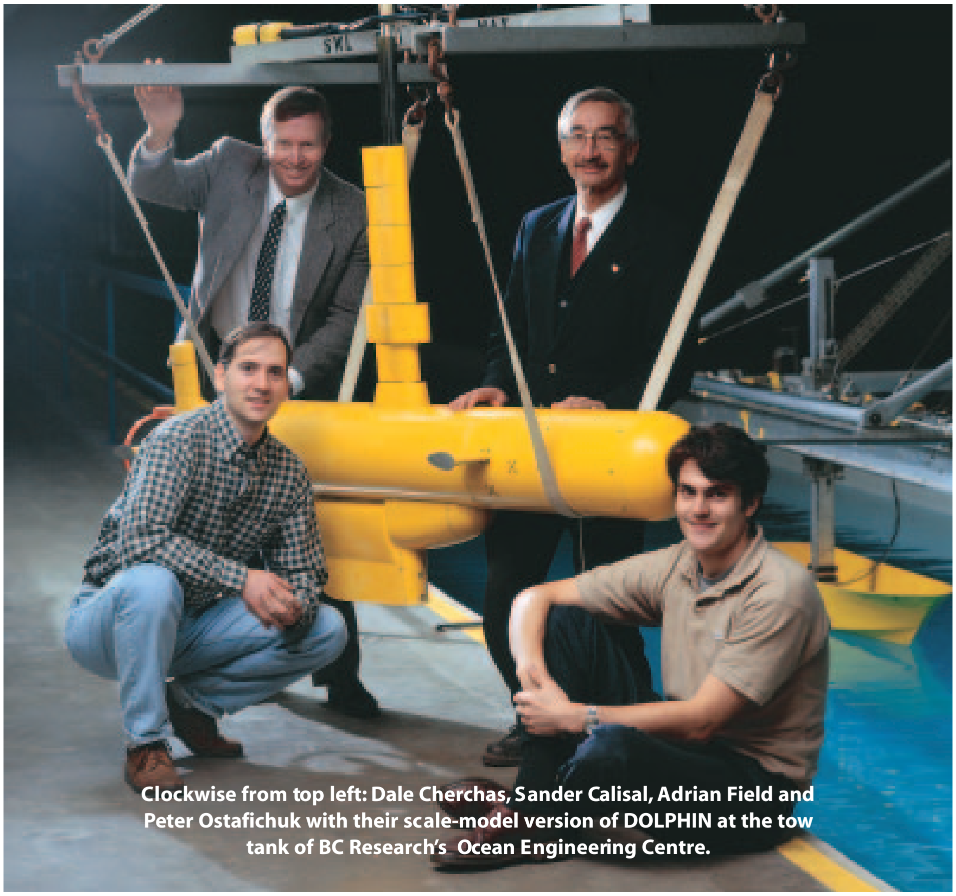
CENTRE FOR INTEGRATED COMPUTER SYSTEMS RESEARCH

CICSR FOCUS

THE UNIVERSITY OF BRITISH COLUMBIA

DOLPHIN highlights collaboration between CICSR & industry

CICSR researchers improving ISE semi-submersible



Clockwise from top left: Dale Cherchas, Sander Calisal, Adrian Field and Peter Ostafichuk with their scale-model version of DOLPHIN at the tow tank of BC Research's Ocean Engineering Centre.

It's yellow, but a full-scale submarine it is not. At just 7 feet in length and 10 inches in diameter, the scale-model looks more like a torpedo. To a group of CICSR researchers, the scale-model is a DOLPHIN—the centrepiece of a two-year collaborative project with International Submarine Engineering (ISE) of Port Coquitlam, BC.

DOLPHIN stands for Deep Ocean Logging Platform for Hydrographic Instrumentation and Navigation. For the past 15 years ISE has been building and developing this unmanned, remotely controlled semi-submersible vessel for ocean surveying.

Evolving demands

ISE has sold a dozen DOLPHINS to various commercial, scientific and naval clients, and their evolving requirements have driven the need for still more vehicle research and development. To that end, the company has contracted a group led by Mechanical Engineering professors Dale Cherchas and Sander Calisal. They are using the scale-model DOLPHIN to optimize and develop control algorithms for the full-size DOLPHIN's control surfaces.

