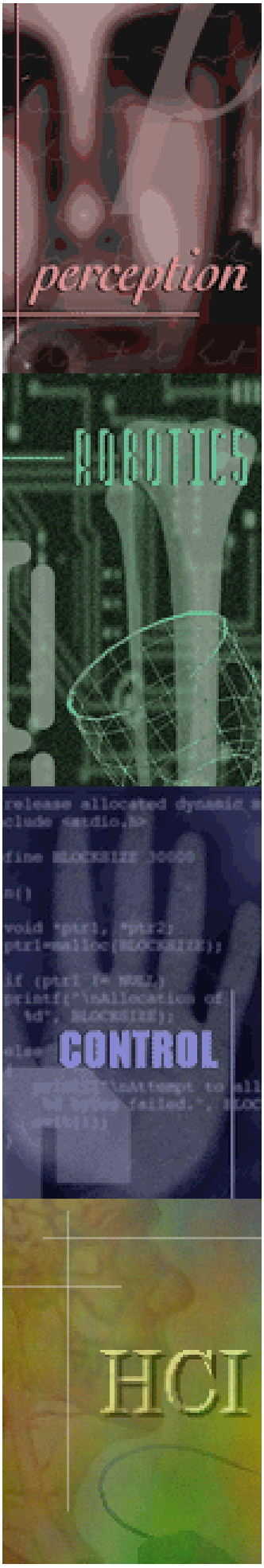

ANNUAL REPORT

JUNE 1, 2003 – MAY 31, 2004

Dr. Vincent Hayward
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Centre for Intelligent Machines
Centre de recherche sur les machines intelligentes
McGill University

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Centre for
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Content

Centre for Intelligent Machines
McGill University 2003-2004

Mission Statement

OBJECTIVES

CIM was formed in 1985 to foster multidisciplinary activities which transcend traditional departmental boundaries.

DEFINITION

Intelligent Systems are capable of adapting their goal-oriented behaviour by sensing and interpreting their environment, making decisions and plans, and then carrying out those plans using physical actions.

MISSION STATEMENT

The mission of CIM is to excel in the field of intelligent systems, stressing basic research, technology and development, and education. CIM seeks to advance the state of knowledge in robotics, automation, artificial intelligence, computer vision, and systems and control theory.

Summary and Background

The Centre for Intelligent Machines (CIM) supports research and graduate teaching in intelligent systems. The Centre includes twelve topical laboratories that support the work of nineteen professors from the Department of Electrical and Computer Engineering, the Department of Mechanical Engineering, and the School of Computer Science. It also has associate members in related disciplines at McGill and neighboring institutions.

The list of CIM full members is:

Jorge Angeles	**Tal Arbel**
Pierre Belanger	**Benoit Boulet**
Martin Buehler	**Peter Caines**
James Clark	**Jeremy Cooperstock**
Luca Cortelezzi	**Gregory Dudek**
Frank Ferrie	**Vincent Hayward**
Michael Langer	**Martin Levine**
Hannah Michalska	**Arun Misra**
Meyer Nahon	**Kaleem Siddiqi**
Paul Zsombor-Murray	

Intelligent Systems are broadly defined as those systems that are capable of sensing and interpreting an environment, be it natural or artificial, making goal-directed decisions and acting on these decisions to modify the environment. Specific examples that are relevant to our research are industrial processes, other intelligent machines such as autonomous robots, or humans interacting from separate locations. Intelligent Systems combine techniques from Artificial Intelligence, Artificial Perception, Robotics, and Systems and Control Theory.[1]

The research program is currently articulated around four themes designed to adapt to the rapid evolution of the sector of Intelligent Systems. These themes are artificial perception, robotics, systems and control, and human-machines interfaces.

The research conducted at CIM involves a considerable number of students and staff, and an important outcome of the Centre is the training of highly qualified personnel. The breadth of CIM's research makes it possible to offer a rich variety of graduate courses. Another important outcome of our Centre is the creation of intellectual property and spin-off companies. Integrated into the

academic activities of two faculties – Engineering and Science – CIM has an established national and international reputation that consistently attracts new faculty and students. Since its inception in 1985, the Centre has maintained a high level of academic excellence and senior members are internationally recognized leaders in their respective areas.

In addition to the present 19 academic members, the human resources amount to over 100 graduate students, and about 10 post-doctoral fellows or visiting scholars, on average). The physical resources comprise a nearly contiguous collection of offices, laboratories, meeting rooms, and space dedicated to house an extensive information system. This adds up to 14,000 square feet distributed over three floors of the McConnell Engineering Building on the main McGill campus and a small section of an adjacent building. We consider this proximity to be an important feature of the Centre. It creates a working community where we naturally and regularly meet, and interact with each other. This year, the Center was allowed to expand with new laboratory space on the 5th floor of the McConnell Engineering Bldg.

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[1] Intelligent Systems is a distinct economic sector which, in Canada, is multi-billion industry. ("A Profile of Canada's Intelligent Systems Industry", Birkenheier & Associates, 2003).

Faculty Members

Name	Email @cim.mcgill.ca	Phone (514) 398-	Department
Angeles, Jorge	angeles	6315	Mechanical Engineering
Arbel, Tal	arbel	8204	Electrical and Computer Engineering
Belanger, Pierre	belanger	8348	Electrical and Computer Engineering
Boulet, Benoit	boulet	1478	Electrical and Computer Engineering
Buehler, Martin	buehler	8985	Mechanical Engineering
Caines, Peter	peterc	7129	Electrical and Computer Engineering
Clark, James	clark	2654	Electrical and Computer Engineering
Cooperstock, Jeremy	jer	5992	Electrical and Computer Engineering
Cortelezzi, Luca	crtlz	6299	Mechanical Engineering
Dudek, Gregory	dudek	4325	School of Computer Science
Ferrie, Frank	ferrie	6042	Electrical and Computer Engineering
Hayward, Vincent	hayward	5006	Electrical and Computer Engineering
Langer, Michael	langer	3740	School of Computer Science
Levine, Martin	levine	7115	Electrical and Computer Engineering
Michalska, Hannah	michalsk	3053	Electrical and Computer Engineering
Misra, Arun	misra	6288	Mechanical Engineering
Nahon, Meyer	mnahon	2383	Mechanical Engineering
Siddiqi, Kaleem	siddiqi	3371	School of Computer Science
Zsombor-Murray, Paul	paul	6311	Mechanical Engineering

Research Highlights and Performance

SCIENTIFIC OUTPUT

CIM's presence in the community of researchers in areas related to intelligent systems remains prominent. In 2003-2004, scientific contributions by CIM's members comprised 29 articles in refereed journals, 71 articles in refereed conference proceedings, 11 book chapters and 2 books published. Three CIM members have been invited to contribute to the planned *Springer Handbook of Robotics*, edited by Professors Siciliano (Naples) and Khatib (Stanford).

RESEARCH TRAINING (HQP)

As in previous years, CIM continued to play a leading role in research and training at the global scale. CIM faculty and students contributed original work at local, national and international forums. The training aspect of this participation is key in the teaching of our graduate students, who are encouraged to face a community of international scholars early in their research careers. In 2003-2004, the student population of CIM consisted of 67 Master's, 54 PhD's and 3 Postdoctoral Fellows, as well as 2 Visiting Scholars, 4 Visiting Foreign Students and 9 Research Assistants/Associates.

