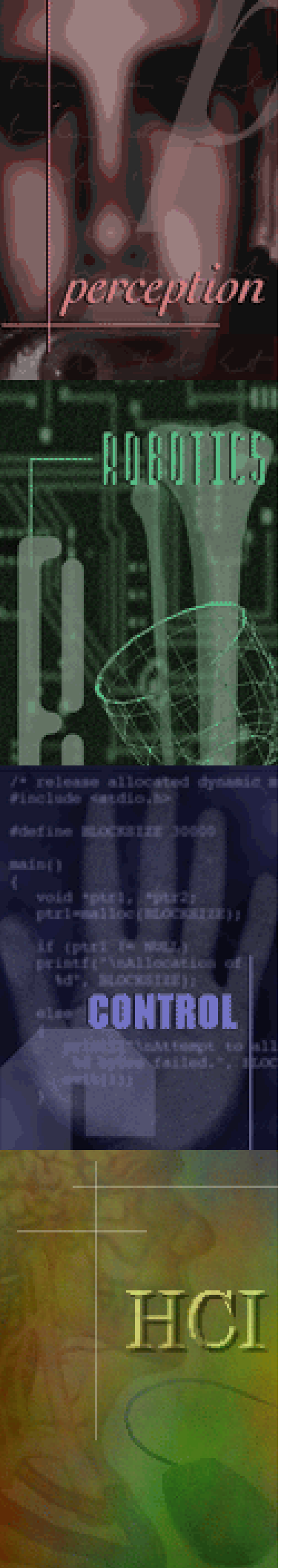

ANNUAL REPORT

JUNE 1, 2004 – MAY 31, 2005

Dr. Gregory Dudek
Director
Centre for Intelligent Machines
Centre de recherche sur les machines intelligentes
McGill University

McGill
Centre for
Intelligent Machines

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Content

Centre for Intelligent Machines
McGill University 2004-2005

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 graduate research, teaching, and applications of intelligent systems. Established in 1985, the Centre now includes eleven 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**
Benoit Boulet	**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**
Inna Sharf	**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]

Under the leadership of Frank Ferrie, a former 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 academic 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.

[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).

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
Boulet, Benoit	boulet	1478	Electrical and Computer 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
Sharf, Inna	isharf	1711	Mechanical Engineering
Siddiqi, Kaleem	Siddiqi	3371	School of Computer Science
Zsombor-Murray, Paul	paul	6311	Mechanical Engineering

Research Highlights and Performance

SCIENTIFIC OUTPUT

Internationally, CIM's presence in the community of researchers in areas related to intelligent systems is prominent. In 2004-2005, scientific contributions by CIM's members comprised 39 articles in refereed journals, 77 articles in refereed conference proceedings, 6 book chapters and 2 books 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 2004-2005, the student population of CIM consisted of 56 Master's, 56 PhD's and 5 Postdoctoral Fellows, as well as 5 Visiting Foreign Students and 5 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 2004-2005, there were 14 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 2004-2005 was approximately $2.8M/year. This funding breakdown is as follows:

- Federal Agencies: $575K/year from NSERC research grants: $797K/year from NSERC Strategic grants and collaborative grants; $654K/year from NCE grants; $100K/year from CFI grants; and $305K/year from industrial and other sources.

- Provincial Agencies: $307K/year from NATEQ/FQRNT/FCAR funding and $140K/year from VRQ funding.

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, two 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 represented by IRIS/PRECARN reached a major milestone in it's 15 year history of providing valuable support to the Canadian robotics industry. As of March 31, 2005, this program came to completion. Discussions continue with PRECARN and the research community to find viable alternatives for funding inter-university research programs.

During it's final year, 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 Prof. Gregory Dudek in "AQUA: Autonomous Aquatic Walking Robots" (with Michael Jenkins of York University).

CIM members are also heavily involved in NCE programs such as MITACS, GEOIDE and AUTO 21.

COMMUNITY NEWS

Professor Vincent Hayward completed his tenure as Director of the Centre for Intelligent Machines in December 2004. In addition to heading several major funding initiatives on behalf of CIM, he is gratefully acknowledged by the CIM community for his tireless efforts

in forming and implementing the CIM Industrial Liaison Program with RICOH Co. Ltd. Of Japan.