The control surfaces are the rudder, dive and stern planes which permit the semi-submersible to smoothly dive, surface and manoeuvre. On DOLPHIN, they are controlled automatically. ISE turned to Calisal and Cherchas in this phase of development because of their expertise in automatic control systems, robotics and hydrodynamics.

Calisal has a background in ship hydrodynamics. He is developing equations for the forces acting on the DOLPHIN, and a time-representation of these forces suitable for control algorithms. Cherchas, a CICSR member, has expertise in system dynamics and automatic controls, and is developing DOLPHIN's adaptive, automatic control algorithms.

Improving performance

"The ultimate goal," says Cherchas, "is to develop and supply control algorithms

continued on page 2

CICSR
Director's Corner

A 1996 report on the BC information technology (IT) industry reported at least 880 unfilled positions. Continued growth in this important sector of the economy means even more demand for skilled professionals.

It is this reality which has led us to plan a new degree program, the Master of Software Systems (MSS).

This new degree—a cooperative effort by CICSR and the departments of Computer Science and Electrical and Computer Engineering—is designed to give students the expertise needed for the IT workplace.

The program is intended for students with Bachelor degrees in the mathematical and physical sciences, engineering and related areas (other than computer science and computer engineering). It will build on the analytical skills they have acquired in those disciplines.

The program will benefit both students and the IT industry; a MSS degree will give students the software system skills needed in today's marketplace, and help the provincial IT industry to expand and innovate with homegrown talent.

We're very excited about this new degree, and hope to see the first MSS students graduate in December of 2000. For more information on the program turn to page 7, or go to the CICSR website at **www.cicsr.ubc.ca**

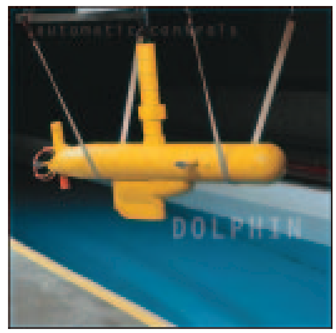
Rabab Ward, CICSR Director

continued from page 1

that will improve the performance of the full-scale DOLPHIN."

The CICSR research group—which consists of Cherchas, Calisal, and Masters students Adrian Field and Peter Ostafichuk—is using both computer simulation and experimental testing to accomplish this goal.

The full-scale DOLPHIN is propelled by an air-breathing diesel engine and has a top speed of 18 knots. As it travels just below the surface on a route programmed by a remote command vessel, DOLPHIN transmits survey data back to the command vessel/station via a communications telemetry link. The telemetry antenna is mounted on the surface-piercing mast, which also serves as an air intake for the engine.



Because DOLPHIN operates at or near the free surface, waves and wind have an affect on its ability to maintain a steady course as it navigates through its GPS-programmed waypoints. This, in turn, has bearing on the design of the control surfaces and the development of the control algorithms.

"We have had to develop a new formulation of fluid dynamics for computer simulation—a procedure to calculate forces at or near the surface," says Sander Calisal.

Simulations help measure performance

Computer simulations help the team to understand the physics of DOLPHIN's motion through the water. The simulations give Adrian Field data on the performance of the vehicle, including the forces and flows generated by the planes as they respond to control inputs.

This data helps Peter Ostafichuk as he works to find the optimal shape, size and configuration for the control planes. The different planes and configurations are then tested experimentally in both a wind tunnel and a tow tank.

"In a given length of time, we can do ten times as many tests in a wind tunnel as in a tow tank," says Peter, "but the tow tank tests are critical because they include the influence of the water surface and waves."

Tow tank testing at BC Research

The tow tank tests will be performed at the Ocean Engineering Centre of BC Research Inc., the only facility of its kind in western Canada. The model DOLPHIN will be equipped with on-board sensors so that forces and moments can be measured during the tow tests.

"The tests will give us very realistic data," says Adrian. "As a result, the control algorithms will be more realistic."

With about 50% of the work completed in the two-year project, the group is now gearing up for experimental testing, and to that end has recently ordered a data acquisition system. Funding for the project comes from ISE and the BC Science Council.

Hotbed for submarine engineering

Spurred by the growth in undersea exploration, similar research is also being conducted at Simon Fraser University and the University of Victoria. BC is becoming a centre of ocean engineering expertise, and the DOLPHIN project has added to that reputation.

