ANNUAL REPORT

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Content

Centre for Intelligent Machines
McGill University 2002-2003

OBJECTIVES

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

DEFINITION

Intelligent Machines 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 machines, 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.

The Centre for Intelligent Machines (CIM) supports graduate research, teaching, and applications of intelligent systems. Established in 1985, the Centre now includes ten topical laboratories that support the work of nineteen members from the Department of Electrical and Computer Engineering, from the Department of Mechanical Engineering, and from 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	

CIM researchers have a common interest in Intelligent Systems, 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 its 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]

[1]Intelligent Systems is a distinct economic sector which, in Canada, is estimated to represent some 3.8 billion dollars in sales.

(http://www.precarn.ca/intelligentSystemsSector).

Under the leadership of Frank Ferrie, the Centre's previous director, the research program was expressed around four themes designed to reflect 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. Another positive outcome of our Centre is the creation of intellectual property and spin-off companies. Well 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. The breadth of CIM's research makes it possible to offer a rich variety of graduate courses. Since its inception, the Centre has maintained a high level of excellence and senior members are internationally recognized leaders in their respective areas.

The human resources amount to approximately 150 people in total (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.

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

Scientific Output

Internationally, CIM's presence in the community of researchers in areas related to intelligent systems is prominent. In 2002, scientific contributions by CIM's members comprised 44 articles in refereed journals, 56 articles in refereed conference proceedings, 13 book chapters and 1 book published.

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 2002-2003, the student population of CIM consisted of 73 Master's, 48 PhD's and 5 Postdoctoral Fellows, as well as 2 Visiting Scholars, 2 Visiting Foreign Students and 18 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 diverse pool of graduate students, and iii) provides a continuous source of undergraduate projects, and the facilities to conduct them, to the various departments. In 2002-2003, there were 44 undergraduates conducting their project thesis work in the labs of CIM.

Funding

CIM members have enjoyed great success in attracting funding for core research and infrastructure. The average annual funding to the members from all sources for 2002-2003 was approximately $3.6M/year. This funding breakdown is as follows:

- Federal Agencies: $0.9M /year from NSERC research grants: $0.4M/year from NCE research grants; and $0.3M/year from CFI grants.
- Provincial Agencies: $0.4M/year from NATEQ/FQRNT/FCAR funding; $0.2M/year from VRQ funding.
- Industry: $1.1M/year.
- Other: $30K/year.

International and national collaborations remained at the forefront of research activities within the Centre, reflected strongly in the CFI 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.

Intellectual Property

In partnership with CAE, Profs. Frank Ferrie and Gregory Dudek are in the final year of an NSERC Strategic Grant entitled "From Sensors to Virtual

Reality". Two key technologies emerged from this research – 1) the development of new methods for acquiring models of real-world environments and 2) the development of methods for on-line updating of 3D model databases. The latter was directly responsible for the creation of a new spin-off company, headed by Philippe Simard, PhD student with Prof. Frank Ferrie.

CIM members recieved patents this year: Prof. Vincent Hayward "Electro-Mechanical transducer suitable for tactile display and article conveyance" (US6,445,284), Prof. Martin Buehler: "Single actuator per leg robotic hexapod". (US US 6,481,513), and Prof. Jorge Angeles "transmission device" (US6,382,038).

New Initiatives

The Réseau québecois de recherche en réalite artificielle distribuée (réseau QERRAnet) is a program funded under the Quebec government's Regroupement stratégiques program of the FQRNT that involves a significant number of CIM members. The network is comprised of 21 members from three institutions – 12 members from McGill University (a sub-set of CIM members), 8 members from Université Laval and one member from Ecole Polytechnique. The key objective of QERRAnet is to create a network comprised of Quebec's leading scientists in the areas of artificial intelligence, computer vision and robotics (collectively known as intelligent systems) for the purpose of developing a new research program in virtualized and shared reality (VSR), with the goal of establishing a virtual laboratory of world-class status. An important milestone of the Reseau is the design and implementation of the QERRAnet Shared Presentation Facility (QPSF), a virtual seminar room enabling participants from Laval and McGill to come together "at a distance". Over the duration of this project, part of our research will be directed at the scientific and technical questions of how to create the illusion that all participants share a common space – with significant impact on important applications such as tele-medicine, distance education, and distribution of cultural content to remote regions. Prof. Frank Ferrie of CIM was voted as the Director (Acting) of QERRAnet, and Prof. Denis Laurendeau of Université Laval is the Associate Director.

