Carnegie Mellon

THE NEXT GENERATION

Center for Wireless and Broadband Networking

As the telecom industry moves toward third-generation networks, ECE is aiming ahead to the fourth generation — to the kinds of networks that will let you communicate anything, anywhere, quickly and reliably. The department intends to be a major player in 4G. Strategic buildup is under way in areas from wireless and optical networking to telecom policy. The mix includes new faculty hires, new labs and curricula, new research and partners.

Research is being focused in the new Center for Wireless and Broadband Networking. Formed last year, CWBN (http://broadband.web.cmu.edu) is meant to be the place where the problems meet the solvers.

Fourth-generation telecom systems will be "high-bandwidth and mobile," says ECE professor Dan Stancil. "The vision that's driving us is the user's vision. You want to be able to send and receive all kinds of information – images, video, big data files – and do it anywhere. You want to be able to access the network from lots of different platforms: cell phones, laptops, PDAs."

And since there is no single network blanketing the globe, but rather a vast patchwork of networks, "the whole thing has to be heterogeneous and seamless," Stancil goes on. "If you're moving around and you go from a high-speed LAN like Wireless Andrew [which covers the Carnegie Mellon campus] to a cell or satellite system, you want the handoff to be smooth. Your applications should adapt gracefully, not choke or drop out."

Stancil is director of the Center for Wireless and Broadband Networking. The mission of the center is to help close the gap between vision and today's imperfect reality, and it is a matter of nudging evolution along from many different angles. Our networks today are like transitional life forms, fleshed out in some ways but rudimentary in others and still mutating.

For instance, most people would agree with professor Ozan Tonguz, an associate director of the center, that "the Internet of the future will be wireless at the edges and fiber at the core." Things are now moving in that very direction: more user devices than ever are going wireless for mobility and flexibility, while main trunk lines use optical fiber for bandwidth and quality. The trouble is that progress is wildly uneven. Bandwidth and quality don't reach the wireless user because the technologies aren't there yet, and the airwaves are congested. Meanwhile there is overcapacity in the backbone – where miles of optical fiber lie mostly dark – but we're not ready to reap the full benefits of fiber anyway, because there are still many points where optical signals must be converted to electrical signals and back, and these constrain performance.

A few examples of how the Center for Wireless and Broadband Networking can help:

• CWBN already is on the wireless case from numerous angles.

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Department of Electrical and Computer Engineering
Carnegie Mellon University
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Pittsburgh, PA 15213

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Electrical & Computer ENGINEERING

Existing research offers new solutions for wireless LANs, a novel approach to boosting cell-phone system capacity on an ad-hoc basis – and new ideas in telecom policy.

Behind the scenes — will the wires ever go away?

• Policy studies are integral to the research agenda. "You hear all this hand-wringing about not having enough spectrum," Stancil says, "but if you put a spectrum analyzer on top of a building and just scan, you find that a lot of spectrum is not being used at any given time. Our advantage, with professors who hold cross-appointments in EPP [Engineering and Public Policy], is that we have strong technical people thinking about things like how to allocate spectrum more efficiently."

To help enable the move to all-optical networks, CWBN will focus on topics that range from optical buffering to security. Optics is an area targeted for growth as the center ramps up.

"We have a lot of good people working on pieces of the puzzle," Stancil says. "The idea behind the center is to leverage the culture of inter-disciplinary collaboration that we have at Carnegie Mellon, and bring together the capabilities to really deal with the issues."

"We have a lot of good people working on pieces of the puzzle," says CWBN Director Dan Stancil (above). "The idea behind the center is to leverage the culture of interdisciplinary collaboration that we have at Carnegie Mellon, and bring together the capabilities to really deal with the issues."

Rohit Negi, who joined the faculty after earning his Ph.D. at Stanford in 2000, is embarked on a project that tries to bridge different levels of thinking about networks. The objective of the research is to help wireless systems handle large, "bursty" data transmissions like real-time video. As Negi noted in an interview last year, two camps have been coming at the problem from dueling perspectives: "The communications-theory camp worries about errors in the bits because of channel noise. The networking camp worries about limits to storage capacity in the system, which give you errors because you lose data." Negi is developing a new theoretical approach that would "capture both these effects, so we can understand what the tradeoffs are." This would then enable different layers of the network to be jointly optimized.