"The ISE/CICSR partnership is creating state-of-the-art underwater industry R&D," says ISE project director Dr. Mae Seto. "This type of collaboration complements the in-house capabilities, objectives and needs of ISE quite well."

Contact Dale Cherchas at (604) 822-4902, cherchas@mech.ubc.ca, or Sander Calisal at (604) 822-2832, calisal@mech.ubc.ca

Developing intuitive, adaptive interfaces

Sid Fels works on the next generation of interfaces to ease human-computer interaction

Human computer interaction is commonly conducted through two interfaces: the keyboard and the mouse. These devices, successful as they are, require that we adapt to their prescribed and limited methods of use. But what if we had interfaces and input devices that adapted to our preferences? Sid Fels believes adaptive computer interfaces have the potential to make computing more human and less rigid.

Fels is a CICSR member and a recent addition to UBC's department of Electrical and Computer Engineering. He is interested in creating adaptive interfaces for embodied systems. Embodied systems are a fusion of body and computer—a virtual extension of the body—and require an understanding not only of software and interface design, but of human psychology as well.

Adaptive interface technology

"I think that adaptive interface technology can be used to make novel interfaces in devices such as virtual musical instruments, and in heavy machinery such as excavators or cranes," says Fels. "These devices would adapt to the human controller, making them easier to learn and use."

Fels began integrating his interests in computer engineering and cognitive psychology as a graduate student at the University of Toronto. His PhD project was a gesture-to-speech system called the Glove Talk II. This embodied system translates hand gestures into speech sounds. Wearing a data-glove and controlling volume with a foot pedal, a user can "speak" in a computer-generated voice by combining gestures which represent parts of speech.

Although the Glove Talk II requires some training for successful use, its adaptive nature is noteworthy: the system learns from the user what gestures are best suited to the sounds the user wants to make. This adaptive aspect is key to Fels' thinking about human-computer interaction.

"I believe that if we can make interfaces that feel good—that appeal to our emotional sensibility—ease of use and desire to use them will follow," says Fels. "As we gain intimate relationships with our machines, and model them on how we relate to people, the more these machines will feel like an extension of who we are."

Intuitive and personal interfaces

Fels sees this intimacy as part of the appeal of embodied systems, such as the Glove Talk II, which promise a technology with more satisfying, intuitive and personal interfaces. Consider the way people use a common device like the pen.

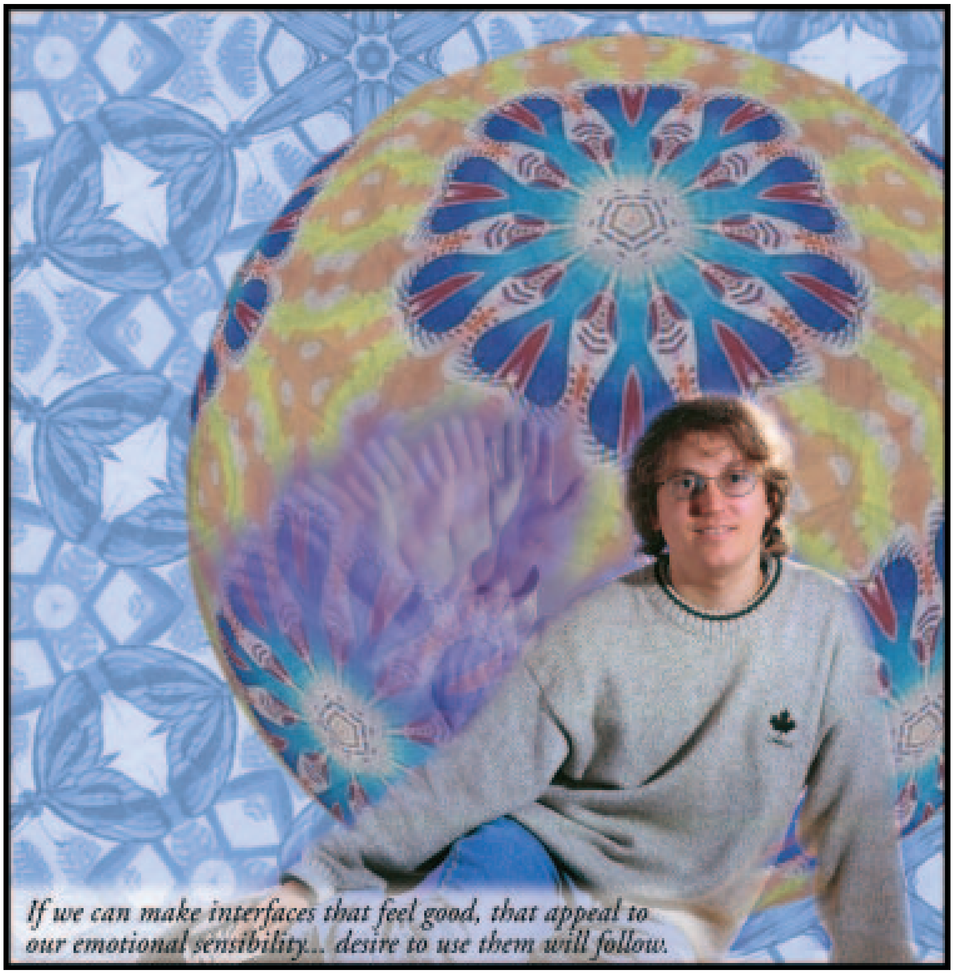
"When I hold a pen it becomes an extension of my hand and is no longer an external thing—I've embodied it," he says. "And there is an aesthetic sense in the act of writing. If we can get that feeling in our common usage with computers, we will have an extremely successful interface."

