



Centre for Intelligent Machines

Annual Report

June 1999 - May 2000

Director: Professor Frank P. Ferrie

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The mission statement of the Centre expresses our goals of excellence in research and graduate student education:

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

More and more this is being achieved by collaborative efforts involving researchers with very different interests. Therefore we see that the original objective of forming the Centre to encourage interdisciplinary activities which transcend the traditional departmental boundaries is being attained.

I Highlights of 1999–2000

I.i Personnel Changes

New Members

- We have been joined by one new member, **Dr. Luca Cortelezzi**, a graduate of the California Institute of Technology, USA, who is considered a leading expert in the control and optimization of fluid mechanics. Dr. Cortelezzi is an Associate Professor in the Department of Mechanical Engineering.
- *Kathleen VanderNoot* left her administrative position at CIM to accept a position in the office of the Director of Libraries; *Ornella Cavaliere* was granted a long-term leave to pursue a developmental assignment in the Department of Atmospheric and Oceanic Sciences.

I.ii Awards and Honourable Mentions

- **Recipient: Prof. Peter Caines**, of the IEEE Control Systems Soc. Awards for authorship of one of 25 seminal papers in Control Theory in the 20th Century: Goodwin, G.C., P.J. Ramadge and P.E. Caines *"Discrete Time Multivariable Adaptive Control"*, IEEE TAC Vol. 25, 3, June 1980, pp. 449-456.
- **Prof. Vincent Hayward** was the recipient of the Distinguished Lecture Series, Department of Computing Science, University of Alberta, April 2000.
- **Prof. Jeremy Cooperstock** was awarded the Best Innovator Award, ECE Student Society (ExCESS).
- **Prof. Venkat Krovi** received McGill's Petro-Canada Young Innovator Award for 2000.
- **Prof. Kaleem Siddiqi** received the FCAR Programme Strategique de professeurs Chercheurs for the next 5 years, beginning in the year 2000.
- **Profs. Vincent Hayward and Gregory Dudek** were appointed Program Chairs for the International Symposium on Robotics, May 14-17, 2000 at the Palais des Congres, Montreal, QC.
- **Prof. Vincent Hayward** accepted an invitation from the *Federal Department of Foreign and Internal Affairs (DFAIT)* to participate in a trade mission with Japan. As part of this mission, Prof. Hayward visited Japan from March 6 - 12, 2000, and met with several senior representatives from Japanese companies with potential research interests with CIM.

- *Tal Arbel*, PhD under the supervision of **Prof. Frank Ferrie**, received the prestigious D.W. Ambridge Award for the graduate in the Physical Sciences or Engineering whose record, including research and thesis, is judged the most outstanding over the academic year.
- *Kourosh Parsa*, PhD candidate with **Profs. Angeles/Misra**, received an Alma Mater Travel Award to attend the 4th International Conference on Mechanical Engineering in Tehran, Iran, May 16-19, 2000.
- *Dingrong Yi*, PhD under the supervision of **Prof. Vincent Hayward**, was the recipient of the C.F. Wong McGill Major Fellowship.
- CIM students graduating with honours: *Ekaterina S. Lemch*, PhD, ECE, supervisor **Prof. Peter Caines**, "Non-linear and hierarchical hybrid control system"; *Gang Shen*, PhD, ECE, Supervisor **Prof. Peter Caines**, "Hierarchical control for finite state machines"; *John Hayes*, PhD, Mechanical, supervised by **Prof. Paul Zsombor-Murray**, "Kinematics of general planar Stewart-Gough platforms".
- A team comprised of **Profs. Buehler, Cooperstock and Dudek** was among a group of 12 institutions world-wide (only 3 of which were in the Americas) that were awarded research robot systems by Sony Inc. on the basis of competitive research bids. These researchers, accompanied by 9 CIM students representing three different disciplines enrolled in both undergraduate and graduate studies, participated in the Robot World Cup Initiative (RoboCup) Competition held in Sweden in July 1999 and competed impressively against more experienced teams.