ANTICIPATE AND ADAPT. WORK ACROSS THE LAYERS

Two major themes run through research at CWBN. One is designing networks that "anticipate and adapt" to requirements, proactively. Researchers at the center call this the Prometheus Concept: the name in Greek means forethought. The other theme is working across all seven of the OSI (Open Systems Interconnection) layers that have been defined as the standard conceptual frame for thinking about networks – from the physical layer (the cable or other medium) up to the application layer.

Named the Prometheus Concept after the Greek word meaning "forethought," a major theme of research in CWBN is to be proactive in anticipating and adapting to requirements.

As explained by Peter Steenkiste, an ECE professor and associate director of the center, the two themes are interrelated. Consider the problem of giving a wireless laptop user enough bandwidth to do a fat upload. "We've found from Wireless Andrew that most cells on campus are empty at any given time while six to ten are extremely busy. And the same is true for a wireless network at, say, an airport, where cells near certain gates get busy when planes are loading," says Steenkiste. One solution that his Ph.D. student Glenn Judd is developing is a wireless bandwidth advisor. Sensing that you're about to send a big file, and also monitoring the loads in nearby cells, "the system could give a screen message that says, 'Please walk to Gate 35.'"

Pretty nifty, but watch out. "You can't tell all the laptops to move to the same cell," Steenkiste says. "And in a system that has many ways to anticipate and adapt, making people walk should be the last option. First you try solutions that are transparent to the user." Such as communicating only with the device – and by the way, "current products are somewhat dumb in how they pick a base station. Usually they pick the one closest, for signal strength. That's not necessarily optimal and there are some changes we can make."

Another option, says Steenkiste, is to make better use of the many studies already done on mapping mobility patterns and projecting movements of people. That is information that can be filtered down and used across multiple layers of the system: "It can affect how your physical network is set up. Or, at the signal-processing layer, it can tell you 'this cell is going to get busy.'" Movement of individual users can also be gleaned from other sources – from peeking (with permission) into e-calendars; from people-locator technologies – and used in many ways: "If you're leaving a conference room, chances are you're going back to your office. The system can start downloading your email."

The Promethean mantra is always: explore many ways to anticipate, many ways to adapt. Steenkiste cites the classic problem of the car heading down the highway, drifting in and out of good wireless coverage. "If you can anticipate what is coming" – from the signal quality degrading, from GPS, from maps the user may have downloaded – "maybe you can change the coding, or the modulation. And the nice thing is, in the center, you have people working on all levels. I know about protocol, somebody else knows about encoding bits."

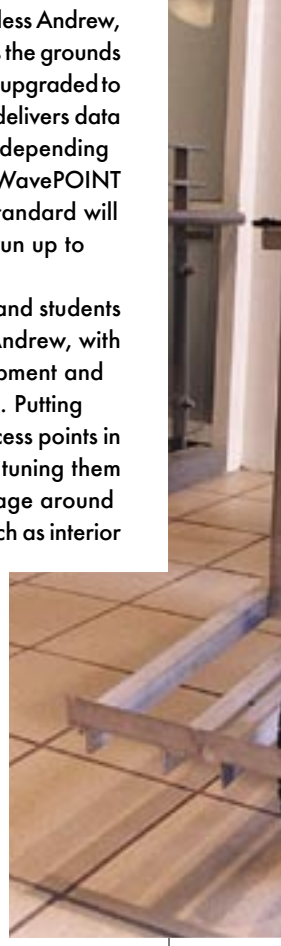
Moreover, people are involved in many projects across campus. Work on automotive wireless is in fact being done for the General Motors lab; the bandwidth advisor is part of the Aura Project on pervasive computing. "If CWBN can be the mechanism for people to extend what they're doing," Steenkiste concludes, "it becomes very interesting."

INDOOR HIGH-SPEED WIRELESS: A PRACTICAL APPROACH PLUS A RADICAL APPROACH

After optical fiber has been laid the proverbial last mile to the curb, major users are left with the problem of the last few hundred feet: how to distribute lots of bandwidth inside a big building. Fiber indoors is too expensive for many. A high-speed wireless LAN, which gives the added benefit of mobility, may be a better choice.

The prototype is Wireless Andrew, covering all buildings plus the grounds at Carnegie Mellon. Now upgraded to the 802.11b standard, it delivers data rates of up to 11 Mbps, depending on proximity to a Lucent WavePOINT unit. The new 802.11g standard will allow such networks to run up to 54 Mbps.