While CIM's role in graduate teaching is well recognized both within and outside the university, at the undergraduate level, CIM contributes substantially in various ways. In addition to the 15-20 undergrad courses taught by the CIM faculty members, the Centre: i) makes its research facilities available to CIM research personnel for purposes of developing courses ii) provides the academic departments with excellent teaching assistants drawn from our pool of graduate students, and iii) provides a continuous source of undergraduate projects, and the facilities to conduct them, to the various departments. In 2003-2004, there were 8 undergraduates conducting their project thesis work in the labs of CIM.

FUNDING

CIM members have enjoyed success in attracting funding for core research and infrastructure. The average annual funding to the members from all sources for 2003-2004 was approximately $3.1M/year. This funding breakdown is as follows:

- Federal Agencies: $607K/year from NSERC research grants: $474K/year from NSERC Strategic grants; $543K/year from NCE grants; $459K/year from CFI grants; and $478K/year from industrial and other sources.

- Provincial Agencies: $350K/year from NATEQ/FQRNT/FCAR funding; $195K/year from VRQ funding; and $22K/year from industrial and other sources. .

International and national collaborations remained at the forefront of research activities within the Centre, reflected strongly in the Canadian Foundation for Innovation program. This past year, seven members were receiving CFI funding; three members were participating in multi-collaborative CFI projects; and three members were involved in major VRQ projects.

The National Centres of Excellence Program continues to play a significant role in inter-university research programs within CIM. IRIS/Precarn projects involve Profs. James Clark and Jeremy Cooperstock: “Parallel Distributed Camera Arrays” and “Visual Information for Surveillance and Teleconferencing Applications” (with James Elder); Prof. Vincent Hayward: “Foundations of Haptic Interfaces for Virtual Environments and Communications”. “Reality-Based Modeling and Simulation of Physical Systems in Virtual Environments” and “Intelligent Tools for Diagnosis and Intervention”; and Profs. Martin Buehler and Gregory Dudek in “AQUA: Autonomous Aquatic Walking Robots”(with Michael Jenkins).

CIM members are also heavily involved in the MITACS, GEOIDE and AUTO 21 of the NCE.

NEW INITIATIVES

In April 2004, CIM was nominated by the McGill Vice-Pricicipal (Research) for the NSERC Brockhouse Prize for Interdisciplinary Research in Science and Engineering. The Brockhouse Prize recognizes outstanding Canadian teams of researchers from different disciplines who have come together to produce achievements of international significance. The results will be known in the fall of 2004.

The QERRAnet group held its first Workshop in Quebec City on November 14, 2003. Approximately 100 participants from McGill and Université Laval met at the Musée de la Civilisation for a full-day workshop. Also in attendance were officials from industry and government. Both students and faculty gave technical talks on current QERRAnet projects and developments.

Professor Benoit Boulet, Director of CIM's Industrial Automation Laboratory and Professor Vince Thomson, Werner Graupe Professor of Manufacturing Automation of McGill's Department of Mechanical Engineering were awarded a $672,000 grant over four years by the Natural Sciences and Engineering Research Council (NSERC) and the National Research Council (NRC) of Canada to establish a research program in advanced control of polymer forming processes. This research will be conducted in collaboration with Dr. Robert DiRaddo's team at the NRC's Industrial Materials Institute (IMI) located in Boucherville, Québec. The total budget of this research program is estimated at 2M$. The contribution from NSERC and NRC will allow the researchers to establish, in collaboration with IMI researchers, a world-class, cutting-edge research program in control of polymer forming processes, in particular thermoforming and blow moulding.

Professor Gregory Dudek and Professor Frank Ferrie received an NSERC Strategic Grant with industrial partner CAE. This award, entitled "Distributed Range Management Systems", will develop analytical methods, techniques and methodologies to support the development of software tools for building 3-D models of large complex environments from disparate physically separated sensors of range data.

CIM 's multidisciplinary training environment was instrumental in the creation of the NSERC Design Engineering Chair awarded to Professor Jorge Angeles in 2003. This Design Chair is also comprised of other CIM members -- Martin Buehler, Paul Zsombor-Murray and associate member Rosaire Mongrain.

INNOVATION

Within the mandate of a James McGill Chair, Professor J. Angeles and his group at the Robotic Mechanical Systems Laboratory are conducting research on the solution of design problems at the preliminary stages, when an embodiment, and hence, a sharp

mathematical model is not available. Various design schools have been scrutinized. Preliminary results indicate that design solutions aim at minimizing the entropy content of a design alternative. The challenge here is how to define the entropy of a design alternative, and to measure the entropy content of the alternative.

Research on mechanical transmissions has been underway at the Robotic Mechanical Systems Laboratory for the last 10 years or so. A family of speed reducers intended to replace spur, helical and bevel gears, has been developed. Novel transmissions under innovation can be implemented equally well using cam-roller pairs where conventional gear trains would be used.

SCARA systems are commonly used in the electronic industry to assemble printed-circuit boards and consumer goods with a flat geometry, such as cellular telephones. Current SCARA systems are invariably of the serial type. The only patented system of this kind, the H4 robot, developed by a French-Japanese team, is still undergoing development work. We are patenting an alternative system of the parallel type that uses fewer joints and links.

The Ambulatory Robotics Lab continued to produce exciting results in the field of legged robots. Many of the highlights of the Lab's work are available in video format on an interactive video display available to the public along the main corridor at CIM. Four robots are being developed in the Ambulatory Robotics Lab: the four-legged Scout II, the leg-wheel hybrid PAW, the six-legged cockroach-inspired RHex, and the RHex-derived swimming AQUA robots.

Scout II is the first robot to demonstrate galloping, and work on this gait has continued throughout the year. Apart from being the first robot to gallop, what is significant about the work conducted in the Ambulatory Robotics Lab is that it illustrates that the minimalist approach taken can produce a stable gallop gait; this is contrast to a group of researchers at Ohio State and Stanford which has to date been unsuccessful in attempting to achieve galloping on a far more complicated robot.

Other work on Scout II has examined how simple, essentially open-loop control laws have tremendous success in stabilizing complex running behaviors on complex systems like Scout II. In an attempt to explain why simple control laws are adequate in stabilizing tasks such as running we performed numerical studies which showed for

the first time that the dynamics of an open-loop passive model of Scout II alone can confer stability of the motion.

The PAW robot, a hybrid wheel-legged robot took its first steps this past year. It combines the bounding motion seen on the Scout II robot with rolling motion found in traditional wheeled vehicles. Unlike traditional wheeled platforms, though, PAW has the ability to change the position of its legs with respect to its body. Work on more energetic bounding gaits, as well as the gallop gait will be performed this year.

The AQUA robot was designed and built this past Fall. This robot has the same ability to walk on land as its predecessor, RHex, and is also capable of swimming underwater to a depth of 10m. By trading its half-circle shaped fiberglass legs for flexible flippers, AQUA is able to swim to a target location, and station-keep to make observations. Equipped with a number of on-board cameras, AQUA's purpose is to enable researchers at CIM, York, and Dalhousie to develop computer vision algorithms that allow the robot to recognize features and create a three-dimensional map of its field of view. The high-level goal of the project is create an autonomous underwater vehicle capable of locomotion by generating thrust via its flippers, or by walking on the ocean floor. It will be able to monitor the health of coral reefs, by making observations of the size and amount of coral and fish present.For more information and pictures of the robot, please see `www.aquarobot.net`

A freshly-assembled AQUA successfully completed field trials this past January at McGill's Bellairs Research Institute in Barbados, generating a good deal of publicity for McGill, and for the project's sponsor IRIS/PRECARN. A paper discussing the design of the AQUA and other RHex-based platforms is being presented at the Canadian Design Engineering Network (CDEN) Design Conference 2004, hosted by McGill. Future platform development plans include adding active buoyancy control, and inertial sensing and navigation to aid operator control, with a view towards becoming fully autonomous.