Effective January 2005, Professor Gregory Dudek officially assumed the title and responsibilities as CIM Director until August 2007.

Professor Dudek began his career at McGill in 1991 when he joined the Centre after completing his PhD in Computer Vision at the University of Toronto. Dr. Dudek was brought on board initially to work as an adjunct professor in the Department of Electrical and Computer Engineering and Research Associate on the IRIS Project A-4 "Multi-Sensor Perception" along with Principal Investigators Martin Levine and Steve Zucker. In January 1994, Dr. Dudek was appointed to a tenure-track position in the School of Computer Science and full member of CIM.

Dr. Pierre Belanger became a CIM Emeritus member in 2005, after having served the McGill community for 3 decades.

On May 2005 Dr. Christophe Pierre, the new Dean of Engineering, visited some of the CIM labs.

Three new Associate Members joined the Centre in 2005: Dr. Shie Mannor, a Systems and Control specialist with ECE: Dr. Joelle Pineau, a roboticists and artificial intelligence expert from SOCS; and Josef Koveces, a roboticist with ME.

INNOVATION AND INITIATIVES

A number of robots are currently under various stages of development and testing within the laboratories of CIM.

The four-legged Scout II robot is capable of bounding and galloping. Apart from being the first robot to gallop, what is significant about it, unlike many other legged robots, is that it is able to accomplish this by combining minimal actuation with leg compliance (springiness). The work on Scout II has examined how simple, essentially open-loop control laws have tremendous success in stabilizing complex running behaviors on 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. A conference paper on experimental galloping results

using Scout II was presented in October 2004 at the IEEE/RSJ International Conference on Intelligent Robots and Systems in Sendai, Japan. In April 2005, a paper on Scout II's mechanical and controller designs and experimentally validated models, was published in the International Journal of Robotics Research.

The PAW robot, a hybrid wheel-legged robot whose development is sponsored by Defence R&D Canada, 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 wheels with respect to its body via its leg motors. This has led to a number of interesting wheeled maneuvers which are useful on both smooth and broken terrains. Work has progressed on implementing auto-levelling features on slopes as well as energetic legged behaviours similar to Scout II's bounding gait.

In addition to a number of demonstrations on the McGill campus throughout the year and an appearance in a Ryerson University student documentary on artificial intelligence, "Dust of the Earth", both Scout II and PAW participated in a full day live demonstration at Department of National Defence Headquarters in Ottawa in 2004.

The AQUA project has continued to achieve new levels of success. This past year much development and testing has taken place. The main focus this year has been to improve the functionality of the robot. To this end, a team of undergraduate students participating in the Mechanical Engineering Project course developed two new sets of amphibious legs. These new legs were successfully tested at McGill's Bellairs Research Institute this past January. The AQUA robot was operated to a new depth of 12.5m, and other tests measured its suitability as a research tool for monitoring marine life in reef environments.

New cameras, sensors and processors have been added to increase the robot's proprioceptive abilities. Algorithms have been developed and tested that allow the robot to successfully track a number of visual targets, as well as to be able to maintain its orientation in a turbulent aquatic environment.

The AQUA robot is now undergoing an extensive redesign that will incorporate the stereoscopic vision research that has been taking place at York University as part of the project. Other goals of the redesign are to reduce the mass and cost of the platform, while

increasing the depth at which it can safely operate. A new series of sea trials will take place in Halifax late in the summer.

The platform itself is comprised of six single degree-of-freedom hip actuators, one for each leg/flipper, on board computing and batteries, and multiple cameras, all enclosed in an aluminum shell. Visual and state information is conveyed to a remote operator via a single fiber optic tether. The robot is capable of operating for more than two hours on a single battery charge. For more information and pictures of the robot, please see http://www.aquarobot.net

Within the mandate of a James McGill Chair, Professor Jorge Angeles and his group at the Robotic Mechanical Systems Laboratory continue 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 complexity of a design alternative. The challenge here is how to define the complexity of a design alternative, and to measure the complexity of the alternative. For that purpose, we propose the use of Kolmogorov complexity theory and entropy concepts from information theory and physics.

