisor: Mr Sofiane ACHICHE, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=294&Langue=A
Co-supervisor: Mr Maxime RAISON, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=434&Langue=A

## #4: Area of Expertise: Biomedical Engineering

**Research Project Title**
Artificial Vision for Rotobic Control in a Rehabilitation/Adaptation Context (undergraduate or Ph.D.)

**University Cycle**
1st cycle (undergraduate) or 3rd cycle (Ph.D.)

**Background Information**
Visual control in robotics is an extensively studied research area; robots such as eye-in-hand can adapt their trajectories based on information recorded by cameras. Several alternatives were explored to enable people with musculoskeletal disorders to better control their wheelchairs. The facial recognition (eye, jaw) was already used while coupling voice recognition and viewing direction was also explored.
However, one's gaze has never been used to control a robotic arm in an adaptation/rehabilitation context such as JACO arm from Kinova (A Montreal Based Company).

Furthermore, when we grasp an object in space, the trajectory of our hand is adjusted through visual information. Moreover, the vision is often fully functional even in patients with heavy motor disorders. It therefore seems appropriate to use the video-motor skills to the benefit of patients. The objective of this project is thus to semi-automate the control of an adaptation robotic arm through the control of the orientation of the actuator with respect to the user, in order to reduce the time needed for the daily tasks of patients daily. Thus the arms would be located and oriented properly in front of the object, and the patient would control the gripping of the object. The number of possible embodiments of the robotic control joystick would thus be reduced, and the task would be made easier for the patient.

**Main Tasks during the Internship**
- Identify and categorize the most common / useful trajectories among users of the arm
- 2. Determine the optimum orientation of the effector strategies to capture the targeted object by the arm trajectory
- 3. Develop a code to guide real-time effector.

**Required Skills for the Internship**
- Computing skills (C++ or Matlab)
- Basic control theory knowledge
- Autonomy
- Analysis capabilities

**Supervisor**
Supervisor: Mr Sofiane ACHICHE, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=294&Langue=A
Co-supervisor: Mr Maxime RAISON, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=434&Langue=A

## #5: Area of Expertise: Biomedical Engineering

**Research Project Title**
Intelligent Evaluation of AIS Severities during GAIT (undergraduate or Ph.D.)

**University Cycle**
1st cycle (undergraduate) or 3rd cycle (Ph.D.)

**Background Information**
Adolescent idiopathic scoliosis (AIS) is a common deformity that touches about 2% to 4% of teenagers, mainly females. AIS patients present a curvature of spine for which treatments such as brace, spine fusion and instrumentation are crucial. In order to apply more effective treatment while lower the risk of late progression and degenerative joint disease, a good classification of the severity is necessary.

Several works have been done in assisting the classification of scoliosis severity based on 2-D data using machine learning techniques.

Since scoliosis is a 3-D curvature, 2-D radiographies do not carry the whole information of the deformities. Recently, some researchers try to use 3-D motion data and force data to accomplish the classification task. Progress has showed that there are possibilities to compete with 2-D and 3-D classification. Besides, gait analysis has shown increasing interests and potential to diagnose pathologies.

**Main Tasks during the Internship**

- Explore the use machine learning techniques to classify severities from a biomechanical point of view. Machine learning techniques include unsupervised learning (including Fuzzy C Means or K Means Clustering) and supervised learning (classifiers trained by expert knowledge, including Artificial Neural Network, Support Vector Machine, Decision Tree, Fuzzy Logic).
- Analyzing kinematics and EMG data during gait with Fuzzy Logic tools to classify patients.
- Developing a special and novel fuzzy Logic based decision support system based on internal force and torque analysis during gait.

**Required Skills for the Internship**

- Computing skills C++ and or Matlab
- Fast learner of new techniques
- Autonomy
- Great analysis skills

**Supervisor**
Supervisor: Mr Sofiane ACHICHE, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=294&Langue=A
Co-supervisor: Mr Maxime RAISON, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=434&Langue=A

## #6: Area of Expertise: Biomedical Engineering

**Research Project Title**

Development of Innovative MRI System for Compensating Respiratory-Related Artifacts

**University Cycle**

3rd cycle (Ph.D.) preferentially, but also possible for 1st cycle (undergraduate)

**Background Information**

The goal of the project is to interface a unique system for compensating image artifacts with a 3 tesla clinical MRI system. The combination of both systems will enable to obtain unprecedented image quality in the human spinal cord, thanks to the reduction of artifacts related to the respiration of the subject. This will have application for the diagnosis of multiple sclerosis and spinal cord injury.

**Main Tasks during the Internship**

- Understand the basics of MRI and shimming
- Interface an innovative real-time shimming coil with a clinical MRI system using Matlab
- Test the system in humans and demonstrate the reduction of respiratory-related artifacts

**Required Skills for the Internship**

- Basic knowledge in electrical engineering, physics, programming (Matlab, C/C++) and image processing.

**Supervisor**

Mr Julien COHEN-ADAD, Assistant Professor, Department of Electrical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=547&Langue=A

## #7: Area of Expertise: Biomedical Engineering

**Research Project Title**
Synthesis of Compliant Mechanisms for a Walking Application (Ph.D.)

**University Cycle**
3rd cycle (Ph.D.)

**Background Information**
Compared to a fully actuated serial mechanism mimicking a human or animal leg, a parallel mechanism (such as a Hoeckens, Klann or Jansen linkage) may use as few as a single degree of freedom to generate the desired leg endpoint trajectory, at the expense of having a fixed gait. Generally, a suitable leg endpoint trajectory is made of an approximatively straight line with respect to the body during the supporting phase and a more arbitrary curve when the leg is raised and brought back during the swinging phase.
Compliant mechanisms use mechanical deformations to generate displacement or transmit forces and have mainly been developed because of their specific advantages such as ease of manufacturing, reduced cost/weight, and absence of maintenance. The robotics laboratory at Polytechnique Montréal has in recent years developed an expertise in compliant finger and gripper design. In complement of this, new research directions are to be developed pertaining to compliant leg mechanisms, for which an initial exploration of possible designs has been undertaken.

