CENTRE FOR INTEGRATED COMPUTER SYSTEMS RESEARCH

CICSR FOCUS

THE UNIVERSITY OF BRITISH COLUMBIA

Innovating with Industry: Martha Salcudean and the Computational Fluid Dynamics Lab

Killam Prize winner Martha Salcudean partners with industry in process simulation lab.

Pulp slurries and engine turbines make for difficult, if not dangerous, lab experimentation. In CICSR's Computational Fluid Dynamics lab, however, these hard-to-handle materials are made safe for detailed study with powerful computer modelling techniques.

Martha Salcudean, a CICSR member and Mechanical Engineering professor, heads the lab. She and her CICSR colleagues are leading the way in developing computer simulations of the complex fluid dynamics encountered in jet turbines and in industrial processes like papermaking.

Modelling Complex Problems

These processes involve turbulent flows, often associated with heat transfer and combustion. The problems they pose require the simultaneous solution of a large number of equations for mass, momentum, energy, and species conservation. Computer simulation can accurately model these flows and provide the basis for improvements in process and equipment design.

"Before the advent of computers there were few analytical solutions available," says Salcudean. "And those that were in use had a high degree of simplification and used assumptions which were often unrealistic."

In one of the lab's major projects, Salcudean—along with Mechanical Engineering colleague Ian Gartshore—collaborated with Pratt & Whitney Canada in developing a more efficient jet-turbine cooling process with the aid of computer simulations.

Turbine Blade Cooling

Turbine blades have to be protected from hot gases produced during engine combustion. This protection is accomplished by feeding and spreading a thin film of coolant over the blades.

"The coolant has to flow along the blade's surface in such a way that it provides adequate cooling without negatively affecting the blade's aerodynamics," says Salcudean.

In a combined computational and experimental program, Salcudean and Gartshore were able to identify a more efficient geometry for cooling the blades which leads to better turbine performance. Pratt & Whitney Canada has now implemented the design change developed by the two engineering professors in its engines.

"The project showed that computational methods have a great deal of potential to narrow the number of experimental

continued on page 6

Martha Salcudean heads the Computational Fluid Dynamics lab which specializes in computer simulations of the turbulent flows encountered in processes like papermaking.

CICSR

Fall 1998 Vol. 9, No. 2

Simulating Large Power Systems 2
Online Optimization 3
Looking for Gold in the Data Mine 4
Building Faster Algorithms 5
Passing Notes 7
Distinguished Lecture Series 8

CICSR Director's Corner

This issue of FOCUS includes a profile of **Martha Salcudean** and the Computational Fluid Dynamics lab. We are proud to be associated with such an accomplished and distinguished researcher. Martha's recent laurels include Canada's equivalent of the Nobel, a Killam Prize, and an Order of British Columbia. Her work with industrial partners such as Weyerhaeuser and Canfor are a model of CICSR's collaborative approach.

We also take a look at the recent accomplishments of **Jim Varah** (former director of CICSR) and examine his research in linear algebra. We owe a great deal to Jim as he, along with KD Srivastava, conceived of CICSR.

It seems as if complex technology is often taken for granted. That was apparent after the ice storms early last January disabled hydro-electric service across great swaths of eastern North America. **José Martí's** work can't prevent natural disasters but his simulation software may help hydro engineers prepare for the worst.

On page 3, we profile **Babak Hamidzadeh**. A welcome new addition to CICSR, Babak's multimedia and web-based work has already garnered industry support.

Raymond Ng's data-mining techniques are also drawing some attention. Raymond will be in Princeton on sabbatical this coming year, where he will continue his investigations in database research.

Rabab Ward, CICSR Director

Simulating Large Power Systems on the Desktop

José Martí's software is an inexpensive testing alternative for power utilities and power control equipment manufacturers.

Testing the control equipment that gets plugged into large power systems such as a provincial power grid is a challenging task.

Large analog labs called Transient Network Analyzers (TNA) have been traditionally used to test new system controllers before they are added to a power network, but recent developments in digital simulation by CICSR researcher José Martí promise more flexible and less costly simulation methods.

