

# 2015 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 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 2015. 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;
- Scholarship of \$1000 CAD per month for a maximum of four (4) months.

### Eligibility Criteria

- Being enrolled in one of Polytechnique Montréal's partner universities;
- Having completed at least two years of an engineering undergraduate program;
- Meet 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:
  - choice of your research 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.

### Application Deadline

All documents must be sent electronically by **August 15, 2014** to the International Relations Office of Polytechnique Montréal: [brin@polymtl.ca](mailto:brin@polymtl.ca). Please specify in the subject "2015 Winter Research Internship Program".

### Announcement

The results will be announced in September 2014 to each candidate. Selected candidates will receive a letter of invitation 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 Office of International Relations and the Office of International Students to make your stay most enjoyable. You can also get further information on Montreal: [www.tourisme-montreal.org/MontrealTV](http://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:**

Nathalie PELLETIER (Ms.), Senior Advisor, International Relations Office ■ [nathalie-m.pelletier@polymtl.ca](mailto:nathalie-m.pelletier@polymtl.ca)

## LIST OF RESEARCH PROJECTS

Click on numbers to access project description

### Aerospace Engineering

- 1 Data treatment module for mechatronics characterization of molding of composites
- 2 Design and analysis of hybrid (bonded and bolted) joints for aerospace structures
- 3 The effect of curvature on local buckling of fuselage frames
- 4 Composites materials

### Biomedical Engineering

- 5 Automated and intelligent evaluation of AIS severities during Gait
- 6 Underactuated robotic grasping and sensing
- 7 Building RF coils for imaging the brain of small animals
- 8 Developing image processing methods for MRI data

### Chemical Engineering

- 9 Versatile photochemical surface engineering

### Civil, Geological and Mining Engineering

- 10 Development of an agent based simulation for pedestrian movement
- 11 Field measurements of evapotranspiration over an urban area with a microwave scintillometer

### Computer and Software Engineering

- 12 Domain specific language integration for hardware-aware software generation
- 13 Probabilistic real-time systems
- 14 Radiation-tolerant FPGA architecture

### Electrical Engineering

- 15 Cooperative mapping with mobile robots
- 16 Simulation, modeling and implementation of a quadrotor drone for concurrent mechatronic design approach

### Mathematics and Industrial Engineering

- 17 Dynamic rebalancing of bike sharing systems

### Mechanical Engineering

- 16 Simulation, modeling and implementation of a quadrotor drone for concurrent mechatronic design approach
- 18 AI tools for pulp and paper quality prediction
- 19 Ballbot – Data acquisition and system refinement
- 20 Designing and prototyping a planar differentially driven cable robot
- 21 Fluidelastic force measurements for steam-generator tube-support

### Physics Engineering and/or Materials Science

- 22 2D monolayers of black phosphorus: determination of the band structures using optical transitions and selection rules
- 23 A promising qubit for quantum computation: excitons bound to small molecules embedded in semiconductors.

## 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/](http://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**

### **Project Title**

Data treatment module for mechatronics characterization of molding of composites

### **Project Description**

The manufacturing of polymer matrix composites consists in impregnating a ceramic fiber with a polymer in a liquid state. Then with the aid of heat, the polymer resin undergoes into a chemical reaction during the molding process known as cure which gives to the piece the mechanical properties and the final part shape. With a growing necessity for composites the aerospace, automotive and sport industries are demanding improvements in the molding process to produce high quality parts at higher production rates. This task is only possible knowing the changes of the constituent materials during the cure of the composite part.

The long term aim of this project is to provide an intelligent device capable of tracking and measuring the cure kinetics of the polymer. The short term objective of the project proposed here deals with the data acquisition device for the purpose of condition monitoring of the composite parts.

The student(s) will be engaged in the data acquisition team to work with doctoral students, who share the responsibility of developing the data acquisition and data conditioner module of the global intelligent device. In particular, the student will review the existing tools for better signal conditioning of sensors data (pressure, temperature, displacement, heat flux, speed, torque sensors, etc).

Finally, the student will implement strategies to noise and error reduction in the measurement and define the protocols of communication to store the measured data.

