CENTRE FOR INTEGRATED COMPUTER SYSTEMS RESEARCH • C • I • C • S • R •

THE UNIVERSITY OF BRITISH COLUMBIA

FOCUS

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SMARTER MACHINES

CICSR team working towards more intelligent control systems for industrial machinery

Not many of us have driven a Caterpillar excavator or feller buncher for harvesting trees. But if you sat in the cab of such a machine, you'd probably be bewildered by the controls. If you were confident enough to try them out, you'd find they don't always achieve the result you'd expect, and you'd feel very awkward trying to accomplish even the most simple task.

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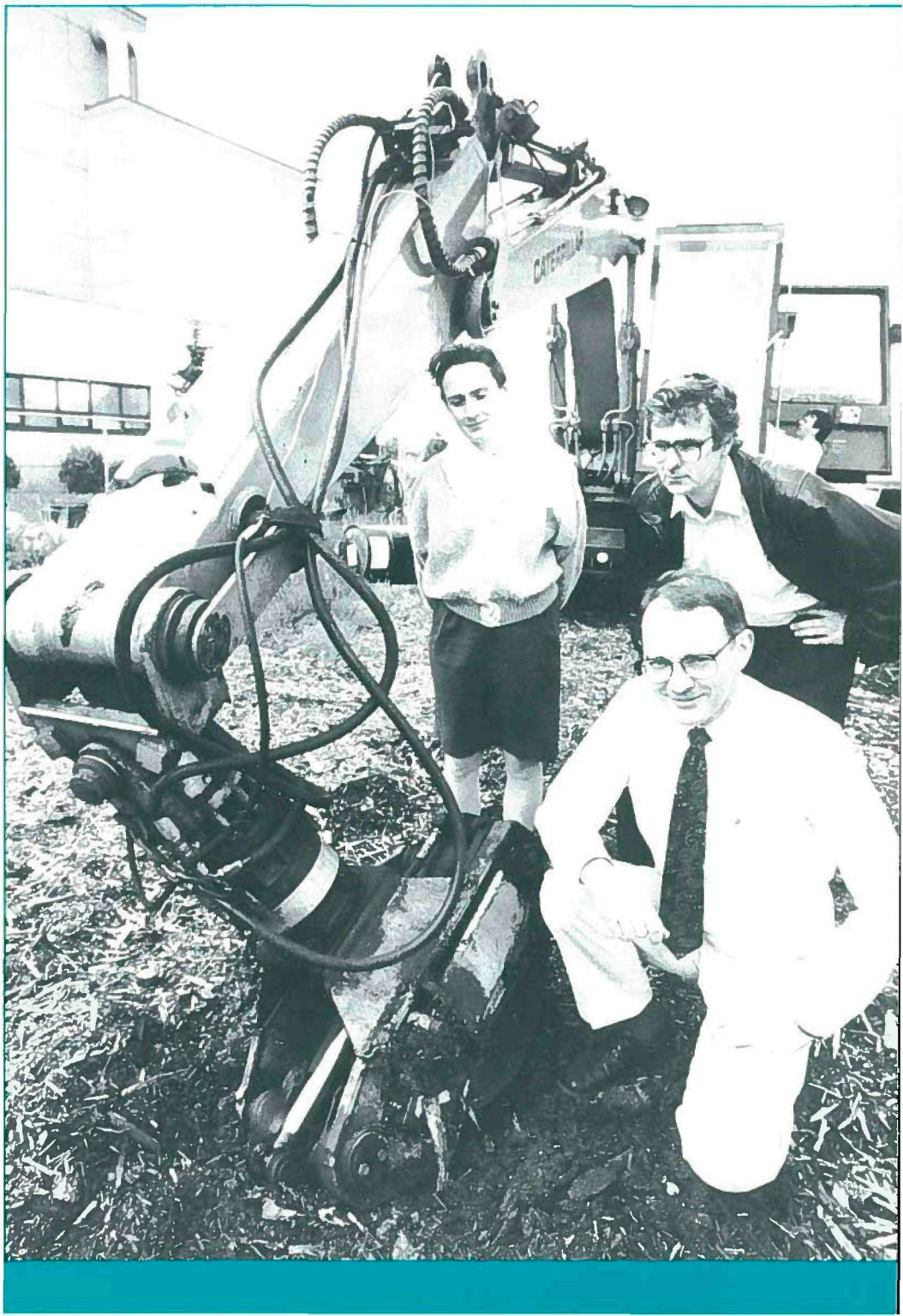

The CICSR research team led by Dr. Peter Lawrence (front) can test their research and development on this excavator donated for the project by Caterpillar. Graduate student Jane Mulligan and computer science professor Dr. Alan Mackworth are among the researchers involved in the research project.