A pilot was completed by the Haptics Laboratory that demonstrated that a variant of the STReSS family of tactile display called VBD for Virtual Braille Display enable blind users to read Braille characters with high rate of success.

In a collaborative effort between the Haptics Laboratory and Professor Ellis of Queen's University, a new type of surgical instrument is being developed. They look and feel like traditional instruments but are able to enhance the tactile sensations experiences by the users.

SPIN-OFF COMPANIES

Traditionally, research at CIM has led to the creation of a number of companies, largely through our students, in the exploitation of technologies associated with our research program. A total of about 15 such companies have been created over the past decade.

This trend continued during the past year. CIM members were involved, either as founders, owners, or consultants in the following companies: ART Advanced Research Technologies Inc., Immersion and Coronado Systems Inc.

Former graduate student Dr. Mahvash founded, with Prof. Vincent Hayward and others at McGill, a company called Real-Contact Inc. involved in surgical simulators for training. Two graduate students supervised by Prof. Frank Ferrie started their own company as a direct result of their studies at McGill. This company, called SimActive Inc., develops software products for 3D modelling.

SimActive is one of only a handful of companies in Canada to receive funding under the Market Development Fund of the National Centres of Excellence GEOIDE program in 2003/2004. This program is intended to assist young entrepreneurs in the development of business strategies and marketing tools to apply effectively in the competitive marketplace.

COMMUNITY AT LARGE

CIM is often in the news and in popular science venues. The MRL laboratory, the ARL laboratory, the SRL, and the HL are frequent contributors to popular science magazines, general press science columns, and TV science shows. In the past few years:

Radio Canada International, PBS (U.K.), The Ottawa Citizen, The New RO, Canal Z Television Program (three times), CBC Radio Montréal and national (four times), Discovery Channel, Discover magazine, MIT Press, Montréal Global TV, McGill

Reporter (four times), Science & Technology News Network, BBC World Service, ABC World News with Peter Jennings, Science, In Focus, Engineering Newsletter, Computerworld, The Toronto Star, Financial Post, Télé-Québec, Maclean's, Discovery Channel, CJAD Radio, Globe & Mail Report on Business, TQS Double Clic!, Journal Le Monde des Affaires, The Montréal Gazette, Elle Québec, Briefing Digital, Interface: La Revue de la Recherche, American Society of Mechanical Engineers, Canal Vox: CityMag, Montréal Mirror (twice), Plan Mega, McGill News (two times), Radio Corporation of Singapore, Radio Canada, Financial Times Life/Technology, Journal de Montréal, Le Devoir, TVA CyberClub, La Presse, Nature News and Views, The Washington Post, Pour la Science, The New Scientist.

SEMINARS

An important aspect of CIM's collaborative and community spirit is the Seminar Series hosted by various groups within the Centre every year. The following is a sampling of the diverse seminar topics held in 2003/2004.

- **Efficient Tracking in Sparse Range Data with the Bounded Hough Transform**, Prof. Michael Greenspan, Robotics and Computer Vision Lab, Queens University, Kingston Ontario, *May 28 2004*
- **Surface Recovery From 3D Point Data Using a Combined Parametric and Geometric Flow Approach**, Peter Savadjiev, McGill University, *May 28, 2004*
- **Entropy-of-Likelihood Feature Points for Image Correspondence**, Matthew Toews, McGill University, *May 17, 2004*
- **Multi-Scale Geometric Flow for Segmenting Vasculature in MRI: Theory and Validation**, Maxime Descoteaux, McGill University, *May 7, 2004*
- **Optimum Design of Complex Mechanical Systems**, Dr. Joseph Zarka, CADLM, France, *April 16, 2004*
- **Mechatronics and Intelligent Control Research at CENIDET**, Dr. José Ascencio, National Centre for Research and Technology Development (CENIDET) Mexico, *March 26, 2004*
- **Real-Time Implementation of Phase-Correlation Stereo Algorithm using FPGAs**, W. James MacLean, ECE, University of Toronto, *March 22, 2004*
- **Remarks on General Spatial Involute Gearing**, Prof. Hellmuth Stachel, Vienna University of Technology, Austria, *March, 17, 2004*
- **Mechatronics Design and Development of Mobile Robots in NTU**, Dr. K.H. Low, Associate Professor, Nanyang Technological University, Singapore*, December 22, 2003*
- **On the Consistent Filtering of Convergent Semimartingales**, Dr. David Levanony, ECE, Ben-Gurion University, Israel, *October, 2003*

- **System Indentification for Ono-Parametric Structured Non-Linear Systems**, Kameshwar Poolla, University of California, Berkley, *September 8, 2003*
- **A Nonlinear System Inversion Approach for Chaos-Based Secure Communications**, Prof. Yufan Zheng, ECE, Melbourne University, Australia, *June 11, 2003*
- **Statistics of the Geometry of Object Populations**, Stephen M. Pizer, University of North Carolina, *June 11, 2003*

Honours, Awards and Recognitions

AWARDS TO FACULTY MEMBERS
(2003-2004)

Jorge Angles	Fellow	Royal Society of Canada
Benoit Boulet	William Dawson Scholar	McGill University
	Best Presentation of Session Award for "An LMI Approach to IMC-Based Robust Tunable Control"	American Control Conference
	Best Poster of Conference Award for "Interior Noise Environment of Future Automobiles"	AUTO21 NCE Scientific Conference
Peter Caines	Fellow	Royal Society of Canada
James Clark	Full Professor	ECE, McGill University
Gregory Dudek	William Dawson Scholar	McGill University
Frank Ferrie	Associate Dean (Research and Graduate Studies)	Faculty of Engineering, McGill University
Vincent Hayward	Outstanding Reviewer for Automatica	International Federation of Automatic Control
Michael Langer	Best Paper Award for "Estimating Camera Motion Through a 3D Cluttered Scene"	1st Canadian Conference on Computer and Robot Vision (CIPPRS) May 2004

AWARDS TO STUDENTS
(2003-2004)

Sylvain Bouix	Dean's Honour List - PhD	McGill University
Pavel Dimitrov	Dean's Honour List - MSc	McGill University
Hanifa Dostmohamed	Scholarship	Precarn
Gurman Singh Gill	Tomlinson Award	McGill University
Minyi Huang	Dean's Honour List - PhD	McGill University
Vincent Lévesque	Dean's Honour List - M.Eng	McGill University
	PGS – B Scholarship	NSERC
	B2 – Scholarship	NATEQ
	Scholarship	Precarn
Jonathan Israel Miller	CGS	NSERC
Jérôme Pasquero	Scholarship	IRIS/Precarn
Stéphane Pelletier	Dean's Honour List - M.Eng	McGill University
Alexandre Pichette	Academic All-Canadian (Swimming-Quebec conference)Canadian national team – World University Games	Royal Bank of Canada
Ioannis Poulakakis	Tomlinson Award	McGill University
Iakov Romanovski	Dean's Honour List - PhD	McGill University
Alessio Salerno	Major Fellowship	Hydro-Quebec/McGill University
Bhavin Shastri	Larson Award – First Place for the 2003 " Best Student Paper"	IEEE – International Conference on Robotics and Automation, Taiwan, Sept. 2003
Chin Pun Teng	Dean's Honour List - PhD	McGill University
Miguel Torres-Torriti	Dean's Honour List - PhD	McGill University

The facilities are now described along with their place in the thematic organization of the Centre – artificial perception, robotics, systems and control, and human-computer interfaces – and are lexicographically labeled for reference.