Building on groundbreaking work in power-system simulation already conducted at UBC, the world-renowned Real Time Simulation Group—led by Martí—is currently developing software capable of performing real-time power-network studies on a Pentium computer.

The simulator program tests protective relays and other control equipment, and can be also used as a tool for on-line power-system supervision, security assessment and operator training.

Currently, real-time simulation of power system controllers is conducted on analog TNAs. There are, however, only two major TNA facilities in the world (located in Quebec and Italy) and they are expensive to build and use.

Cost Advantage

A TNA costs about $10-million, occupies 10,000 square feet, and requires a crew of 10 to operate. In contrast, Martí's desktop simulator costs $10,000, needs only 10 square feet of desk space, and can be operated by one person.

"Apart from the cost, there are technical limitations to analog simulators (such as TNAs)," says Martí, an associate professor of Electrical and Computer Engineering. "With our digital simulator, we can create much more accurate models and tests of fast transient phenomena such as short circuits."

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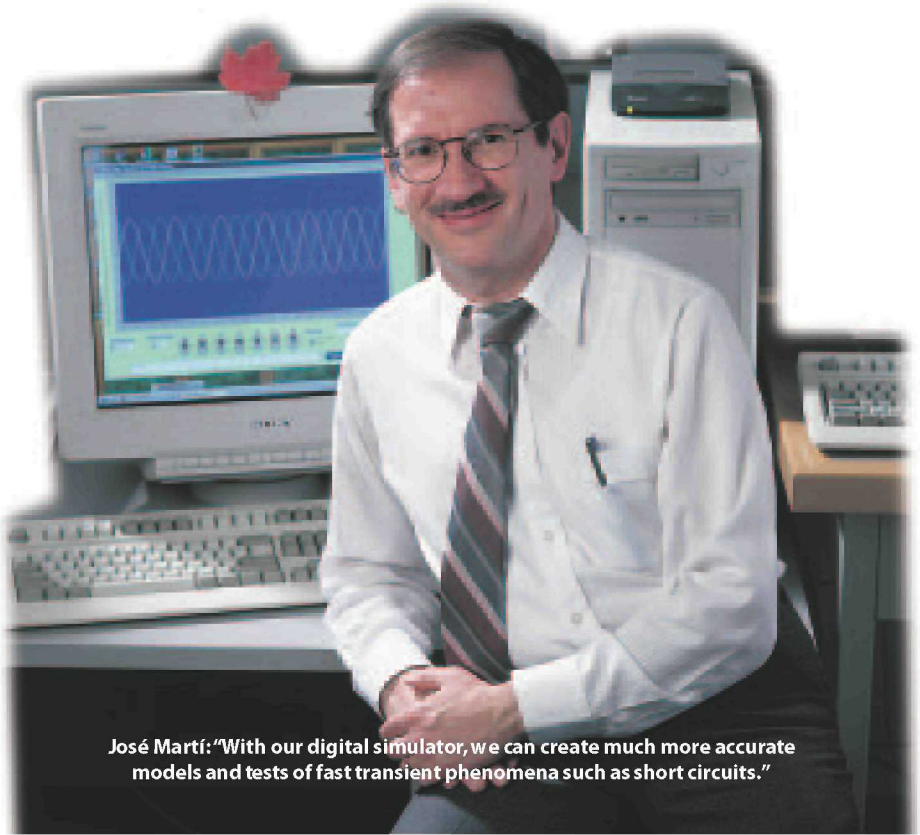