While full compliance may not be achieved for a typical leg mechanism (for instance, a crank must be able to freely rotate, which compliant joint aren't capable), it is expected that even a partially compliant design shall offer easier manufacturing and reduced complexity.

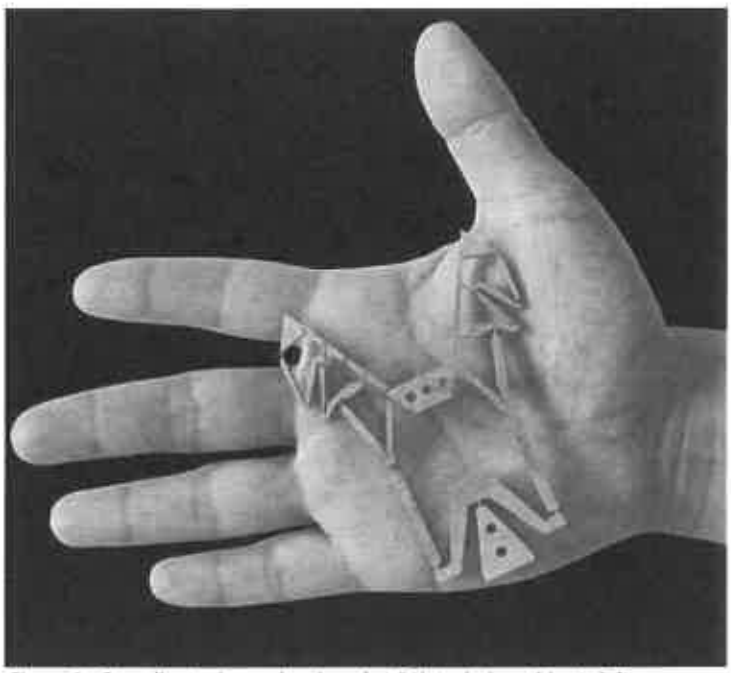

Figure 1 : Compliant gripper developed at Polytechnique Montréal

Objectives :

- Develop a method for the synthesis of function generators for compliant mechanisms.
- Mechanical conception of practical compliant designs.
- 3D printing or laser cutting of prototypes for performance analysis.

**Main Tasks during the Internship**

- Analyze the feasibility of compliant versions of existent parallel leg mechanisms.
- Review available literature on function generator synthesis for various types of mechanisms
- Generate designs based on the characteristics of the desired trajectory and the constraints of compliant mechanisms (such as maximum hinge displacement)
- Explore further possible advantages of compliant leg mechanisms, such as obstacle avoidance, shock absorption or energy storage and restitution during various phases of the leg endpoint trajectory.
- Formulate performance criteria to evaluate the proposed designs and perform optimization to determine the most promising solutions.

**Required Skills for the Internship**

- Experience with the following techniques is desirable:
- - Planar linkage synthesis
- - Compliant mechanism analysis

**Supervisor**

Mr Lionel BIRGLEN, Associate Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=341&Langue=A

## #8: Area of Expertise: Biomedical Engineering

**Research Project Title**
Twisting Wire Actuation in Self-Adaptive Fingers

**University Cycle**
3rd cycle (Ph.D.)

**Background Information**
Mechatronic fingers and hands are used in a wide range of applications, ranging from spatial teleoperation to medical devices. These hands are made of multiple systems, including the actuation, the transmission, the control scheme, and the sensors. To enhance these electromechanical systems and to simplify grasping and manipulation, underactuated mechanisms have been used in recent years. With a minimized number of actuators and some compliant elements, an underactuated hand is capable of mechanically self-adapting itself to numerous objects during grasping without any complex control law. Thus, a low-cost versatile artificial hand can be designed and manufactured. To provide actuation, DC motors, cables and pulleys are commonly used. However, a new technique in robotics has recently emerged that we would like to investigate, namely twisting wire actuators (TWA). Instead of having a single cable winding around a pulley, in TWA at least two wires are twisted around each other with various degrees of tightness thereby modifying their overall length. This can be advantageous in terms of space, transmission and efficiency. The objective of this internship is to assess the possibility of using twisting wire actuation in existing and future underactuated robotic fingers. The intern will have to mathematically model the relationship between the twisted wires length and the torque produced by the actuator. The intern will then have to replace the actuation mechanism of an existing underactuated robotic hand prototype and replaced it by the twisting wire actuation mechanism he/she will proposed. This work will be included in a future scientific paper on a novel prototype.