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CICSR: Promoting collaborative research

■ The traditional university structure, which divides subject areas into departments and faculties, is not conducive to the development of initiatives that overlap these units. CICSR was set up to bridge these boundaries between the three UBC departments (Computer Science, Electrical Engineering and Mechanical Engineering) in three faculties (Science, Applied Science and Graduate Studies). CICSR is also affiliated with other computer-related campus units such as the Media and Graphics Interdisciplinary Centre (MAGIC) and the Management Information Systems (MIS) Division of the Faculty of Commerce.

One of CICSR's principal goals is to foster and facilitate collaborative research among its faculty members, allied external research organizations (SFU, UVic, NRC, ASI, etc), and its external colleagues.

"A more cohesive framework ... makes it easier to attract new faculty members, graduate students, industrial partners and research funding."

With the advent of special funding through the Fund for Excellence in Education program of the B.C. government, CICSR has been able to provide monetary incentives for collaborative research: funding for technical and administrative support staff, equipment funding (including a workstation subsidy program), and the new shared software initiative.

When the CICSR/CS building is completed in late 1992, other incentives for collaborative research will be available, such as shared laboratory space for finite-term, externally-funded research projects. There will also be space available for visiting researchers from industry and government research labs.

This shared, cooperative approach to research in information technology has many advantages: it provides a multi-level integration of research programs across traditional disciplines; it increases the critical mass of people available for a given project; it permits sharing of equipment and infrastructure, thereby lowering costs; and it provides a more cohesive framework to view university research, which makes it easier to attract new faculty members, graduate students, industrial partners and research funding.

CICSR intends to continue to expand its liaison role, both internally and externally, and welcomes advice and suggestions from the research community. ■

Director's Statement

■ First, I would like to thank Peter Lawrence for all the work he did as Acting Director while I was away. Peter has gone on to his reward: more time for research !

For this issue of FOCUS, we thought it was time to re-examine CICSR's roots and focus on its objective of collaborative research in information technology. We have provided several examples of projects currently under way involving faculty members and graduate students from different departments, and personnel from industrial research firms. The intent is not only to make people aware of these projects, but also to inspire new projects that will lead to results and products of lasting and significant benefit. ■

Dr. James Varah, CICSR Director

SMART MACHINES ... continued from cover

Part of your problem would undoubtedly be inexperience, but even experienced heavy machinery operators sometimes have problems. A team of CICSR researchers at UBC, led by Dr. Peter Lawrence, is working on developing more intelligent controls for large machines, using computer vision, artificial intelligence and robotics.

According to Lawrence, the basic objective of the project is to make the operator's life easier and safer. For example, the intelligent machine will be able to detect when it is about to tip over, or when the stress on its limbs is excessive. Lawrence says the machines produced as a result of his team's research will increase productivity of operators and, in the case of remotely-operated machines, be less fatiguing and much safer.

"Some operators are now four times as productive as other, equally-experienced operators," said Lawrence. "We hope to even out their performance by making the relationship between the visual space and manipulator control directions the same."

But even when controls and the machine's movements correspond, that doesn't solve all the problems for an operator. In the operation of an excavator, for example, with its various joints, dragging the bucket flat across the ground requires the operator to perform a series of complex motions to carry out what appears to be a simple task. "The control positions are not always obvious with respect to the task you're trying to accomplish," said Lawrence. "Eventually, we hope to pre-program certain tasks. We'd like to let the operator work out the strategy and let the machine carry out the actual task."

But before a machine can perform complex tasks simply by being told, it has to be able to figure out the position of its limbs, and of the objects it is working with. CICSR researchers are working on various aspects of this problem.