But the faculty, staff and students who installed Wireless Andrew, with corporate-donated equipment and support, will tell you this. Putting numerous hard-wired access points in just the right places and tuning them to get acceptable coverage around and through obstacles such as interior walls and elevator shafts, with enough bandwidth in high-use areas, is not easy. ECE professor Alex Hills, the Wireless Andrew team leader, calls it a process of "test and redesign" – which basically means you must keep trying without many rules of thumb to go by, because every building is unique. For those not interested in the learning process, the difficulty of getting it right can be a deal-breaker.



So Hills has devised a tool called the Rollabout, a sensor-equipped cart that carries a laptop with proprietary software. Once transmitters are temporarily placed, the Rollabout is pushed through halls and rooms in the desired area. The software builds highly detailed coverage maps,

and other graphic displays, to help relocate and tune the transmitters. Coming to market soon, the Rollabout may be what many customers have always wanted.

Unless they prefer Dan Stancil's far more radical approach to bringing high-speed wireless indoors. For Archimedes the eureka moment was inspired by bathwater; for Stancil it was sheet metal. "Seeing the difficulties they had in laying out Wireless Andrew got me thinking," he says. "Just about every building comes with hollow metal pipes that run from the core throughout the building." Could the heating, ventilating and air conditioning ducts act as waveguides for wireless signals? And aren't waveguides a better medium than free space for wireless?

Subsequent research, sponsored by Asea Brown Boveri (ABB), has led to stunning results. The findings indicate that wireless signals can be piped through HVAC systems at up to gigabit speeds, over convoluted duct runs of up to 500 meters, cost-effectively. A typical building should need only one hard-wired transmitter per floor, to boot the signals out into the ductwork. And tapping into the network at any point should be easy.

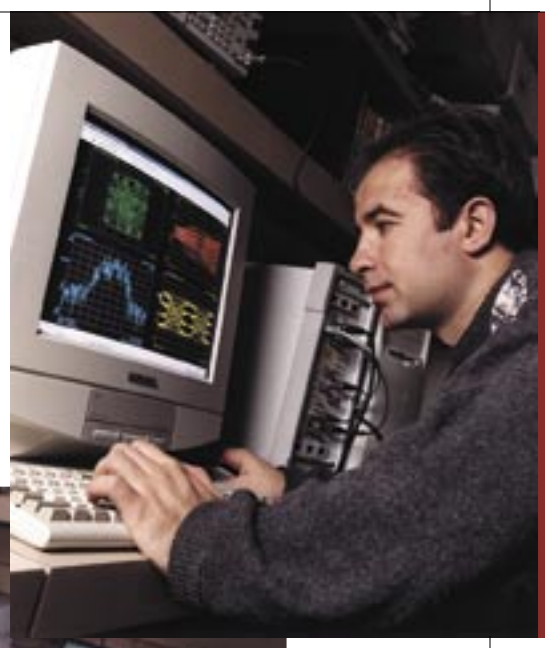
"Let's say you want Internet access in here," says ECE professor Ozan Tonguz. Sitting in his office in the B level of Hamerschlag Hall, Tonguz points at the ceiling. "You could get an antenna from Radio Shack and put it up into that duct." To finish the link to the user you would either rig the antenna to re-radiate through the room, or run a short cable drop. How it's done can vary according to need.

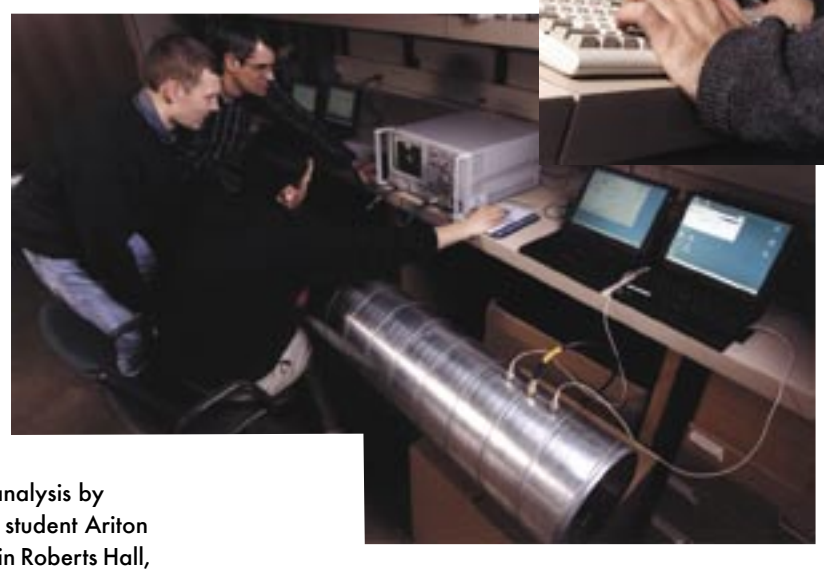
Core patents for high-speed wireless over HVAC were granted to Carnegie Mellon in 1999, based on Stancil's early work. Tonguz joined the research team when he arrived on the faculty in fall of 2000. To verify and expand upon what Stancil had done, a series of experiments and tests were carried out along with a theoretical capacity analysis by Tonguz and his Ph.D. student Ariton Xhafa. Testing began in Roberts Hall, then moved to nearby Lawrenceville, in the converted industrial building owned by the Robotics Engineering Consortium. There the researchers hung a full prototype duct system, complete with bends and splits, for large-scale testing.