LABORATORIES SUPPORTING RESEARCH IN ARTIFICIAL PERCEPTION

APL – The *Artificial Perception Laboratory* addresses machine vision problems that combine appeal for applications with theoretical implications. Its primary goal has remained the same since the pioneering work of Profs. Levine and Zucker, i.e., to incorporate elements from biology, psychology, mathematical analysis, artificial intelligence and information theory to develop a computational theory that describes how visual data are interpreted in terms of form, structure, function and identity. Three professors are associated with this laboratory. Prof. Ferrie's research addresses, among others, feature detection in remote sensing imagery, and synthetic vision for use in search and rescue helicopters during missions with poor visibility conditions. Prof. Arbel develops a research program designed to develop statistical inference techniques to the analysis of medical images. She applies in particular the theory of probability to problems in neurology and neurosurgery. Prof. Langer is interested in modelling the visual appearance of natural scenes including phenomena such as shading, shadows and inter-reflections, occlusionsm and motion to solve fundamental vision problems. The facilities of APL include specialized sensors such as rangefinders, a LIDAR, high resolution cameras and supporting equipment such as a gantry positioner, controlled illumination sources, and stereo heads.

VRL – The *Computation, Visualization and Realization Laboratory* investigates another aspect of the processing of medical images. Prof. Siddiqi focuses on the problems of curve and surface evolution for segmentation and identification of anatomical structures. This is developed in a larger framework concerned with visual shape analysis for computer vision drawing from singularity theory, partial differential equations, and graph theory. This computational framework is common with the research of Prof. Cortelezzi concerned with the evolution of the solutions of partial differential equations. The facilities include a Beowulf cluster and scientific visualization tools.

VML – The *Vision-Motor Research Laboratory* investigates covert attention phenomena in humans for application to intelligent and adaptive displays. This research is carried out by modeling the link that exists between eye-movement generation and attention in humans. Prof. Clark's research also leads to the development of theories of perception described by mathematical manifolds and of their applications to machine vision. The Vision-Motor Research Laboratory's work relies on head and eye trackers, specialized electronics for high temporal resolution displays, and imaging devices.

LABORATORIES ASSOCIATED WITH HUMAN-MACHINE COMMUNICATION

HL – The *Haptics Laboratory* investigates the role of the sense of touch in human-machine systems. It began its activities with projects in rehabilitation and computer aided design, which subsequently attracted the interest of the Canadian Space Agency. This laboratory investigates problems in high-fidelity haptic simulation for surgical trainers and visualization. The laboratory develops devices, sensors and actuators which have a history of commercial outcomes. The facilities include a precision machining shop, haptic devices, a high-speed imaging system, and experimental real-time stations.

SRL – The *Shared Reality Laboratory* is concerned with systems that make it possible for persons or groups of persons to carry out collective activities (such as play music or attend courses), while being physically distant. This research uses immersive visual and audio environments connected by high-speed communication networks. Facilities include a Silicon Graphics Onyx II computer, sensors, high-performance networking and streaming equipment.

LABORATORIES INVESTIGATING MANIPULATION AND LOCOMOTION

RMSL – The *Robotic Mechanical Systems Laboratory* was founded over fifteen years ago by Profs. Angeles and Zsombor-Murray. Prof. Misra, a specialist in the dynamics of space mechanical structures, joined it several years ago. The laboratory addresses general problems in manipulator design and control via fundamental mathematical criteria that describe performance and robustness. For example, the concept of natural orthogonal

complement that describes the reciprocity relationships in multibody systems, rigid or flexible is a contribution of the laboratory that broadly advanced the theory of mechanisms. Two recent hires, Prof. Meyer Nahon and Prof. Inna Sharf (associate member) are specialists in space and other complex structures. A noteworthy output of the laboratory is a suite of computer packages for synthesis and design of advanced mechanical systems, as well as high-performance stiff, friction-free, and backlash-free transmissions. The laboratory activities are supported by computer-aided design tools, test benches, and associated instrumentation.

ARL – The *Ambulatory Robotics Laboratory* is devoted to dynamic legged robot development. Prof. Buehler's research combines elements of biology, animal locomotion, mechatronics, advanced systems and control engineering to build robots which have the unparallelled ability to successfully cope with unpredictable environments, indoors or outdoors, in urban or in natural locations. This research also pursues basic research such as the robust stability of nonlinear systems or hierarchical control theories. The applications are as diverse as the automation of lawnmowers and the development of de-mining vehicles. The research relies on facilities such as machining equipment, rapid prototyping, embedded system development benches, sensor and actuator test benches, telemetry, as well as an array of special sensors.

MRL – Autonomy, from the viewpoint of a robot's ability to know where it is and to decide what to do, is the focus of the research of the *Mobile Robotics Laboratory*. Prof. Dudek looks at fundamental problems in data fusion to provide information relevant to navigation, given evidence provided by multiple sensors, be it visual, telemetric, odometric, sonar, or inertial. One other aspect of this research is concerned with the generation of goal-directed behaviors with an emphasis on multiple robots or agents capable of collaborative coordination. This facility includes a family of mobile wheeled robots, image acquisition and processing hardware, wireless communication devices, and a suite of specialized sensors.

THEME OF SYSTEMS AND CONTROL

CG – The control group, consisting of Profs. Belanger, Boulet, Caines and Michalska, works on stochastic, hybrid, hierarchical and discrete-event systems. Developments in each of these areas combine vigorous theoretical advances with far ranging implications

that concern many contemporary technological and industrial systems. Recent theoretical breakthroughs include state aggregation techniques (using dynamic consistency) that effectively reduce the nominal combinatorial complexity of systems for robust control purposes. Other advances address non-linear controllability theory, discrete-event systems, vector systems and the recently developed "multi-agent product". The facilities that support the work of this group are computational in nature, since the simulation of these systems require large amounts of mathematical calculations.

IAL – The *Industrial Automation Laboratory* works on robust control of Industrial processes that typically change over time. The control must be tunable and guarantee a given level of performance. Prof. Boulet investigates approaches such as robust multivariable tunable control using H^{∞} theory and robust model predictive control. Other work is concerned with robust flight control necessitating model reduction techniques of models of uncertainty. The facilities, in addition to high performance computing, include an experimental process simulator that can represent the systems of interest.

Common Facilities

SCIENTIFIC LINKAGES

Profs. Arbel, Ferrie, Siddiqi, and Hayward share a common interest in biomedical problems that involve the identification and localization of anatomical structures from imaging data. This refers to segmentation, registration, movement tracking, and classification of cerebral structures for purposes of pre-operative planning, intra-operative guidance and visualization. Some of this research is carried out under the auspices of the federal Network of Centres of Excellence (NCE) in collaboration with researchers at the Montreal Neurological Institute (MNI), the Robart Research Institute (RRI), or in other cases as part of national and international collaborations (Yale, University of Toronto, University of Venice). These activities benefit from common tools, such as visualization toolkits, and techniques.

