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ICICS

FOCUS

THE UNIVERSITY OF BRITISH COLUMBIA

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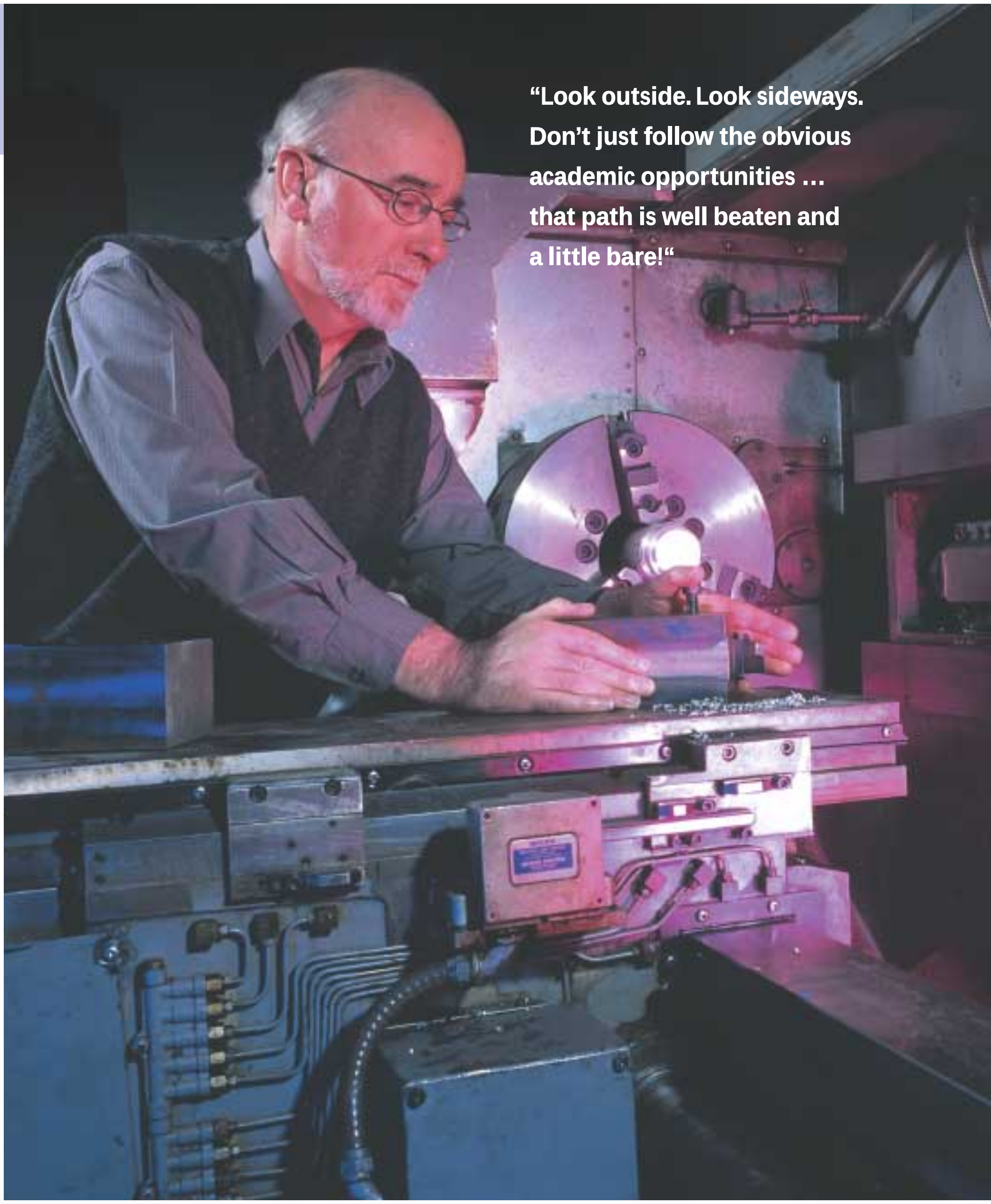
Staying in Control

- Design-Directed Learning
- Machine Control
- Survival Mechanisms



"Look outside. Look sideways. Don't just follow the obvious academic opportunities ... that path is well beaten and a little bare!"

Professor of Mechanical Engineering and ICICS member Ian Yellowley has been working in the areas of product development and machine control for over 30 years, 27 of them in academia. FOCUS uncovers the secret to his long and vibrant career.

Back in 1965, when fellow students were tuning in, turning on and dropping out, Ian Yellowley was working as a university apprentice with Rolls Royce. At that time, the field of numerical control was burgeoning with innovations in digital electronics and discrete logic. "There I was, an eighteen-year-old student in the middle of a very large manufacturing plant watching these amazing automated machines," he recalls. "I knew that this was what I wanted to do with my life."

Yellowley's early years with Rolls Royce, and as Industrial Engineering Manager at Westinghouse, were pivotal to his career. He considers the time he now spends working with industry his 'safety valve.' "Once a week I try to get out of the university environment and look at real problems," he says.

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ICICS Director's Corner

In this issue of FOCUS, we introduce seven recent ICICS members from the faculties of Applied Science, Science and Education. We also profile the successful career of one of our more senior members. Ian Yellowley joined Mechanical Engineering in 1988. Since then, his work in product development and machine control has made a major impact in industry and in teaching.