Research on mechanical transmissions has been underway at the Robotic Mechanical Systems Laboratory for the last ten years or so. The last three years, a novel family of transmissions based on cams and rollers, which offer high precision, low friction, and high stiffness, has been developed. Moreover, conceptual design and embodiment of epicyclic cam-follower trains with compact structures and high speed-reduction ratios have been studied. A generalized transmission index for spatial mechanisms based on the virtual coefficient has been defined too. Currently, the development of virtual prototypes of central and offset dual-wheel transmission units, which can provide quasi-omnidirectional and omnidirectional capabilities of wheeled mobile robots, respectively, are under development. Besides, the kinematic of general WMRs with different drives and the transmission efficiency of epicyclic systems are being analyzed as well.

Another RMSL research project deals with "Rigid Body Pose and Twist Estimation from Point-Acceleration Measurements". Accordingly, the goal of this research work is to use accelerometer measurements to estimate the position and the attitude of a rigid body in space. To do so, an algorithm was devised which allows the computation of the rigid body kinematic parameters. Current work focuses on the analysis of the error amplification taking place

at each step of the algorithm. Another way of improving the accuracy of this accelerometer-only method is to reduce the error embedded in the accelerometer readouts. Therefore, a new accelerometer design was proposed, a prototype of which is to be micro-machined this summer at the McGill Micromachining Lab. This new sensor will be tested this fall.

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. Contrary to the systems of the serial type, the SCARA system being developed is of the parallel type, uses fewer joints and links. Besides its workspace is large and its four motors are fixed to a common base. Accordingly, the mechanical design, the kinematic and dynamic analyses, a solid modeling, and a animation of the mechanism have been done over the past year. Currently, the prototype of the mechanism is being built.

Professor Langer's group in the Appearance Modelling Laboratory is researching two problems involving the analysis and synthesis of visual motion. The first problem is to estimate the 3D motion of a camera from a video sequence. To constrain the problem it is assumed that the video is taken by a camera moving through a rigid cluttered 3D scene. There are several computational issues that arise concerning how to estimate motion parallax and what is the accuracy of these estimates as a function of the 3D scene structure and parameters of camera motion. The second problem is how to synthesize image motion fields, in particular, how to take advantage of strengths and limitations of the human visual system in processing layered motion fields. The motion fields of interest are those that arise from optical flow and from fluids.

Professor Vincent Hayward’s research group in the Haptics Laboratory focuses on the identification of a small number of "primitive" tactile signals of perceptual importance which can be used to synthesize the stimulus space. The knowledge of these primitive signals will drive the development and the engineering of more effective haptic interfaces which seek to establish communication between humans and machines via touch. This research is as much motivated by the pursuit of new knowledge, as it is by the desire to apply this knowledge to practical ends. For example, a recent discovery has potential to radically change the design and the cost of refreshable Braille displays. Prof. Hayward’s research is also concerned with techniques for "realtime physical modeling" which are relevant to virtual reality simulations. The mastery of these techniques is key to the development of

applications of strategic importance such as surgical trainers and data visualization systems. Prof. Hayward pursues numerous collaborations at CIM, in Canada, and abroad. For example, at CIM he works with Prof. Clark (attention processes) and Prof. Michalska (nonlinear dynamics). He also collaborates with A. M. Smith of the Department of Physiology at the University of Montréal and Prof. K. E. MacLean of the University of Colombia.

On sabbatical leave at the Industrial Materials Institute (IMI) of the National Research Council of Canada, Professor Benoit Boulet has focused his research on advanced control of polymer forming processes. With a team of six graduate students and research assistants working at the IMI (Guy Gauthier, Mark Ajersch, Gino Lalli, Dominic Lalli, Ammar Haurani, Alexandre Boyer) the research work on control of thermoforming and blow molding machines has resulted in two major inventions. These inventions are control systems that are in the pre-commercial development phase.

The spin-off company MAGI Control Inc. was founded by Gino Lalli and Mark Ajersch for potential commercial exploitation of these inventions.

Prof. Boulet's work on active control of road noise in vehicles was completed for the end of the first four-year phase of the AUTO21 NCE. This work was conducted in collaboration with Prof. Michalska and Professors Patrice Masson and Alain Berri of the Department of Mechanical Engineering at Université de Sherbrooke. Students involved in this noise control project included Marie-Pierre Jolicoeur, Steven Vanreusel and Dany Dionne. The project was renewed for another four years as part of AUTO21's second phase with more emphasis on experimental research.