Iamascope developed in Japan

Fels's interest in embodied systems came to fruition in Japan. After working on a gesture recognition system for a California company, Fels took an appointment as a visiting researcher at Advanced Telecommunications Research (ATR) in Kyoto. It was at ATR while working on an artificial intelligence project that Fels began development of the Iamascope.

The Iamascope combines video, audio and gesture-recognition components that translate the gestural input of a user into a shifting kaleidoscope of music and imagery.

continued on back page



If we can make interfaces that feel good, that appeal to our emotional sensibility... desire to use them will follow.

Exploring the boundaries of complexity

Nick Pippenger unravels problems in complexity theory and computational topology

Nick Pippenger, a CICSR member and professor of Computer Science, inhabits a field at the intersection of mathematics and computer science. He explores computational problems from a mathematical perspective, and although the research is abstract, it builds the foundation for future solutions in day-to-day computing.

"I am more of a problem-solving type of researcher than a theory-building one," says Pippenger, a specialist in complexity theory and computational topology.

Complexity theory and computational topology

Complexity theory seeks to establish as precisely as possible the number of basic components or operations needed to carry out various tasks. It also plays a role in determining the difficulty of such problems as knot recognition and knot equivalence in computational topology.

"The unifying theme of my work is an interest in mathematical methodology," explains Pippenger, who has an engineering background. "If I can't formulate a problem mathematically, then I won't work on it."

One problem that has occupied Pippenger is determining whether or not a closed curve embedded in space is unknotted. A closed curve without self-intersections in three-dimensional space is said to be unknotted if it can be deformed continuously, without breaking it or passing it through itself, to lie in a plane. Until recently, no good algorithm for recognizing unknottedness was known.

Knots and polymers

The question has intrinsic significance to topologists, but has importance as well to polymer physicists looking at the entanglement, or knotting, of polymers. For example, scientists examining DNA—a biological polymer—are using mathematical models to analyze how certain enzymes allow DNA strands to pass through each other.

"A great deal of effort has been devoted to a quest for algorithms for recognizing unknottedness," says Pippenger. "It was only in the 1950s that it was first proved that this question could even be answered using a computer."

First bounds on problem

As Pippenger was working on a paper giving the first bounds on the complexity of recognizing unknottedness, he learned of two other researchers working on the problem. Pippenger and Joel Hass, of the University of California at Davis, and Jeffery Lagarias, of AT&T Labs in New Jersey, produced a paper together which they presented at the IEEE's 38th Annual Symposium on Foundations of Computer Science.

"The knot is one of the more fundamental objects in topology," says Pippenger. "There is a great deal of intrinsic mathematical interest in the questions involved."