Several of our profiled members work in wireless communications. Vikram Krishnamurthy (ECE) designs and analyses high-performance, self-learning control algorithms for wireless and sensor networks. Vincent Wong (ECE) works in the emerging field of mobile ad hoc networks and wireless mesh networks, exploring the use of laptops, PDAs and other mobile devices to help transmit data. Also in Electrical and Computer Engineering, Dave Michelson's research in channel modelling simulates and predicts how radio waves interact with different environments.

John Willinsky, professor of Language and Literacy Education, is developing new electronic publishing models to increase public access to academic research. Juri Jatskevich (ECE) works in power electronics and simulation of electrical systems to help ensure a stable power supply in changing and demanding times. In Computer Science, Chen Greif's research in numerical linear algebra provides fast, reliable solutions to a wide variety of large-scale problems.

Last but certainly not least, Joseph Yan (ECE) and his robotic dragonfly—the flipside of our cover story in the last issue of *FOCUS*—are creating a flap in the area of micromechatronics. I hope you enjoy reading about this exciting and innovative work.

Rabab Ward, ICICS Director

***Yellowley:* Continued from page 1**

Designing for Real-World Applications

The focus of Yellowley's work over the past 12 years has been the design of an innovative open architecture control system that integrates planning with both process and motion control. The system, which resulted in several patents, provides high-performance, low-cost control architectures for use in automated manufacturing systems.

"In the old days, typical industrial control architectures would require several micro controllers, all connected to a bus or network," notes Yellowley. "These days, almost the entire architecture is packed into a field programmable gate array (FPGA)." Imagine an entire machine control system the size of a box of chocolates. In 2001, Yellowley formed the UBC spin-off company Cameleon Controls to write the firmware and software needed for others to adopt the control system. Major industry partners include Exor/Ultimodule who use the architecture in modular electronics, and Teleflex Canada.

Current activity within Yellowley's lab focuses on using the architecture in the real-time process control of complex metal cutting operations, and the development of new methods to allow the dynamic reconfiguration of control systems. These go beyond the normal "plug-and-play" to improve safety and productivity in automated manufacturing processes.

Developing Design-Directed Learning

Yellowley is trying to move his philosophy of solving real-world problems from the lab into the classroom—and the curriculum. It is a hard sell, as design-directed learning not only builds on the problem-based learning approach, but also adds a layer of technology between the problem and the underlying science. In addition, it forces the student to define the real problem first.

Understanding the technology—and having the ambition to improve it—becomes the motivation for learning basic science and mathematics. In 2000, with a one-time grant of more than $1 million from NSERC, Yellowley and colleagues from across the country founded the Canadian Design Engineering Network (CDEN/RCCI). He was the first chair of the network and currently serves on the steering committee. More recently, Yellowley became the founding editor of the network's new *Journal of Engineering Design Innovation.*

"I have friends who have stressful jobs, and I tell them they need a sandbox to play in. My lab is my sandbox."

A great proponent of doing as well as thinking, Yellowley encourages his students to be more "hands-on." His advice for young researchers coming up through the ranks? "Look outside. Look sideways. Don't just follow the obvious academic opportunities… that path is well beaten and a little bare!"

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Getting to the Math of the Problem

Computer scientist Chen Greif works in numerical linear algebra and scientific computing to find fast, reliable, and robust numerical solutions to large-scale linear problems.

- **Numerical Linear Algebra**
- **Scientific Computing**
- **Constrained Optimization**

Behind every complex problem is a mathematical solution. When researchers encounter such a problem in mathematics, computer science, or engineering, the first step to solving it is to model it, says ICICS member Chen Greif. The next step is to solve it numerically, using computers. This is where his research comes in. “My work is not so much about the description of the application; it is more about the method of solving problems,” explains Greif, professor in Computer Science.

For example, Greif helped to solve a data outlier problem in functional MRI, where failing to correct for patient motion during a procedure can lead to false-positive or false-negative results. The success of motion correction depends on the accuracy of the detection algorithm. “You need to take into account the ‘noise’ in the data, so that it will not dominate the solution,” he says. “This presents a very challenging, large-scale numerical problem, and solving it accurately is crucial to being able to successfully detect these motions.”

Breaking the Computational Bottleneck

Constrained optimization problems, another area related to Greif’s work in numerical linear algebra, arise in numerous practical applications. “These can be described simply as trying to minimize or maximize an objective function, subject to some constraints.” He sites the example of a financial advisor assessing risk. “In this case, it is trying to maximize profits subject to the constraint on risk.”

Greif is a member of the Scientific Computing and Visualization Laboratory, and he is also very active in the Pacific Institute for the Mathematical Sciences (PIMS) at UBC. He notes that scientific computing is the focus of PIMS activities from 2003 to 2005. While the crux of his work is to devise reliable algorithms and analyze both the numerical properties of large linear systems and the methods used to solve them, he is also interested in the continuous mathematical problems from which linear systems arise, and in many cases these are partial differential equations. “Under almost any continuous mathematical problem hides a linear system that needs to be solved in an efficient way,” Greif says. “What I do is attack the bottleneck by solving problems in the underlying linear systems.”