- **I.iii New Research Projects**

- Thanks to funding from the Canadian Foundation for Innovation, an entirely new initiative is being pursued at CIM. The *Laboratory for Computation, Visualization and Realization (CVR)* is presently being created within CIM. The CVR Laboratory, headed by **Profs. Cortelezzi, Siddiqi and Krovi** will provide the Centre with a leading-edge single integrated environment supporting three major infrastructure components to foster collaborative research between the team members. It is comprised of (1) a network of processors connected together as a hypercube to form a parallel computer to carry out computationally intensive scientific computations (2) a cluster of visual workstations to support the real time visualization of complex physical processes and the manipulation of high dimensional data and (3) a rapid prototyping machine for the physical realization of three-dimensional (3D) models. The CVR Laboratory offers significant opportunity to promote interdisciplinary research within CIM and McGill.
- **Profs. Ferrie and Dudek** received an NSERC Strategic Grant, "From Sensors to Virtual Reality" with industrial partner CAE.
- **Prof. Venkat Krovi** is the Principal Investigator in an NSERC Research Grant entitled: "*Minimal Complexity Manipulation Assistive Devices*". He is also the PI for the FCAR Nouveau Chercheur Award "*Cooperation Frameworks for Actively Articulated Wheeled Vehicles*".
- **Profs. Angeles, Krovi and Zsombor-Murray** received an FCAR Team Grant entitled "*Computational Kinematics*".

- **Prof. Vincent Hayward** was awarded a T-Gap Grant , IRIS/PRECARN for "*Mass Producible Tactile Displays*". The work was carried out in collaboration with *Manuel Cruz-Hernandez*, Research Engineer.
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I.iv Conferences Attended and Visits Hosted

- CIM organizes three series of lectures on a regular basis throughout the year: seminars in Computer Vision, in Systems and Control and in Robotic Mechanical Systems. The latter is supported by a Seminar Grant from the Faculty of Graduate Studies and Research. Among the seminars presented in 1999 were: "*Coastal Navigation with Mobile Robots*", October 1999, Nicholas Roy, PhD candidate, Carnegie Mellon University; "*Recursive Nonlinear System Identification by a Stochastic Gradient Algorithm: Stability, Performance and Model Nonlinearity Considerations*", October 8th, Prof. David Levanony, Ben Gurion University; "*Mechanisms for Ground Simulation of Vibration in Microgravity*", Prof. Marek Kujath, Dalhousie University; "*Robotics and Projective Geometry*", Prof. Manfred L. Husty, Institut fuer Mathematik und angewandte Geometrie.
- Every year, various students from local summer camps and high schools visit CIM's labs to ask about research activities and career opportunities in engineering and computer science. This year, for example, over 30 students visited from two high schools in the Ottawa region, *Laurentian and Ridgemont High* in May 2000. These students were all active members of a Robotics Club and wanted to share information with our researchers and graduate students studying legged locomotion.
- Other visitors to the Centre this year included: *Ahmed Nazif*, Minister of Communications and Information Technology of the Arab Republic of Egypt; *Dr. Raj Madhavan*, Australian Centre for Field Robotics, University of Sydney; and *Mr. Denis Lafeuille*, Delegeue aux Echanges Technologiques, Canadian Embassy; *Dr. Shinji Hokamoto*, Associate Professor, Department of Aeronautics and Astronautics, Kyushu University, Japan; and and *Drs. Claudio Boer, Lorenzo Tasatti, and Irene Fassi* of the Institute of Industrial Technologies and Automotation, NRC Research Park Milano Italy.
- *Julie Payette*, CSA astronaut and former PhD student with *Prof. Vincent Hayward*, visited CIM on January 17, 2000 to give a brief talk to the students and staff on her experiences on the Shuttle Mission of May 1999 and to return the CIM flag that had accompanied her during the mission.
- A Japanese Delegation from the *Ministry of International Trade and Industry (MITI)* visited CIM's facilities on February 28, 2000 as part of an initiative by the Japanese government to learn more about international robotics research activities. Of the dozen sites chosen, McGill/ CIM was the only research centre in Canada to be visited by this delegation; all others were situated in the USA.
- A senior official, Vladimir Shkolnik, from the *Minister of Science and Higher Education of Kazakstan* visited CIM on October 6, 1999 and was given presentations and demos of the labs.