Prof. Frank Ferrie, a former Director of CIM, headed an inter-departmental/faculty team that put together a $52 million dollar infrastructure proposal under the CFI program that includes a highly novel building project – the McConnell Design Centre. Drawing on the success of the 18-year-old CIM model, the Design 21 project seeks to redefine research within the Faculty from an individual/department centric activity to one that is theme oriented, and that encompasses all units within the Faculty of Engineering and the School of Computer Science. Based on approval from CFI, this major initiative will go forward in early 2004.

Innovation

Prof. Vincent Hayward was awarded The E. (Ben) and Mary Hochausen Award from the Canadian National Institute for the Blind, for his research proposal "The Braille Cell Revisited: Achieving an Order-of-Magnitude of Cost Reduction". This award is in recognition of innovative scientific research in the field of adaptive technology for blind and visually impaired persons. This award, along with a special citation by Dr. Euclid J Herrie, President Emeritus CNIB and President World Braille Association was presented to Prof. Hayward in the CIM Seminar Room at McGill University on January 23, 2003.

Prof. Jeremy Cooperstock and his research team have acheived several breakthroughs in real-time networked media. In late 2001, a violin duet was performed over a wide area high computer network in full-screen video as part of the RISQ 2001 Conference. Although separated by several kilometers, the two performers were able to hear each other in "near real time" (approximately 20ms delay) allowing them to synchronize their playing as if standing on the same stage. This marked the first demonstration of such a high quality and low-latency system, using internet protocol communications. In October 2002, Prof. Cooperstock, in collaboration with musicians from McGill University (CIRMMT) and Stanford University of California (CCRMA) joined in a highly successful evening of cross-continental jazz, playing together in surround sound and full-screen video, over the Internet, using

ultraconferencing systems designed by Prof. Cooperstock and collaborators. Despite the fact that performers were at opposite sides of the continent, the system maintained a delay below 50 milliseconds, which feels to the musicians almost like being on the same stage. In June 2002, musicians from McGill and Stanford again jammed together, using Prof. Cooperstock's low-latency ultra-videoconferencing system. The event featured full-screen, bi-directional video and multi-channel audio, in what was heralded as the first demonstration of it kind. This event was considered a major success in demonstrating the feasibility of highly interactive events over the Internet.

In the field of underwater robotics, the Ambulatory Robotics Lab's six-legged submersible robot is making waves. AQUA can crawl at the bottom of the sea, similarly to a crab, like a few existing legged underwater robots. Unlike these robots however, AQUA can also swim underwater. It is unique it that it propels itself with its six flexible flippers, allowing researchers to attempt novel control and propulsion concepts. Earlier this year, we adapted a waterproofed and ruggedized version of RHex, a six-legged robot, for use in the AQUA Project and ran a number of exciting experiments with it in McGill's Currie Memorial pool. The robot was tele-operated from the pool deck while students equipped with SCUBA gear swam alongside, supervising. The robot demonstrated great maneuverability and the ability to move in all directions in a 3D environment. The AQUA Project has since generated a great deal of interest, including 200,000 visits to the ARL's webpage in a two day period after an article describing the work was posted on *Slashdot.org*, an online news site.

Earlier this year James Smith, a PhD student in CIM's Ambulatory Robotics Lab demonstrated the world's first artificial gallop on the Scout II robot. The research began in the summer of 2002 but picked up speed once researchers at Stanford announced that they were attempting to implement galloping with their robot first. By January 2003, a round of experiments conducted in the CIM hallways showed that Scout II could use the rotary gallop gait, similar – although much slower – to the type of gallop used by cheetahs. A second new gait, the half-bound, was developed in the process of making Scout II gallop. In March, the work was presented at the "2nd International Symposium on Adaptive Motion of Animals and Machines" (AMAM 2003) in Kyoto, Japan. Much to the delight of the conference participants live demonstrations of Scout II were performed, adding to the credibility of the research. Scout's impressive accomplishment, as well as other noteworthy scientific developments at the Centre for Intelligent Machines, was featured in an article in the McGill Reporter of May 22, 2003 entitled "Beasts with Byte".

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. Examples of these companies includes – Skygazer Technologies Inc.; Mayan Automation Inc., Deus ex Machina Inc., Espace Courbe Inc., Haptic Technologies Inc., VisionSphere Tech. Inc., AutoVu Technologies Inc., CIMMETRY inc., Noyod Inc., and Robosoft Consultants, out of a total of about 15 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. As mentioned earlier, two graduate students supervised by Prof. Frank Ferrie also have started their own company as a direct result of their studies at McGill. This company called SimActive Inc., develops software products for 3D modelling.