Dr. Farrokh Sassani of mechanical engineering, for example, is working on calibration and parameter identification of existing machinery. The intelligent control system will first be retrofitted to existing machinery which has been in use for a number of years, says Sassani. Before a new control system can be used, the researchers need to know precisely how the machine responds.

Sassani is interested in developing a hydraulic subsystem to control the machines. He is exploring the possibility of using neural networks in his work, "because they have the ability to learn and to extract unknown relationships. They can recognize certain limits. For example, if a machine is about to malfunction, a neural network can figure that out in advance and issue a warning."

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Another advantage to neural networks, a highly parallel approach to computing somewhat analogous to the workings of the human brain, is that they're fast. Since any control system used on working machines has to work in real time, speed is an important consideration, said Sassani.

Dr. Alan Mackworth of computer science is working with graduate student Jane Mulligan on the machine vision portion of the project. A remotely-operated telerobotic machine needs a model of the actual machine and where it is in the environment. One of the first skills we learn as babies is determining where our arms are, observes Mackworth. "Hand-arm co-ordination is critical in the development of telerobotics."

There are various ways for a machine to sense the position of its arm. Joint angle sensors, for example, can be used, but they are expensive, exposed to the elements and need to be calibrated. Vision is a possible method, though at this point it's not clear how well it will work, said Mackworth. "Redundancy of sensors is a good idea, with co-ordination of information from a variety of sources."

In Mackworth's current vision system, the machine uses a straightforward computer graphic model of its arm, does analysis by synthesis and uses its own internal model to match what it sees. Mackworth has used fast parallel algorithms and standard computer vision techniques such as edge identification to accomplish the job at video speed (30 times per second).

"The system can find the boom fairly quickly, and then the stick and bucket [on the excavator the research team was given by Caterpillar to carry out its work]. It currently takes three seconds to identify the arm using a rough initial guess where it might be," said Mackworth. He is now working on speeding up the system using more parallel hardware, more information to predict where the arm will be next time you look at it, and by taking advantage of new, faster computer architecture.

The evolution of the computer hardware industry is a positive trend for the project. Increasing amounts of speed and power are being packed into smaller packages, making it feasible to put a lot of sophisticated systems into a relatively confined space like the cab of Caterpillar.

Dr. Dale Cherchas of mechanical engineering is working on robotic control for the project. He is using adaptive control to maintain smooth and accurate motion for different weights and bucket positions.

Cherchas is also interested in the ability to run the controller with no previous knowledge of the mathematical model of the machinery and its responses. He is developing a scheme to allow the controller to determine for itself the form of the mathematical response as well as detailed parameters. By next summer, he hopes to have combined the two abilities: a control system that determines its model automatically and adapts to machine parameters as they change.

Dr. Chris Ma of electrical engineering is working on endpoint sensing for the project, to enable the machine to sense where the bucket, arm or other point of interest is at any given time.

Ma is currently exploring several ideas to determine the best method, including flashing lights and photosensors, and radio triangulation. "One of the goals is to develop a system that is so robust it can operate outdoors in fog, rain, and possibly even fire," said Ma.

Once the machine control project is complete, Lawrence hopes to see the technology transferred to the forest industry and the manufacturing industries, preferably in B.C. Some of the research projects may take longer than others to be applied in the field, said Lawrence. "There are several engineers in the department whose role will be to implement the technologies onboard the machines as they become feasible."

Lawrence's own research in resolve-motion control was the first technology to reach this stage, and receive a number of patents. Lawrence studied the human-joystick relationship and showed how a

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This CICSR research team is working towards development and application of more intelligent machines and better control systems to operate them. Researchers in this group include Dr. Dale Cherchas; Dr. Chris Ma and Dr. Farrokh Sassani.

The research project is initially aimed at developing more intelligent controls for forest industry machinery. But there are many more potential applications of the various facets of the project research. Many will take advantage of the benefits of telerobotics .

Fishy business for CICSR researcher

The Canadian fish processing industry is important to the nation's economy, but is not as efficient or competitive as it could be. CICSR researcher Dr. Clarence de Silva, professor of mechanical engineering and an ASI fellow, heads the research team working to change that.