Vision research is of historical importance for CIM. Arbel, Ferrie, Langer, Levine, Siddiqi, Clark, and Dudek form the largest vision research group in Canada. As a whole, this group addresses almost all of the contemporary areas of vision research. Examples of a cross-cutting issues are the topics of active vision, gaze planning, and segmentation, which prominent problems in almost all domain-specific applications already mentioned: medical image processing, remote sensing, robotics, perception, and human-machine interfaces. Hardware and software tools, laboratory facilities, computational techniques, and know-how are shared so that these research activities greatly benefit from resource leverage in terms purchases, maintenance and operation. Collaborations include Laval University, UQAM, Ecole Polytechnique, Université de Nice, the Canadian Space Agency and others.

A subset of CIM members share an interest in human perception. In vision, Langer's research on models of visual appearance, Siddiqi's work on shape analysis, and Clark's pre- and post-motor models of visual attention are all motivated to a large extent by problems in biological perception. In the domain of touch/haptics, Hayward investigates shape perception mediated by distributed skin deformation and by net displacement-force relationships. These researchers are involved in psychophysical experiments related to the above problems. Most of the experiments have in the past been carried out elsewhere, for example, at Rutgers and Yale (U.S.A.), the Max-Planck-Institute for Biological Cybernetics

(Germany), the University of Paris (France), AIST-Tsukuba (Japan), and here in Canada at UBC, York, or Queen's University.

High-Performance Computing is also of common interest for Siddiqi, Ferrie (medical image processing, geomatics), Caines (hierarchical and large systems, discrete-events and hybrid systems), Dudek (multi-agents), Cortelezzi (simulation and control of unsteady flows) and Hayward (tissue response). High performance computing facilities are essential to many of CIM's activities in visualization and physical modeling. Similarly, multi-media streaming and related facilities are central to the research of Profs. Cooperstock (sound and video), Clark (video), and more recently Hayward (vibro-tactile).

Robotic and mechatronic control is also an area of interest that is common to several CIM researchers. This research is closely linked to work in design since prototypes must invariably be developed from components and, as it is more the rule than the exception, directly from materials. Buehler's ambulatory robots, Dudek's instrumented mobile robots, Angeles' high-performance manipulators and transmission, Hayward's haptic devices and tactile displays, are examples of research activities that will benefit from improved access to existing facilities. Similarly, the activities often take place within national and international collaborations including the University of Singapore, Laval University, Technion, Xerox Parc, LAAS-CNRS, The University of Michigan, Carnegie Mellon, DRES, and others.

LARGE PHYSICAL FACILITIES

As a result of several successful CFI grant applications, the Centre became equipped with several facilities of common interest. The summary of awards is:

CFI awards within CIM:

- "Shared Reality Environment" (*Cooperstock***,** *Clark*, 0.5 M$ **)**
- "Computation, Visualization and Realization Laboratory" (*Siddiqi*, Cortelezzi, 2 others, 0.5M$)
- "Industrial Automation Laboratory"(*Boulet*, 0.25M$)
- "Computer Vision,Medical Imaging and Perceptual Modelling Lab" (Arbel, Langer, 0.4M$)

CFI awards and applications with CIM involvement:

- "Centre for Interdisiciplinary Research in Music, Media and Technology" (*Wozcznyk*, Cooperstock, Hayward, and 3 others, 10M$)
- "Research Facilities for Non-intrusive, Near field, Subsurface Sensing and Imaging of Geo-structures and Civil Infrastructure" (*Hassani*, Ferrie, and 3 others, 0.4 M$)
- "Consortium Laval-UQAM-McGill and Eastern Québec (CLUMEQ) for High Performance Computational Simulation and Visualization" (*Habashi*, Ferrie, and 8 others, 4M$)

VRQ awards and applications with CIM involvement:

- "Image, video et multimedia: search, indexation and navigation" (*Ziou*, Ferrie and 4 others, 1M$) Awarded
- "Real-time communication of high-resolution multi-sensory content via broadband networks" (*Wozcznyk*, Cooperstock, Hayward, and 9 others, 2.5M$).

The "Computation, Visualization and Realization Laboratory" comprises three related facilities. For computation, a Beowulf cluster (presently 32 nodes, 64 planned) makes it possible to develop and test algorithms for large-scale matrix problems such as those arising in computer vision, fluid dynamics, and other computational simulation of physical phenomena. Current efforts are focused on the creation of computer code able to simulate complex phenomena involving vorticity and boundary free problems and to also simulate intelligent control of these phenonema. This facility is concerned with the computational simulation of the evolution of surfaces and curves processes as they related to computer vision and in bio-medicine problems. For visualization, a suite of graphical tools (installed or under development) provide high speed three-dimensional rendering to accurately represent complicated time-dependent vector fields associated with the results of these simulations. The centerpiece of the realization facility is a rapid prototyping machine that makes it possible to create free-form parts made from a variety of plastic materials for visualization.

The "Shared Reality Environment" is a facility that involves a variety of sensors and displays that are networked so that their response, their behavior, and the content can be manipulated with accuracy. One use of this facility is to provide an immersive environment that enables users to carry out a common activity from different locations to create the experience of sharing a common space. Important components of this facility are software packages and

hardware devices capable of human-rate compatible media-streaming. This means data-streams holding a human-compatible content (such as visuals, sound, or haptic signals) can be transmitted, processed, logged, stored and retrieved at human compatible rates. This also means that the transduced physical signals must be spatially and temporally registered with an accuracy that is compatible with the task in which the users are engaged. This implies that the system's behavior must be correlated with its users' actions, and possibly, with their intentions and their attention. This facility includes high resolution multiple visual displays, sound sampling and reproduction with spatialization. Work is under way to include also vibrotactile signals.

Uniqueness of the Centre

The history of the Centre for Intelligent Machines dates back to the late 1960's with the founding of the McGill Computer Vision and Graphics Laboratory by Martin D. Levine, the first such laboratory in Canada and one of a pioneering handful in the world. At that time the very idea of processing images by computer was revolutionary, hence a collaborative effort in developing new technologies to acquire and display information in order to do the basic science. Availability of this infrastructure led to some of the first research in automated cytology and biomedical image processing in the early 1970's. In the 1980's CIM was one of the first ARPANet sites outside of the US – mcrcim.mcgill.edu – and spawned the first robotics laboratory in Canada. Today CIM is comprised of twelve topical laboratories (excluding shared computational facilities) organized along specific themes that are available to the entire community. This uniqueness, relative to similar resources in Canada and abroad, is briefly summarized below.

AMBULATORY ROBOTICS LABORATORY
(ARL)

Director: Martin Buehler

This is one of the top 5 laboratories in North America devoted to the study of legged locomotion, with a particular emphasis on biologically inspired design, and is the only laboratory of its kind in Canada. It includes numerous hopping and walking robots developed by laboratory scientists, including the Hexapod and AQUA robot featured prominently in IRIS/PRECARN autonomous robotics research. The laboratory also includes special purpose test, measurement and data acquisition systems necessary to support this research.