AWARDS TO FACULTY MEMBERS
(2002-2003)

Jorge Angeles	James McGill Professor Design Engineering Chair	McGill University NSERC
Tal Arbel	University Faculty Award	NSERC
Benoit Boulet	Nomination-Faculty's Outstanding Teaching Award Nomination- Principal's Prize for Excellence in Teaching	McGill University McGill University
Martin Buehler	William Dawson Scholar	McGill University
Peter Caines	Fellow	Royal Society of Canada
Gregory Dudek	William Dawson Scholar	McGill University
Vincent Hayward	E.(Ben) & Mary Hochhausen Fund for Research in Adaptive Technology for Blind and Visually Impaired Persons	Canadian Institute for the Blind
Arun Misra	Professor of the Year	McGill Association of Mechanical Engineering Students (MAME)

AWARDS TO STUDENTS AND STAFF
(2002-2003)

Gianni Campione	Scholar	Precarn
Cynthia Davidson	Nominated for Award for Excellence in Service to Graduate and Postdoctoral Studies	McGill University
Maxime Descoteaux	Fellowship	FCAR
Hanifa Dostmohamed	Scholar	Precarn
Tina Ehtiati	Best Student Poster Award	Precarn/IRIS Cionference
Christina Georgiades	Scholarship	Hellenic Foundation
	Scholar	Precarn
Melita Hadzagic	Scholarship	NSERC/Lockheed Martin Canada Ltd.
Ziad Hafed	Postdoctoral Fellowship	NSERC
	Scholar	Precarn
	Major Fellowship	McGill University
Vincent Levesque	Scholar	Precarn
	Best Demonstration of IRIS technology Miniature Tactile Display	IRIS/Precarn Conference
	Scholarship	NSERC
	Fellowship	FQRNT-FCAR
Muhua Li	J. W. McConnell Award	McGill University
Neil Neville	Scholarship	Governor General Award
Svetlana Ostrovskaya	Dean's Honour List	McGill University
Jerome Pasquero	Scholar	Precarn
	Best Demonstration of IRIS technology Miniature Tactile Display	IRIS/Precarn Conference
Ioannis Poulakakis	Scholarship	Tomlinson Award
Alessio Salerno	Fellowship	Hydro-Quebec
	Major Fellowship	McGill University
Qi Wang	Scholar	Precarn

AWARDS

The ten topical laboratories are now described along with their place in the thematic organization of the Centre, and are lexicographically labeled for reference.

Laboratories supporting research in artificial perception

A P L - 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.

V R L – 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

H L – 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.

S R L – 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 15 years ago by Profs. Angeles and Zsombor-Murray. Prof. Misra, a specialist in the dynamics of space mechanical structures, joined it six 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.

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.

The uniqueness of our facility is a reflection of the membership: a complementary blend of scientists and engineers with a penchant for novel problems. The facility dates back to the late 1960's, to the McGill Computer Vision and Graphics Laboratory founded 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. This pattern has repeated itself many times in subsequent years, with network computing in the early 1980's (we were one of the first ARPANet sites outside of the US – mcrcim.mcgill.edu), along with the first robotics laboratory in Canada. Today the Centre is comprised of ten topical laboratories (excluding shared computational facilities) organized along specific themes that are available to the entire community. The uniqueness, relative to similar resources in Canada and abroad, are briefly summarized below.

Ambulatory Robotics Laboratory **(ARL)**: 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 which features prominently in DARPA autonomous robotics research. The laboratory also includes special purpose test, measurement and data acquisition systems necessary to support this research.

Artificial Perception Laboratory **(APL)**: 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)**: 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)**: 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)**: World renowned for both fundamental scientific contributions as well as applied research, the Haptics laboratory is only one of 3 in Canada. 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 **(IAL)**: 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.

Mobile Robotics Laboratory **(MRL)**: 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)**: 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.

Robot Mechanical Systems Laboratory **(RMSL)**: 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 **(SRL)**: 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 a 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 Mbs). Management is centralized through an Auspex Model NS2000 network server supporting cross-platform file sharing Unix and NT with 500 GB of RAID5 configured disk space, and NDMP based backup system.

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 (at least monthly) 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

In the following we briefly summarize the results of some of the metrics used to quantify a Centre such as ours.

Publications

During the past 6 years, the applicants have contributed a total of 134 articles in leading international journals, 189 articles in high quality refereed conferences, 15 book chapters, 3 books and monographs, and 6 patents for invention.