- This year again CIM faculty and students presented papers and seminars at conferences around the world. Some of the major ones attended were: May 2000: IRIS/PRECARN Conference, Montreal, QC; International Symposium on Robotics 2000 (ISR2000), Montreal QC, May 2000; Canadian Society of Mechanical Engineers Forum 2000 (CSME2000), Montreal QC May 2000; Canadian Conference of Applied Mechanics (CANCAM99) McMaster University, Hamilton ON June 1999; ASME Design Eng. Technical Conferences, Las Vegas, Nevada, Sept. 1999; IASTED International Conference on Robotics and Applications, Santa Barbara, CA, Oct. 99; IEEE/ASME International Conference on Advanced Intelligent Mechantronics, Atlanata, GA, Sept. 99; Ninth International Conference on Advanced Robotics, Tokyo, Japan, Oct. 99; Tenth World Conference on the Theory of Machines and Mechanisms, Opulu, Finland, June 1999; Asian Conference on Computer Vision, Taipei, Taiwan, Jan. 2000; 16th International Joint Conference on Artificial Intelligence, Stockholm, Sweden, July 1999; AAS/AIAA Astrodynamics Specialists Coonference, Girdwood, Alaska Aug. 99; Conference on Computer Vision and Pattern Recognition (CVPR) Kerkyra, Greece, Sept. 1999; Workshop on Perception for Mobile Agents, Fort Collins, CO, June 1999; IEEE Int. Conf. On Robotics and Automation, San Francisco, CA, April 2000; Int. Federation of Aut. Control, Beijing, China, July 1999; Conf. On Decision and Control, Arizona, Dec. 1999; American Control Conference, San Diego, CA, June 1999; Workshop on Applications and Developments in Turbulence Control, Udine, Italy, Sept. 1999; Computer Supported Cooperative Learning Conference, Stanford, CA, Dec. 99; IEEE Pacific Rim Conference on Communication, Computers, Visualization and Signal Processing, Aug. 99.

I.v Public Relations

- CIM welcomed the new Dean of Engineering, **Professor John Gruzleski**, on June 28, 1999. The day involved general discussions with staff and presentations and demos by faculty and students in the labs. He quickly became acquainted with the many research activities ongoing in the labs, as well as the main issues surrounding the Centre as it faces the new millennium.
- CIM was represented by **Prof. Vincent Hayward** at the "*Ceremonie de Remise du Prix du Fonds FCAR*" hosted by Jean Rochon, Ministre de la Recherche, Science et Technologie, that took place in Quebec City on June 17, 1999.
- September 26, 1999: *La Presse* published an article on CIM in the section on Sciences et techniques.
- Several of CIM's students and staff volunteered to act as judges at a science fair held at *St. George's High School* in Montreal in February 2000.
- The June 7, 1999 edition of *Maclean's* featured Scout II from the Ambulatory Robotics Lab along with comments from **Prof. Martin Buehler** and students.
- **Prof. Martin Buehler**, and his students *Geoff Hawker*, *Liana Mitrea*, *Martin de Lasa* and *Didier Papadopoulos* appeared in an article on the cover page of *Computerworld's* June 18, 1999 edition featuring Scout 1.
- **Prof. Jeremy Cooperstock's** lab, Shared Reality Environment, was a popular place for the media during the past year. A small sampling includes: CFCF (CTV) Pulse News, Feb. 2000; Interface, La Revue de la Recherche, Vol. 21, No. 2, Mar/Apr. 2000; Financial Times,

Life/Technology, Nov. 1999; Le Devoir, Nov. 1999; and CBC Radio, As It Happens, Nov. 1999.