APPEARANCE MODELLING LABORATORY
(AML)

Director: Michael Langer

The Appearance Modelling Laboratory carries out basic research in computer vision, computer graphics, and human visual psychophysics. It is the only lab in Canada that addresses vision problems from all of these perspectives. The equipment in the lab is provided by CFI and includes several high end workstations and measurement devices such as digital cameras, a spectral radiometer, and a photometer for carrying out calibrating imaging.

ARTIFICIAL PERCEPTION LABORATORY
(APL)

Director: Frank Ferrie

This lab is one of 3 in Canada (excluding facilities at the NRC) equipped to perform 3-D imaging using a number of different modalities (laser triangulation using plane of light and autosynchronized scanning, LIDAR, stereography, depth from defocus, and sonar). The laboratory also includes several precision manipulator systems (CRS 3000 series gantry robot system, PUMA 500 & 260 manipulators, and numerous linear and rotational positioning stages), as well as an extensive software library for data acquisition, robot control, and interpretation of 2-D and 3-D images.

COMPUTATION VISUALIZATION AND REALIZATION LABORATORY
(CVRL)

Director: Kaleem Siddiqi

Made possible by a recent CFI award, the CVRL includes facilities for high performance computation (a Beowulf cluster with 32 CPU's), rapid prototyping (Stratasys FDM 3000 rapid prototyping machine), and scientific visualization (SGI workstations and software). It is our only accessible facility for rapid prototyping in the Montréal area, and a tremendous boon to our research program.

CONTENT-BASED IMAGE RETRIEVAL
(CBIR)

Director: Martin Levine

The CBIR facility is the repository of an extensive set of software tools for non-textual database indexing and image retrieval. Developed over the years at McGill, the CBIR facility ranks among the top tier of research worldwide and has led to the development of several commercial successes.

HAPTICS LABORATORY
(HL)

Director: Vincent Hayward

The work is world renowned for both fundamental scientific contributions as well as applied research. It is equipped to cover a broad spectrum of research, ranging from the development of novel displays to systems involving haptic interaction (e.g. force feedback). The laboratory includes facilities for the fabrication and

testing of haptic devices (machining, electronics, and measurement systems), specialized computational resources (real-time systems, high performance numerical simulation) and psychophysical testing (specialized manipulators and force measuring systems).

INDUSTRIAL AUTOMATION LABORATORY (IAL)

Director: Benoit Boulet

The result of another recent CFI award, the IAL was designed to provide an experimental platform for investigating systems and control theory in a context relevant to modern industrial control. It includes a Feedback Systems Model 38-100 Basic Process Rig and a Model 38-600 Temperature Process Rig, which are capable of emulating the kinds of processes typical of real-world environments. Together with the related computational facilities, the IAL is one of 3 comparable facility in Canada.

MEDICAL IMAGE ANALYSIS LABORATORY (MIAL)

Director: Tal Arbel

Resulting from a recent CFI award, the MIAL focuses on applications of research in computer vision to problems in medical imaging, with particular emphasis on building tools for image-guided neurosurgery and spine surgery. The laboratory includes cutting edge equipment found in modern operating rooms worldwide including a portable ultrasound machine, a POLARIS tracking system, and high-end workstations.

MOBILE ROBOTICS LABORATORY (MRL)

Director: Gregory Dudek

This laboratory addresses high-level aspects of autonomous systems research such as environmental modeling, task planning, cooperative execution involving multiple robots, and distributed intelligence. The largest facility of its kind in Canada, and one of the top 10 in North America, its equipment includes six mobile robots (one Nomadic Technologies Nomad 200, 3 Nomad Superscouts, 1 RWI B-12, and a Cyberworks prototype maintence robot), analog and digital telemetry systems, optical and sonar sensing systems (LIDAR, optical triangulation, sonar arrays, etc.),

plus an extensive library of software developed over a period of 10 years.

***MOTOR VISION LABORATORY* (MVL)**

Director: James Clark

The MVL is another laboratory created as a result of a recent CFI award, with emphasis on the understanding of visual attention. As such the laboratory is equipped with facilities for tracking the state of human observers as they perform visual tasks. Equipment includes an ISCAN eye tracking system, numerous video capture systems, calibrated displays for psychophysical experiments, and robotic systems for positioning various imagers.

***ROBOTIC MECHANICAL SYSTEMS LABORATORY* (RMSL)**

Director: Jorge Angeles

The RMSL provides experimental support for research in manipulator design and control, ranging from computational support in the form of computer aided design and simulation to the physical realization of novel manipulator systems. In addition to the manipulators designed by laboratory scientists (DIESTRO, RE-DIESTRO), facilities include generic robot control systems, test facilities for servomechanisms, measurement systems such as end-point trackers, force transducers, and various data acquisition systems for performance measurement. The RMSL ranks among the top robotics research facilities in Canada.

***SHARED REALITY LABORATORY AND ENVIRONMENT* (SRL)**

Director: Jeremy Cooperstock

The SRL is another facility made possible by a recent CFI grant, and is perhaps the most unique facility of its kind in Canada (and one of a handful in the world). Its novelty lies in the concept of interconnected room-sized immersive displays, modeled on the University of Chicago CAVE, but 3-sided, for the purpose of creating virtual shared environments across different physical locations One display room has been completed with others under construction. In addition to the display hardware, facilities include various kinds of imagers and sensors, high speed networking

facilities, video streaming facilities, as well as a Silicon Graphics Onyx II computer system equipped with dual processors.

GENERAL COMPUTATIONAL FACILITIES

Each of the Centre's laboratories share a large and commonly-supported information system, partially funded by the recent NSERC Major Equipment Grant as well CFI awards held by CIM members. General facilities include approximately 100 high performance workstations coupled through a fully switched network (100/1000 Mbps). Management is centralized through an Auspex Model NS2000 network server supporting cross-platform file sharing NFS and CIFS with 800 GB of RAID5 configured disk space, and centralized backup system. Work is underway to replace the current network server with the EMC Network Attached Storage (NAS) Model NS600 comprised of 1.8 TB of high performance, high reliability disk storage.

Operation and Management

OPERATION

The operation of the facility is driven by our collective research needs with an eye towards innovation and economies of scale. Resources are fully shared among a Faculty of 19 scientists and in excess of 100 graduate students (not to mention postdocs, visitors, and associate members from the McGill community and the Montréal area). In fact, five of our most recent hires in the Faculties of Science and Engineering accepted positions at McGill largely because of the presence of the Centre and the opportunity to interact with CIM members. There are over 100 research programs (research grants, collaborative research programs, research contracts, etc.) currently supported by the CIM facilities. This amounts, on average, to between 2 and 3 million dollars per year of funded research. Perhaps more importantly, there are few institutions in the world that can provide comparable training for graduate students and postdoctoral fellows.

With regard to the ability of the Facility to accommodate the needs of the research community, we have been successful over the years in attracting funding from numerous sources (NSERC, NCE, CFI, FCAR, DARPA, Canadian, U.S., and other foreign industries), and have used this, in part, to support the acquisition of state-of-the-art research facilities.