### **Supervisor**

Mr. Sofiane ACHICHE, Assistant Professor, Department of Mechanical Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=540&Langue=A>

### **Co-supervisor**

Mr. Eduardo-Antonio-Julian RUIZ, Associate Professor, Department of Mechanical Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=316&Langue=A>

## **#2: Area of Expertise: Aerospace Engineering**

### **Project Title**

Design and analysis of hybrid (bonded and bolted) joints for aerospace structures

### **Project Description**

To make useful structures using composites materials, consideration must be given to the way structural components are joined together. Two types of composite joining methods are commonly used: adhesively bonded joints, hereafter known as *bonded joints*, and mechanically fastened joints, hereafter known as *bolted joints*. An ability to model both bonded and bolted joints leads to a good understanding of joint design. In most designs, one or the other is used, but in this project, combinations of bonded and bolted joints will be considered. This is a problem that is essential to design of joints in the Aerospace industry, and is of great academic interest because of the complexity of the problem.

The goal of this project is to develop an optimized design methodology for combined bolted and bonded joints for attaching composite structures. When analyzed independently, there are existing methodologies for both bonded and bolted joints. Combined together as load transfer mechanisms within a joint, the problem becomes more complex. The interactions and failure modes must be understood in order to avoid overdesign and weight penalty in aerospace structures. The benefits of using a combined bolted/bonded joint must be clearly defined so that this joint option can be a logical design choice or alternative. The underlying complexity due to the large number of expected design variables means that any design methodology will benefit from optimization techniques in order to arrive at an optimal solution for the design of bolted/bonded joints. This project combines the efforts of three Universities, McGill, Ecole Polytechnique and Carleton, the National Research Council Institute for Aerospace Research Structures, Materials and Propulsion Laboratory (NRC-IAR-SMPL), and three industrial partners: Bombardier Aerospace, L-3Com and Delastek

### **Supervisor**

Mr. Rachid BOUKHILI, Ph.D., Professor, Department of Mechanical Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=202>

### **#3: Area of Expertise: Aerospace Engineering**

#### **Project Title**

The effect of curvature on local buckling of fuselage frames

#### **Project Description**

To increase flight performances, payloads and fuel efficiency of new aircrafts, their design must emphasise weight reduction. To build ever lighter aircrafts, the aerospace industry seeks lighter materials and must ensure that every bit of material is used to its full capacity. The nature of the problem addressed in the present project is to seek better knowledge of buckling phenomena to relax conservative assumptions made in the design phase regarding the load capacity of structural members.

There exist some closed-form solutions and abaci to evaluate rapidly the critical loads of common configurations of frames and stringers. However, to use these solutions, conservative assumptions must often be made allowing the use of general formula more or less specific to the considered case. One common assumption is to neglect the curvature of frames when calculating their critical local buckling load. Neglecting curvature of frames is a minor approximation when designing the fuselage a large commercial jet several meters in diameter. However, for business jets and smaller commercial aircrafts, the important curvature of the smaller fuselage can have a significant rigidifying effect on the frames and delay torsional buckling instabilities. Neglecting the curvature leads to overdesigned and heavier parts especially for smaller aircrafts. We propose to develop closed-form solutions or criteria on the curved frame properties for designing stiffeners with critical loads matching exactly the design requirements without excess weight.

#### **Skills Required**

The project is analytical and numerical in nature. The candidate sought has experience with the finite element method. Preferably, he is familiar with linear stability analysis and has had exposure to plate and shell theories.

#### **Supervisor**

Mr. Frédérick GOSSELIN, Assistant Professor, Department of Mechanical Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=542&Langue=A>

#### **#4: Area of Expertise: Aerospace Engineering**

##### **Project Title**

Composites materials

##### **Project Description**

The Chair on Composites of High Performance (CCHP), Mechanical Engineering Department, École Polytechnique of Montreal, is offering internships in the advanced field of composite materials for aerospace application. These internships are made in collaboration with industrial partners which are mayor aeronautical and space companies.

The CCHP is part of to the Center of Applied Research on Polymers and Composites (CREPEC). CREPEC includes five academic institutions and over fifty researchers specialized in new materials and process development in the field of polymer composites. The R&D program aims to develop industrial applications in the automotive and aerospace industries, which sponsor this research. The work will be carried out in a multicultural team of students, researchers and industrial partners.

##### **Skills Required**

Applicants should have completed at least 3 years of degree in mechanical, chemical, material engineering or polymer science. Basic knowledge in composites manufacturing or advanced material characterization would be an asset. Fluency in English or French is mandatory. Candidates should have a working capability in written English.

##### **Supervisor**

Mr. Eduardo-Antonio-Julian RUIZ, Associate Professor, Department of Mechanical Engineering  
<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=316&Langue=A>

## **#5: Area of Expertise: Biomedical Engineering**

### **Project Title**

Automated and intelligent evaluation of AIS severities during Gait

### **Project Description**

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.