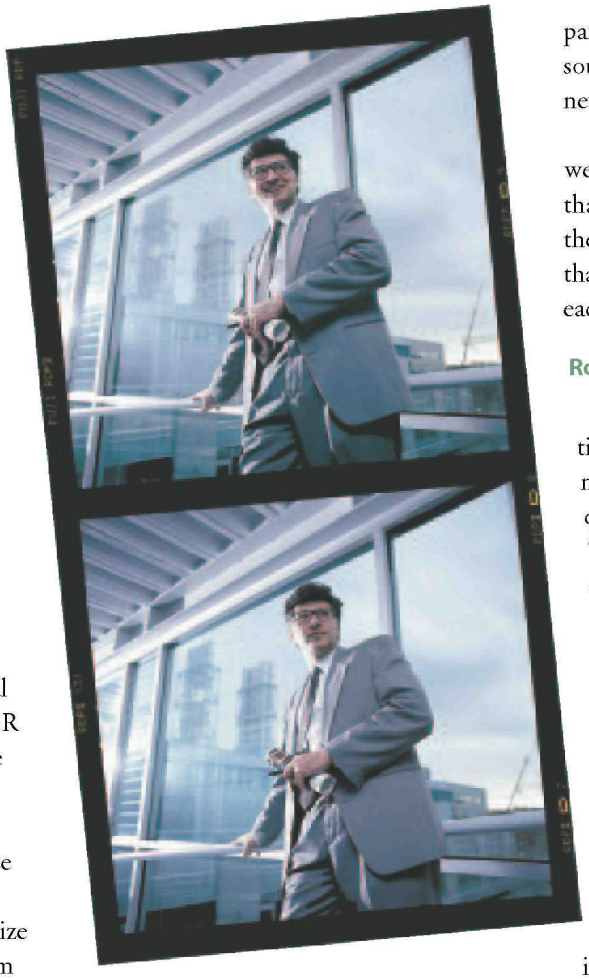
José Martí: "With our digital simulator, we can create much more accurate models and tests of fast transient phenomena such as short circuits."

Improving Real-Time Applications with On-line Optimization

Multimedia and web-based applications will benefit from Babak Hamidzadeh's research in resource scheduling and optimization.

The demands made on computer performance grow quickly as new and more powerful applications make it to market. Real-time applications such as video-on-demand have a huge appetite for memory and processing power; for scientists like Babak Hamidzadeh the challenge is to develop responsive systems that can meet this increasing demand load.

Hamidzadeh's research has a broad range of possible applications, including multimedia and web-based databases. Efficient scheduling and resource management are critical to the performance of these applications which must process an unpredictable stream of user demands.



Tetris Analogy

To explain his work, Hamidzadeh, who is an assistant professor of Electrical and Computer Engineering and a CICSR member, draws a parallel with Tetris, the popular computer game. He also uses a variation of Tetris as a benchmark for demonstrating and evaluating his resource management and scheduling techniques.

In Tetris, players must quickly organize a series of different shapes dropping from the top of the computer screen into complete rows at the bottom. The player has no advance knowledge of the shapes to come. As complete rows are formed, they disappear, freeing up space. If the falling shapes aren't placed so as to make a complete row, they can pile up, clog the screen and end the game with a low score.

"The key to Tetris is to think and act collectively and as quickly as possible," says Hamidzadeh. "Acting without sufficient thought will cause problems, as will thinking too long. You have to optimize the two. The same is true for multimedia systems and many other applications."

Since multimedia or database systems can't anticipate the frequency, order or the characteristics of requests (just as in Tetris), Hamidzadeh has developed on-line optimization. The process ensures the efficient use of computer resources by a continuous real-time assessment of user-demands made on a system.

On-line Scheduling

"Admission tests, through which a system determines if it can meet your request, tend to be conservative," Hamidzadeh says.

"The test assumes a worst-case scenario and over-allocates resources to guarantee a given request can be met. What we're doing with on-line scheduling allows the system to track the actual resource demands of a particular request and redirect any resources that have been over-allocated to new requests."

Although multimedia applications and web-based databases are similar in the way that unpredictable demands are made of them, Hamidzadeh points out differences that require software tailored specifically to each application.

Role of Multimedia Systems

"The emphasis in multimedia applications is to provide a collective resource management mechanism that guarantees quality of service," says Hamidzadeh. "When a request for a particular data segment—a video clip, for example—is made, the system need only locate the data and allocate resources sufficient to make it available to the user."

Web-based database applications can benefit from the use of parallel processing. This technique is aimed at taking advantage of the collective hardware resources of several processors accessing a database.