Tinkering and refining continues. The analysis by Tonguz and Xhafa shows that optimum transmission – at data rates of up to one gigabit per second, over 500 meters – can be achieved with impedance matching at the end of the duct, plus absorbers in some problem sections, to counter the internal signal reflections at bends, Ys and Ts. Taking less trouble you can expect about 300 Mbps over shorter runs. Either way, projected data rates are much higher than those possible with 802.11 systems in free space – and projected costs are very much lower than fiber. Says Tonguz, "this has the potential to be a disruptive technology."

The potential market niche is wide: office buildings and more. Speaking on an unrelated subject recently, Peter Steenkiste began a sentence by saying "If hotels had wireless, which for some strange reason they don't … "

Soon they may have no excuse.





Core patents for high-speed wireless over HVAC were granted to Carnegie Mellon in 1999 based on CWBN director Dan Stancil's (below) early work.

Professor Ozan Tonguz joined the department in 2000 and began a series of experiments to verify and expand on the earlier project, including a full prototype duct system. Analysis by Tonguz and Ph.D. student Ariton Xhafa (right) has shown that projected data rates are much higher than those possible with the 802.11 systems in free space — and projected costs are much lower than fiber.

SPECTRUM AND POLICY: HOW SMART SHARING CAN HELP

"Spectrum shortage is a myth. It's only scarce because people get exclusive access to it and it sits idle much of the time," says Jon Peha.

A professor in ECE and in Engineering and Public Policy, Peha has studied several ways to use the airwaves more efficiently. He's high on secondary access, whereby users other than the license holder could get onto a channel as needed.

For instance, every major metro area has more than one cell-phone company. At least one of them is liable to have, at any given time, a channel in a nearby cell that it might be willing to rent to you – an unlicensed user – on a spot basis, for an appropriate fee. "You'd need software-defined radio for this," Peha says. "Jump from band to band, ask operators like Sprint and Verizon, 'have you got any spectrum I can use? Can you let me have 20 minutes to operate in this particular place?'"

"Spectrum shortage is a myth. It's only scarce because people get exclusive access to it and it sits idle much of the time," says Jon Peha, Engineering & Public Policy.

Other possibilities abound. TV stations license spectrum for their mobile action-cam news teams to send remote feeds a few times per day. Obviously that sort of spectrum could be opened to secondary access the rest of the time. Better still, it could be freed up entirely, by having action-cam itself become a secondary user. TV crews might protest that they can't risk even a few seconds of delay, but as Peha notes "there may be other applications in which, if the spectrum is busy, the user can just wait a bit: reading gas and electric meters."

Pay-as-you-go secondary access is not currently legal by FCC rules. There are implications to be weighed, such as the chance that cell phone subscribers – who are themselves paying "rent" for the spectrum – might find their calls being dumped or blocked by secondary traffic. Peha and his research partners are considering the implications. The research question, he says, is "How much would this kind of secondary use interfere with the primary users? Or, put another way, how much would a secondary user have to pay the primary user to make it worth his while?"

Ultrawideband (UWB), a quite different form of secondary access recently approved by the FCC, is the subject of growing controversy even though the technology is not nearly ready for market. With UWB a great variety of short-range wireless apps would use a very low-power signal spread over an enormously wide band. No licenses or fees would be called for; the basic idea is that interference with any licenseholder or primary user on a channel within the band should be negligible – but critics worry that it will not be. Peha and others are studying potential uses and power levels required.

And speaking of controversy, if the goal is to free up the airwaves, how about creating more unlicensed spectrum? Peha's view here is that yes, outright free spectrum is good and has a place. It just needs to be regulated a little. "Unlicensed spectrum does not mean unconstrained behavior," as he likes to say. "Effective etiquette" is needed, meaning rules that encourage effective, efficient sharing of the band.