MANAGEMENT

The Centre for Intelligent Machines was formally recognized by McGill University 18 years ago and is therefore subject to university approved regulations and operating procedures. CIM reports annually to the Dean of the Faculty of Engineering and the University Vice-Principal (Research). Scientific leadership is provided by a Director, a position that is voted upon every three years by an advisory committee as mandated by the University. Internally, formal policies and procedures are followed with respect to recruitment of new members and the review process for existing members. The membership meets regularly to discuss and sometimes vote on formal matters of collective importance: membership issues, space allocation, major purchases and Centre

grant applications. There is a natural partition between the scientific management of the Centre, represented by the Director and the membership, and the operational side, represented by administrative and technical staff.

The technical and administrative personnel comprises four persons, two of whom have technical responsibilities, and two have administrative responsibilities: a manager and an administrative assistant. The ratio of support personnel to scientific user population (professors and students) is thus 1:30.

Director:	Vincent Hayward
Manager:	Marlene Gray
Systems Manager:	Jan Binder
Systems Programmer:	Daniel (Danny) Chouinard
Administrator:	Cynthia Eileen Davidson
Faculty Members:	19

Student Information

Professor	Department	Masters	PhD	Researcher	PDF	Visiting Prof.	Foreign students	Under-graduates	
Angeles	ME	5	5.5†	2	2	2	2	0	
Buehler	ME	2	0	0	0	0	0	0	
Cortelezzi	ME	3	1	0	0	0	1	0	
Misra	ME	0	0	0	0	0	0	0	
Nahon	ME	4	4	1	0	0	0	1	
Zsombor-Murray	ME	3	1	1	0	0	1	0	
Total		**17**	**13.5**	**4**	**2**	**2**	**4**	**1**	
Arbel	ECE	3	2	0	0	0	0	0	
Belanger	ECE	0	0	0	1	0	0	0	
Boulet	ECE	6.5	2	1	0	0	0	0	
Caines	ECE	2	1	0	0	0	0	0	
Clark	ECE	4	6	0	0	0	0	0	
Cooperstock	ECE	7	6	2	0	0	0	0	
Ferrie	ECE	4	4	0	0	0	0	3	
Hayward	ECE	5	3	1	0	0	0	0	
Levine	ECE	6	2	1	0	0	1	1	
Michalska	ECE	3	9.5	0	0	0	2	0	
Total		**40.5**	**35.5**	**4**	**1**	**0**	**0**	**5**	
Dudek	SOCS	3.5	3	1	0	0	0	3	
Langer	SOCS	4	0	0	0	0	0	0	
Siddiqi	SOCS	2	2	0	0	0	0	0	
Total		**9.5**	**5**	**1**	**0**	**0**	**0**	**0**	
GRAND TOTAL		**67**	**54**	**9**	**3**	**2**	**4**	**8**	**147**

Summary

Faculty Members	19	PhD Students	54
Technical Staff	2	M.Eng. and M.Sc. Students	67
Administrative Staff	2	Research Associates	9
Postdoctoral Fellows	3	Visiting Research Students	4
Visiting Scientists	2	Undergraduate Project Students	8

† 0.5 = co-supervised

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Ahmedali, Trevor	M.Eng.	Clark	Reconfigurable Computing for Video Processing
Ajersch, Mark	M.Eng.	Boulet	Modelling and Control of Sheet Reheat in Thermoforming
Ayoub, Omar	M.Eng.	Hayward	TBA
Bhattacharyya, Jisnu	M.Eng.	Levine	Linear Virtual Sensor to Eliminate the Effects of Shadows and Specularities
Boussemart, Yves	M.Eng.	Cooperstock	Gestural Interfaces in Immersive Environment
Boyer, Alexandre	M.Eng.	Boulet	SISO Robust Tunable Control Design
Campion, Gianni	M.Eng.	Hayward	High Fidelity Computer Graphics for Surgical Simulation
Cardou, Philippe	M.Eng.	Angeles	Estimation of the Pose and Twist of a Rigid Body From Acceleration Measurements
Castrillon, Manuel	M.Eng.	Clark	Partial Reconfiguration
Deschênes, François	M.Eng.	Nahon	Study of Some Leash Control Techniques For the LAR Radio Telescope
Dostmohamed, Hanifa	M.Eng.	Hayward	Presentation of a Haptic Device for Relay of Shape Information Without the Use of Force Feedback
Duquette, Jonathan	M.Eng.	Cortelezzi	TBA
Epstein, Neil	M.Eng.	Cortelezzi	Characterization Of Jet In Crossflow Parameters For Optimum Mixing

Garroway, Diana	M.Eng.	Hayward	Haptic Interaction for 3D Animation
Georgiades, Christina	M.Eng.	Nahon	Simulation and Control of a Six-Legged Robot in a 3D Environment
Gipsman, Daria	M.Eng.	Langer	TBA
Haccoun, Laurent	M.Eng.	Boulet/Michalska	Three-Dimensional Position Control of a Magnetically Levitated Object
Hadjimichael, Basil	M.Eng.	Boulet	Modular-Based Control for Manufacturing Execution Systems Applied to Steel Scheduling
Harmouche, Rola	M.Eng.	Arbel	TBA
Hilario, Maria Nadia	M.Eng.	Cooperstock	Camera-Projector Calibration for Occlusion Detection in Front Projection Environments.
Jin, Ming	M.Eng.	Zsombor-Murray	Arc-Length Based Parametric Cubic for Real-Time Gaming
Jolicoeur, Marie-Pierre	M.Eng.	Boulet	TBA
Kadoury, Samuel	M.Eng.	Levine	Locally Linear Embedding for Face Detection
Lalli, Gino	M.Eng.	Boulet	Control of Extruded Parison Lengths
Laporte, Catherine	M.Eng.	Arbel	Entropy-Based Aspect Graphs for Active Object Recognition
Laprise, Pierre-Olivier	M.Eng.	Clark	Computer Vision Using Parallel Distributed Processing and Reconfigurable Computing
Law, Albert	M.Eng.	Ferrie	TBA
Liu, Guoxin	M.Eng.	Angeles	TBA

Ma, Zhongjing	M.Eng.	Caines	Rate Control
Mbonye, Kwizera Philip	M.Eng.	Ferrie	TBA
McCallum, Jacqueline	M.Eng.	Buehler	Rhex Downstairs Climbing
Miller, Jonathan Israel	M.Eng.	Nahon	TBA
Nair, Vinod	M.Eng.	Clark	Distributed Video
Ndrialisoa, Rija Y Raserijuonia	M.Eng.	Angeles	The Design of a Parallel Shoenflies-Motion Generator
Neil Neville	M.Eng.	Buehler	Dynamic Behaviours for the RHex Hexapod Robot
Nie, Jun	M.Eng.	Zsombor-Murray	Planar Dyads, Four-Bar and Image Space Insight Upon the Design Problem
Patel, Ketan	M.Eng.	Sharf	Contact Parameter Estimation in Frequency Domain
Perez, Michael	M.Eng.	Cooperstock	Automated Door Attendant
Pichette, Alexandre	M.Eng.	Michalska	TBA
Qu, Wei	M.Eng.	Caines	TBA
Rajwade, Ajit	M.Eng.	Levine/Dudek	Facial Pose Estimation, Feature Extraction and Recognition From 3D Shape Information
Riggi, Frank	M.Eng.	Arbel	TBA
Rouix, Francois	M.Eng.	Cooperstock	Gesture Recognition