The large aggregate memory of individual units working in parallel allows the processing of queries at even greater speeds. Scheduling and resource management become a matter of determining which processor will tackle what query and when, with the goal of maximizing query throughput.

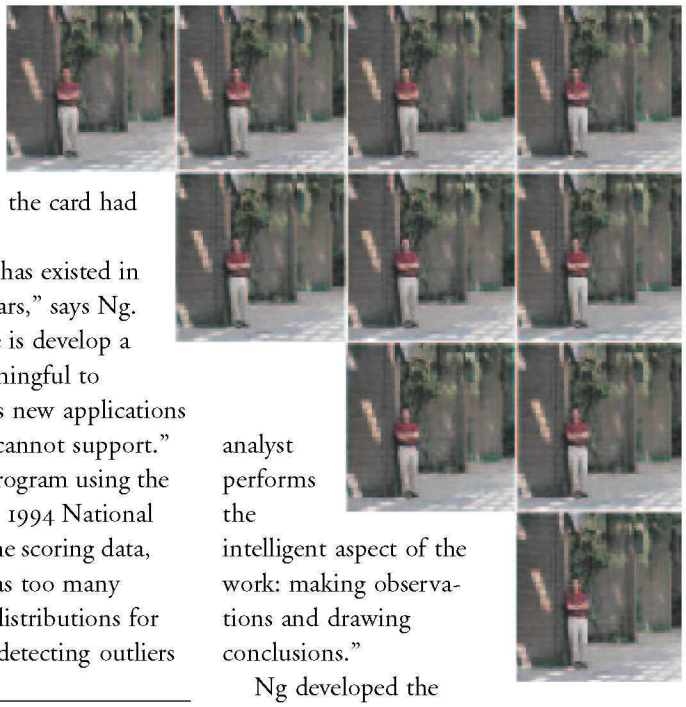
Other applications for Hamidzadeh's on-line optimization techniques include automated manufacturing environments, in which software can be used to monitor production processes and make adjustments as manufacturing conditions change.

Hamidzadeh's research is supported by the BC Advanced Systems Institute and Brooks Automation. ■

Babak Hamidzadeh can be reached at babak@ece.ubc.ca or at (604) 822-9181.

Looking for Gold Down in the Data Mine

Raymond Ng seeks unusual relationships and patterns with data-mining software.

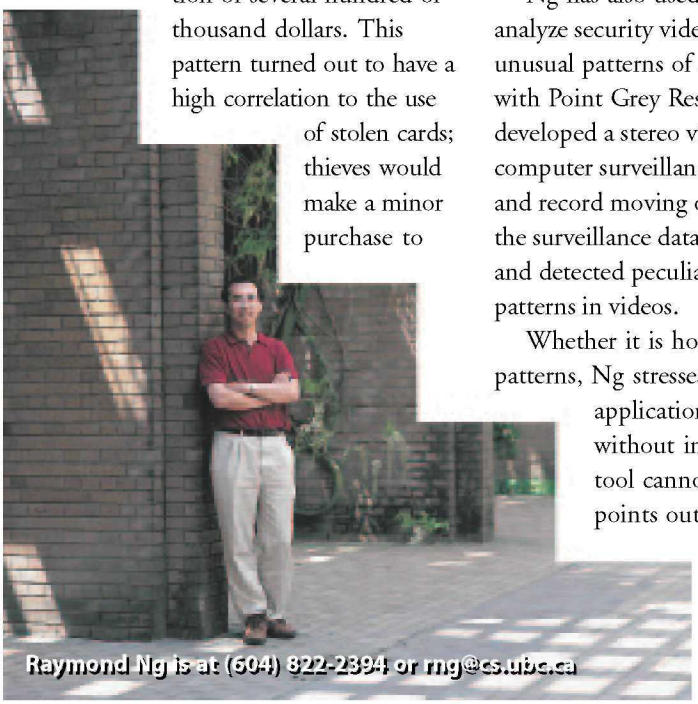


Data mining may be a virtual activity, but the fact that it requires powerful tools is something any hardrock miner might appreciate. A data miner uses software instead of drills and explosives in the search for gold—the nuggets of unusual information and hidden relationships that databases contain.