In this project we will explore the use machine learning techniques to classify severities from this new 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).

This study contains two steps: first, analyzing kinematics and EMG data during gait with Fuzzy Logic tools to classify patients. Second step will focus on developing a special and novel fuzzy Logic based decision support system based on internal force and torque analysis during gait. Potential results will be compared with 2-D and 3-D classification of scoliosis severity.

### **Supervisor**

Mr. Sofiane ACHICHE, Assistant Professor, Department of Mechanical Engineering  
<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=540&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>

## #6: Area of Expertise: Biomedical Engineering

### Project Title

Underactuated robotic grasping and sensing

### Project Description

Robotic hands can be used in a wide range of fields, including medical devices as well as spatial and industrial robots. To enhance these electromechanical systems and to simplify grasping and manipulation, underactuated mechanisms can be used. 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.

A common subsequent step is to add tactile sensing to these underactuated hands, making it possible to provide information about the objects seized without any prior knowledge of shape and weight. While conventional tactile sensors are very common in the industry, they are not always suitable depending on the application. For example, biocompatibility is essential for medical instruments, which is not always possible with tactile sensors. Thus, an efficient alternative is necessary. Proprioceptive algorithms such as these that have been designed in the laboratory can be used to this end. Proprioceptive tactile sensing uses internal low-cost sensors far from the fingers and the fact that forces applied at the fingertips are reflected to the actuator. Thus, the sensors' measurements acquired by a computer on which algorithms are implemented can be used to provide information about magnitude and location of the contacts.

The main objective of the internship is to design a mechatronic hand capable of providing proprioceptive tactile sensing. The tasks to achieve this are:

- 1) Provide a literature review of existing underactuated hand architecture;
- 2) Understand how proprioceptive tactile sensing works;
- 3) Design a sensing mechanism capable of proprioceptive tactile sensing;
- 4) Manufacture a prototype;
- 5) Test and improve the tactile sensing algorithms.

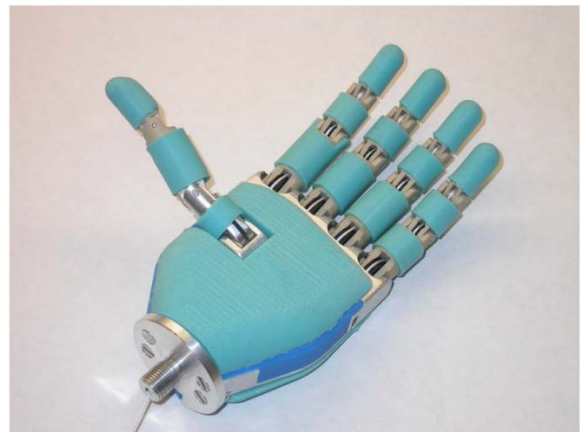
### Preliminary schedule (4 month internship)

Jan.: literature review and preliminary analysis

Feb.: design of the mechanism and the test bench

Mar.: manufacture of the prototype

Apr.: tests and technical report



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.

### Supervisor

Mr. Lionel BIRGLEN, Associate Professor, Department of Mechanical Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=341&Langue=A>



## **#7: Area of Expertise: Biomedical Engineering**

### **Project Title**

Building RF coils for imaging the brain of small animals

### **Project Description**

The NeuroPoly lab is developing advanced methods for magnetic resonance imaging (MRI). Projects involve methodological developments such as hardware (antennas), image processing (segmentation, motion correction, multimodal registration) and clinical applications (multiple sclerosis, spinal cord injury). Our environment is highly multi-disciplinary: you will interact with physicists, engineers, radiologists and neurologists. More information about our research projects can be found here: [www.neuro.polymtl.ca](http://www.neuro.polymtl.ca).

### **Skills Required**

- For the project in image processing, the candidate must have solid knowledge in programming (Python, Matlab, C/C++).
- For the project in coil building, the candidate must have strong knowledge in electrical engineering (soldering, RF antennas at 100-300 MHz) and mechanical designs.

### **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>

## **#8: Area of Expertise: Biomedical Engineering**

### **Project Title**

Developing image processing methods for MRI data

### **Project Description**

The NeuroPoly lab is developing advanced methods for magnetic resonance imaging (MRI). Projects involve methodological developments such as hardware (antennas), image processing (segmentation, motion correction, multimodal registration) and clinical applications (multiple sclerosis, spinal cord injury). Our environment is highly multi-disciplinary: you will interact with physicists, engineers, radiologists and neurologists. More information about our research projects can be found here: [www.neuro.polymtl.ca](http://www.neuro.polymtl.ca).