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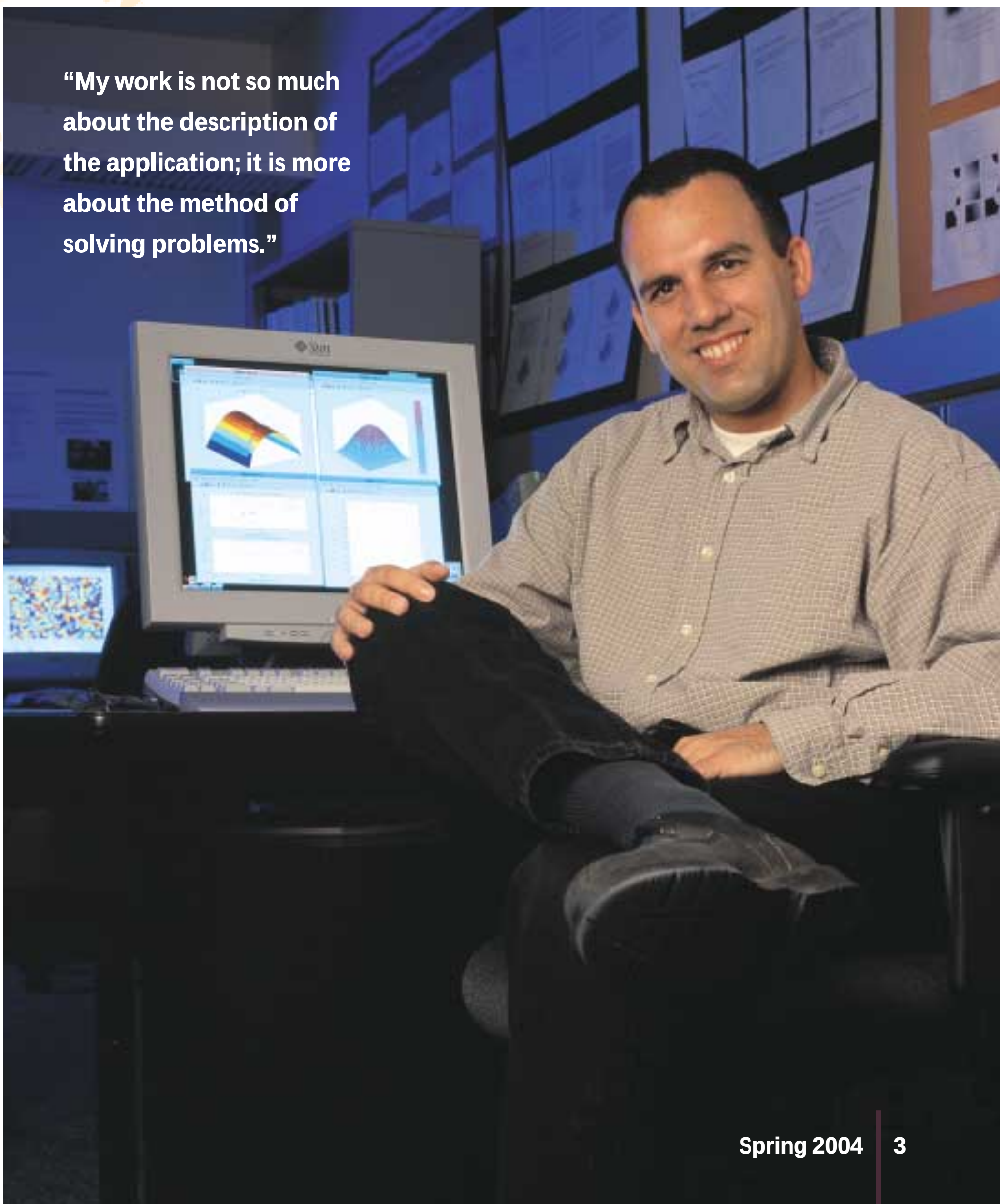

“My work is not so much about the description of the application; it is more about the method of solving problems.”

Making Wireless Systems More Reliable

Recent ICICS member Dave Michelson's work in propagation and channel modelling is setting international standards.

- **Radiowave Propagation**
- **Channel Modelling**
- **Next Generation Wireless**

The infiltration of wireless technology into homes, offices, and industry during the past decade has been nothing short of phenomenal. Dave Michelson, a professor in Electrical and Computer Engineering, is helping to improve the performance and reliability of wireless systems through his work in radiowave propagation and channel modelling.

"We're using wireless technology in situations that would have been unheard of only a decade ago, yet we're increasingly expecting them to perform as well as their wired counterparts," says Michelson. "The key to improving the performance and reliability of wireless systems is to thoroughly understand and characterize the environment in which they operate. Only then can appropriate solutions be devised."

Prior to joining UBC, Michelson spent five years as a member of a joint AT&T Wireless Services and AT&T Labs research team charged with developing propagation and channel models for fixed wireless and next generation wireless systems. The experience and expertise that he acquired there are in high demand.

Among the many projects and collaborations that he currently has underway, Michelson is developing propagation and channel models that will help ORBCOMM (Dulles, VA) improve the performance of their land mobile satellite system in urban and suburban environments. He is also working with Nokia Mobile Phones (Vancouver Product Creation Centre) to develop more effective next generation cell phones, and Inco (Sudbury, ON) to more effectively deploy wireless LANs in mining tunnels located almost 3 kilometres beneath the earth's surface.