Raymond Ng, a CICSR member and associate professor in UBC's Computer Science department, hopes that his data-mining tool will help people gain new and valuable insight into their databases. His software employs a new method of finding outliers, the statistical term for unusual or exceptional instances in data sets.

Outliers Useful in Fraud Detection

Outliers have proved useful, for example, in the detection of credit card fraud. In an analysis of consumer purchases, card companies found an abnormal pattern consisting of a small purchase of a dollar or less, followed soon after by a major transaction of several hundred or thousand dollars. This pattern turned out to have a high correlation to the use of stolen cards; thieves would make a minor purchase to test a card's validity and buy expensive goods once the card had been proved active.



Raymond Ng is at (604) 822-2394 or rng@cs.ubc.ca

"The study of outliers has existed in statistics for at least 20 years," says Ng. "What we have done here is develop a new notion which is meaningful to statistics yet which admits new applications that traditional methods cannot support."

Ng demonstrates his program using the scoring statistics from the 1994 National Hockey League season. The scoring data, with its 16 dimensions, has too many attributes and unknown distributions for traditional techniques of detecting outliers to work. Ng's software, however, is able to find a number of interesting relationships in the data, such as the value of unheralded players to their teams.

> **"A job that used to take five days now takes five minutes."**

Ng has also used his data-mining tool to analyze security videos and help identify unusual patterns of movement. Working with Point Grey Research—which has developed a stereo video-camera and computer surveillance system that can track and record moving objects—Ng converted the surveillance data into movement paths and detected peculiar speed and movement patterns in videos.

Whether it is hockey statistics or spatial patterns, Ng stresses that data-mining applications cannot succeed without intelligent analysis. "This tool cannot replace a human," Ng points out. "The goal is to strike a division of labour, where the computer does what it does best—number crunching—and the analyst performs the intelligent aspect of the work: making observations and drawing conclusions."

Ng developed the software with PhD candidate Ed Knorr. Together they are investigating the tool's application in tracking electronic commerce. They hope to find the sort of useful patterns in web usage that credit card companies discovered in their data.

Other Data-Mining Techniques

In addition to his work with outliers, Ng is sharpening two other data-mining techniques: constrained associations and sequential patterning. Data-mining applications are successful at establishing associations among events, but trivial information is often produced as well. Ng hopes to deliver faster, more meaningful analyses by defining better association rules. Sequential patterns are also of interest to Ng, especially in regards to web commerce, as they may shed light on user behaviour on the web.

Ng has demonstrated his software to a number of BC companies, applying his data-mining techniques to their data-sets. One of the key selling points of the software is the speed with which it analyses data.

"A job that used to take five days now takes five minutes," says Ng. "That is a successful tool. Now I want it being used and evaluated in the real world." ■

Building Faster Algorithms for Complex Problems

Jim Varah's research in linear algebra aims to improve computational problem-solving in many disciplines of science and engineering.

The word algebra comes from Arabic; translated literally, it means the "reunion of broken parts." For CICSR researcher Jim Varah, the challenge in Numerical Linear Algebra (NLA) is to reunite those "broken parts" with faster and more accurate solutions in the form of algorithms.

These metaphorical broken parts are matrices and equations which mathematically represent many natural phenomena, such as the flow of water around a moving object. They may also be used to model the reconstruction of a complex shape, such as a tumour recorded by a medical imaging device.

Numerical Solutions

"NLA is an important area of study because it provides the numerical solutions for a wide variety of problems encountered in science and engineering," says Varah, a Computer Science professor and founding director of CICSR. "What we are doing now is improving algorithms, developing even better ones, and applying them in novel ways to new problems."

Varah's research ranges over the spectrum of numerical analysis and scientific computation, and he is currently centred on two problems: shape reconstruction in 2-D and cyclic reduction in 3-D.