Pippenger's expertise in knots also led him recently to serve on the supervisory committee for CS graduate student Rob Scharein's PhD thesis. Scharein has created a software program called KnotPlot that generates complex knot images.

Pippenger next wants to determine the complexity of recognizing knot equivalence.

Exploring mathematical richness

"I'm interested in exploring the richness of mathematical situations," says Pippenger, summing up his approach. "Because of the nature of certain questions, definitive answers cannot be obtained by experimental or empirical methods. Progress is made exclusively through mathematical methods."

Such methods may seem abstract but as Pippenger notes, "The transformations in physics which have occurred in this century have shown us embodiments in the physical world of things that were previously known only in people's minds."

For more information, contact Nick Pippenger at (604) 822-4030, or nicholas@cs.ubc.ca

Real-time systems: multimedia delivery and landmine detection

Mabo Ito works to increase real-time system performance

Multimedia and landmines have little in common, but to Mabo Ito they pose a similar challenge in computer and software engineering. CICSR member Ito wants to improve the performance of real-time multimedia delivery over Internet Protocol (IP) networks and the detection of landmines in battlefield conditions.

Real-time systems require fast data processing, and accurate error detection and correction methods, to ensure acceptable system performance.

"In a real-time system there is often no time to retransmit the data—you have to work with what you get," says Ito, a professor in UBC's department of Electrical and Computer Engineering.

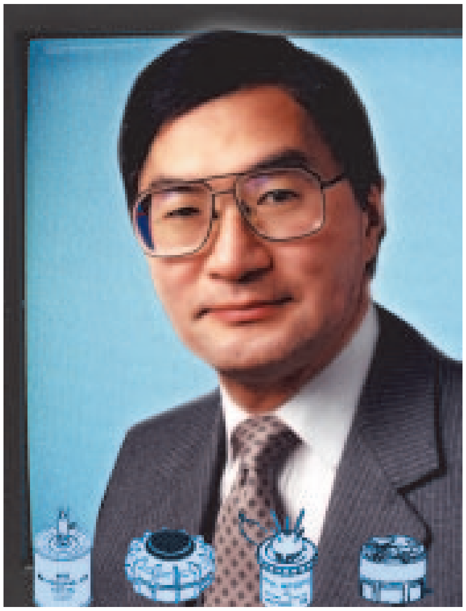
Real-time challenges

Traffic on the internet, and the demand for video, is growing fast. Real-time encoded video faces two problems: congestion, which in turn leads to data loss, and delay. During high-traffic periods, routers (that switch and direct data packets over the internet) commonly lose packets.

This does not present a problem with e-mail messages and static data files because packets can be resent. But this solution fails with real-time multimedia and video transmission because they require a continuous stream of live data. When packets are lost or delayed excessively, image quality suffers with gaps, bands and other artifacts appearing in the video image.

"What we've been doing is trying to understand what kinds of errors occur and their severity," says Ito. "We've found that the objective measurement of quality does not correlate with a subjective view of quality. Small errors are more visible and annoying in relatively static video images, such as a news broadcast, and less noticeable in high-activity scenes."

Armed with an understanding of these errors, Ito is developing correction algorithms which can fix errors on the fly. For



example, these algorithms can detect badly affected areas in a video frame and restore them by using adjacent areas of the image to fill in the degraded area. Error-riddled frames can also be totally replaced by neighbouring frames.

Error prevention at the source

These techniques work at the receiver's end; Ito is also looking at error-prevention at the source. Such methods include error correction codes, transmission of multiple picture headers, and prioritizing video transmission. This last approach—known as differential service—flags certain kinds of encoded video packets and gives them a higher priority in internet traffic.

Ito has been working on this project with Gerald Neufeld of Computer Science (also a CICSR member) for the past two years. Neufeld (currently on leave in Silicon Valley) has been looking at the protocol and network aspects of the problem.

The project is part of a major undertaking in network resource management by the Canadian Institute for Telecommunications Research (CITR), one of the Networks of Centres of Excellence administered by NSERC. Hewlett Packard Canada has provided strong support, including funding, equipment and advice. Nortel has also contributed funding.

Landmine detection

Landmines became an area of interest when one of Ito's graduate students went to work at the Canadian Forces' Defence Research Establishment in Suffield, Alberta. A research project undertaken there to find buried, unexploded shells using magnetic pulse induction led to Ito's current work in landmine detection.