Research Funding

The average annual funding to the applicants from all sources is approximately $3.3M/year, broken down into $1.6M/year in research grants from Federal agencies, $0.6M/year from Provincial agencies, and $1.1M/year in contract research from all sources, including a significant part from foreign agencies or companies (5 NSERC Strategic Grants, significant involvement in NCE programs: IRIS, GEOIDE, and MITACS).

HQP

During the past 6 years, the Centre has graduated 40 Ph.D's, 40 M.Eng. and M.Sc.'s, and hosted over 20 postdoctoral fellows and visitors. In addition, the Centre has supported a large number of senior undergraduate projects and theses from all Departments affiliated with the Centre.

Marks of Recognition

As a whole, CIM members serve on the editorial boards of 10 scientific journals and received 11 peer-recognition awards.

Spin-Off Companies

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. A list of companies includes: Skygazer Technologies Inc., Mayan Automation Inc., Deus Ex Machina Inc., Espace Courbe Inc., Haptic Technologies Inc., VisionSphere Tech. Inc., AGES Technologies, Solutions par/by Design, AutoVu Technologies Inc., CIMMETRY Inc., Noyod Inc., Robosoft Consultants, out of a total of about 15 over the past decade.

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 two years:

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 (twice), Globe & Mail Report on Business, TQS Double Clic! (twice!), Journal Le Monde des Affaires, The Montréal Gazette (twice), 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 (twice), TVA CyberClub, La Presse, Nature News and Views, The Washington Post, Pour la Science, The New Scientist.

CIM also contributes winning entries to national and international robotics competitions such a RoboCup and ACM robot competitions.

Professor	Department	Masters	PhD	Researcher	PDF	Visiting Prof.	Foreign students	Under-graduates	
Angeles	ME	9	6	3	2	1	0	0	
Buehler	ME	6	2	5	0	0	1	0	
Cortelezzi	ME	1	1	0	0	0	1	0	
Misra	ME	5	2	0	0	1	0	1	
Nahon	ME	4	2.5	0	0	0	0	1	
Zsombor-Murray	ME	3.5†	1	0	0	0	0	1	
Total		**28.5**	**13.5**	**8**	**2**	**2**	**2**	**3**	
Arbel	ECE	3	1	0	0	0	0	2	
Belanger	ECE	0	0	1	1	0	0	0	
Boulet	ECE	6.5	3	1	1	0	0	5	
Caines	ECE	0.5	3	0	0	0	0	0	
Clark	ECE	7	3.5	1	0	0	0	7	
Cooperstock	ECE	7	4	2	1	0	0	5	
Ferrie	ECE	2.5	5	0	0	0	0	14	
Hayward	ECE	5	1	3	0	0	0	1	
Levine	ECE	3	1	1	0	0	0	6	
Michalska	ECE	2	6.5	1	0	0	0	1	
Total		**36.5**	**28**	**10**	**3**	**0**	**0**	**41**	
Dudek	SOCS	1	5	0	0	0	0	0	
Langer	SOCS	3	0	0	0	0	0	0	
Siddiqi	SOCS	4	2	0	0	0	0	0	
Total		**8**	**7**	**0**	**0**	**0**	**0**	**0**	
GRAND TOTAL		**73**	**48.5**	**18**	**5**	**2**	**2**	**44**	**192.5**

Summary

Faculty Members	19	PhD Students	48.5
Technical Staff	2	M.Eng. and M.Sc. Students	73
Administrative Staff	2	Research Associates	18
Postdoctoral Fellows	5	Visiting Research Students	2
Visiting Scientists	2	Undergraduate Project Students	44

† 0.5 = co-supervised

Student	Program	Supervisor & Co-Supervisor	Topic/Thesis
Ajersch, Mark	M.Eng	Boulet	Control in Thermoforming
Boussemart, Yves	M.Eng	Cooperstock	Gestural Interfaces in Immersive Environment
Boyer, Alexandre	M.Eng	Boulet	SISO Robust Tunable Control Design
Campbell, Don	M.Eng	Buehler	Bounding in the Hexapod RHex
Campion, Gianni	M.Eng	Hayward	High Fidelity Computer Graphics for Surgical Simulation
Castrillon, Manuel	M.Eng	Clark	Partial Reconfiguration
Deschenes, Francois	M.Eng	Buehler	Velocity Control of a Quadruped Robot
Dostmohamed, Hanifa	M.Eng	Hayward	Haptic Display of Shape without Force Feedback
Farasat, Yousef	M.Eng	Langer	TBD
Garroway, Diana	M.Eng	Cooperstock	Haptic Interaction for 3D Animation
Georgiades, Christina	M.Eng	Buehler	Simulation and Control of a Six-legged Robot in a 3D Environment
Gipsman, Daria	M.Eng	Langer	TBD
Haccoun, Laurent	M.Eng	Boulet	Three-dimensional Position Control of a Magnetically Levitated Object
Hadjimichael, Basil	M.Eng	Boulet	Manufacturing Planning and Control
Hilario, Maria Nadia	M.Eng	Cooperstock	Object Detection and Recognition using Infrared Sensors
Jin, Ming	M.Eng	Zsombor-Murray	Constraints Of Kinematics Formular