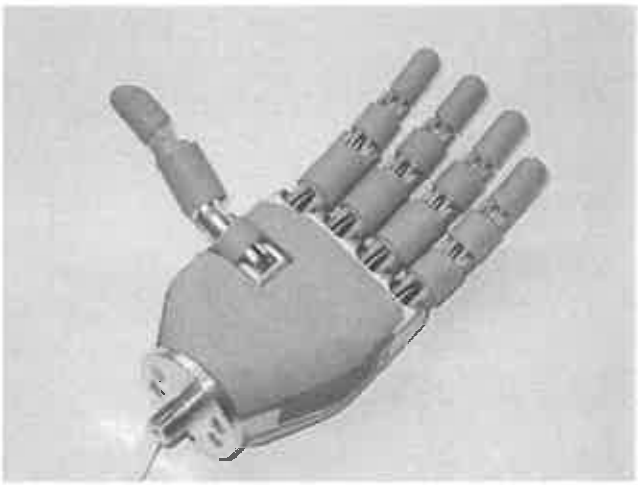

Figure 1: Example of a robotic hand [Baril, M. *et al.* 2012, *On the design of mechanically programmable underactuated anthropomorphic robotic and prosthetic grippers*, Proc. of ASME Mechanisms and Robotics Conference, Chicago, USA, August, DETC2012-70705.]

**Main Tasks during the Internship**

The main objective is to model, design and manufacture an actuation mechanism for self-adaptive robotics hands. The intern will have to:

- Create a the theoretical model of the twisting wire actuator;
- Perform numerical simulations of the system and validate them experimentally;
- Provide the drawings to manufacture the components of
- the prototype;
- Choose the standard parts needed;
- Assemble the parts of the prototype and test it.

More specifically:

- Literature review
- Mathematical modelling
- Numerical simulations
- Mechanical design
- Selection of the standard parts and ordering
- Electronic design
- Manufacturing of the custom parts
- Assembling the parts
- Running the system and testing its performance
- Writing a report

**Required Skills for the Internship**

- Excellent skills in mathematics
- Good skills in computer-assisted design (CAD);
- Prior experience in robotics and mechatronics;
- Having a bachelor degree in mechanical engineering, electrical engineering or equivalent.

**Supervisor**

Mr Lionel BIRGLEN, Associate Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=341&Langue=A

## #9: Area of Expertise: Chemical Engineering

**Research Project Title**
Photochemical Surface Engineering of Polymer Substrates

**University Cycle**
3rd cycle (Ph.D.) preferentially, but also possible for 1st cycle (undergraduate)

**Background Information**
For many applications, materials need to serve multiple functions at the same time. Some of these functions stem from their bulk properties (e.g.: mechanical strength, thermal conductivity), while others are surface-driven (e.g.: wettability, reactivity, biocompatibility). Often, we need the surface of a material to serve a different function from what its native properties allow. In that case, we must engineer the surface to meet the needs of a given process. Photo-initiated chemical vapour deposition (PICVD) shows promise as a scalable process to facilitate surface engineering. Work at Polytechnique Montreal's PhotoSEL (photochemical surface engineering laboratory) has focused lately on adapting this method at near atmospheric pressure and under mild conditions to tailor the surface properties of metal surfaces, polymer substrates and nanoparticles of various types at both small and large scales. This internship would aim to pursue this exploration on polymer substrates and improve the surface characterization processes.

**Main Tasks during the Internship**
- Pursue the investigation of a novel photochemical surface treatment approach, photo-initiated chemical vapour deposition (PICVD), on polymer substrates
- Assess the impact of light stabilizers present in the polymers (if applicable)
- Characterize the treated surfaces chemically and physically
- Design a scale-up approach to treat larger surfaces

**Required Skills for the Internship**
- Reactor engineering and operation
- Surface characterization techniques (tensiometry, zeta potential, XPS, FTIR)
- Gas phase characterization (GC-MS, IR)
- Strong communications skills
- Lab safety

**Supervisor**
Mr Jason TAVARES, Assistant Professor, Department of Chemical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=456&Langue=A

## #10: Area of Expertise: Electrical Engineering

**Research Project Title**
Path Planning for High-Precision 3D Mapping with Mobile Robots

**University Cycle**
1st cycle (undergraduate)

**Background Information**
Mobile robots are increasingly being used for inspection tasks, but are still typically simply remote controlled and thus their operation requires one or even several operators per robot. The goal of this project is to explore path planning strategies to map in 3D and autonomously a structure or environment as precisely and as fast as possible using an autonomous robot. An envisioned extension is to use multiple robots acting as a team with heterogeneous capabilities (e.g., quadrotors and ground robots). Available sensors include different cameras and RGB-D sensors (kinect), LIDARs, an ultrawide-band system with cm-level positioning accuracy, as well as standard navigation sensors (inertial, GPS, etc.) for localization.

The robot(s) should take into account the current uncertainty about the 3D map, which depends on occlusions, shadows, etc., in order to replan trajectories in real-time and refine the map. In the long term for this project, we will develop path-planning algorithms coupled with 3D SLAM techniques, a simulation environment, a proof-of-concept indoor system, and ultimately an advanced outdoor system relying on state of the art hardware.

More information on our activities can be found here: http://www.professeurs.polymtl.ca/jerome.le-ny/

**Main Tasks during the Internship**
[The specific tasks of the student will be adapted based on his technical background and interests (ex: interest in theory vs. system design and programming), as well as the state of the project at the time of his/her arrival.]

- Developing a tailored simulation environment for rapid testing of algorithms.
- Developing the hardware and low level embedded software for the multi-robot setup.
- Implementing 3D vision algorithms for localization and mapping in software.
- Designing new multi-robot coordination algorithms.
- Programming robots via ROS (Robot Operating System) to execute the algorithms.
- etc.

**Required Skills for the Internship**
Some background in one or more of the following areas is desired: robotics, computer vision, control systems, signal processing, embedded system programming.