II Evaluation of the Past Academic Year

II.i Goals and Objectives

Adapting to Change

- The mandate of the McGill Centre for Intelligent Machines is: to be a unique and internationally renowned centre of excellence in the research, teaching and application of intelligent systems and machines. Since 1996, the Centre has undergone many changes to its organization, membership and research directions. While the primary scientific focus has remained constant since its inception in 1985, numerous changes have been made to its structure, membership and research directions. These changes were necessary in order to keep pace with the dynamic nature of our research and its impact on the economy, exemplified by the explosive growth of information technology.
- The Centre's objectives vis-à-vis teaching, research and collaboration have been redefined to ensure the continuity of our scientific and technical leadership, and to promote to the greatest degree possible, the integration of all of these themes. By developing critical mass in selected areas we have fostered new scientific collaborations internally, nationally and internationally. This is evidenced by our group participation in new National Centres of Excellence (GEOID and MITACS) Programmes and our continued strong presence in the renewed IRIS NCE Programme. The efficient operation of the Centre was key to successful funding diversification as seen in two successful CFI awards and in the large number of grants (82) from various NSERC and FCAR programs. This increased awareness has resulted in the development of successful links with industry (both with established companies and new initiatives started by our former graduate students). The interdisciplinary nature of the Centre also translates into a considerable number of joint projects that expose many undergraduate students to the research environment at CIM.
- Our success in each of the Centre's research areas is evidenced by the number of articles in leading journals and international conferences (507) during the past 3 years and the international profile of the Centre and its members. Our members regularly serve on the program committees of the leading international meetings in each of the key areas, on the editorial boards of leading journals, and as external reviewers for programs in Europe and the U.S [A member of CIM is an elected member of the IRIS research management committee]. Although there are close ties between Centre members, notably in collaborations under the IRIS Centres of Excellence (NCE) and in some of the more high profile projects cited above, we tend to publish primarily with our students. During the past 3 year period, approximately 200 joint publications have been held between members and their students. Of these approximately 175 have a student listed as first author. In contrast, 14 articles among two or more Centre members have been published during the same period. However, there exists strong collaboration among the centre members. Both Clark and Ferrie work within the same sub-domain in the area of artificial perception, active vision. However Clark's work focuses more on computational models of biological vision where Ferrie's is directed at 3D modeling

and machine vision. Each area has its own literature and research community, but the day-to-day collaboration between these scientists and their common research environment greatly enhances the inspiration and quality of their work. Although the fruits of our collaborations are less frequently published currently, we expect this to change as our focus shifts more to the theme of human computer interaction for which there is a significant literature in the kinds of experimental work that mark our collaborations. This increase is already evident in the large CFI grant that was jointly awarded to Clark and Cooperstock for development of the infrastructure to be used for their collaborative human computer interaction research.