### **Skills Required**

- For the project in image processing, the candidate must have solid knowledge in programming (Python, Matlab, C/C++).
- For the project in coil building, the candidate must have strong knowledge in electrical engineering (soldering, RF antennas at 100-300 MHz) and mechanical designs.

### **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>

## **#9: Area of Expertise: Chemical Engineering**

### **Project Title**

Versatile photochemical surface engineering

### **Project Description**

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 to other substrates, including glass and UV-sensitive wood, and improve the surface characterization processes.

### **Supervisor**

Mr. Jason R. TAVARES, Assistant Professor, Department of Chemical Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=456>

## #10: Area of Expertise: Civil, Geological and/or Mining Engineering

### Project Title

Development of an agent based simulation for pedestrian movement

### Project Description

Sustainable planning, design, and operations of urban pedestrian facilities (trains stations, shopping malls, concert venues etc.) require an extensive investigation of the pedestrian dynamics. Such



an effort gives us a detailed insight into demand, usage patterns, and reaction to infrastructure changes. A key aspect of this research is to develop simulation models of the pedestrian flow and behaviour.

In this software engineering internship, the student will help us in our ongoing effort of developing an open source software to simulate the pedestrian flow and their individual behaviour in public spaces. The student will build upon our earlier efforts of a mesoscopic simulator and help us extend it to a microscopic simulation environment, where individual pedestrians are modelled as intelligent agents. The internship will also include enhancing the existing visualization environment for presentation and analysis.

The proposed internship is very multidisciplinary in nature. The student will have a unique opportunity to be exposed to: planning design and operations processes; software engineering; simulation concepts; graph theory; queueing theory; sustainable urban systems; behavioural modelling; and traffic flow theory. The student will be working under my direct supervision and will benefit from my 10+ years of research and 3+ years of software industry experience. Student will be exposed to real-life ongoing projects with the Montréal public transit authority (STM) and Greater Montréal's regional transportation authority (AMT). The internship is expected to last for a duration of 6 months.

### Skills Required

We are looking for a student with strong programming and mathematical background and an interest in sustainability, urban living, transportation, biking and walking. The student will have the option to work either in C++, Java, or C#. He/She is required to have strong background in data structures and algorithms. Some knowledge of OpenGL and/or Processing will be preferred. We are looking for a highly motivated individual who is eager to learn and is capable of working in team environment.

### Supervisor

Mr. Bilal FAROOQ, Assistant Professor, Department of Civil, Geological and Mining Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=558>

## **#11: Area of Expertise: Civil, Geological and/or Mining Engineering**

### **Project Title**

Field measurements of evapotranspiration over an urban area with a microwave scintillometer

### **Project Description**

In hydrology, an accurate estimation of evapotranspiration is essential, as it connects the water and energy budgets, and can account for up to 65% of annual precipitation. Unfortunately, traditional measurement methods to monitor water vapor fluxes in the field, such as the eddy covariance, rely on point measurements that may not be representative of the land-atmosphere exchanges throughout the watershed. Here, this study proposes to use a newly developed sensor, the microwave scintillometer, which can provide path-averaged measurements of evapotranspiration fluxes for distances up to 6 km. The intern student will be asked to assist a Ph.D. student to operate the microwave scintillometer in a field campaign over a building rooftops in a neighborhood of Montreal and to perform a series of tests in the laboratory. Overall this study will allow us to gain a better understanding of energy and water fluxes partitioning in urban areas, but also to develop appropriate formulations for evapotranspiration over these surfaces in hydrological models.

### **Supervisor**

Mr. Daniel NADEAU, Assistant Professor, Department of Civil, Geological and Mining Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=557&Langue=A>

## **#12 : Area of Expertise : Computer and Software Engineering**

### **Project Title**

Domain specific language integration for hardware-aware software generation

### **Project Description**

When developing simulation software, the development team has to rely on the competence of subject matter experts (SMEs) in different areas and with expertise from a multitude of domains, such as mechanics, power electronics, avionics, and more. In general, expecting SMEs to translate their domain knowledge into an imperative programming language is quite unrealistic, leading to the use of domain-specific languages. When considering modern processors, with their increasing core count, specialized programming languages and software development paradigms have emerged, each offering different ways on how to fully exploit their power. The purpose of this project is to define a methodology for hiding software complexity from SMEs by automating the software generation, mapping and optimization according to inputs from SMEs and hardware and software experts, who describe the execution platform in sufficient detail.