Kiriy, Evgeni	M.Eng	Buehler	A Localization System for Autonomous Golf Course Mowers
Lalli, Gino	M.Eng	Boulet	Control in Extrusion Blow Molding
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
Levesque, Vincent	M.Eng	Hayward	Measurement of Skin Deformation Using Fingerprint Feature Tracking
Liu, Jinbo	M.Eng	Boulet	Magnetic Levitation System
Liu, Yu	M.Eng	Angeles	TBD
Ma, Zhongjing	M.Eng	Caines	Rate Control
McCallum, Jacqueline	M.Eng	Buehler	Rhex Downstairs Climbing
Nair, Vinod	M.Eng	Clark	Distributed Video
Ndrialisoa, Raserijuonia	M.Eng	Angeles	The Design of a Parallel Shoenflies-Motion Generator
Neville, Neil	M.Eng	Buehler	Dynamic Behavious for the RHex Hexapod Robot
Pasquero, Jerome	M.Eng	Hayward	A Tactile Display using Lateral Skin Stretch
Perez, Michael	M.Eng	Cooperstock	TBD
Roumy, Jean-Gabriel	M.Eng	Boulet	Active Control of Vibrations of a Car Chassis
Sato, Akihiro	M.Eng	Buehler	Development and Control of a Bipedal Robot using Electric Motors
Savadjiev, Peter	M.Eng	Ferrie	Surface Recovery from 3D Point Data
Steeves, Charles	M.Eng	Buehler	Design and Behavioural Control of a Dynamic Quadruped with Active Wheels

Sud, Daniel	M.Eng	Cooperstock	Hand Tracking for Gesture Recognition
Sugiharto, Rainer	M.Eng	Angeles	Path Planning of a Wheeled Mobile Robot
Tang, Fan	M.Eng	Angeles	Kinematics and Design of a Wheeled Mobile Robot
Toews, Matthew	M.Eng	Arbel	Optimal Feature Points for Image Correspondence
Yao, Hsin-Yun	M.Eng	Hayward	Tactile Amplifying Diagnostic Probe for Orthopaedic Applications
Zhang, Weimin	M.Eng	Angeles	Application of Speed-o-Cam in Dual Epicyclic Transmission
Zhang, Xiang	M.Eng	Angeles	The Innovative Design of Planetary Cam-Roller Trains
Bhattacharyya, Jisnu	M.Eng.	Levine	Linear Virtual Sensor to Eliminate the Effects of Shadows and Specularities
Epstein, Neil	M.Eng.	Cortelezzi	Characterization of Mixing Generated by Vortical Structures
Nie, Jun	M.Eng.	Zsombor-Murray	TBD
Patel, Ketan	M.Eng.	Sharf	Contact Parameter Estimation in Frequency Domain
Pichette, Alexandre	M.Eng.	Michalska	TBD
Qiao, Guirong	M.Eng.	Zsombor-Murray	Unification of Planar Linkage Synthesis Through Kinematic Mapping
Rajwade, Ajit	M.Eng.	Levine	TBD
Descoteaux, Maxime	M.Sc.	Siddiqi	Blood Vessel Segmentation
Dimitov, Pavel	M.Sc.	Siddiqi	Shapes, Parts and Recognition
Garden, Matthew	M.Sc.	Dudek	TBD
Ghandi, Maulin	M.Sc.	Levine	Automatic Age Progression in Human Face Images