II.ii Research and Contributions to Teaching and Training

- CIM's reorganization has also extended to our teaching program through a revamping of our course offerings and increased opportunities for senior year undergraduates to do projects in one of the Centre's eight laboratories. Interdisciplinary research still remains at the forefront of our activities with most members actively involved in more than one research theme and a considerable number of joint projects.
- The Centre brings together 17 professors from 3 departments and 2 faculties and approximately 85 graduate students into a single shared research environment. This provides each participant with access to roughly 30 times the equipment available to members of the corresponding academic departments. The level of interaction is demonstrated by the fact that students at the Centre typically take 20% of their courses from CIM personnel outside their home department, dramatically unlike typical McGill students. The continuum of training within the Centre emphasizes integration, interaction and collaboration. The concept of working in isolation simply does not exist. Post-docs, visiting scholars, scholarship students and all other researchers at CIM share common space, labs and equipment, making integration a natural and seamless process. This open environment produces a hierarchy of training where information is passed on through both formal and informal channels, and exposes individuals to a variety of methodologies, and approaches to problem solving. As in the previous years, CIM continued to play a leading role in research at the global scale. CIM faculty and students contributed original research work at local, national and international forums. Internationally, our presence in the community of researchers in areas related to intelligent machines was prominent, as per our list of papers presented at conferences the world over. Needless to say, the training aspect of this participation is key in the teaching of our graduate students, who are thus encouraged to face a community of international scholars early in their research careers.
- The Centre's students, along with its faculty members, have an established influence in prominent conferences worldwide, complemented by a high-degree of student co-authorship of papers (193/372) over the past 3 years. This summer, the Centre played a major role in the International Symposium on Robotics held in Montreal, May 2000. A key training objective at the Centre is to support a strong representation of students to these conferences, considered vital and relevant to their research, where they must face a community of prestigious, international scholars early in their academic development. Since 1997, with financial support provided by both FCAR funds and the Centre, students affiliated with the Centre presented papers or posters (135) in the most important conferences in the world in vision, robotics and control systems, eg. ASME, ICRA, ICCV and CVPR. A major Canadian conference, IRIS/PRECARN, is industry intensive, thus adding perspective to our students

on industrial concerns and technology transfer. Additionally, the Centre organizes three series of lectures on a regular basis throughout the year: seminars in Computer Vision, Systems and Control and in Robotic Mechanical Systems.

II.iii Inter-University and Industrial Collaboration

- The MITACS project, with **Prof. Peter Caines** as a Network Investigator, is inherently an inter-university project. The local project leader is Professor Brigitte Jaumard of École Polytechnique.
- **Prof. Vincent Hayward** is working on Computational Models of Friction with Professor Armstrong, Univ. Wisconsin, and is also collaborating with Prof. J. Rovin, Florida State School of Music.
- **Prof. Martin Buehler** presently holds a research contract with DARPA in collaboration with University of Michigan and UCB on the design of a robotic hexapod prototype.
- **Prof. Frank Ferrie**, Director, is involved in several inter-institutional and industrial collaborations: as part of the GEOIDE (National Centres of Excellence Program) he is investigating how remotely sensed imagery can be used to automatically synthesize databases for flight simulator and synthetic vision systems; he also participates in IRIS on a project in collaboration with Universities of Laval, Western, and Victoria in developing systems for real-time simulation linked with VR environments. His industrial collaboration includes work as part of an NSERC Strategic grant with CAE to investigate the use of synthetic vision systems for flying helicopters in low to zero visibility situations.
- Laboratoire Universitaire Bell Emergis (LUBE): A Shared Visualization Environment, Principal Investigator **Prof. Jeremy Cooperstock**, inter-university project with École Polytechnique de Montreal.
- Other inter-university projects involving **Prof. Jeremy Cooperstock**: INET demonstration development with University of Tokyo; AES demonstration development with University of Southern California; Augmentation of Eclass system with Georgia Tech.
- **Prof. Martin Buehler**, Director of the Ambulatory Robotics Lab, is collaborating with Carnegie Mellon University and TORO Inc. on automation of golf course lawn mowing. This collaboration involved a visit to the Palm Springs Golf Course with TORO to test the site in February 2000 for initial on-site data acquisition.
- **Prof. Jeremy Cooperstock** is presently collaborating with industrial partners Canarie, RISQ (Canada), Cisco Systems, Dolby Laboratories (US), Data Conversion Systems (UK) and Fraunhofer Institute (Germany) on high-bandwidth streaming applications.
- We can cite collaboration between **Professor Jorge Angeles** and **Professor Arun Misra** on a STEAR Quebec Project involving Bombardier: "*Macro-micro manipulator system*"; and further collaboration with CAE on "*Simulation of flexible multibody system dynamics in the ROSE environment*".