He cites the case of the unlicensed UPCS band, for wireless LANs and personal uses such as cordless phones and baby monitors. To keep order, UPCS has a "listen before talk" rule: before a device can transmit, it must sense an open channel for 10 milliseconds. "That's helpful in some ways," Peha says. "But an intelligent designer can make a 'greedy' device that will grab the channel and hold onto it for a long time." The solution

THE ROLLABOUT'S ROLE IN WIRELESS

Started in 1994 as a National Science Foundation-funded research network to support Carnegie Mellon's wireless research initiative, the Wireless Andrew network originally provided coverage in seven campus buildings; it now covers the entire campus.

As anyone involved in the project will tell you, the challenges in building such a large network are far from trivial. For one thing, placing transmitters in just the right places within large complicated buildings is not easy. The solution is the Rollabout, a sensor equipped cart equipped with a laptop and proprietary software. Developed by Wireless Andrew team leader and ECE Distinguished Professor Alex Hills, the Rollabout can be easily pushed around a building obtaining data from temporarily located transmitters.

he has proposed is "to make the amount of time you have to listen depend on how much you've used the channel in the past," literally imposing a "penalty period" for greedy use.

Other prominent policy-oriented faculty in the Center for Wireless and Broadband Networking include Alex Hills and Marvin Sirbu. Both hold cross-appointments in ECE and EPP; Sirbu is in GSIA as well. The center also provides a Telecommunications Policy Forum for industry partners, in which companies can learn about and debate issues of relevance to them – and seek consensus on points where they may differ.

OPTICAL CHALLENGES AND OPTICAL SECURITY

Migrating to an all-optical Internet requires learning how to do things that cannot now be done (or done well) in the optical domain. For example, Internet protocol is based on packet-switching: Every message sent is broken into packets of bits, to be routed through the busy network by the "best available" paths and re-assembled at their destination. Currently this means that at every node in the branching optical-fiber pathways, optical signals must be converted to electrical signals for routing and then reconverted. That is exactly the kind of performance constraint we hope to eliminate by going all-optical, but one thing stands in the way.

An electronic router has a buffer, for temporarily parking any packets of bits that can't yet be dispatched properly. A good optical buffer is hard to find.

Professor Ozan Tonguz, who heads optical research in CWBN, is studying alternatives. One is deflection routing: "At a given node, if several packets are coming in and there are conflicting requirements, send these packets around the network to come back and try their luck again," says Tonguz. "You're using the network itself as memory."

Other issues arise in trying to implement IP and packet-switching over an all-optical, WDM (wavelength-division multiplexed) network – such as maintaining the very high quality of service that is, as Tonguz says, among the reasons "why people love fiber" in the first place. CWBN will study these issues as well.

Finally comes a topic of great concern, security. The same features that make optical networks attractive could also make them vulnerable to new forms of hacking. Here is an example:

Multiplexing allows each strand of fiber to be packed with signals carried at different optical wavelengths. They all need to have their gain boosted every 100 meters or so, which can be done rather simply with an erbium-doped fiber amplifier, or EDFA. This optical "pump" applies external energy (typically from an IR source) to a short section of fiber doped with the rare-earth element erbium. Atoms in the doped section are excited and presto, beams passing through come out brighter than before.

However, the supply of gain is being doled out among many signals in many strands. An EDFA could thus become the vehicle for a gain-competition attack. A high-power signal, injected at a slightly different wavelength from the rest, could "starve" the others of gain. And the effect would then cascade through the amps all down the line, with the attack signal propagating, others dimming out. The ominous result would be denial of service on the Internet backbone.

"Even with encryption, an attacker who is sophisticated enough could log on, as a legitimate user, and cause massive disruption," says CWBN Associate Director Ozan Tonguz (left). "Over the past 30 years we have done a good job of designing optical networks for quality of service, but not for security."

Many similar sorts of attacks may be possible, on amplifiers and other optical components. "Even with encryption, an attacker who is sophisticated enough could log on, as a legitimate user, and cause massive disruption," Tonguz says. "Over the past 30 years we have done a good job of designing optical networks for quality of service, but not for security."

The research objectives are: find ways to detect and localize denial-of-service attacks, develop countermeasures, and reconsider network design in light of security. This work will be done in conjunction with ECE's new Center for Computer Communications and Security (C3S), which made headlines in September when it received a five-year, $35 million operating grant from the Department of Defense.