Ito developed a real-time system to detect mines at or near ground surface using an airborne active infrared system. Infrared lasers scan the ground, and sensors analyze the resulting light reflection and absorption patterns. Since all materials—including plants, earth, metal, plastic, and paints—have a characteristic reflection signature, the system can scan a cluttered field and detect a landmine according to its signature.

A further development of this system relies on a passive, airborne multispectral scanner to measure heat and radiation signatures. Again, different materials have characteristic reflective properties, and these signatures are used to distinguish objects on a battlefield. Yet another development is the use of a passive, vehicle-mounted, forward-looking infrared sensor to provide real-time detection of landmines.

"The last thing you want to do on a battlefield is to stop, even in defensive or peacekeeping situations," says Ito. "This system can tell you whether there are mines there or not, and help identify a safe route."

Ito's detection system is a timely development as the global ban on landmines comes into effect. He also has a number of other interests, including requirements specification and system implementation using programmable logic controllers.

For more information, contact Mabo Ito at mito@ece.ubc.ca or at (604) 822-4572.

How the Giraffe got its spots

Alain Fournier seeks better ways to simulate and animate natural phenomena

Computer animation has quickly grown in power and sophistication. Witness the change in the world of entertainment, where computer graphics have migrated from video games to the big screen and taken a leading role in such Hollywood blockbusters as *Toy Story*.

Computer animation continues to develop as programmers seek better ways of creating realistic effects. Surfaces and textures—illuminated and shadowed by falling light—present a number of problems, which CICSR member Alain Fournier wants to solve.

Rendering natural phenomena

Fournier, a professor of Computer Science, specializes in the computer modelling and rendering of natural phenomena. In earlier work, he built a simple but realistic model to simulate ocean waves, and used fractals to create terrain. Now Fournier is focussing on the generation of natural textures and surfaces, such as the coats of patterned mammals like the giraffe and tiger.

Working with graduate student Marcelo Walter and postdoctoral fellow Daniel Meneveaux, Fournier has created a pattern generation system that automatically integrates mammalian coat patterning with body growth and animation.

Normally, surfaces such as a giraffe's reticulated coat are generated separately from the modelling of the animal's geometry. The patterned surface and geometry are then integrated—texture mapped—to render the animated animal.

"We are pretty good at getting an animal's geometric model," says Fournier, "but it is harder to map a realistic pattern to its surface without distortion."

In the new pattern generation system, the pattern is "grown" in tandem with the animal's geometry. Fournier and his partners have achieved this by simulating the biological process of pattern growth, according to the clonal mosaic (CM) model. The CM model accurately describes natural growth processes on the skin of mammals from embryo to adult. In the case of the giraffe, it describes the spatial arrangement and growth of pigment-producing cells in the giraffe's skin as the animal matures.

Fournier and his team apply a simplified CM model to generate computed "cells." These cells are tied to the geometric model by "growing" them directly on the polygons that compose the model. The model itself is described and controlled by a cylindrical coordinate system that covers the major body parts. With the input of real giraffe measurements, a model can be grown from embryo to adulthood with a realistic, corresponding patterned coat. And that model can then be animated.

Integrating growth & patterning

"The point of integrating growth and pattern processes is to create more accurate models of patterned animals," says Fournier.

The pattern generation system is attractive because it can produce a large number of animal patterns with a relatively small number of parameters, which can be applied to a variety of shapes. As well, the cylindrical model can generate unique, individual giraffes by inputting real giraffe measurements.

Fournier is also interested in computer-simulated illumination. He is currently exploring how to accurately reproduce the reflective properties of woven fabrics such as velvet and silk. These fabrics, along with fur and hair, share self-shadowing properties that are hard to simulate.

"Self-shadowing is the effect of the material casting a shadow on itself," says Fournier, pointing to silk as an example. "It is an important visual property that is part and parcel of the texture."

These effects, however, are difficult to compute, so Fournier is examining different filtering techniques that simulate the self-shadowing look.

Technology increasing in sophistication

"As the technology increases in sophistication, people's expectations increase as well," says Fournier. "So our simulations have to keep up with the technology by being more and more detailed. It's a great time to be in computer graphics!"