Roumy, Jean-Gabriel	M.Eng.	Boulet	Active Control of Vibrations of a Car Chassis
Ruzzeh, Bilal	M.Eng.	Cortelezzi	TBA
Sato, Akihiro	M.Eng.	Buehler	Development and Control of a Bipedal Robot using Electric Motors
Sud, Daniel	M.Eng.	Cooperstock	Hand Tracking for Gesture Recognition
Toews, Matthew	M.Eng.	Arbel	Optimal Feature Points for Image Correspondence
Wei, Wei	M.Eng.	Zsombor-Murray	Extreme Distance Between Spatial Circles
Wozniewski, Michael	M.Eng.	Cooperstock	Gesture Acquisition & Gesture-Based Interaction
Yao, Hsin-Yun	M.Eng.	Hayward	Touch Amplication On Instrument Applied to Arthroscopy
Zhang, Xiang	M.Eng.	Angeles	The Innovative Design of Planetary Cam-Roller Trains
Zoughbi, Gregory	M.Eng.	Levine	TBA
Bhatia, Aditya	M.Sc.	Langer	TBA
Descoteaux, Maxime	M.Sc.	Siddiqi	Multi-Scale Geometric Flow for Segmenting Vasculature in MRI: Theory and Quantitative Validation
DiMarco, Paul	M.Sc.	Dudek	TBA
Dimitov, Pavel	M.Sc.	Siddiqi	Shapes, Parts and Recognition
Farasat, Yousef	M.Sc.	Langer	TBA

Ghandi, Maulin	M.Sc.	Levine	Automatic Age Progression in Human Face Images
Marinakis, Dimitri	M.Sc.	Dudek	TBA
Mathur, Moses	M.Sc.	Langer	TBA
Phillips, Carlos	M.Sc.	Siddiqi	View-Based Object Representations
Rao, Malvika	M.Sc.	Dudek/Whitesides	A Randomized Algorithm for Robot Localization in a Self-Similar Environment
Zhang, Linqiao	M.Sc.	Langer	Rendering Falling Snow Using an Inverse Fournier Transform
Alstrom, Bruce	Ph.D.	Michalska	TBA
Al-Widyan, Khalid	Ph.D.	Angeles	Robust Design of Robotic Mechanical Systems
Arseneau, Shawn	Ph.D.	Cooperstock	Occlusion Detection In the Spatiotemporal Domain
Bégin, Isabelle	Ph.D.	Ferrie	Blind Super-Resolution Using a Learning-Based Approach
Boily, David	Ph.D.	Michalska	TBA
Bourque, Eric	Ph.D.	Dudek	Automated Parameter Estimation for Procedural Texturing
Brooks, Rupert	Ph.D.	Arbel	Active Vision for Optimal Sensor Placement in Image Guided Neurosurgery
Cadotte, Patrick	Ph.D.	Michalska	Control of Systems With Repeated Pertubations and Time-Domain Performance Objectives
Campbell, Jennifer	Ph.D.	Siddiqi	TBA

Cayouette, Francois	Ph.D.	Cooperstock	Tracking Objects in a Generic Scene in Real-Time
Cebula, Andrzej	Ph.D.	Zsombor-Murray	Use of NURBS to Avoid Boundary Orientation Poses in Serial Manipulators
Chen, Chao	Ph.D.	Angeles	The Conceptual Design of Epicyclic Mechanical Transmission
Dionne, Dany	Ph.D.	Michalska	Application of a GLR Detector/Estimator to the Terminal Guidance Problem…
Drissi-Smaili, Fatima	Ph.D.	Clark	Object Recognition
Duan, YingXuan	Ph.D.	Boulet	Robust Tunable Control
Ehtiati, Tina	Ph.D.	Clark	Attention Models for View-Based Object Recognition
Garden, Matthew	Ph.D.	Dudek	Enhancing Recommendation Using Multiple Cues
Gauthier, Guy	Ph.D.	Boulet	Iterative Learning Control
Gill, Gurman Singh	Ph.D.	Levine	TBA
Hadzagic, Melita	Ph.D.	Michalska	TBA
Haurani, Ammar	Ph.D.	Michalska	Robust H_infinity Control of Time-Delay Systems
Hernandez-Alonso, Diana	Ph.D.	Clark	Modelling the Spatial Structure of Image Surrounds
Khan, Waseem Amhad	Ph.D.	Angeles	Distributed Dynamics of Systems with Closed Kinematic Chains
Kiriy, Evgeni	Ph.D.	Michalska	TBA

Lala, Prasun	Ph.D.	Ferrie	Characterizing Motion in Video using Psychophysical Correlates
Lambert, Casey Marcel	Ph.D.	Nahon	TBA
Lévesque, Vincent	Ph.D.	Hayward	TBA
Li, Jie	Ph.D.	Clark	Statistical Modelling and Tracking of Covert Attention
Li, Muhua	Ph.D.	Clark	Maintaining Perceptual Stability across Self-Actions
Lu, Mu-Chiao	Ph.D.	Michalska	Stability Study for Time-Varying Receding Horizon Control Systems with Time Delay
McCloksey, Scott	Ph.D.	Siddiqi/Langer	TBA
Min, Byung No	Ph.D.	Misra	Object-Oriented Modelling for the Dynamics of Tree-Topological Flexible Multibody Systems
Mitran, Marcel	Ph.D.	Ferrie	TBA
Nasrallah, Danielle	Ph.D.	Angeles/Michalska	Dynamics and Control of an Anti-Tilting Two-Wheeled Mobile Robot Moving on Uneven Terrain
Nava-Hernandez, Sergio	Ph.D.	Angeles	Optimization of Epicyclic Transmissions of Spherical Cam-Roller Pairs
Pasquero, Jérôme	Ph.D.	Hayward	TBA
Poulakakis, Ioannis	Ph.D.	Sharf	TBA
Qin, Zhongkai	Ph.D.	Zsombor-Murray	Direct Analysis of Spatial Parallel Manipulators
Ranganathan, Shivakumar	Ph.D.	Nahon	Mechanics and Control of Thrown Tethers

Sahambi, Harkirat Singh	Ph.D.	Levine	People Detection and Tracking
Salerno, Alessio	Ph.D.	Angeles	Design, Dynamics and Control of a Fast Two-Wheeled Quasiholonomic Robot
Savadjiev, Peter	Ph.D.	Siddiqi	TBA
Selman, Abdulrazzak	Ph.D.	Michalska	Model Predictive Tracking Control for Constrained Systems with Time Delays
Shaikh, Mohammed	Ph.D.	Caines	Optimal Control of Hybrid Systems
Simhon, Saul	Ph.D.	Dudek	Sketch Interpretation and Refinement Using Statistical Models
Skaff, Sandra	Ph.D.	Clark	Similarity Detection and Video Surveillance
Smith, James Andrew	Ph.D.	Sharf	Analysis and Implementation of Quadruped Four-Beat Gaits
Sun, Wei(Victoria)	Ph.D.	Cooperstock	Object Tracking with Multiple Cameras
Torres-Mendez, Luz Abril	Ph.D.	Dudek	Sensor Fusion for a 3D Environment Modelling
Wang, Qi	Ph.D.	Hayward	Tactile Perception
Yin, Jianfeng	Ph.D.	Cooperstock	Video Interpolation and Synthesis for View Reconstruction
Zhao, Hujun	Ph.D.	Cortelezzi	Robust Control of Convective Processes
Zhi, Qi	Ph.D.	Cooperstock	TBA