John Peha (left, above), a professor of Engineering and Public Policy and ECE, has studied several ways to use the airwaves more efficiently. He currently favors secondary access, allowing users other than license holders to get onto a channel as needed.

The stakes are high, for as Tonguz notes, "terrorism in the future may be more sophisticated than we have seen. If you can disrupt the Internet, you disrupt a lot of vital communication. You disrupt our way of life." And in this game the combination of the two centers, C3S and the Center for Wireless and Broadband Networking, could form a crucial line of defense.

EXTENDING THE NETWORK

The research agenda in CWBN is expanding. There are many more projects (and topics, and researchers) than the few spotlighted here.

Nor is research the only story. ECE's strategic emphasis on networking includes a big ramp-up in education. New instructional labs in Networking and Wireless have been built, each with a groundbreaking curriculum package geared to seniors and first-year master's students; and a new master's program in security will deal extensively with network security: see the story on page 9.

In further exciting news, the education effort now extends overseas. ECE and the Information Networking Institute – which is directed by ECE faculty – have struck a unique partnership with a new education-and-research center in Greece called Athens Information Technology (http://www.ait.gr).

Students in the charter class on AIT's campus this year are earning the Master of Science in Information Networking. Yes, that is a Carnegie Mellon degree, the same MSIN offered here in Pittsburgh. Several courses are even taught by the same faculty, and delivered live by interactive video to the students in Greece (where AIT's faculty teach the remainder of the courses on-site). It's the first time a Carnegie Mellon degree – or perhaps any university's degree – has been offered in such a fashion.

The partnership is the first step to globalization for ECE, says department head Pradeep Khosla. It gives ECE a presence in an emerging tech-oriented country that is both a member of the European Union and a gateway to Asia. The Master of Science in Information Networking was chosen as the launch degree for an obvious reason: because networking is a hot topic everywhere. There is no better way to network than through networking.

By Mike Vargo

Alumni Spotlight

Kettler Plays A Full Hand As Product CTO At Dell:

Kevin Kettler, M.S. 1989, Ph.D. 1999

These are heady times at Dell Computer. Still a prolific PC maker, with double-digit sales growth through the recent slump, Dell is pushing into new territory on several fronts – designing and selling its own printers and PDAs, navigating a broad technology shift in the server market, and exploring new wireless interconnect technologies for home and business use. At the center of the action is Kevin Kettler (B.S. 1984 (Lehigh); M.S. 1989, Ph.D. 1999, Carnegie Mellon), VP and chief technology officer for the Dell Product Group.

"Kevin's schedule is beyond hectic," his administrative assistant has warned. Yet in a phone interview Kettler sounds calm and genial, not like a CTO with too many balls in the air. In fact, along with his work at Dell – plus the course in PC architecture that he teaches as an adjunct at the University of Texas, plus a full slate of family activities – Kettler is planning to put one more ball in the air that evening by playing pickup basketball at a local gym. He figures it costs him "about ten dollars per jump shot" time-wise, but sees the ability to set aside the time as an indicator of how well he's been coping: "If I find that I've gone two weeks without getting out and playing, I know I have to go back and re-evaluate my time management."

Learning from the Ground Up

Taking on a lot, and taking responsibility for it, has long been a way of life for Kettler. As he says, "I was a little unusual compared to my peers in engineering school." Raised as one of seven children in a close-knit family, Kettler married the former Julie Worley from Boiling Springs High School in rural central Pennsylvania. "I was unusual in that I entered college with a wife and daughter while doing my undergraduate at Lehigh," Kettler recalls. "By the time I did my master's work at Carnegie Mellon we had two children. Then four for my Ph.D." The clan is now holding steady at that number.