**Supervisor**
Mr Jérôme LeNY, Assistant Professor, Department of Electrical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=546&Langue=A

## #11: Area of Expertise: Electrical Engineering

**Research Project Title**
Accelerators for 5th-Generation Wireless Networks (undergraduate or Ph.D.)

**University Cycle**
3rd cycle (Ph.D.) preferentially, but also possible for 1st cycle (undergraduate)

**Main Tasks during the Internship**
In collaboration with other students, explore need for hardware support and accelerators for 5th-Generation Wireless Networks. The intership may imply analysis of algorithms with Matlab, architecture design and analysis with suitable tools.

**Required Skills for the Internship**
Knowledge in hardware design, signal processing methods and wireless standards such as 4G wireless standards.

**Supervisor**
Mr Yvon SAVARIA, Professor, Department of Electrical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=107&Langue=A

## #12: Area of Expertise: Electrical Engineering

**Research Project Title**
Analysis and Design of Emerging Monitoring and Control Networks

**University Cycle**
3rd cycle (Ph.D.)

**Background Information**
My group's research interests are broadly concerned with the design of sensor and actuator networks that are increasingly forming the technological substrate necessary to build intelligent environments (e.g., the much discussed "Internet of Things"). We use tools from control theory, signal processing, communications and systems theory more generally to study these systems. In terms of applications, our current focus is on estimation and control for intelligent transportation systems with an emphasis on privacy, demand response in smart grids, avionics networked control systems, distributed autonomous robotic teams, and quantitative methods to analyze human-automation interactions.

More information on our activities can be found here: http://www.professeurs.polymtl.ca/jerome.le-ny/

**Main Tasks during the Internship**
The topic for the internship would be defined jointly with the student directly prior to his arrival, based on his expertise and current PhD topic, advancement in his PhD program, and interests. I would see such an exchange as an opportunity to establish a collaboration with the student on a research topic of mutual interest, which could continue in the future.

**Required Skills for the Internship**
My group can receive for a short-term visit a current PhD student, preferably working in control theory or perhaps signal processing, with a taste for theory and an interest for the types of applications mentioned above.

**Supervisor**
Mr Jérôme LeNY, Assistant Professor, Department of Electrical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=546&Langue=A

## #13: Area of Expertise: Mechanical Engineering

**Research Project Title**
Designing and Prototyping a Planar Differentially Driven Cable Robot

**University Cycle**
1st cycle (undergraduate)

**Background Information**
Cable manipulators are particular parallel robots where cables are used instead of rigid linkages to manipulate the moving platform (MP). This characteristic gives special properties to these mechanisms. That means in addition to some advantages of linkage-driven parallel robots, they have a simple structure, lightness and low inertia of the moving parts, a high dexterity, typically low friction, large workspace, etc.

On the other hand, they suffer from some drawbacks such as limits in the cable tensions, poor compactness, possible interferences between cables, and vibrations . Also, as a result of the unilateral nature of the cables which can only produce tension forces, redundancy in the actuation is necessary. This means that to completely constrain the MP of an n-DOF cable robot, m>n cables are required. Several researches have shown that using more cables results in larger workspace and generally better performance of the robot.

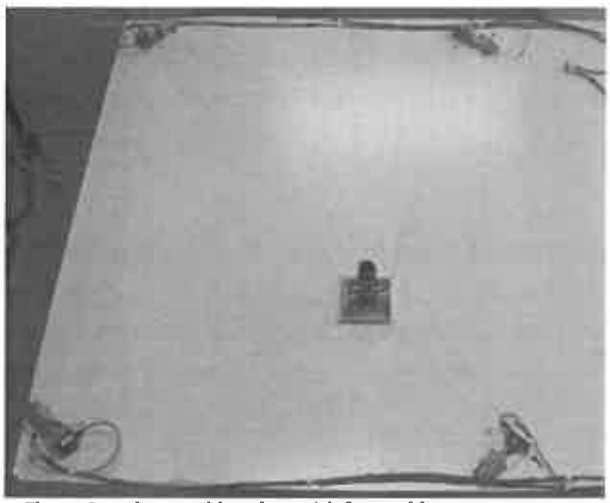
Figure 1 a planar cable robot with four cables

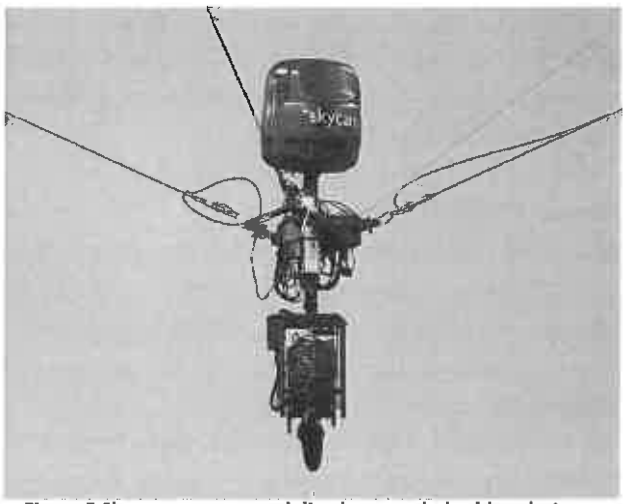

Figure 2 Skycam: a commercialized suspended cable robot

Therefore, in cable robots the number of required actuators is always greater than the number of degrees of freedom (DOF) which increases the cost and complexity of the control equipment. This issue is more critical if the more cables are used in the structure of the robot to obtain better the performance in terms of the size of the wrench-feasible and wrench-closure workspaces (WCW & WFW). Thus, to keep the number of actuators at minimum while the number of cables (and thus the performance of the mechanism) is increased, it was proposed to use cable differentials in the architecture of the cable-driven robots. They are used in different machines and mechanisms to distribute an actuation source to several degrees of freedom. These mechanisms were first introduced and their properties were described. Afterwards, through some examples it was shown

that using these systems in the structure of planar cable-driven mechanisms increases their workspaces comparing to the fully-actuated cable robots driven by the same number of actuators. It is then required to design and built a small –scale prototype of this robot with a simple architecture to evaluate these results in practice.