Alain Fournier's e-mail is fournier@cs.ubc.ca, or call (604) 822-6770. Check out his website at www.cs.ubc.ca/spider/fournier/home.html

CICSR Passing Notes

New Master of Software Systems

A new CICSR Masters program will help fill the growing number of jobs in the information technology sector. The Master of Software Systems (MSS) is designed for students with Bachelor degrees in areas such as the mathematical and physical sciences, operations research and engineering (other than computer science and computer engineering). The MSS is a 30-credit program over 3 semesters and will take 16 months to complete. Students must have some computer program design and data structures knowledge. Students who do not have the appropriate course requirements, but have the necessary technical experience or background, may be accepted for the program. The MSS is scheduled to begin in September 1999, subject to approval by the BC Ministry of Advanced Education, Training and Technology. The program is a joint effort of the departments of Computer Science and Electrical and Computer Engineering. For more information see **www.cicsr.ubc.ca/mss.html**

CICSR members elected as IEEE Fellows


Ward & Dumont

CICSR Director **Rabab Ward** and ECE professor **Guy Dumont** were recently elected Fellows of IEEE. Their election acknowledges their outstanding contributions to the field of electrical engineering. The IEEE cited Ward's work in digital signal processing and Dumont's contributions to the process industries.

Isaacson appointed EIC Fellow

Dr. Michael Isaacson, Dean of Applied Science and a professor of Civil Engineering, has been elected a Fellow of the Engineering Institute of Canada.

World Automation Congress award


O'Dor & Croft

Matthew O'Dor, a recent Masters graduate in Mechanical Engineering, received the Best Student Paper Award at the 1998 World Automation Congress (WAC). The paper, co-written with his supervisor **Elizabeth Croft**, is entitled "Identifying Salmon Can-Filling Defects Using Machine Vision." WAC is the major international symposium devoted to automation; it was held in May 1998 in Anchorage, Alaska.

New Networks of Centres of Excellence

CICSR faculty members will participate in two of the three new Networks of Centres of Excellence (NCE) recently announced by the federal government. **David Kirkpatrick**, **Jack Snoeyink** and **Craig Boutilier** (CS) will take part in the Mathematics of Information Technology and Complex Systems Network (MITACS); Kirkpatrick and Snoeyink will also join the Geomatics for Informed Decisions Network (GEOID). The new NCEs, including the Canadian Arthritis Network, will share $41-million over the next four years.

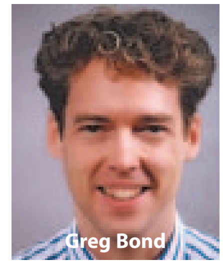
Business/Education Partnership award

Michael Jackson (ECE), his graduate students and Thomas & Betts Photon Systems Inc., have won the first Business/Education Partnership Award from the BC Science Council. The award was given for their collaboration in fibre optics technology.

Tan back from teaching in Mexico

Joseph Tan (a CICSR associate from the Faculty of Medicine) has returned from a special teaching engagement on behalf of CICSR at CETYS in Mexico. Tan co-taught a course in Analysis of Decision Processes to students enrolled in the university's DEng (Doctoral in Engineering) program from September to December 1998.

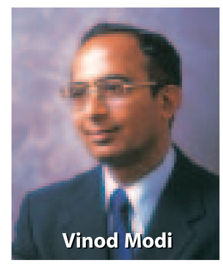
Killam prizes for Bond, Kallel & Snoeyink


Greg Bond


Jack Snoeyink

Greg Bond (ECE), **Samir Kallel** (ECE), and **Jack Snoeyink** (CS) are among the most recent crop of Killam award winners. Bond won a Killam Teaching Award; Snoeyink was awarded a Killam Research Prize; and Kallel won an Isaac Walton Killam Memorial Fellowship.

Vinod Modi wins AIAA award


Vinod Modi

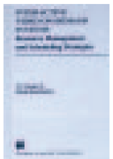
The American Institute of Aeronautics and Astronautics (AIAA) has awarded **Vinod Modi** (ME) the 1999 AIAA Pendray Aerospace Literature Award. The award, the AIAA's highest, honours Modi's extraordinarily significant contributions to the literature of aerospace vehicle dynamics, controls and robotics, as well as his teaching.

GOT PROBLEMS?