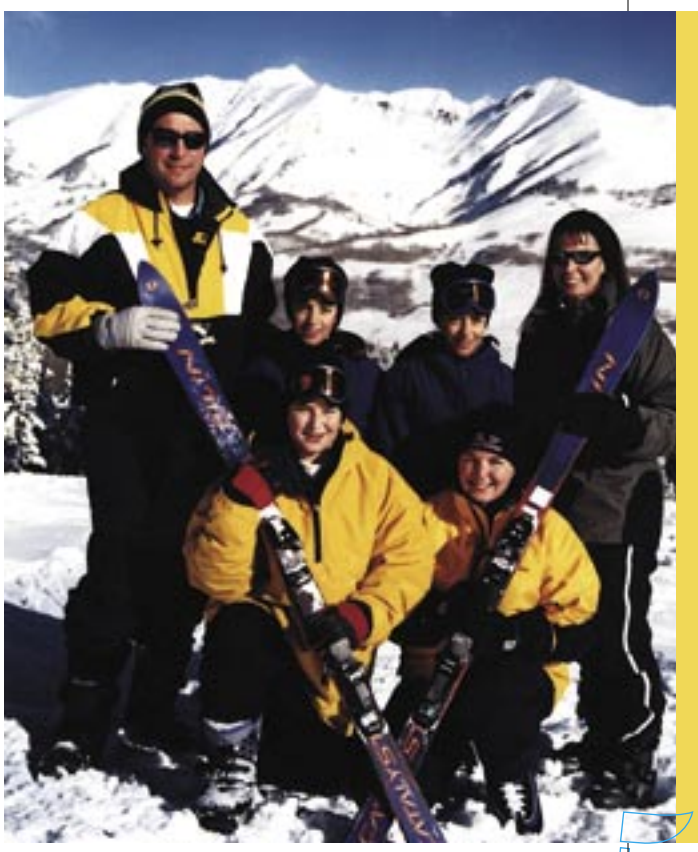
Before and between stints as a graduate student, Kettler worked at IBM. The company steered him into the then-emerging field of personal computers and sponsored his studies. Kettler's first job, in the mid-1980s, was to test memory IC devices; he then wrote a master's thesis on the use of current-sensing circuitry for chip testing. Returning to IBM just as the first multimedia PCs were in development, he worked on hardware design for high-quality audio and video systems, which eventually led him back to campus for a doctorate. But he finished his dissertation – on a bus framework for real-time/multimedia applications – while shuttling back and forth from Austin, Texas. He had been hired by Dell and put onto the management track.

Technologies in the Pipeline

With his background in multimedia, Kettler is excited about Dell's move into the consumer markets. "Our focus is more on what customers will use the system for, and how we can facilitate that. Manipulation of audio/video files is still a strong emerging market."

So is the market for new modes of interconnection. The company's founder Michael Dell has pointed out that the long-awaited "convergence" of technologies for video, voice and data doesn't necessarily mean convergence into a single do-it-all appliance. "You're going to have lots of different devices," Dell told an audience this summer – "and they'll all be connected." And as Kettler adds, the prevailing vision of wireless as the way to go – combined with industry trends like the new PCI Express standard (the next generation Peripheral Component Interconnect bus) – points to "a whole new technology of interconnect" with "a major upshift in performance, features and functions."

Whatever the technology, Kettler enjoys the CTO's prerogative of getting to deal with all the pieces of the puzzle. In servers, for instance, "we're moving from tower- and rack-based systems to more modular, computing-based systems." This entails laying out new system architectures as well as working with vendors and partners "to line up the silicon and software we need." And always, there are the nuts-and-bolts engineering challenges like those presented by power density: "As we build out this modular platform, putting multiple cards side by side to get the most processing power in the smallest square footage, how dense can we make the design?" he asks. "What comes with performance is heat. Then, since most cooling technology involves the flow of air, this gets you into acoustics. It also gets you into EMI and other shielding technologies, because when you open up a design for airflow you open it up to radiation." These are issues, Kettler notes, "not only in the server space but in smaller form-factor notebooks and desktops" industry-wide.



The cornerstone of Kettler's life is his family. Taken a couple of years ago while on a ski trip, this photo shows Kettler with daughters Stephanie and Laura and wife Julie (back row, L to R) and son William and daughter Christen in the front.

Building the Basics

Kettler says graduate work at ECE was good preparation for his role at Dell. "I think Carnegie Mellon's real value proposition is the emphasis on solving practical problems," he says. "One component of that is breadth and depth, with a lot of interaction among research areas, and the other is emphasizing research with relevance to the real world." Looking beyond his own IBM-funded research, Kettler notes that "across the [ECE] department, the areas that have developed have strong tie-ins to industry or government needs." The mindset he acquired at Carnegie Mellon has carried forward into his three-step formula for being a CTO: "One, have a good breadth of technical knowledge. Two, understand what is relevant to the customer. Three, apply a business model that creates value for the shareholder."

But there is one more part of the equation. "I'm fortunate in the family that I have, and in the relationship that I have with my wife," Kevin Kettler says. "We are very much a team. A lot of the ability to balance work and personal life, to balance all of the pressures, depends on how happy you are with your relationship. A positive relationship provides a strong cornerstone when balancing work and family," he concludes.