**Main Tasks during the Internship**

Mechanical designing and manufacturing a prototype of a planar differentially actuated cable robot:

- Modeling the robot according to the existing schematic and design parameters;
- Providing the drawings for manufacturing the components of the prototype;
- Assembling the parts of the prototype and test it.

More specifically:

- Reviewing the background
- Conceptual design of the robot
- 3D modeling of the Concept of the robot
- Generating the drawings to be manufactured
- Selecting and ordering the standard parts
- Construction of the components
- Assembling the parts of the robot
- Running the robot and testing its performance
- Writing a report on the results of the tests

**Experience with the following is desirable:**

- 3D modeling and design (CAD)
- Basic Electronic circuit design
- Basic programming skills

**Supervisor**

Mr Lionel BIRGLEN, Associate Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=341&Langue=A

## #14: Area of Expertise: Mechanical Engineering

**Research Project Title**
Designing and Prototyping of Tactile Sensors for Mechatronics Hands

**University Cycle**
1st cycle (undergraduate)

**Background Information**
Mechatronic fingers and hands are used in a wide range of applications, from spatial teleoperation to medical devices. These hands are made of multiple systems, including the actuation, the transmission, the control scheme, and the sensors. For the latter, different technologies exist and are used to acquire data to provide a feedback to the user and to control the device. Tactile sensors are among them and are critical in grasping and manipulation tasks, as robotic hands have to seize objects with different sizes and textures. These objects can also either be solid or very fragile. In this project, the intern will have to design and manufacture low-cost tactile sensors to be used with existing and future prototypes. The desired sensors will be similar to the one shown in Fig. 1. These sensors are made of several small standard MEMS pressure sensor cells commercially available. Underneath them, a relatively simple circuit board will be used to power the individual cells and to route the output signals. The sensors will have to be designed to fit on custom robotic fingers whose drawing will be provided to the intern. Another application will be the design of custom force sensors.

Figure 1: Typical tactile sensor

**Main Tasks during the Internship**
The main objective of this project is to design and manufacture a tactile sensor array / force sensor for mechatronic hands. The intern will have to:

- Model the sensor (mechanically and electronically) in its envrironment (robotic fingers);
- Research standard parts required;
- Provide the drawings to manufacture the components of the prototype;
- Assemble the parts of the prototype and realize experiments.

More specifically:

- Literature review

- Mechanical design
- Electronic design
- Selection of the standard parts and ordering
- Manufacturing of the custom parts
- Preliminary tests on the components
- PCB manufacturing
- Assembling the final sensor
- Running the system and testing its performance
- Writing a report
-

**Required Skills for the Internship**

- Good skills in computer-assisted design (CAD such as CATIA, SolidWorks, Pro/Engineer, etc.)
- Prior experience in electronic prototyping (PCB design, Eagle, SMC soldering);
- Basic knowledge of data acquisition hardware and software (Labview)
- Familiarity with microcontrollers a plus (e.g. Arduino)
- Having completed courses in electronics, statics of mechanical systems.

**Supervisor**

Mr Lionel BIRGLEN, Associate Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=341&Langue=A

## #15: Area of Expertise: Mechanical Engineering

**Research Project Title**
Design and Fabrication of a Legged Robot Prototype

**University Cycle**
1st cycle (undergraduate)

**Background Information**
In the context of mobile robotics, traversability is defined as the capability of a robot to cross a given terrain and is a valuable indicator of it's effectiveness. This performance index needs to be experimentally evaluated, and compared with simulation results, for a novel leg mechanism developed in the robotics laboratory of Polytechnique Monbtréal and based on a self-adaptive mechanism.

Self-adaptive mechanisms aim at reducing the number of actuators and simplify the control scheme for a given mechanical system and have in the past been used mainly for grasping. By means of linkages, connecting the actuated input to the output degrees of freedom, such as differentials or compliant elements, the number of actuators can be kept low without actually reducing the number of degrees of freedom.

For the proposed linkage, recently designed in our laboratory, a first degree of freedom is used to drive a Hoeckens linkage to generate an ovoid curve, which is desirable in the case of a leg endpoint trajectory. This trajectory is subsequently amplified by means of a pantograph linkage, which pivot can be moved to increase step height on demand. This second degree of freedom is intended to be passive such that this change and resulting adaptation is carried without exterior intervention.

This approach is different from that of a fully actuated robotic leg mimicking a human or animal gait, and aims to provide good traversability using a single actuator with controlled torque.

Figure 1 : Proposed novel mechanism

**Main Tasks during the Internship**
It is required to design and build a prototype of a legged robot implementing the developped leg mechanism for concept validation and performance analysis purposes.