De Silva holds the NSERC chair established to apply advanced technology to the fish processing industry in Canada. B.C. Packers is also funding the research and providing data, materials and testing facilities for the research team. Other supporters include the B.C. Advanced Systems Institute and Science Council of B.C.

Currently, fish is processed in one of two ways: either by hand, or using outdated machines nicknamed "iron butchers." There are drawbacks to both. The manual method requires skill and training, but the job is tiring, repetitious and unpleasant. The machine processing is inaccurate and about five per cent of the fish is wasted.

De Silva said that just one per cent of wastage accounts for $5 million. "By improving recovery, there is a potential for revenue increases of $25 million. The main objective of the funding is to develop better machines," he said. Current machines often remove some of the meat when they remove the fish's heads.

De Silva's research team, which includes Dr. Ray Gosine of mechanical engineering, holder of the NSERC junior chair, is using three different technologies in combination to improve yield: vision, robotics and intelligent control.

The vision system will use a camera and computer to analyze the image of the fish as it passes by on a conveyor belt. That way, the fish won't be cut blindly as they are using current methods. The problem to overcome in vision is that the image processing must be done very quickly — two fish are processed per second.

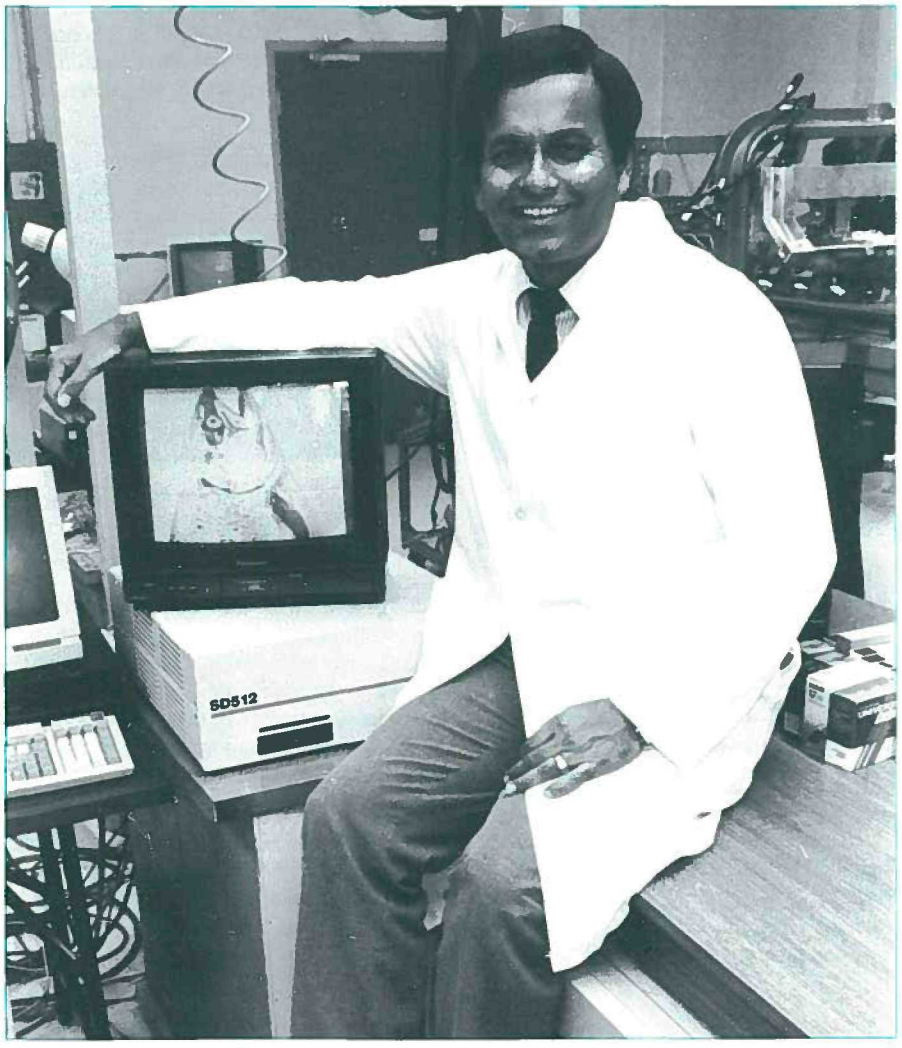
That's where the intelligent control comes in. De Silva has built up a knowledge base of information about fish, so that given a few key measurements, the control system can quickly determine the best place to cut. Sophisticated control is also used to determine the position of the fish and the cutting equipment.