Closer to home, Michelson is collaborating with Victor Leung, Resve Saleh, and Robert Schober, fellow ICICS members and colleagues in Electrical and Computer Engineering on an NSERC-funded three-year study concerning Enabling Technologies for Wireless Personal Area Networks. A member of the management committee that oversaw the planning and deployment of the world's largest campus wireless LAN—at UBC!—he is currently working with UBC's IT Services and Cisco Systems to model the factors that affect wireless LAN performance in campus and enterprise environments.

"Collecting propagation data can be expensive and time-consuming, but it's only half the task," says Michelson. "Reducing the data to models useful in system design and simulation is the essential and perhaps most demanding step in yielding the results that my colleagues in both industry and academia need to pursue their own work."

Michelson is also an active member of the international wireless community. He serves as Chair of the IEEE Vehicular Technology Society's Technical Committee on Propagation and Channel Modeling and as an Associate Editor for propagation and channel modelling for *IEEE Transactions on Vehicular Technology.* He also participates in, and has contributed to, several IEEE 802 working and study groups that develop many of the internationally recognized technical standards that wireless hardware and software developers follow when designing products.

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"The key to improving the performance and reliability of wireless systems is to thoroughly understand and characterize the environment in which they operate."

Self-Learning Control of Wireless Networks

Canada Research Chair in Signal Processing, Vikram Krishnamurthy designs and analyses high-performance, self-learning control algorithms for complex wireless and sensor networks.

The task of controlling the performance of a wireless communications network or battlefield sensor network involves making automated decisions, which, until recently, were computationally too expensive. “Over the past ten years, clever randomized algorithms have been developed in the mathematical and statistical communities for solving these problems,” says Vikram Krisnamurthy, ICICS member and professor in Electrical and Computer Engineering. He devises and analyses statistical signal processing and control algorithms to run increasingly complex systems, such as cellular wireless networks, radar systems, and defence networks.

Algorithms that Use Assimilation

An interesting aspect of stochastic control algorithms is their self-learning capability, which is based on an “assimilation” approach. Instead of previous “cursive” models of learning, which require an understanding of every detail of a system, the algorithms study and then optimize output by strategically tweaking input. Krishnamurthy likens the randomized process to learning to drive a car. “Most people don’t know how an entire car operates, yet we learn to drive by observing its overall response to our actions.”

Krishnamurthy’s research focuses on three main areas: mobile telecommunications, radio signal processing and neurobiology. With funding from NSERC, he and fellow ICICS member Victor Leung, also from Electrical and Computer Engineering, are working on third generation (3-G) cross layer optimization for wireless networks. Traditional research in 3-G has been focused on either designing better receivers or optimizing the software to better handle incoming data. In addition, wireless systems involve different degrees of randomness, since random data signals are corrupted by noise. They are also prone to atmospheric effects, interference from other users, buildings, and stray reflections, which all produce channel fading. “In wireless systems, we are looking at joint optimization of the physical hardware layer and the higher level software layer, which increases the complexity of the task significantly.”

Smart Sensors on the Battlefield

Helping to automate the decision process of a commander-in-chief in a battlefield scenario is another aspect of Krishnamurthy’s research. In modern warfare, several battleships, submarines, aircraft, and satellite systems are continually scanning the battlefield. Each is equipped with a range of sensors, such as radar, sonar, and imagers to compile a picture of the battlefield. “How can an automated system analyse this huge amount of data, extract the important information, adapt to the situation at hand, and respond in a fashion that is less error-prone than a human being?” asks Krishnamurthy. With funding from Defence Research and Development Canada and Defence Advanced Research Projects Agency in the US, he is working to develop intelligent sensors that can screen and process data.

Ion Channel Modelling and Control

Understanding the mechanisms of ion channels at the molecular level is a fundamental problem in biology. A single ion channel is a large protein molecule in a nerve cell membrane. All electrical activities in the nervous system, including communications between cells and the influence of hormones and drugs on cell function, are regulated by membrane ion channels. In collaboration with neurobiologists at the Australian National University, Krishnamurthy currently develops signal processing algorithms to maximize the amount of information that can be extracted from ion channel experiments.