Pelletier, Stephane	M.Sc.	Cooperstock	High-Resolution Video Synthesis from Mixed-Resolution Video Based on the ...
Phillips, Carlos	M.Sc.	Siddiqi	View-based Object Representations
Rao, Malvika	M.Sc.	Dudek	A Randomized Algorithm for Robot Localization in a Self-similar Environment
Zhang, Linqiao	M.Sc.	Langer	Rendering Falling Snow Using an Inverse Fournier Transform
Al-Widyan, Khalid	Ph.D.	Angeles	Robust Design of Robotic Mechanical Systems
Arseneau, Shawn	Ph.D.	Cooperstock	Occlusion Detection In the Spatiotemporal Domain
Begin, Isabelle	Ph.D.	Ferrie	Learning-based Methods for Integration and Super-resolution of Images
Benoit, Stephen	Ph.D.	Ferrie	Direct Motion and Shape Parameter Recovery from Image Sequences
Bouix, Sylvain	Ph.D.	Siddiqi	Medial Surfaces and Applications
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	Global Optimisation Approaches for the Twice-Repeated Time-Varying Structured
Cayouette, Francois	Ph.D.	Cooperstock	Gesture Recognition using Multiple Cameras
Cebula, Andrzej	Ph.D.	Zsombor-Murray	Use of NURBS to Avoid Boundary Orientation Poses in Serial Manipulators
Chen, Chao	Ph.D.	Angeles	The Conceptual and Optimal Design of Epicyclic Mechanical System
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	TBD

Ehtiati, Tina	Ph.D.	Clark	Attention Models for View-based Object Recognition
Gauthier, Guy	Ph.D.	Boulet	Iterative Learning Control
Hadzagic, Melita	Ph.D.	Michalska	TBD
Hafed, Ziad	Ph.D.	Clark	Motor Theories of Attention
Haurani, Ammar	Ph.D.	Michalska	Robust H_infinity Control of Time-Delay Systems
Huang, Minyi	Ph.D.	Caines	Stochastic Control for Distributed Systems with Applications to Wireless Communication Systems
Khan, Waseem Ahamad	Ph.D.	Angeles	Distributed Dynamics of Systems with Closed Kinematic Chains
Lala, Prasun	Ph.D.	Ferrie	TBD
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
Min, Byung No	Ph.D.	Misra	Object-Oriented Modelling for the Dynamics of Tree-Topological Flexible Multibody Systems
Mitran, Marcel	Ph.D.	Ferrie	Active Surface Reconstruction From Optical Flow (M.Eng)
Nasrallah, Danielle	Ph.D.	Angeles	Dynamics and Control of an Anti-tilting Two-Wheeled Mobile Robot
Nava-Hernandez, Sergio	Ph.D.	Angeles	Optimization of Epicyclic Transmissions of Spherical Cam-Roller Pairs
Ostrovskaya, Svetlana	Ph.D.	Angeles	Motor Theories of Dynamics of Quasiholonomic and Nonholonomic Reconfigurable Rolling Robots
Parsa, Kourosh	Ph.D.	Misra	Dynamics, State Estimation, and Control of Manipulators with Rigid and Flexible Subsystems
Poulakakis, Ioannis	Ph.D.	Buehler	On the Dynamics of Quadruped Running

Qin, Zhongkai	Ph.D.	Zsombor-Murray	Direct Analysis of Spatial Parallel Manipulators
Rekleitis, Iaonnis	Ph.D.	Dudek	Cooperative Localization and Multi-Robot Exploration
Romanovski, Iakov	Ph.D.	Caines	Multi-agent Product Systems: Analysis, Synthesis and Control
Sahambi, Harkirat	Ph.D.	Levine	Object Recognition and Retrieval
Salerno, Alessio	Ph.D.	Angeles	Design, Dynamics and Control of a Fast Two-Wheeled Quasiholonomic Robot
Shaikh, Mohammed	Ph.D.	Caines	Optimal Control of Hybrid Systems
Sim, Robert	Ph.D.	Dudek	On the Autonomous Construction of Visual Maps
Simard, Philippe	Ph.D.	Ferrie	Online Updating of Synthetic Vision Systems' Databases
Simhon, Saul	Ph.D.	Dudek	Sketch Interpretation and Refinement Using Statistical Models
Skaff, Sandra	Ph.D.	Clark	Recognition of Familiar Scenes in Video Sequences
Smith, James Andrew	Ph.D.	Buehler	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
Torres-Torriti, Miguel	Ph.D.	Michalska	Design of Stabilizing Feedback Controls for Strongly Nonlinear Systems
Wang, Qi	Ph.D.	Hayward	Tactile Perception
Yin, Jianfeng	Ph.D.	Cooperstock	Video Interpolation and Synthesis for View Reconstruction
Zhao, Hujiu	Ph.D.	Cortelezzi	Robust Control of Convective Processes