Challenge CICSR students to solve them!

Does your company or organization have a problem that needs fixing? Why not challenge a CICSR student to develop a solution! We invite you to post a $500 award, and the CICSR Office will match an appropriate student to your particular problem. If you are interested, please contact Gale Ross in the CICSR Office at **(604) 822-6601** or at **ross@cicsr.ubc.ca** for more details.

Interactive Video-on-Demand Systems: Resource Management & Scheduling Strategies



ed. Babak Hamidzadeh and T.P. Jimmy To (Boston: Kluwer Academic Publishers, 1998)

Interactive Video-on-Demand Systems addresses issues in scheduling and management of resources in an interactive continuous-media (e.g., video and audio) server. The book emphasizes dynamic and run-time strategies for resource scheduling and management. Such strategies provide effective tools for supporting interactivity with online users who require the system to be responsive in serving their requests, and whose needs and actions vary frequently over time.

Computational Intelligence: A Logical Approach

David Poole, Alan Mackworth & Randy Goebel (New York: Oxford University Press, 1998)

Computational Intelligence: A Logical Approach provides an integrated introduction to artificial intelligence (AI). It weaves a unifying theme—an intelligent agent acting in its environment—through the core issues of AI. The authors develop AI representation schemes and describe their uses for diverse applications, from autonomous robots to diagnostic assistants to infobots that find information in rich sources. For more information about the book see www.cs.ubc.ca/spider/poole/ci.html

Health Decision Support Systems

ed. Joseph Tan with Samuel Sheps (Gaithersburg: Aspen Publishing Inc., 1998)

Health Decision Support Systems covers the theories, methods and applications of decision support technology in health care. It explores how medical and health care decision making can be effectively supported through linked databases, simulated models, and intelligent graphical user interfaces. The book covers the use of data mining techniques, neural networks and other expert methods. The book also illustrates how health decision support system technology is applied in the health care field.

Intuitive interfaces, continued from page 3

The device has drawn international attention—last year, the Iamascope won first prize at the Petrobas Virtual Reality exhibition in Brazil and was highlighted at Opera Totale in Venice. It is now on exhibit at the Museum of the Future in Linz, Austria.

Fels has noted with interest the active and passive interactions of people using the Iamascope, where control shifts from the user to the machine and back again. The relationship of user to machine is not just a physical interaction, but a cognitive and emotional one as well.

"How can we understand these interactions to make better interfaces?" Fels asks. "If you can develop an interface that people can bond with, they're going to be able to be expressive with it—even if it's an on/off switch. Whatever it is, it's going to be satisfying. I'm working on developing that."

Fels's intelligent agent and intelligent environment projects also focus on designing with the emotional, cognitive and physical constraints of the user in mind.

Currently, Fels is extending the Glove Talk II system into the musical domain. He is in the process of developing virtual musical instruments which can be played gesturally.

Fels's other projects and interests include using neural networks to perform system identification and non-linear data compression with constraints. His work on the Iamascope was funded by ATR MIC Research Laboratories (www.mic.atr.co.jp), while Glove Talk II received funding from NSERC and IRIS.

For more information contact Sid Fels at (604) 822-5338 or at ssfels@ece.ubc.ca

CICSR Centre for Integrated Computer Systems Research www.cicsr.ubc.ca

The UBC Centre for Integrated Computer Systems Research (CICSR) is an interdepartmental research organization made up of computer-related research faculty members in the departments of Computer Science, Electrical and Computer Engineering, and Mechanical Engineering. Currently, there are more than 70 CICSR researchers who direct over 300 graduate students and collaborate with dozens of industrial firms in areas such as robotics, artificial intelligence, communications, VLSI design, multimedia, and industrial automation.

Return Address:

CICSR, University of British Columbia
289-2366 Main Mall, Vancouver, BC, V6T 1Z4
CANADA

Editors: William Knight, Linda Sewell
Design: wilyum creative
Photos: Janis Franklin, Biomedical Communications
Office: University of British Columbia
289-2366 Main Mall
Vancouver, BC, Canada, V6T 1Z4
Tel: (604) 822-6894 **Fax:** (604) 822-9013
E-mail: cicsrinfo@cicsr.ubc.ca
Contact: Linda Sewell, Publications Coordinator, CICSR Office