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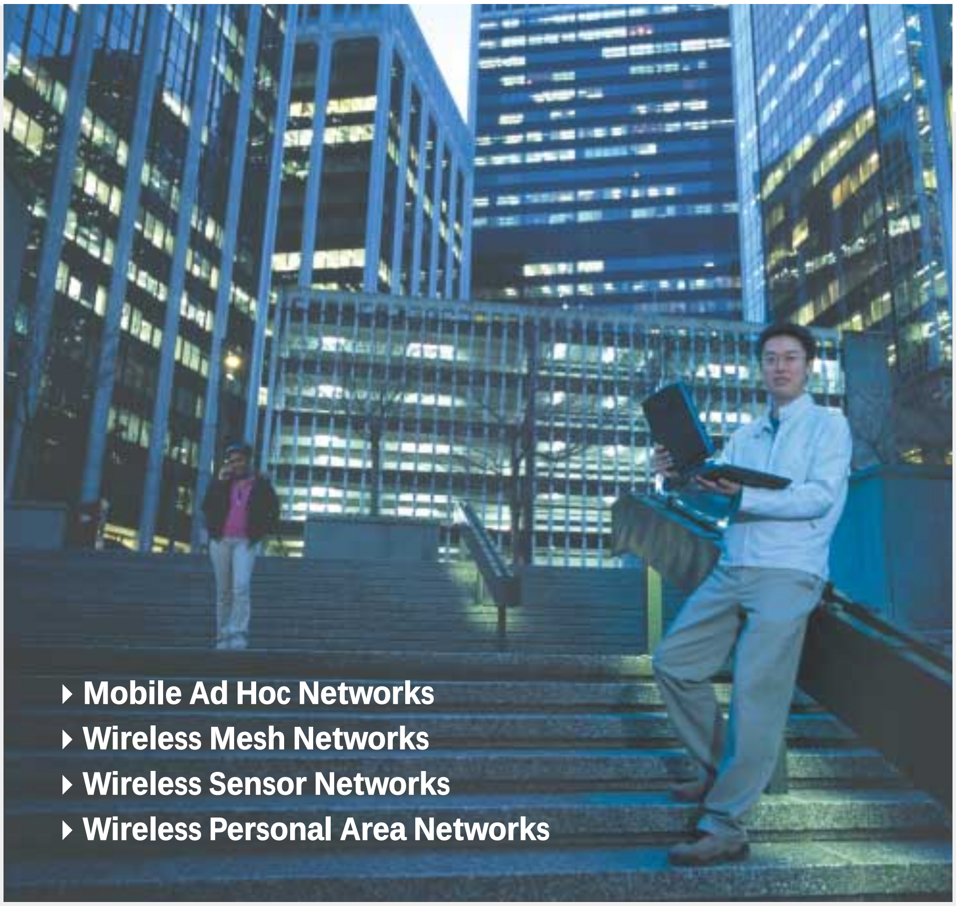
“If you think of a wireless system as several people sharing a common resource, how can you equitably allocate that resource—in real time?”

Sharing Systems with Wireless Pirates?

Tomorrow's wireless networks will use personal devices such as laptops to springboard data transmission and Internet access. Encouraging users to share their computing resources while keeping wireless pirates at bay are two challenges for ICICS member Vincent Wong



When we think of wireless communication, the ubiquitous cell phone comes to mind. Vincent Wong, Electrical and Computer Engineering professor, is working on mobile networks that take the concept of wireless communication to new dimensions. One example is wireless personal area networks, which allow short-range wireless transmission across multiple devices, such as computers, printers, PDAs, and digital cameras, using Bluetooth technology. Wong also works on wireless sensor networks for surveillance and military applications.

Perhaps the most intriguing and ingenious aspect of Wong's work is Mobile Ad Hoc NETworks (MANETs) and wireless mesh networks, which allow notebook computers, PDAs, and other mobile devices to relay data traffic to each other. Wireless users (or nodes) outside the transmission range of the stationary gateway node (i.e. an Internet access point) can continue to communicate with the gateway via their neighbours' notebooks using multi-hop pathways. In effect, wireless mobile computers become jumping off points for the transmission of data.

Managing Wireless Mobile Ad Hoc Networks

To complement the new mobile ad hoc routing protocols being standardized within the Internet Engineering Task Force (IETF), Wong works on load balancing and secure routing protocols for MANETs and wireless mesh networks. Since users are mobile, the routing paths between devices change constantly. Control messages must be sent to locate these "intermediate" transmission nodes. Wong's work in "load balancing" aims at reducing control traffic, which can slow down the network, while distributing data across multiple access points. "If we can do this then we will have more bandwidth for the data traffic," he says.

Selling the Sharing of Mobile Resources

The concept of MANETs is ingenious, but it is also susceptible to very human shortcomings. Wong notes that whenever users transmit or relay packets for other users, they draw on energy from their own device. What if a user doesn't want to share computing resources? While all users can opt in or out of the network, MANETs will only work if the majority of users participate. "We will probably need to give some kind of incentive to users so that they will be willing to relay or accept packets for others," admits Wong.

Foiling Wireless Pirates

And what about malicious users who want to steal data or sabotage the system just for the fun of it? Users can attack the system—and other users—in a number of ways. They can send back messages saying they have the transmission path, when they do not, in order to gain access to information. They can change the content of a message, or simply drop it, which eventually plays havoc with the system. They can also reduce the capacity of the network by flooding it with redundant control messages. Data security is a hot area in general, says Wong. Designing protocols to manage MANETs and keep one step ahead of wireless pirates is the work he relishes.

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Keeping the Lights On

ICICS member, Juri Jatskevich's work in simulation of electrical systems will help to ensure a stable power supply in unstable and demanding times.

- **Power Deregulation**
- **Power Electronic Systems**
- **Independent Power Production**

"Now, different utilities are breaking up into sub-companies that have their own financial goals. By pursuing these goals they sometimes forget about the physics behind these systems and that's when blackouts happen."

Last summer's power blackout cut a swath across eastern North America, leaving millions with the stark realization that we can no longer take power for granted. Increased demand by growing populations, extreme temperatures due to global warming, an aging infrastructure, and a changing relationship between service providers are key problems. The goals of power deregulation may be to increase quality of service by increasing competition, but in Ontario, California and Britain that has not happened; service has been reduced and power prices have escalated. Juri Jatskevich, professor in Electrical and Computer Engineering, is working in power electronics to help "keep the lights on" in deregulated environments.