Robotics do the actual work. De Silva is developing special cutters that make V-shaped incisions, minimizing wasted fish meat. He is also working on more sophisticated cutters to reduce waste even further. As well, robotics are used to hold the fish in position for cutting.

The UBC mechanical engineering department has working prototypes for the vision system and cutters. De Silva also plans to develop a very complex cutter for filleting and trimming fish.

One of the project engineers is now in the planning stages of forming a company to manufacture and market the improved fish processing equipment. The equipment will be available first to B.C. Packers, and then will be sold across Canada. De Silva said the products may eventually find their way to export markets, but not for awhile — the goal of the project is to make Canadian fish processing more competitive.

De Silva expects his work to be ongoing, long after the first machines are shipped out. There will be incremental improvements as new technologies are made available. As well, he is working on other aspects of the fish processing industry, including herring roe inspection and fish tagging.



Dr. Clarence de Silva's lab is filled with equipment to research applications of technology in the fish processing industry. One system under development is a vision system that uses a camera and a computer to quickly analyze the image of a fish as it passes by on a conveyor belt.

CICSR researcher Rabab Ward of electrical engineering, working with graduate students, is conducting promising research on improving picture signal quality for Rogers Cable.

Research promises better television picture quality

When Rogers Cable sends out signals from the Rogers Cantel Tower in Burnaby to thousands of television sets in B.C., the company has no idea what kind of picture is being received at the other end. They can monitor the signals being sent out, but monitoring the signal received by the customer has always been very difficult.

Rogers Cable has awarded CICSR researcher Rabab Ward of electrical engineering a three-year grant to tackle the problem. Her goal is to develop a system that can detect the presence of picture impairments, determine their nature and inform the head-end which sends the signal out.

"We have to digitize the [television] pictures, then filter them to separate out the impairments. Then we can correct the problem. We didn't know this was possible before we started our research."

"One of the difficulties is that you can send *any* picture over the cable network," explains Ward. "So how can the computer tell if there is an impairment?"

Compounding the difficulty is the fact that there are more than 25 different kinds of impairments, including snow noise, ghosting, beats (moving diagonal bars) and co-channel interference.

Ward is first working with snow noise and beats because they are among the most common and annoying impairments. Beats are usually caused by intermodulation distortion which is created by over-driven cable amplifiers. Snow noise is caused by a weak signal, often due to poor weather, faulty cable splices or thermal heat in the cable.

Ward has examined several approaches to the problem of determining the presence and type of impairments viewers receive. One approach is to send a known test signal which can be subtracted from the received image and determine if there is a problem. "But using a test signal would interfere with the broadcast signal," said Ward. "The approach we have taken can detect impairments irrespective of the picture you send."

When a picture is transmitted over the cable network, it is transmitted in one dimension. At the receiving end it is interlaced, filling up first the odd, then the even lines to produce a two-dimensional image. Ward has developed a way to take any 2-D image and isolate the original picture from its impairment.

Ward has found that all impairments appear in the high frequency range, while the original picture does not. However, she qualifies this by stating this is true only for the types of impairments she has worked with so far. Even more promising, Ward has been able to correct the pictures customers receive, without even fixing the cause of the problem.

"We have to digitize the pictures, then filter them to separate out the impairments. Then we can correct the problem," said Ward. "We didn't know this was possible before we started our research."

She adds that these results are very preliminary. There is a lot more work to be done before the results of Ward's research will be implemented at Rogers Cable, but her initial findings have lots of potential.

B.C. Advanced Systems Institute: bringing universities and industry together

■ B.C. Advanced Systems Institute programs manager Jeff Berryman said he has met more people from various UBC departments in his current job capacity than during the 20 years he worked at the university.