Prof. Boulet is working on the control of the Canadian Large Adaptive Reflector radiotelescope concept, a project led by Prof. Meyer Nahon. Graduate student Alexandre Boyer has recently completed his M. Eng. thesis on the kinematics of the reflector and the control of the tethered feed platform supported by an aerostat. Another graduate student, Gabriel Meunier, will continue the work.

One area of interest in control theory which has ramifications in many applications is the concept of robust tunable controllers (RTC). Ph.D. student Yingxuan Duan has been working on developing such a theory with success. A wing flutter control problem is now being tackled with the RTC approach, in collaboration with Dr. Sunil Kukreja and Dr. Marty Brenner of

NASA's Dryden Flight Research Center. Drs. Kukreja and Brenner visited Prof. Boulet in October of 2004.

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.

In 2004-05, one such company, MAGI Control Inc., was formed by two graduate students of Professor Benoit Boulet. Headed by President: Gino Lalli (B.ENG '01, M.ENG '05) and Vice-President: Mark Ajersch (B.ENG '00, M.ENG '05), the technology being developed by MAGI Control Inc. is focused on the multivariable multi-loop thermoforming control algorithm which uses pre-existing hardware (infrared temperature sensors) to monitor the temperature at the sheet surface. Based on these measurements and the initial sheet surface temperature setpoints, the algorithm will establish new desired temperatures for the heating elements. The heating elements then converge towards these new desired temperatures, creating a corresponding reaction on the sheet surface. This cycle is repeated throughout the sheet reheat process, until forming occurs.

Thermoforming is an industrial process in which plastic sheets are heated and then formed into useful parts. The sheet is heated in an oven until it becomes pliable. The softened sheet is then formed over the mold and cooled until it hardens. The purpose of the plastic sheet temperature control system developed at CNRC-NRC IMI is to reach the "best" temperature profile at every location on, and inside the sheet so that the subsequent forming stage of the process will produce a part that meets the specifications with good repeatability. The commercial applications of the controller are mainly for the retrofitting of existing thermoforming machines, but can also be implemented in new machine designs.

MAGI Control Inc. principals will remain affiliated with the existing McGill-NRC program as co-directors. This is highly beneficial in that it will allow MAGI Control Inc. to direct research along the specific needs of a project. Other benefits to MAGI from this relationship include future developments in the control of polymer component forming processes, such as blow molding and injection molding, as well as potential employment for graduates of the program.

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 as RoboCup and ACM robot competitions.

CIM VISITORS
(June 1, 2004- May 31, 2005)

Aurélien Ramseyer	Visiting Student – Master's	FRANCE	2004.04.13 – 2004.07.31	Angeles
Christohpe Nègre	Visiting Student- Master's	Institut de Recherche en Communications et Cybernitique de Nantes, FRANCE	2003.04.14 - 2004.07.12	Angeles
Giorgio Figliolini	Visiting Professor	University of Cassino - Dept. of Industrial Engineering- ITALY	2004.07.26 - 2004.07.31 2004.10.04 – 2004.10.09	Angeles
Paul Lorne	Visiting Student – Master's	Institut de Recherche en Communication et Cybernitique de Nantes, FRANCE	2004.04.22 – 2004.07.27	Angeles
Rita-Helena Hage	Visiting Student – Master's	FRANCE	2004.04.13 – 2004.08.16	Michalska
Juan Victor Hoyos	Visiting Professor	Universidad Politecnica de Valencia Camino de Vera S/N, Valencia, SPAIN	2004.06.14 – 2004.11.19	Angeles
Naly Rakoto - Ravalontsalama	Visiting Researcher	Département Automatique et Productique, Ecole de Mines de Nantes, FRANCE	2004.06.04 – 2004.07.31	Caines
Richard Neumayr	Visiting Student - Master's	Institute of Engineering Mathematics, Geometry and Computer Science Innsbruck, AUSTRIA	2003.09.02 - 2004.06.30	Zsombor - Murray
Jose Ruiz Ascencio	Visiting Professor – Sabbatical	Centro Nacional de Investigacion y Desarrollo Tecnologico, Cuernavaca MEXICO	2003.07.31- 2004.07.28	Angeles