Problems of Interconnectivity and Control

Before deregulation, power utilities were all interconnected, which provided an inherent compatibility and stability. That no longer holds true. Systems are becoming less robust because the interconnection between utilities is no longer consistent. Private companies can also install power conditioning devices that control and limit the power exchange agreed upon between utilities. "Contracts are based on a fixed number of megawatts—no more, no less," says Jatskevich. "And this limits the system's natural ability to handle some disturbances."

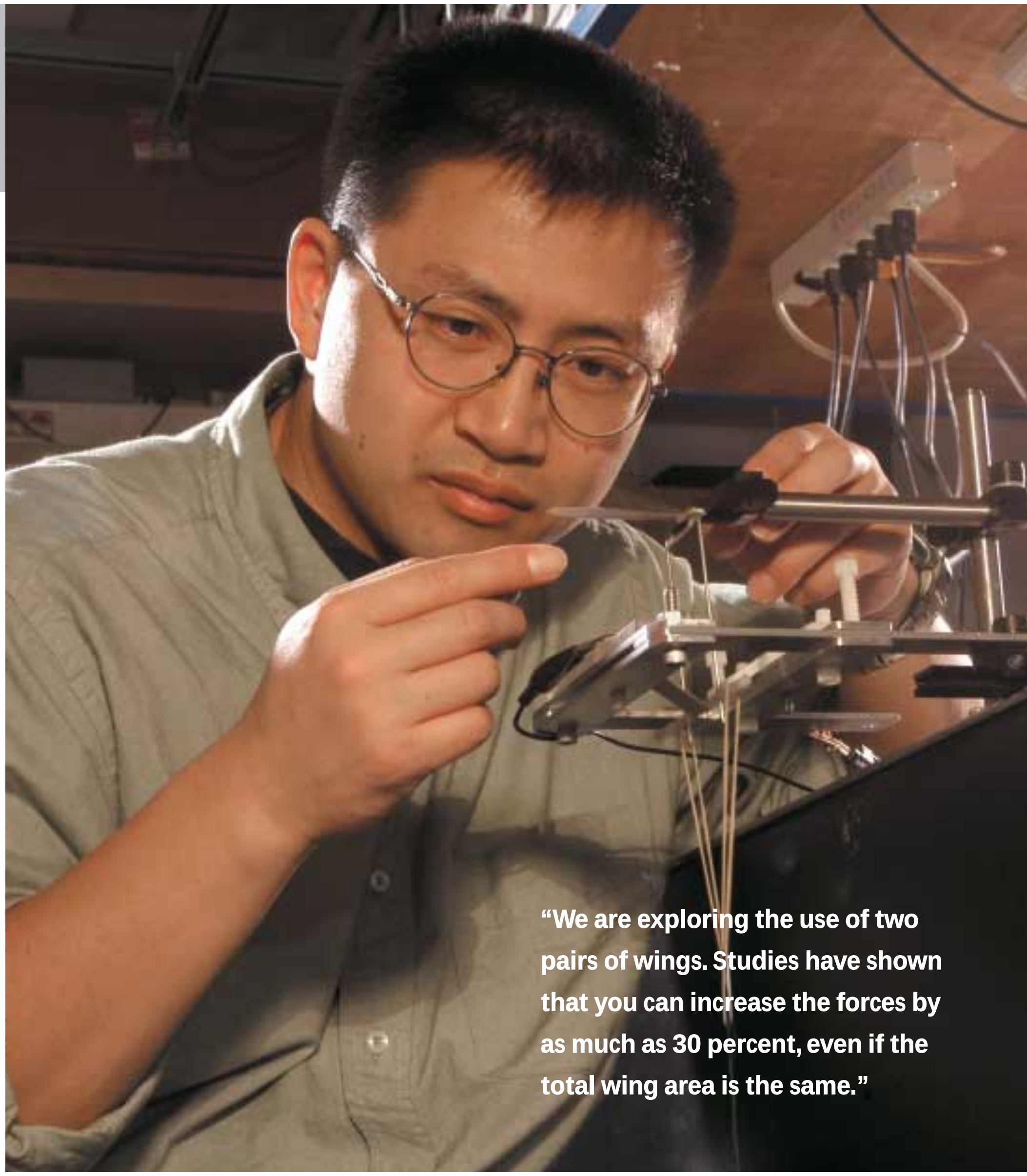
One way to prevent escalating blackouts is to design local, smart controllers that would prevent some loads from drawing more power than the system could handle. Jatskevich is also working to develop simulations to analyse these large complex systems at a high level of detail, and then distribute simulation models over a large network of computers to get the results faster. "In the future, we will have to rely more on active control in power utilities," he says.

Continued on back page

In a Flap Over Flying Robots

ICICS member Joseph Yan is fascinated with the aerodynamics of insect flight. His work on a robotic dragonfly is at the forefront of micromechatronics and involves collaboration with mechanical engineers, biologists and physicists.

- **Biomimetic robots**
- **Micromechatronics**
- **Micro-aerial vehicles**



"We are exploring the use of two pairs of wings. Studies have shown that you can increase the forces by as much as 30 percent, even if the total wing area is the same."