This internship will revolve around the implementation of an optimization framework (in C++) together with other students working on the project.

### **Skills required**

The student should have a basic knowledge of computer architecture (processor structure, memory hierarchy, etc.) and have good C++ programming experience. The student should also understand benchmarking and general computing systems performance metrics. Knowledge of the LLVM compiler framework is an asset, as well as experience with AADL.

### **Supervisor**

Mr. Giovanni BELTRAME, Assistant Professor, Department of Computer Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=508&Langue=A>

## **#13 : Area of Expertise : Computer and Software Engineering**

### **Project Title**

Probabilistic real-time systems

### **Project Description**

For high-performance time-critical aerospace computer system, such as a satellite, the accurate timing prediction of software execution plays an important role. If events are not dealt with within a certain timeframe, the result may be catastrophic. However, to address increasing complexity in computer applications, more advanced architectures using multi-stage pipelines, several memory hierarchy levels and even Multi-Processor System-on-Chip (MPSoC) designs are proposed for high performance computing. These traditional deterministic computer architectures make software timing behavior almost impossible to accurately predict. Normally the execution time of an application on a deterministic architecture follows a distribution that might have some corner cases which are beyond normal operations. A conservative estimation will place the Worse Case Execution Time

(WCET) far away from the actual maximum time used by the application, especially when considering possible interactions with other tasks. This would lead to a large overestimation of the computing resources needed for the task. In this research project, we propose to address the issue using probabilistic real-time system software. The idea is that the timing behavior of a system can be defined by probabilistic metrics applied to software. With probabilistic software methodology for timing prediction, the execution time will have a smoother distribution and avoid corner cases. This will reduce overestimation and time-critical system can benefit tremendous in terms of cost of integration, verification and certification.

The objectives of the project are (a) to define a methodology for probabilistic software development, and (b) demonstrate its effectiveness at system-level. The intern will collaborate with the MIST Lab's PhD students to demonstrate the software by implementing a Data Handling and Management System (DHMS) for a small satellite.

### **Supervisor**

Mr. Giovanni BELTRAME, Assistant Professor, Department of Computer Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=508&Langue=A>

## **#14 : Area of Expertise : Computer and Software Engineering**

### **Project Title**

Radiation-tolerant FPGA architectures

### **Project Description**

Outside the protective cocoon of Earth's atmosphere, extreme temperature changes, vacuum and a high radiation, make for a particularly harsh environment for electronic systems. The design of space-grade hardware (usually referred to as “hardened components”) requires large investments in infrastructure, and its development usually relies on government or military projects. However, with the recent opening of the space sector to private enterprises, the market faces a growing interest for the use of low-cost, off-the-shelf components (COTS). These components have to be properly screened and the design of computer systems has to take into account and work around their vulnerabilities.

Current research focuses on using COTS in fault-tolerant configurations to obtain reliable systems that can be successfully used in space missions.

The benefits of this research are not limited to the space segment:

current technology trends— smaller feature sizes, lower voltage levels, higher operating frequencies — are projected to cause an increase in the failure rate of integrated circuits. Similar fault-tolerance strategies used in space applications can be used to mitigate these effects.

Field Programmable Gate Arrays (FPGAs) are programmable hardware devices, and are generally used for hardware prototyping. FPGAs typically have a higher cost per device manufactured, and lower performance when compared to custom devices produced in large volumes.

Nevertheless, their constant evolution has made them a very attractive proposition for the small-volume aerospace market: they can be programmed with complex architectures with sufficient performance, for a fraction of the cost of producing a custom integrated circuit. FPGAs come in different flavours, and the most common, are the FLASH and SRAM kinds. These, in their non-military versions, are particularly sensitive to particle radiation (neutrons, protons and other ions), the effects of which, called Single Event Effects (SEEs), can disrupt their normal behaviour. Our objective is to define low-cost systems, based on FPGAs, that are tolerant to SEEs, without excessively reducing their performance or functionality.

The project will integrate previous works regarding SEEs and radiation-induced aging effects into a single lifetime model for FPGAs in space.