Seigo Harashima	Visiting Researcher	RICOH, JAPAN	2001.04.16 - 2004.07.15	Hayward
Jacob Montiel López	Visiting Student – Master's	Instituto Tecnológio Puebla, Pe MEXICO	2004.08.09 – 2005.01.31	Levine
David Levanony	Visiting Researcher	Technion, ISRAEL	2004.09.19 – 2004.10.09	Caines
Sze Kui Ng	Visiting Professor	Dept. of Maths Hong Kong Baptist University, HONG KONG, PRC	2004.11.17 – 2004.12.03	Caines
Sophie Pinchinat	Visiting Researcher/Lecturer	IRISA- campus universitaire de Beaulieu 35042 Rennes Cedex, FRANCE	2004.12.06- 2004-12.10	Caines
William C. Rounds	Visiting Lecturer	AI Laboratory, University of Michigan Ann Arbour, Michigan, USA	2004.12.06 - 2004.12.07	Caines
Christian Wojek	Foreign Student – Masters'	Universitaet Karlsruhe 76128 Karlsruhe GERMANY	2005.01.07 - 2005.04.31	Siddiqi
Guillaume Hirigoyen	Visiting Researcher	8 rue de Rouen 92400 COURBEVOIE, FRANCE	2005.01.18 - 2005.08.31	Angeles
Fredriika Berna de Rijke	Foreign Student	Tu Delft, The Netherlands, Mehelweg 2	2005.01.01 – 2005.04.30	Caines

Nahum Shimkin	Visiting Prof.	Technion, EE Dept. Haifa, ISRAEL	2005.02.14 – 2005.02.18	Caines
Joseph Luk	Visiting Student Researcher	Dept. Computer Science UBC, Vancouver BC, Canada	2005.02.22 – 2005.04.05	Hayward
Lucas Chabert	Foreign Student	Ecole Centrale Nantes 1, rue de la Noe BP 92 101 44 321 NANTES Cedex 3 FRNCE	2005.04.11 – 2005.08.15	Angeles
László Gerencsér	Visiting Researcher	MTA SZTAKI, H-1111 Budapest Kende 13-17, Hungary	2005.05.09 – 2005.05.13	Caines
Tudor-Ioan Stiharu	Visiting Researcher	Collège Jean-de-Brébeuf 302 Chemin de la Côte-Ste-Catherine Montréal QC	2005.05.240-2005.08.31	Angeles

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 2004/2005

Control, Networks and Games

A Game-Theoretic View of Efficiency Loss in Network Resource Allocation	Prof. Shie Mannor	ECE, McGill University	September 17, 2004
Introduction to Mechanism Design	Prof. Jacques Robert	HEC Montreal	September 24, 2004
Price-Based Rate Control in Random Access Networks	Prof. Peter Marbach	CS, University of Toronto	October 1, 2004
Survey of Pricing Based Approaches for a QoS-enabled Internet	Kang Bin Wang,	Ph.D. Candidate, McGill University	October 8, 2004
In Search of Sensitivity in Network Optimization	Prof. Sean Meyn	ECE and CSL, University of Illinois at Urbana-Champaign	October 14, 2004
Management of Demand-Driven Production Systems	Prof. Sean Meyn	ECE and CSL, University of Illinois at Urbana-Champaign	October 14, 2004
Dynamics of Ancillary Service Prices in Power Networks	Prof. Sean Meyn	ECE and CSL, University of Illinois at Urbana-Champaign	October 15, 2004
Mechanism Design: Applications to Networks	Prof. Jacques Robert	Haute Études Commerciales, Montreal	October 22, 2004