How do insects dart and hover, or stop and start in mid-air? In the last issue of *FOCUS*, we read about fellow ICICS member John Madden's (ECE) work in molecular actuators—artificial muscle with the power to lift a robot into flight. ICICS member Joseph Yan's work in micromechatronics is the flip side of the story. The Electrical and Computer Engineering professor is delving into the intricate aerodynamics of insect flight in order to build a mechanical dragonfly based on its biological forebear, with a 7.5 cm wingspan, 300 mg mass and a target wing beat frequency of 40 Hz, or 40 beats per second.

But why build a flying insect? Search and rescue, hazardous environment inspection, surveillance, power line inspection, and personal robotics are all potential applications. Prior to coming to UBC, Yan worked with biomimetic and micromechanical pioneer Ron Fearing at U.C. Berkeley. "We discovered for these micro-aerial vehicles that need to work in more confined spaces, flapping wings seem to be the way to go," says Yan. "There we were using single crystal piezoelectric actuators, which work well, but are very expensive and have small ranges of motion," he notes. "The electroactive polymers John is working on are cheap, easy to fabricate and have larger ranges of motion."

Insect Aerodynamics

Mimicking the intricate mechanisms of nature is always a daunting task. Insect flight, known for its unsteady aerodynamics, is intriguing on several levels. First, insects do not merely flap their wings. At the beginning of a stroke, or wing beat, an insect accelerates its wings at a high angle of attack, usually 45 degrees or more. For aircraft which rely on steady aerodynamics, wing angles are typically less than 30 degrees as higher values would cause the vehicle to stall.

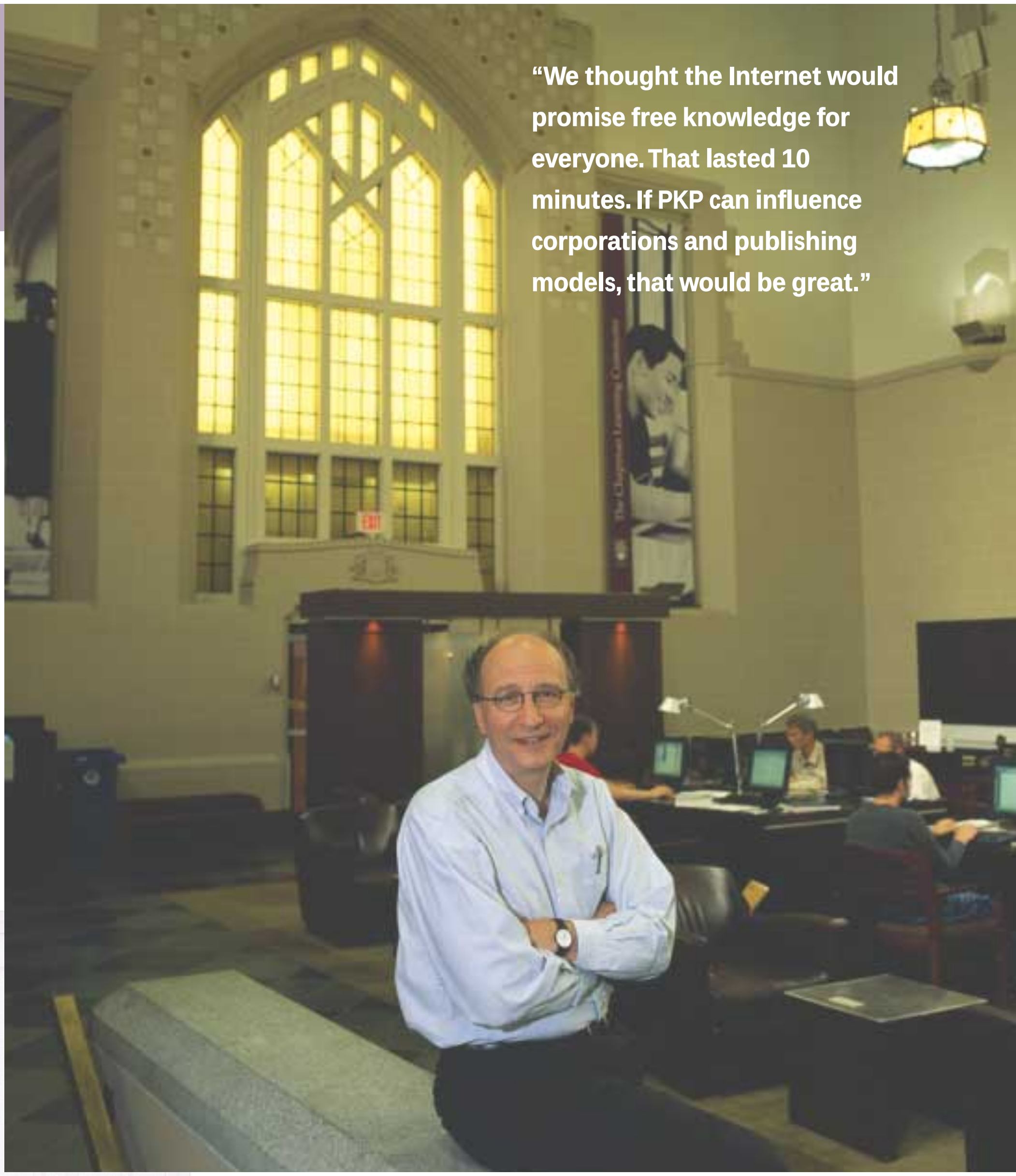
"An insect doesn't experience this stall, because before it gets to that effect, its wings reverse direction," says Yan. In fact, at the end of the stroke they also rotate their wings very rapidly. "This motion results in a rotational lift force analogous to the one experienced by a curve ball," explains Yan.