With scientists in California at Stanford and SRI International, Varah has been working on problems associated with shape reconstruction in 2-D. One application of this work is to improve the accuracy of computer imaging, which uses shape reconstruction to help pinpoint tumours in the brain or mineral deposits on the ocean's floor.

In a computer tomography scan, for example, a thin cross-section image of the brain is taken. The image itself is approximated by polygons, the polygon being the easiest shape to construct a mathematical approximation of a tumour.

Jim Varah: "We've been able to solve systems of half a million variables in a few minutes on a fairly standard workstation."

Varah and his colleagues have developed a new method for reconstructing a polygonal figure from its moments, the moments being the mathematical vertices of the tumour as recorded by the imaging probes. The problem is considered mathematically ill-conditioned, meaning that it is numerically sensitive and prone to inherent error.

"One has to be careful in designing the right algorithm to use," says Varah. "It has to be stable to minimize the inherent errors." The algorithm Varah designed is stable, and computes more accurate polygons than previous methods.

"It produces the best estimate of the polygon," says Varah. "This in turn gives us a more accurate way of determining the shape and location of a tumour or mineral deposit."

Another area of interest to Varah is cyclic reduction in 3-D, which his PhD student, Chen Greif, is working on. This involves a unique way of solving the huge linear systems of equations associated with the commonly occurring convection-diffusion equation.

Reducing Systems

"We have extended a technique known as cyclic reduction to 3-dimensional problems," says Varah. "The idea is to 'reduce' the size of the system using a clever transformation and solve the reduced system by various iterative methods."

The big stumbling block was ordering the system. Grief developed a two-plane approach which proved to be the key. The solution can now be applied to other problems in the domain of fluid mechanics. (Grief won an NSERC postdoctoral fellowship earlier this year, and will continue his work in cyclic reduction at Stanford this fall.)

"We've been able to solve systems of half a million variables in a few minutes on a fairly standard workstation," says Varah. ■

Contact Jim Varah at (604) 822-2979 and at varah@cs.ubc.ca

Simulating Large Power Systems *cont'd from page 2*

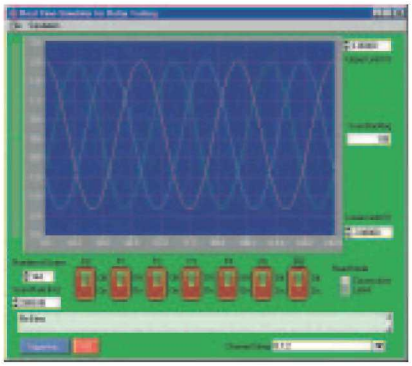
Using ordinary 200 MHz Pentiums and highly-optimized software, Martí and his team have been able to simulate realistically sized power networks and conduct closed-loop testing of protective devices with real-time constraints of under 50 microseconds per solution step.

They have also been able to maintain these solution times in the simulation of highly complex 24-valve high voltage direct-transmission converters and associated controllers. These timings are the fastest reported by any research group to date.

Real Time Simulation Group

The UBC Real Time Simulation Group is one of six major research groups worldwide involved in real-time power-system simulation, but the only one to be using desktop computers as the simulation workhorse. Other groups are using custom-made equipment and supercomputers which are orders of magnitude more expensive to buy and difficult to configure.

"Our main claim is that we are building fast and accurate real-time simulators with off-the-shelf computer components," says Martí. "Another great advantage over other groups is our solution algorithms. These are very fast so we are able to compensate for not using a supercomputer."



Martí and his team have been able to simulate realistically sized power networks on desktop systems with software they created.

Simulation Market

Martí sees the simulator being marketed to manufacturers of power system controllers and protective relays, as well as power utilities who desire realistic testing of equipment in their systems.

In addition, the simulator can also be used to play "what-if" scenarios and help power control-centre operators during emergency procedures.

UBC's Dommel a Pioneer

Martí's group is building on the foundation of work begun by CICSR's Hermann Dommel, a UBC electrical engineer who supervised Martí's PhD thesis on frequency-dependent transmission line models. The model developed in that thesis has become standard in power system transient analysis programs and in the new generation of real-time simulators.