### **Supervisor**

Mr. Giovanni BELTRAME, Assistant Professor, Department of Computer Engineering

<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=508&Langue=A>



## **#15: Area of Expertise: Electrical Engineering**

### **Project Title**

Cooperative mapping with mobile robots

### **Project Description**

The goal of this project is to explore active sensing strategies to map an environment as precisely and as fast as possible using teams of mobile robots, such as quadrotors and ground robots. Available sensors are assumed to include various types of cameras and RGB-D sensors (kinect), as well as standard navigation sensors (inertial, differential GPS, etc.) for localization. The robotic networked team should take into account at each time the current uncertainty about the map, which depends on occlusions, shadows, etc., in order to replan the trajectories in real-time. For this project, we will develop algorithms, a simulation environment, a proof-of-concept indoor system involving cheap platforms such as AR drones, and finally an advanced outdoor system relying on state of the art hardware.

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.]

The student will be involved in tasks such as:

- Developing a tailored multi-robot simulation environment
- 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.

### **Skills required**

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 LE NY, Assistant Professor, Department of Electrical Engineering  
<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=546>

## **#16: Area of Expertise: Electrical Engineering and Mechanical Engineering**

### **Project title**

Simulation, modeling and implementation of a quadrotor drone for concurrent mechatronic design approach

### **Project Description**

Mechatronic systems (MeSy) are a combination of cooperative mechanical, electronics and control software components which make their design a highly tedious task to achieve. Due to this inherent complexity a systematic and multi objective design methodology is crucial to replace the sequential design approaches generally used and that tend to deal with the different domains (mechanical, electrical, software, fluid, thermal, etc.) separately. This project is part of an ongoing research aimed at developing a Mechatronic Multi-criteria Profile (MMP) formulated for conceptual, preliminary and detailed design stages. It will take into consideration the intelligence, the flexibility, and the complexity.

In order to validate the MMP, real world case studies are needed. And to achieve this, the student will need to participate in the modeling of an Intelligent Quadrotor Drone for the purpose of building a well described mechatronic case study that will be used for implementing and validating the newly developed MMP.

### **Supervisors**

Mr. David SAUSSIÉ, Assistant Professor, Department of Electrical Engineering

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Mr. Sofiane ACHICHE, Assistant Professor, Department of Mechanical Engineering

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## **#17: Area of Expertise: Mathematics and Industrial Engineering**

### **Project Title**

Dynamic rebalancing of bike sharing systems

### **Project Description**

The growing popularity of Bike Sharing Systems (BSS) throughout the world has led to an increase in demand and in operation complexity. In December 2007, only 68 cities had a BSS and those cities were mostly situated in Europe. In December 2012, there was 493 BSS in operation across the world. Imbalances between stations are a common issue amongst BSS and bicycle redistribution is key to ensure adequate level of service (LOS) in order to retain users. However, bicycle redistribution is costly and hard to plan because it relies on a good knowledge of users' current and upcoming behaviour and involves complex mathematical modeling. Bicycle redistribution can be divided in two main categories: static redistribution and dynamic redistribution. Static redistribution is done during the night when users' impact on the system (transport of the bikes between stations) is negligible while dynamic redistribution is done during the day when users' impact on the system has to be taken into account.

Static and dynamic redistribution can be compared to the following operations research problems: the pickup and delivery Problem (PDP); the one-commodity pickup and delivery traveling salesman problem (1-PDTSP); the inventory routing problem (IRP) and the swapping problem (SP). None of these really fit with the specific definition of the static and dynamic redistribution problems so other authors have proposed new definitions.

The main objective of the static redistribution problem is to bring each station from an initial level of bicycles to an optimal level using a given number of trucks of finite capacity in a certain time. The solution is a set of routes for each vehicle and a number of bikes that need to be delivered or picked-up at each station.

The dynamic redistribution problem differs from the static redistribution problem because the model needs to consider real time demand from users. The solution is still a set of routes and a number of bikes to pick-up or to deliver at each station. The objective is double: to minimize the cost of the route and to maximize LOS.

Research works have been conducted on both static and dynamic redistribution in BSS but no practical solution has emerged as being easily applicable in the industry. Therefore, the development of an optimization mechanism for the redistribution of bicycles in BSS is essential to ensure good LOS at a minimum cost for the BSS operator. The main objective of this internship is to present a tool that was developed to help BSS operators minimize the cost of operation while maximizing LOS.