Objectives :

- Model the robot according to the existing design parameters;
- Provide the drawings for the manufacturing of the components of the prototype;
- 3D printing and assembling of the parts of the prototype.
- Select and assemble the electronic drives.
- Proceed with performance and traversability experiments.
- Implement a simple controller on an onboard microcontroller

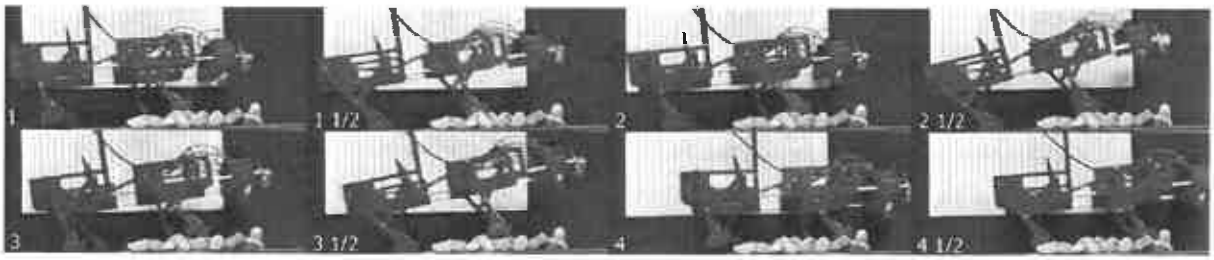


**Figure 2 : Traversability experiments with an older prototype**

More specifically:

- Reviewing the background
- Conceptual design of the robot
- 3D modeling of the Concept of the robot
- Generating the drawings to be manufactured
- Selecting and ordering the parts
- Construction of the components & circuit design
- Assembling the parts of the robot
- Running the robot and testing its performance
- Writing a report on the results of the tests

**Required Skills for the Internship**

Experience with the following techniques is desirable:

- 3D modeling and design
- Rapid prototyping (3D printing & laser cutting)
- Electronic circuit design
- Basic programming skills

**Supervisor**

Mr Lionel BIRGLEN, Associate Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=341&Langue=A

#16: Area of Expertise: Mechanical Engineering

**Research Project Title**
3D Printing of Mechanical Microsystems (undergraduate)

**University Cycle**
1st cycle (undergraduate)

**Main Tasks during the Internship**
This internship will be performed at the Laboratory of Multiscale Mechanics (LM2) of Polytechnique Montreal. Under the supervision of Prof. Therriault, the intern will assist a current PhD student with the realization of his research project. The LM2 is currently developing new 3D printing methods and various advanced materials with enhanced mechanical, thermal and electrical properties.

**Required Skills for the Internship**
- Strong Mechanical Engineering or Material Sciences background
- Interest for applied research, 3D printing technologies, CAD
- Familiar with material characterization (e.g., optical microscopy, SEM)
- Good team worker

**Supervisor**
Mr Daniel THERRIAULT, Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=294&Langue=A

## #17: Area of Expertise: Mechanical Engineering

**Research Project Title**
3D Printing of Advanced Materials for Mechanical Microsystems

**University Cycle**
3rd cycle (Ph.D.)

**Main Tasks during the Internship**
This internship will be performed at the Laboratory of Multiscale Mechanics (LM2) of Polytechnique Montreal. Under the supervision of Prof. Therriault, the intern will assist a current Post-Doctoral Fellow with the realization of several research projects. The laboratory is currently developing new 3D printing methods (3D freeform printing, multi-materials printing) and various advanced materials with enhanced mechanical, thermal and electrical properties (e.g., nanocomposites, metallic-polymer).

**Required Skills for the Internship**
- Strong Mechanical Engineering or Material Sciences background
- Strong applied research experiences
- Experienced user of 3D printing technologies
- Design of advanced materials (e.g., thermoset or thermoplastic nanocomposites, twin-screw extruder, three-roll mixer)
- Material characterization (e.g., SEM, TEM, DSC, TGA, XRD, mechanical)
- Good team worker

**Supervisor**
Mr Daniel THERRIAULT, Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=294&Langue=A

## #18: Area of Expertise: Physics Engineering and/or Materials Science

**Research Project Title**

Biomimetic of Spider Silk: Instability-assisted Microfabrication of Tough Fibers

**University Cycle**

3rd cycle (Ph.D.)

**Background Information**

Instability-assisted microfabrication.

Spider capture silk outperforms most synthetic materials in terms of specific toughness. We developed a technique to fabricate tough microstructured fibers inspired by the molecular structure of the spider silk protein. To fabricate microfibers (with diameter ~30µm) with various mechanical properties, we yield the control of their exact geometry to the liquid rope coiling instability. We flow a filament of viscous polymer solution towards a substrate moving perpendicularly at a slower velocity than the filament flows. The filament buckles repetitively giving rise to periodic meanders and stitch patterns. As the solvent evaporates, the filament solidifies into a fiber with a geometry bestowed by the instability. Tensile tests performed on fibers show interesting links between the mechanical properties and the instability patterns. Some coiling patterns give rise to high toughness due to the sacrificial bonds created when the viscous filament loops over itself and fuse. The sacrificial bonds in the microstructured fiber play an analogous role to that of the hydrogen bonds present in the molecular structure of the silk protein which give its toughness to spider silk.

Passieux, R., Guthrie, L., Rad, S. H., Lévesque, M., Therriault, D. and Gosselin, F. P. (2015), Instability-Assisted Direct Writing of Microstructured Fibers Featuring Sacrificial Bonds. Adv. Mater.. doi:10.1002/adma.201500603

**Main Tasks during the Internship**

The student will perform microfabrication experiments and material tests. He will also develop theoretical/numerical models to bring a better understanding of the process.

**Required Skills for the Internship**

A good understanding of fluid flow instability phenomena and the material science of polymers is necessary. Ideally, the candidate can perform finite element analyses with Ansys or some other commercial software.