III CIM Staff

Director: F. P. Ferrie
Manager: M. Gray

Members:	J. Angeles	Professor	ME
	P.R. Bélanger	Professor	ECE
	B. Boulet	Assist. Prof.	ECE
	M. Buehler	Assist. Prof.	ME
	P.E. Caines	Professor	ECE
	J.J. Clark	Assoc. Prof.	ECE
	J. Cooperstock	Assist. Prof.	ECE
	L. Cortelezzi	Assoc. Prof.	ME
	G. Dudek	Assist. Prof.	SOCS
	F. Ferrie	Assoc. Prof.	ECE
	V. Hayward	Asssoc. Prof.	ECE
	V. Krovi	Assist. Prof.	ME
	M.D. Levine	Professor	ECE
	H. Michalska	Assoc. Prof.	ECE
	A. Misra	Professor	ME
	K. Siddiqi	Assist. Prof.	SOCS
	P.J. Zsombor-Murray	Assoc. Prof.	ME

CIM Associates:	C. Charalambous	University of Ottawa
	E. Papadopoulos	University of Athens, Greece
	H. Galiana	McGill University
	N. Hori	McGill University
	R.V. Patel	University of Western Ontario
	M. Husty	Mining Univ., Austria

Technical Staff:	J. Binder	Systems Administrator
	M. Cruz-Hernandez	Research Engineer
	Alexei Morozov	Post-Doc
	Gabriel Robles	Post-Doc
	M. Parker	Systems Programmer
	L. Slutski	Research Associate
	G. Soucy	Research Engineer

IV CIM Students and Postdoctoral Fellows

The students at CIM are all graduate students associated with either Electrical and Computer Engineering, Mechanical Engineering or with the School of Computer Science. During the 1999-00 academic year the statistics were as follows:

	Masters	Ph.D.	Total
Electrical Eng.	16	19	35
Mechanical Eng.	11	11	22
SOCS	6	7	13
Total	33	37	70

	Postdocs
Electrical Eng.	1
Mechanical Eng.	1
SOCS	0
Total	2

V. List of CIM Students Graduating in 1999-2000

- **Master's of Engineering:**

Arseneau, Shawn (Electrical)	J. Cooperstock
Domerque, Alain (Electrical)	J.J. Clark
Hawker, Geoffrey (Mechanical)	M. Buehler
Lau, Hang Fai (Electrical)	M. Levine
Obaid, Sami (Mechanical)	M. Buehler
Papadopoulos, Didier (Mechanical)	M. Buehler
Wang, Qingyuan (Electrical)	V. Hayward

- **Master's of Science:**

Daum, Michael (SOCS)	G. Dudek
Burlington, Scott (SOCS)	G. Dudek

- **PhD Graduates (Engineering):**

* Arbel, Tal (Electrical) <i>Active object recognition conditioned by probabilistic evidence and entropy maps</i>	F. Ferrie
Astley, Oliver (Electrical) <i>A software architecture for surgery simulation using haptics</i>	V. Hayward
Grant, Danny (Electrical) <i>Accurate and rapid control of shape memory alloy actuators</i>	V. Hayward
* Hayes, John (Mechanical) <i>Kinematics of general planar Stewart-Gough platforms</i>	P. Zsombor-Murray
Hubbard, Paul (Electrical) <i>Hierarchical supervisory control systems</i>	P. Caines
Kim, Sun-Wook (Mechanical) <i>Contact dynamics and force control of flexible multi-body systems</i>	A. Misra

***Lemch, Ekaterina (Electrical)**
*Nonlinear and hierarchical hybrid
control systems*

P. Caines

***Shen, Gang (Electrical)**
*Hierarchical control for finite
state machines*

P. Caines

*** Dean's Honour List**