Submodular Games: Quality, Efficiency and Applications	Prof. Adrian Vetta	School of Computer Science McGill University	November 5, 2004
Scheduling Adversarial Flows in Packet-Switched Networks	Constantine Caramanis	PhD Candidate, Laboratory for Information Decision Systems, MIT	November 12, 2004
Metastable Regimes for Multiplexed TCP Flows	Prof. David R. McDonald	Dept. of Mathematics and Statistics, University of Ottawa	December 3, 2004
Maximally Permissive Controllers	Sophie Pinchinat	Lecturer IRISA, Université de Rennes I	December 7, 2004
Minimal Communication in Decentralized Discrete-Event Systems	Prof. Laurie Ricker	Department of Mathematics & Computer Science, Mount Allison University, Sackville, NB	December 8, 2004
Adaptive control for robot manipulators using a linear observer	Dr. Lin Maoqiong	Post-Doctoral Research Associate, Dept. of Systems and Computer Engineering, Carleton University, Ottawa	January 28, 2005
User-Optimal Routing in Congested Networks Uniqueness and Structure	Nahum Shimkin	Assoc. Prof. Dept. of Electrical Engineering, Technion Israel	February 15, 2005
Multigrid-based Algorithms for Temporal Difference Learning	Nahum Shimkin	Assoc. Prof. Dept of Electrical Engineering, Technion, Israel	February 16, 2005
Load Sharing Sequential Routing in MPLS Networks	Fariba Heidari	PhD candidate, ECE, McGill University	March 11, March 18, 2005
Optimum Public-Private Contracts with Applications to Toll Roads	Geoffrey Hyman	Integrated Transport & Economic Appraisal Division, UK Department for Transport	May 19, 2005
The Price of Selfish Behavior in Bilateral Network Formation	Jacomo Corbo	PhD student, EECS Department, Harvard University	May 30, 2005

School of Computer Science			
Models and Methods in Real-Time Vision for Tele-Assistance	Dr. Martin Jagersand	Dept. of Computing Science, University of Alberta	June 9, 2004
Graph exploration by Finite Automata	David Ilcinkas	Université Paris-Sud	October 4, 2004

Honours, Awards and Recognitions

AWARDS TO FACULTY MEMBERS
(June 1, 2004- May 31, 2005)

Jorge Angeles	James McGill Professor	NSERC Design Engineering Chair McGill University
Tal Arbel	University Faculty (2001-2006)	NSERC
Benoit Boulet	William Dawson Scholar, Jan. 2004	McGill University
Peter Caines	James McGill Professor, Jan 2004 Macdonald Professor, Dept EECS	McGill University McGill University
Gregory Dudek	William Dawson Scholar Director, Centre for Intelligent Machines	McGill University McGill University
Frank Ferrie	Associate Dean, Research and Graduate Studies	Faculty of Engineering McGill University
Vincent Hayward	Keynote speaker	Eurohaptics, Munich, Germany, June 2004
Arun K. Misra	Fellow	American Astronautical Society – Nov. 2004
Kaleem Siddiqi	William Dawson Scholar, Jan 2005 – Dec. 2009 Nominated for the Carrie M. Derrick Award for Graduate Teaching and Supervision	McGill University McGill University

AWARDS TO STUDENTS
(June 1, 2004- May 31, 2005)

Gianni Campion	J.W. McConnell Major Fellowship	McGill University
Jérôme Pasquero	Scholarship	FQRNT/NATEQ
	Scholarship	PRECARN/IRIS
Vincent Lévesque	PGS – B Scholarship	NSERC
	B2 Scholarship	FQRNT/NATEQ
Alessio Salerno	Werner Grauper International Fellowship	McGill University
Qi Wang	J.W. McConnell Major Fellowship	McGill University
Mohammad Shahid Shaikh	Dean's Honour List - PhD	McGill University
Catherine Laporte	Dean's Honour List - MEng	McGill University
	Doctoral Scholarship	NSERC
Gurman Singh Gill	Tomlinson Award	McGill University
Hsin-Yun Yao	Scholarship	PRECARN/IRIS
Sandra Skaff	Scholarship	PRECARN/IRIS
Dany Dionne	Outstanding Teaching Assistant	Faculty of Engineering - McGill
Melita Hadzagic	Industrial Scholarship	Lockheed Martin Canada Inc.
David McConkey	USRA	NSERC
Yves Boussemart	Invited Student Researcher: Software Engineering Research Laboratory	Massachusetts Institute of Technology
Evgeni Kiriy	Industry – NSERC Scholarship	Lockheed Martin Canada Inc.
Donovan Parks	NSERC CGS Scholarship	NSERC
Frank Rudzicz	Graduate Scholarship	FQRNT/NATEQ
Chao Chen	Graduate Student Fellowship	FQRNT/NATEQ
	Scholarship	American Society of Mechanical Engineers Quebec Section
Phillip Sawbridge	PGSA Scholarship	NSERC

Research Themes and Facilities

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 Professors 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 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.

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. Dudek's instrumented mobile robots and underwater 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 eleven 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.

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

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 LABORATORY* (IAL) AND SYSTEMS AND CONTROL LABORATORY**

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.