In 1985, Martí ported Dommel's fast transient analysis program, EMTP—in use all over the world—to run on a PC which led to the creation of a successful UBC spin-off company called Microtran in 1987.

Martí is currently collaborating with BC Hydro and Powertech Labs in the prototyping of a real-time closed loop relay tester. He is also working with several international partners who are involved in real-time simulation research. ■

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Innovating with Industry *cont'd from page 1*

parameters which need to be investigated," says Salcudean. "This also significantly lowers the cost."

Advancing Fluid Dynamics Research

The pulp and paper industry is another major partner of the Fluid Dynamics group. Salcudean was awarded the Weyerhaeuser Industrial Research Chair of Computational Fluid Dynamics in 1996, and she is using that position to advance fluid dynamics research in pulp and paper processes.

Along with Gartshore, Salcudean has undertaken a major research project on the modelling and optimization of recovery boilers. These expensive pieces of pulpmill equipment recover the inorganic chemicals from the pulping process by burning combustible organics. The recovered chemicals are then redirected into the pulping process, while the steam generated during combustion is used in the mill.

Recovery Boilers Optimized

Industrial partners such as Weyerhaeuser, Canfor, Georgia-Pacific Corp., and Kvaerner who have collaborated in the research project, have also benefited from it—10 recovery boilers have been optimized. The research group is now expanding its research to include other equipment used in pulp and paper mills, such as headboxes, kilns and digesters.

"The goal is to make the papermaking process more efficient," says Salcudean. "We want to lower energy requirements, improve environmental performance and keep the industry competitive."

The fluid dynamics research group has identified many interesting fundamental problems through its modelling research, and a number of PhD theses have resulted. Currently the lab has ten graduate students and research associates working on various problems. With strong support from its main industrial sponsors Canfor and Weyerhaeuser, the group will continue to expand its research scope.

"This is a big job," says Salcudean. "The number of applications is endless!" ■

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CICSR Passing Notes

Clarence de Silva (Mech.Eng.) has been granted a doctorate from Cambridge University. The degree was "earned" on the basis of de Silva's publications record which includes 13 books and over 100 journal papers. De Silva has also organized the Green College lecture series entitled **Myths & Realities of Intelligent Machines**, co-sponsored by CICSR, ASI and IEEE. Contact Green College at (604) 822-8660 (see box below for lecture titles.)

Steve Wilton (Elec. & Comp.Eng.) has won the 1998 Douglas R. Colton Medal for Research Excellence. The prize is given "to recognize excellence in research leading to new understanding and novel developments in microelectronics or the application of microelectronics in Canada."

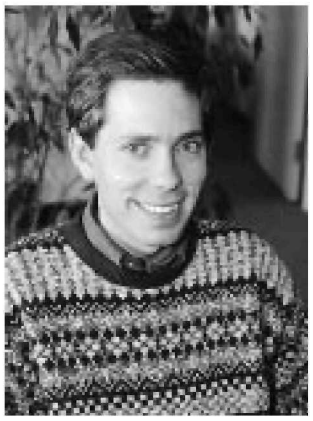
Martha Salcudean (Mech.Eng.) has won two prestigious awards. She was recently awarded a 1998 Killam Prize by the Canada Council and named to the Order of BC. In its announcement for the Killam Prize, the Canada Council said that "In her fields of engineering research and academe, Martha Salcudean's achievements stand as a brilliant model of university/industry collaboration and of practical engineering and research excellence."

Sid Fels (Elec. & Comp.Eng.), who joined UBC in January 1998, won first prize in the best virtual reality interactive category in a recent exhibition in Rio de Janeiro. The exhibition highlighted his Iamascope interactive multimedia project.

Professor Emeritus **KD Srivastava** (Elec. & Comp.Eng.) has been honoured as this year's recipient of IEEE's Outstanding Engineering Educator Award. The award recognizes KD's enormous contributions to technical education and educational administration.