### **Supervisor**

Mr. Louis-Martin ROUSSEAU, Professor, Department of Mathematical and Industrial Engineering  
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### **Co-supervisors**

Ms Catherine MORENCY, Associate Professor, Department of Civil, Geological and Mining Engineering  
<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=322&Langue=A>

Mr. Martin TRÉPANIÉ, Professor, Department of Mathematical and Industrial Engineering  
<http://www.polymtl.ca/recherche/rc/en/professeurs/details.php?NoProf=190>

## **#18: Area of Expertise: Mechanical Engineering**

### **Project Title**

AI tools for pulp and paper quality prediction

### **Project Description**

This project deals with the investigation of the performances of different Artificial Intelligence tools (Linear Regression, KNN, NN and FIS) to predict ISO brightness of thermo mechanical pulp from experimental data.

For this purpose, data collected from an industrial setting carried out in collaboration between École Polytechnique and CRIQ are to be used.

The developed models use different type of wood chip properties as inputs and the ISO brightness of the obtained pulp as an output. The ISO brightness in this case represents the paper/pulp quality.

The performances of the developed models are to be evaluated by analyzing the prediction capabilities based on root mean square error.

A comparative study of the performances of the different AI tools as well as the usage of different inputs for ISO brightness prediction will be carried out. From this comparative study the importance of which inputs to use in order to better predict the wood chips transformation is to be concluded upon.

### **Supervisor**

Mr. Sofiane ACHICHE, Assistant Professor, Department of Mechanical Engineering

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## #19: Area of Expertise: Mechanical Engineering

### Project Title

Ballbot – Data acquisition and system refinement

### Project Description

Self-balancing robots have been present in the scientific literature for many years. The most well-known example of such robotic systems is the two-wheeled electrical vehicle known as the *Segway Personal Transporter*. These systems move by dynamically stabilizing a center of mass change induced by the user. In other words, the user shifts its weight forward, creating an unbalance which is detected by the sensors driving the actuators. The controller then stabilize the vehicle by making it move forward.

This concept can be pushed further by designing a robot capable of self-balancing itself in every direction, using a support ball instead of wheels. These systems are commonly known as ballbots, such as the *Rezero* illustrated below. A combination of motors and smaller wheels rotate the ball, enabling the robot to stabilize itself in every direction on a near flat surface.

A preliminary prototype was designed and built at Polytechnique, but it has to be tested and refined to have the desired self-balancing capabilities. This is the topic of the internship.

The main objective of this internship is to obtain a functional ballbot which can be decomposed in the following tasks:

- 1) Add a data acquisition system to the prototype;
- 2) Test the prototype to identify existing problems;
- 3) Design solutions to overcome the current issues;
- 4) Implement the solutions on the prototype;
- 5) Improve the ballbot's capabilities;
- 6) Write a technical report.

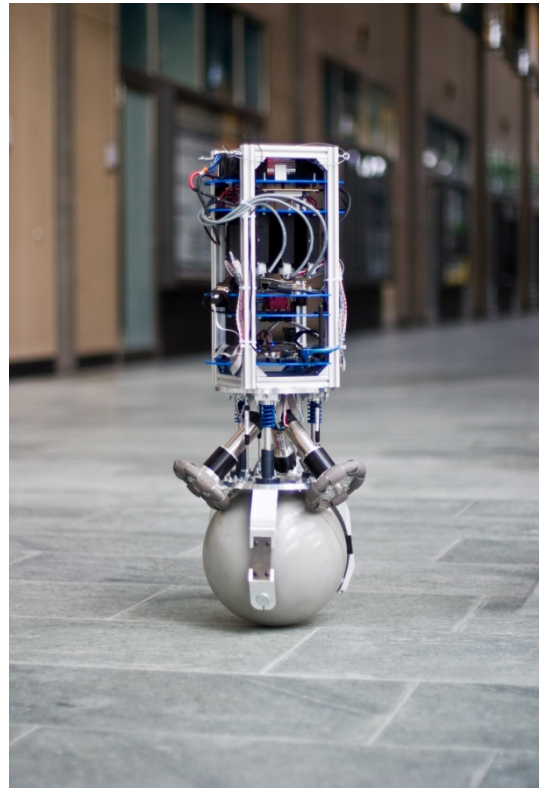
### Preliminary schedule (4 month internship)

Jan.: data acquisition system and preliminary testing

Feb.: extensive testing and solution research

Mar.: implementation

Apr.: tests and technical report



*Ballbot Rezero*, (2010) Focus Project Ballbot at ETH Zurich, Switzerland.

### Supervisor

Mr. Lionel BIRGLEN, Associate Professor, Department of Mechanical Engineering

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## #20: Area of Expertise: Mechanical Engineering

### Project Title

Designing and prototyping a planar differentially driven cable robot

### Project Description

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. It means that in addition to some advantages of linkage-driven parallel robots, they have a simple structure, are light with 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  $n$  degree of freedom cable robot,  $m$  ( $>n$ ) cables are required. Several works have shown that using more cables results in larger workspace and generally better performance of the robot.