**Supervisor**

Mr Frederick GOSSELIN, Assistant Professor, Department of Mechanical Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=542&Langue=A
Website: http://www.fgosselin.com

## #19: Area of Expertise: Physics Engineering and/or Materials Science

**Research Project Title**
Characterization of Thermal and Electrical Transport Properties and Thermoelectric Alloys

**University Cycle**
3rd cycle (Ph.D.)

**Background Information**
This project is a result of a joint collaboration between the departments of Mechanical engineering and Engineering physics to develop advanced thermoelectric materials. The thermoelectricity group at École Polytechnique (ÉPM) has established fabrication procedures to synthesize thermoelectric (TE) alloys by powder metallurgy. These alloys are the constituent materials for TE modules operating at temperatures close to ambient temperature, and up to 500 C.

**Main Tasks during the Internship**
(i) Measurement of Hall Effect and resistivity of thermoelectric alloys as a function of temperature.

(ii) Evaluate, by the Harman method, the thermoelectric performance, and indirectly the thermal conductivity of the alloys

The candidate responsible for this project will also have the opportunity to assist other members of our research group in the synthesis of thermoelectric alloys by mechanical alloying and hot extrusion, and thus also learn procedures to evaluate the structural and mechanical properties of the produced alloys.

For this project, the student will have access to: (1) the Microfabrication laboratories of the department of engineering physics, for Hall Effect measurements and for X-ray diffraction measurements; (2) The thermoelectricity facilities of the department of Mechanical engineering and (3) the Centre for the microscopic characterization of materials, of Polytechnique Montréal.

The methodology is that frequently used for the evaluation of thermoelectric and transport properties: (a) Hall Effect and resistivity by the Van der Paw technique, and (b) implementation of Harman's method for the measurement of the TE figure of merit.

**Required Skills for the Internship**
Ideally, the candidate for this internship has already followed a course on solid state and semiconductor physics, and has some hands-on laboratory experience, particularly in the use of electrical instrumentation.

**Supervisor**
Mr Remo MASUT, Professor, Department of Engineering Physics
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=144&Langue=A

## #20: Area of Expertise: Computer and Software Engineering

**Research Project Title**
Identifying Bottlenecks in Build System Performance

**University Cycle**
1st cycle (undergraduate) and 3rd cycle (Ph.D.)

**Background Information**
When mentioning the term "software development", people immediately think about source code and programmers. Of course, many more activities play a role in software development, and many more artifacts than just the source code. One such artifact is the build system. This is the crucial infrastructure that developers use on a daily basis to compile and package the source code into executables and other deliverables, such that the developers can test their software after adding a new feature or bug fix. People typically use technologies like GNU Make, autotools, Maven, Ant, SCons, Rake or CMake to implement their build system.

Since build systems are used so often and the software system that they build typically is huge, developers risk losing a lot of time waiting for their build to finish. It is not uncommon for very large systems to require hours to finish a build. For this reason, most build technologies provide incremental build modes to minimize the time a build takes, by just re-building the source code files that changed and reusing the previously built version of other files. In addition, most technologies also provide parallel build support that builds multiple files at the same time.

However, build technologies are not understood very well by software developers, and often use arcane technology that is hard to change. Furthermore, although build systems play a central role in software development, surprisingly little research has been performed on them up until a couple of years ago, and most of this research focused on the quality of the actual build system instead of on build system performance. As such, many companies end up with a slow build system and no concrete idea on how to speed up the build.

The goal of this internship is to study how the performance of a build system evolves during daily development, analyze and document which build system or source code changes are related to build system performance degradations and improvements, and apply our findings on a concrete open source system to validate our findings. This work will build on our existing MAKAO infrastructure for reverse-engineering GNU Make build systems (http://mcis.polymtl.ca/makao.html).

Similar to energy consumption in software, the performance of a build system cannot be easily estimated statically using just the build system code, one needs to run and measure the build process. Such measurements need to be done on multiple build configurations (a set of features to build on a specific platform and architecture). This is because a developer might have introduced a build problem on his development platform, but not on the other ones, or one specific feature might result in extra build steps to be executed for all other components of the system.

Once we have measured the performance per configuration, we automatically know how much time each file takes to build. We can use this information to calculate (instead of measure) the performance of incremental builds. For this, we can exploit MAKAO's underlying model of a build system execution. This model knows all the dependencies followed by the build system during execution, so it allows to find out which files need to be recompiled when a particular file changes.

Given the differences in programming languages, build system technologies and software project sizes, we will perform our measurements for multiple systems and multiple versions. For each of these, we will analyze the evolution of build performance across time using statistical techniques and visualizations. We will determine statistically significant increases and decreases in performance between versions, as well as fluctuation-heavy parts of the build system. We can also compare build performance per programming language, build technology and project size. In the end, our aim is to develop techniques and tools to help practitioners understand and improve the performance of their build system.

The lab on Maintenance, Construction and Intelligence of Software (MCIS) studies ultra-large scale software systems and the development processes and tools used to build them, in order to identify bottlenecks and problems, and to come up with innovative solutions and support. These solutions and support enable developers, testers, team leads, and everyone up until management level to develop software more effectively and in a better informed way, such that the typical risks associated with software development (not making the deadline, insufficient quality or running out of resources) are reduced or even mitigated.

In the context of this proposal, the mission of MCIS is to help practitioners understand and improve the performance of their build system. Through empirical research on software development process data stored in revision control systems (CVS, Subversion, Git, ...), mailing list archives, bug repositories (Bugzilla, Jira, ...), online documentation and any other kind of data source available, we build models and distill process knowledge that are immediately applicable in practice.