Charles Laszlo (Elec. & Comp.Eng.) has been named to both the Order of Canada and the Order of British Columbia. The awards recognize Laszlo's achievements in biomedical engineering research, and particularly his advocacy on behalf of the hard-of-hearing community. The Order of BC was presented on June 18, 1998, at Government House in Victoria.

Guy Dumont (Elec. & Comp.Eng.) has been awarded the Universal Dynamics Prize for Leadership in Process Control Technology. The prize recognizes the widespread industrial application of the "BrainWave" adaptive controller which is based on Guy's work. Guy is also one of 12 distinguished colleagues who have been invited to present papers at a conference in Sweden to honour the retirement of Karl J. Åström, a world authority in process control.



Steve Wilton

Clarence de Silva

Yusuf Altintas (Mech.Eng.) has won the Best Manufacturing Research and Research Collaboration Award from Pratt & Whitney Canada for his work in computer-controlled machining. Altintas and his group have also formed the Machining Research Consortium whose members include UBC, GM, Pratt & Whitney Canada, and the Boeing Corporation.

Oxford University Press has published *Computational Intelligence, A Logical Approach,* a textbook introduction to artificial intelligence by Comp.Sci. members **David Poole**, **Alan Mackworth** and U. of Alberta's **Randy Goebel**.

Starting this fall, **CICSR**, **ASI**, **Texas Instruments**, **Spectrum**, **Gleynare** and **Image Power** are co-sponsoring a new lab course entitled Real-Time Implementation of DSP Algorithms. Organized by **Faouzi Kossentini**, it will be offered by Electrical and Computer Engineering and provide hands-on experience in the design of digital signal processing (DSP) systems. CICSR will also use the course lab for week-long industry seminars next summer.

As we go to press, **Maria Klawe** (Comp. Sci.) has been appointed as UBC's Dean of the Faculty of Science.We are delighted at this news. Maria was formerly head of Computer Science, is currently the Vice President, Student & Academic Services, and holds the NSERC-IBM Chair for Women in Science and Engineering.

Myths & Realities of Intelligent Machines: Green College Lecture Series

Daniel Repperger, Using an Intelligent Machine to Modify or Adapt Human Behaviour, Sept.7/98

Devendra Garg, Research in Intelligent Machines, Oct.5/98

Takeo Kanade, Vision-Guided Intelligent Machines, Nov.9/98

Lotfi Zadeh, The Intelligent Systems Revolution, Dec.7/98

Mo Jamshidi, Soft Computing Control of Complex Systems, Jan.11/99

Patri Venuvinod, Intelligent Machines: Benefiting from Synergy Amongst Modelling, Sensing and Learning, Feb.8/99

Vinod Modi, Machines and the Elusive Wisdom, Mar.8/99

Jim Poo, Intelligent Control of Machines, Mar.30/99

Alistair MacFarlane, Machines, Information and Knowledge, Apr.12/99

1998-99 CICSR Distinguished Lecture Series

CICSR is hosting its tenth annual **Distinguished Lecture Series**, bringing in academic & industrial leaders in the forefront of their respective fields. Lectures will be held from 4:00 to 5:30 pm in the CICSR/CS building, room 208, 2366 Main Mall, UBC, and there is no charge.

1

"It is Dangerous to Put Limits on Wireless Communications"
September 24, 1998
Dr. Vijay K. Bhargava
University of Victoria

2

Computer Graphics and Interactive Entertainment
October 22, 1998
Mr. Tim Bennison
Radical Entertainment, Vancouver

3

Silicon, Systems and Society: Design Challenges for the 21st Century
November 19, 1998
Dr. Kurt Keutzer
University of California, Berkeley

4

Life after Geometric Modelling in CAD/CAM
January 21, 1999
Dr. Bahram Ravani
University of California, Davis

5

System-on-a-Chip: A New Challenge for the Electronic Design & Test Community
February 18, 1999
Dr. Bozena Kaminska
École Polytechnique de Montréal

6

AM-FM Image Models and Applications
March 18, 1999
Dr. Alan Bovik
University of Texas, Austin

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.

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