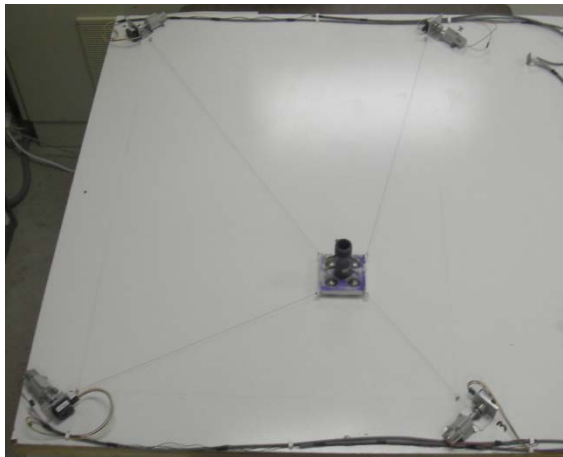


Figure 1 a planar cable robot with four cables



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 critical if more cables are used in the structure of the robot to obtain better performance in terms of size of wrench-feasible and wrench-closure workspaces (WCW & WFW, indices commonly used to estimate performances). Thus, to keep the number of actuators at minimum while the number of cables is increased, it was proposed by our laboratory to use cable differentials in the architecture of the cable-driven robots. It is now required to design and built a small-scale prototype of such a cable-driven robot with a simple architecture to evaluate the results in practice.

## Project Description

The objective of the internship is mechanical designing and manufacturing a prototype of a planar differentially actuated cable robot:

1. Model the robot according to the existing schematic and design parameters;
2. Provide the drawings for manufacturing the components of the prototype;
3. Assembly of the parts of the prototype and experiments;
4. Write a technical report.

## Suggested Timetable

Task	Duration	Month 1				Month 2				Month 3				Month 4					
		Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15	Week 16	Week 17	Week 18
Phase 1	Reviewing the background	3 weeks	■	■	■														
	Conceptual design of the robot	2 weeks				■	■												
Phase 2	3D modeling of the Concept of the robot	2 weeks				■	■												
	Generating the drawings to be manufactured	1 weeks						■											
Phase 3	Selecting and ordering the standard parts	1 weeks							■										
	Construction of the components	4 weeks								■	■	■	■						
	Assembling the parts of the robot	1 weeks											■						
Phase 4	Running the robot and testing its performance	4 weeks												■	■	■	■		
	Writing a report on the results of the tests	2 weeks																■	■

## Supervisor

Mr. Lionel BIRGLEN, Associate Professor, Department of Mechanical Engineering

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## **#21: Area of Expertise: Mechanical Engineering**

### **Project Title**

Fluidelastic force measurements for steam-generator tube-support

### **Project Description**

Objectives of this internship are:

- a) To measure the fluid dynamic destabilizing (or stabilizing) force induced by flow through the SG support.
- b) To determine the fluid dynamic (negative or positive) damping induced by flow through the SG support.

The annular flow through the tube-support gap has been shown to induce tube instability. Experimental tests to determine the associated negative damping were successful only for the first mode tube instability. High mode instabilities have been shown to occur. These higher frequency modes have a much higher potential for causing tube wear. Due to the complexity of the support geometry, it is nearly impossible to estimate theoretically or numerically-via CFD - the instability forces responsible for tube wear. A direct dynamic force measurement test setup is therefore proposed. A short tube section is mounted on a pair of dynamic shakers. The tube section is subjected to flow (as done in the vibration tests); at the same time, it is subjected to a known motion to simulate a given mode. Force sensors measure the flow induced forces while tube motion is captured by laser vibrometers. The apparatus can measure the instability forces for different mode shapes and corresponding frequencies. Since the actual ROTSG support geometry is used, the true dynamic instability forces can be determined. These forces can be used for SG vibration design analysis and accurate estimation of tube wear.

### **Supervisor**

Mr. Njuki W.MUREITHI, Professor, Department of Mechanical Engineering

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

### **Project Title**

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

### **Project Description**

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.

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.

### **Skills required**

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>

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

### **Project Title**

A promising qubit for quantum computation: excitons bound to small molecules embedded in semiconductors.

### **Project Description**

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 Bloch 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.

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.

### **Skills required**

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  
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