**Main Tasks during the Internship**

The project basically consists of a large empirical study on "real" open source distributions and projects. Our lab has significant expertise in such studies as well as the necessary tools and infrastructure. Since the more projects are analyzed, the better, more than one student can work on this project.

This proposal largely consists of the 3 typical software intelligence phases:

(1) Data Extraction: The student will search for open source systems with sufficient development history and online data sources, such as bug reports, mailing list messages and online fora. Then, the student needs to build multiple versions, for different configurations.

(2) Quantitative Analysis: The student first will gather simple statistics, like the evolution of the performance of full builds. This will give an initial idea about the scale of the data as well as possibly interesting parts of the data. Second, the performance of incremental builds will be calculated, followed by analysis of the resulting incremental performance.

(3) Qualitative Analysis: The student will manually study code changes and documentation for the versions with build system performance drops. By analyzing the qualitative data like mailing list discussions, the student will be able to identify possible causes of the performance problems. Through interaction with other people in the lab, these causes can be fleshed out into more general patterns that can be documented in a structured way.

The project is quite large in scope, so multiple internships could be offered. Furthermore, we believe that completion of phases (1) and (2) with some initial results for phase (3) would be a successful outcome of this project.

**Required Skills for the Internship**

Through this project, students will become experts in software intelligence, an emerging area many companies are trying to get into. To extract data, a student needs the motivation to actively contact open source developers, search online data sources, understand their format and interconnections, and use scripting languages (bash, perl, python, ...). For the quantitative analysis, (s)he again needs scripting languages and the desire to learn the R language to visualize data. For the qualitative analysis, (s)he needs persistence, conscience and patience to read through and summarize textual artifacts like bug reports and email threads.

**Supervisor**

Mr Bram ADAMS, Assistant Professor, Department of Computer Engineering
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=514&Langue=A
http://mcis.polymtl.ca/

**#21: Area of Expertise: Physics Engineering and/or Material Sciences**

**Research Project Title**

2D monolayers of black phosphorus: determination of the band structures using optical transitions and selection rules

**University Cycle**

1st cycle (undergraduate) and 3rd cycle (Ph.D.)

**Background Information**

Inspired by the unusual properties of graphene, the search for other 2D materials has unveiled that monolayers of black phosphorus also offer unusual and spectacular characteristics. In contrast to gapless graphene, black phosphorus monolayers are perfectly adapted for logic electronics and optoelectronics with a gap of about 1.5 eV. Carrier mobilities exceeding those of silicon have been reported, which could make black phosphorus the ideal candidate for high performance flexible electronic applications.

However, the properties of thin black phosphorus samples remain to be unveiled, as little is known on its electrical, optical and mechanical properties. One of the most fundamentally characteristic of a material is its band structure close to the Fermi level, as it determines most of the optical and electronic properties.

**Main Tasks during the Internship**

This project consist in providing the experimental values for reconstructing the band structure of this new 2D material. Using electroreflectance spectroscopy and differential reflectance in a wide spectral range, the student will determine all optically allowed optical transitions, along with their polarization selection rules. Using this information, the student will unveil the evolution of main critical points as a function of the number of monolayers and as a function of perturbations like temperature, strain and magnetic field.

The student will familiarize himself with single monolayer preparation and manipulation, low-temperature cryostats, supercontinuum lasers, advanced optical microscopy techniques at high magnification, and a very exiting research topic.

**Required Skills for the Internship**

The student should have a background in engineering physics, physics, or any closely related disciplines. We seek students sharing our passion for experimental physics.

**Supervisor**

Mr Sébastien FRANCOEUR, Associate Professor, Department of Engineering Physics
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=328&Langue=A

**#22: Area of Expertise: Physics Engineering and/or Material Sciences**

**Research Project Title**
A promising qubit for quantum computation: excitons bound to small molecules embedded in semiconductors

**University Cycle**
1st cycle (undergraduate) and 3rd cycle (Ph.D.)

**Background Information**
Single impurity atoms in semiconductor crystals can be spatially resolved and studied individually. Carefully selecting the nature of the impurity and the host material, an impurity center composed of one, two or three atoms can bind electrons and holes, thereby forming an exciton bound to a quantum structure. Although the electronic properties of these atomic-size quantum dots are similar to those of conventional quantum dots composed of tens of thousand atoms, their size is comparable to the volume of a few atoms. This offers excellent opportunities for the realization of a spin-based qubit of atomic dimensions for the field of quantum computation.

Using ultrafast laser pulses and optical spectroscopy techniques, we have recently demonstrated that it was possible to initialize an exciton qubit and manipulate its state over the whole Block sphere. Doing so revealed a very high optical dipole moment and a very low power induced dephasing, making this system a very attractive building block for high-fidelity quantum operations.

**Main Tasks during the Internship**
The student will assist a team formed by two Ph.D. students by 1) making samples using low-dose and low-energy implantation techniques at our on-campus state-of-the-art facility, 2) improving our ultrafast pulse preparation system by implementing complex multi-pulse excitation sequences, 3) operating our cryogenic microscope and measuring the luminescence from single molecules, and 4) assisting with quantum control experiments.

The student will familiarize himself with implantation facilities, ultrafast lasers, cryostats, advanced optical microscopy techniques, and a very exiting research topic.

**Required Skills for the Internship**
The student should have a background in engineering physics, physics, or any closely related disciplines. We seek students sharing our passion for experimental physics.

**Supervisor**
Mr Sébastien FRANCOEUR, Associate Professor, Department of Engineering Physics
http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=328&Langue=A