ASI's promotes interaction between university researchers and industry, offers fellowships for advanced systems researchers, and funds research consortia and projects.

According to Berryman, ASI's main program for universities is the fellowship program. Currently 24 ASI fellows receive up to $70,000 per year. "The idea of the money is to support industrial innovation and interaction with colleagues, similar to the goals of CICSR" said Berryman. "The funding is often used for teaching relief, support of research assistants and for purchase of lab equipment. The fellowship program has contributed materially to the establishment of sustaining laboratories." For example, CICSR member Ian Yellowley used his ASI fellowship to help establish an industrial robotics lab at UBC.

ASI has also helped to found Kinetic Sciences Inc. a research company specializing in health sciences and computer vision. President Guy Immega has subcontracted the research services of CICSR's Dr. Peter Lawrence of electrical engineering and Dale Cherchas of mechanical engineering. Contracts awarded to date include a $900,000 contract to research autonomous robotics for the space station Freedom, and a $450,000 contract from the Department of National Defence to develop a simplified robotic hand.

"The company is a mediator of technology transfer — a valuable and rare kind of company," said Berryman. ASI provided working capital under its product development fund, and provided ASI fellowships to Lawrence and Cherchas for three years "to enable them to develop their research profile to the point where this could happen."

One of ASI's goals is to help incorporate new technologies into resource industries.

"The biggest challenge in university-industry liaison is to get the time scales reconciled. Industry tends to have short time lines, while universities' are long and open-ended. The more universities can put together sustaining facilities, the more compatibility there will be."

Lawrence is lead researcher on a project to put better controls into forestry machinery. The project has received substantial support, and is described in detail in this newsletter. ASI also supports Dr. Clarence de Silva's work with B.C. Packers, also described in this issue of *CICSR FOCUS*.

"ASI is one step out of the university and towards industry," said Berryman. "We provide a comfort factor for both sides. University and industry don't always speak the same language."

Berryman said the biggest challenge in university-industry liaison is to get the time scales reconciled. Industry tends to have short time lines, while universities' time lines are often long and open-ended. "The more universities can put together sustaining facilities, the more compatibility there will be."

Berryman sees ASI's role as one of inspiring research, though not directing it in any heavy-handed way. "In the future, we want to create opportunities by bringing universities and industry into the same room. If the people in the room have common interests, some excellent ideas can be traded back and forth."

ASI looks for input from its fellows on how it should conduct its business and facilitate technology transfer. The institute's goal is to increase the resources

ASI's Jeff Berryman

devoted to this kind of intellectual liaison in the future. "We are always looking for more ways to move technology into industry," said Berryman.

One of the best ways to move technology is to move people. ASI is working to improve the calibre of graduate students in B.C., and also to encourage them to stay and work in the province, transferring their knowledge to B.C. companies. As well, ASI offers a visiting fellowship program to encourage short working visits moving researchers from universities to industry and vice versa.

Berryman said ASI is now in a consolidation phase, and has been building its image and refining its goals since executive director Mike Volker came aboard in 1988. He expects ASI to be able to offer more resources in the future towards getting the good research ideas in universities practically implemented. ■

CICSR sponsors VLSI CAD course

■ Computer science graduates need to recognize hardware as just another tool to solve problems in computer science, alongside various high level languages and assembly codes, says Dr. Peter Robinson.

Robinson is assistant director of research in the computer laboratory and the University of Cambridge. He visited UBC July 15-19 to teach a course on semi-custom VLSI CAD. A four-day course, and an intensive one-day workshop were held during the week.

The one-day workshop, focusing on educational programs at the undergraduate and graduate level, covered the role of VLSI education, support needed by universities, employment opportunities, the need for semi-custom VLSI CAD education to support research in other areas, course outlines, instruction on system design, and links with CASE technology.

The four-day course on semi-custom VLSI CAD used the QuickChip logic design system developed by Qudos Ltd., Cambridge, U.K.