Continued on back page

Opening the Door to Public Knowledge

Recent ICICS member John Willinsky looks to new electronic publishing models to increase public access to academic research.

- **Public Access to Academic Scholarship**
- **Academic Journal Management**
- **Online Publishing Systems**



"We thought the Internet would promise free knowledge for everyone. That lasted 10 minutes. If PKP can influence corporations and publishing models, that would be great."

When John Willinsky talks about the "serials crisis" in higher education, he is not talking about a tempest in a librarian's teapot. Increasing subscription rates have forced universities everywhere to cancel academic journal subscriptions. Libraries everywhere, particularly in the developing world, are suffering the consequences. The Agricultural Sciences University in Bangalore, for example, has cut journal subscriptions by 40 percent, depriving both faculty and students of access to the latest research and thinking.

Willinsky, a professor of Language and Literacy Education in the Faculty of Education, witnessed the impact of the serials crisis when he toured African and Indian universities in the spring of 2003. "Knowledge is critical to development," he emphasizes. "What I've seen in Africa and India is that basic access to the research literature in print has been decimated."

With a grant from the MacArthur Foundation, Willinsky visited both continents to take stock of the situation and to promote a solution to the crisis—the development of publishing models that support free, public access to scholarly journals and the knowledge they contain.

Public Knowledge Project

Willinsky leads the Public Knowledge Project (PKP), a federally-funded initiative that brings together computer and social scientists to develop software tools that will help spread academic research to a wider audience.

The Open Journal System (OJS) is one such tool. A free journal management and publishing system, OJS automates several publishing tasks. It offers online article submission and tracking, peer reviewing, comprehensive indexing, and issue creation tools—and requires little or no technical expertise to operate. (OJS may be downloaded for free from the PKP website at www.pkp.ubc.ca.)

"It gives small journals a viable option for publishing an online journal," says Willinsky, who is concerned that the growing concentration of ownership of academic journals is limiting the free circulation of knowledge.

Continued on back page

Jatskevich: ***Continued from page 7***

Independent Power Production

On the brighter side, a parallel goal of deregulation is to encourage the development of alternative, independent power sources. With funding from ASI, BC Hydro and Powertech Labs, Jatskevich is working with fellow ICICS members and department colleagues Jose Marti, Tak Niimura, and William Dunford to develop ways to connect independent power sources into the grid. This is good news for the environment, and for people living in remote areas, who are most likely to see the highest price hikes. Independent power production increases efficiency and also encourages local development, particularly of green power sources such as photovoltaic and wind turbine technology. “Independent producers would be able to use whatever they need and sell excess power back to the province,” he says. Whether this benefit will offset other risks is not yet understood. Regardless, researchers like Jastskevich will help make the transition to deregulated power as smooth as possible.

Juri Jatskevich can be contacted at 604.827.5217 or jurij@ece.ubc.ca

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Yan: ***Continued from page 8***

Insects also manage to recapture some of the kinetic energy from the wake of air following their wings. In addition, the momentum generated by vortices, or swirls of air, contribute to an insect’s amazing manoeuvrability. Yan works with fellow ICICS member Sheldon Green (ME) to study these mechanisms on a slightly larger scale. “We are exploring the use of two pairs of wings.” he notes. “Studies have shown that you can increase the forces by as much as 30 percent, even if the total wing area is the same.”

The Flight Crew

In addition to Madden and Green, Yan’s collaborators include UBC zoologist Robert Blake, who specializes in biological locomotion, and Professor Emeritus Boye Ahlborn, whose interest is in zoological physics. Along with funding from NSERC and the Institute of Robotic Intelligence (IRIS), he credits a diverse team of researchers and very motivated students for helping to get the Dragonfly Project off the ground.

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Willinsky: ***Continued from page 9***

Public Good on a Global Scale

With OJS, both journals and readers win. Journals can increase their readership with online editions and readers are granted free and open access to knowledge—“a public good on a global scale” as the PKP website puts it. Willinsky says that PKP can be seen as part of a wider movement to “defend the public sphere within the Internet, ensuring that it serves the democratic right to know.”

“We thought the Internet would promise free knowledge for everyone. That lasted 10 minutes,” he says wryly. “If PKP can influence corporations and publishing models, that would be great.”

Find the Public Knowledge Project website at www.pkp.ubc.ca

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UBC’s Institute for Computing, Information and Cognitive Systems (ICICS) is an umbrella organization that promotes collaboration between researchers from the faculties of Applied Science, Arts, Commerce, Dentistry, Education, Forestry, Medicine, Pharmacy, and Science. ICICS supports the collaborative computer-oriented research of more than 125 faculty members and over 500 graduate students in these faculties. ICICS researchers attract approximately $15 million in annual grants and contracts. Their work will have a positive impact on us all in the future.

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