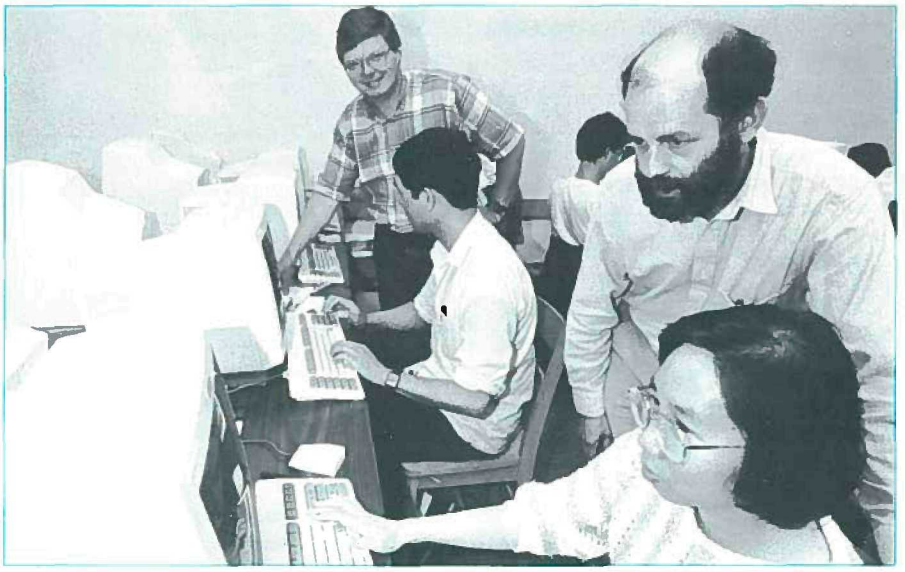
Drs. J. Joyce and C. Seger from the department of computer science, and Drs. A. Ivanov and D. Camporese from the department of electrical engineering were the course organizers. They took on the job because they felt that it was important for their students to be exposed to semi-custom VLSI CAD. Dr. Joyce says that "the technology is becoming incredibly important. They can be made quicker and less expensively than full custom design chips".

Joyce notes that a lot of universities hold full-length custom chip design courses where student design chips from scratch. He feels semi-custom makes more sense in many cases because few students end up doing full custom design in their jobs. As well, when they design a semi-custom chip as part of a course, they are more likely to produce something that's going to work.

Joyce's own research interests are in formal verification of hardware and software. He says that very few software programs are known to be correct, though errorless programming is critical in some cases, such as in software controlling aircraft or anti-lock braking systems.

Joyce commended CICSR for organizing the course. CICSR provided funding and organizational support, and facilitated interaction between computer science, electrical engineering and mechanical engineering faculty members. "It makes sense to co-operate with other CICSR departments because they have complementary expertise in aspects of VLSI design and its applications," said Joyce.

He sees semi-custom VLSI design and related technologies closing what has traditionally been a big gap between hardware and software. Says Joyce, "The distinction is becoming blurred, and to some extent, educational institutions haven't kept up." ■



Dr. Jeff Joyce (back) of UBC computer science and Dr. P. Robinson of University of Cambridge, oversaw students at the semi-custom VLSI CAD course sponsored by CICSR and held at UBC in July.

SMART MACHINES ... continued from page 3

hydraulic system model can be employed to close the loop in a hydraulic system. Real Frenette, a hardware engineer in the department of electrical engineering, implemented the research onto the machine.

Throughout the life of the project, many industrial and government organizations have provided support. Industrial collaborators include RSI Research, MacMillan Bloedel Research, Caterpillar and Finning. Other organizations that have contributed to the project include the Canadian Institute for Advanced Research, B.C. Advanced Systems Institute, the federal Networks of Centres of Excellence under IRIS (Institute for Robotics and Intelligent Systems), National Sciences and Engineering Research Council (NSERC), and UBC Industry Liaison Office.

While the project is initially aimed at developing more intelligent controls for forest industry machinery, there are many more potential applications of the various facets of the project research. Mackworth noted that the three main advantages of telerobotics are scale, safety and distance.

Distance advantages can be used in the forest industry, where cable logging methods often require machines to be moved along the top of a ridge. Remote operation saves an operator from having to climb up and down the hill repeatedly. It's also safer in a lot of cases. Safety is also a consideration in telerobotics for mining, bomb disposal, subsea tasks and work at nuclear power stations. Telerobotics help a human operator deal with large differences in scale, from microsurgery to large-scale construction. And once intelligent machines are developed and become more advanced, we will find new uses for them — they will likely change the way we do a lot of things today. ■

Passing notes

Two CICSR researchers awarded ASI fellowships

■ Two CICSR researchers, Dr. Clarence de Silva and Dr. Tim Salcudean, were recently awarded fellowships from the B.C. Advanced Systems Institute.

De Silva's fellowship will run until December 31, 1994. His research interests fall within the broad category of control and process automation, and he holds the NSERC chair to apply advanced technology to the fish processing industry.

Salcudean's fellowship runs until June 30, 1996. His research goal is to devise optimization-based computer-aided control system design methods and to apply them to electromechanical devices, with robotics and teleoperation applications in mind.

New ASI fellows Dr. Clarence de Silva (left) and Dr. Tim Salcudean.

ASI GRAP tour a success

Through funding from the B.C. Advanced Systems Institute Graduate Assistance Program (GRAP), 38 potential UBC graduate students were given a four-day tour of UBC and Vancouver.

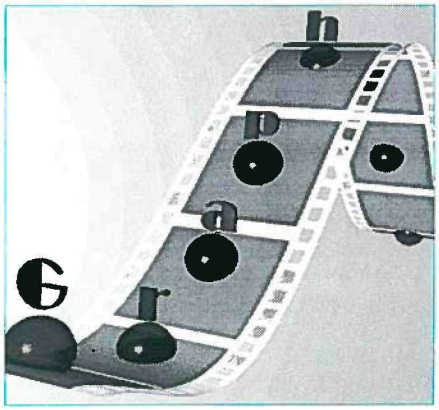
Students visited various laboratories, met with faculty members and other graduate students. The goal of GRAP is to encourage top-quality graduate students to attend B.C. universities.

CASE course scheduled

CICSR is co-sponsoring a course September 27 entitled "Trends and Directions in CASE." Cadre Technologies co-founder Read Fleming will speak about computer-aided software engineering trends, and separate afternoon sessions will be geared to managers and developers interested in CASE.

Cadre Technologies of Bellevue, Washington recently supplied several tools for CICSR's shared software initiative, including Teamwork. ■

C·A·L·E·N·D·A·R



Graphically Speaking

The Distinguished Lecture Series For 1991-92

Six Academic and Industrial Leaders Address the Future of Computer Graphics, Visualization and the Man-Machine Interface

October 10, 1991
Shared Workspaces: A Look at Supporting Distributed Workgroups
Dr. Sara Bly
Researcher, Xerox Palo Alto Research Centre

November 7, 1991
Unravelling the Physics and Chemistry of Environmental Problems Using Visualization
Dr. Gregory J. McRae
Professor, Engineering and Public Policy and Chemical Engineering, Carnegie Mellon University

December 5, 1991
Electronic Books: User-Controlled Animation in a Hypermedia Framework
Dr. Andries van Dam
Professor of Computer Science, Brown University

January 16, 1992
Technological Mindset
Dr. Marilyn Mantei
Associate Professor of Computer Science and Management Information Science, University of Toronto

February 13, 1992
Realistic Image Synthesis: Progress and Problems
Dr. Donald P. Greenberg
Director, Program of Computer Graphics and Professor of Computer Graphics, Cornell University

March 12, 1992
Fluid Dynamics, Massively Parallel Processors and Real-Time Flow

Dr. James A. Sethian
Professor of Mathematics, University of California, Berkeley and Senior Scientist, Physics Division, Lawrence Berkeley Laboratory

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This is CICSR's fourth Distinguished Lecture Series. It provides an opportunity for those interested in graphics to learn from the experience and ideas of world-class researchers. Advance registration is not required.

Lectures run from 1:00 p.m. to 2:30 p.m., Room 100, SCARFE Building. Lectures are complimentary.

CICSR:

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 Engineering and Mechanical Engineering. Currently there are more than 60 CICSR researchers which direct over 100 graduate students and collaborate with dozens of industrial firms in areas such as robotics, artificial intelligence, communications, VLSI design and industrial automation.

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