Alumni spotlight

No one quite remembers how it all started, but ECE alumni, faculty and current students of the CAD Center (later CEDA and now CSSI) have been getting together at the Design Automation Conference for the past 15 years. Photos here are from the 39th DAC held in New Orleans last summer.

Plans are under way for ECE-sponsored alumni events elsewhere around the country. Stay tuned!

Undergraduate Program in Computer Engineering Ranked #2 in U.S. in Fall 2002

In specialty undergraduate engineering areas, Carnegie Mellon was ranked second in Computer Engineering by engineering school deans and senior faculty in the U.S. News & World Report magazine's annual survey of America's Best Colleges. The specialty area of Electrical Engineering ranked ninth.

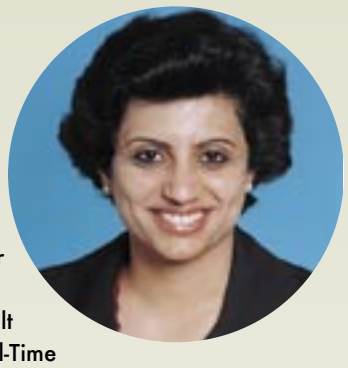
The entire undergraduate engineering program retained its 7th overall ranking, and the university's overall undergraduate programs rose to 21st place from 23rd last year.

Cendes Elected IEEE Fellow

Zolton Cendes, adjunct professor of ECE, was elected an IEEE Fellow, Class of 2003. He was cited "for contributions to the application of finite element modeling to microwave guides, structures and circuits."

Cendes founded Ansoft Corporation in 1984 and is the Chairman and CTO of the company today. He was a professor of ECE from 1982-1996.

Narasimhan Receives NSF Career Award



Priya Narasimhan, assistant professor of ECE and CS, is the recipient of a National Science Foundation CAREER Award (2003-2008) for her proposed research on "Integrated Fault Tolerance and Real-Time SupportforMiddlewareApplications." The prestigious CAREER program "recognizes and supports the early career-development activities of those teacher-scholars who are most likely to become the academic leaders of the 21st century." Narasimhan's proposal focuses on furthering our understanding of the precise trade-offs and complex interactions between real-time and fault tolerance, thereby enabling middleware-based mission-critical applications to be developed with simultaneous real-time and fault-tolerant support.

Diana Marculescu Interviewed in Swedish Electronics Journal

Diana Marculescu, assistant professor of ECE, was interviewed in Elektroniktidningen, Sweden's largest electronics publication, similar to the EETimes, on the Globally Asynchronous Locally Synchronous (GALS) design style, one of the "hot topics" in architecture and system design. In the piece, "Without GALS, Moore's Law Will Perish" (available in Swedish), Marculescu predicts, "I think IBM, Intel and others are aware that only by using GALS can they keep Moore's law alive for another 5–10 years using current technology." The article expects the SoCs of the future will be built on asynchronous communication between islands of synchronous circuits, with GALS technology raising the performance of semiconductors. "GALS is a good compromise between synchronous and asynchronous design," Marculescu said.

Towe Elected IEEE and Optical Society Fellow

Elias Towe, professor of ECE and Materials Science and Engineering, has been elected a Fellow of the IEEE and of the Optical Society of America. He was recognized by the Optical Society for "original contributions to semiconductor optoelectronic devices and for leadership in optics and optoelectronics." The IEEE recognized him "for contributions to nanostructure optoelectronic technology."

Prior to joining our faculty last year, Towe was a program manager in the Microsystems Technology Office at DARPA since 1997, and on the faculty of the University of Virginia since 1990.

Department & Faculty Development News

Official Kick-off for Cybersecurity Center

By Chriss Swaney
CIT Public Relations Director

Carnegie Mellon's Center for Computer and Communications Security (C3S) will receive $35.5 million over the next five years from the Department of Defense to create a new network security paradigm to tackle the challenges related to Internet security, data storage and privacy issues stemming from America's ongoing war against terrorism.

The new multidisciplinary center will pull research faculty from the school's Electrical and Computer Engineering Department, the Department of Engineering and Public Policy, the School of Computer Science, the Department of Statistics, the Heinz School, the Software Engineering Institute and the CERT Coordination Center, the nation's first and best-known computer emergency response team.

Pradeep Khosla, head of Electrical and Computer Engineering and the newly formed C3S, said the crucial role that information technology plays in warfare and homeland security inspired Carnegie Mellon to create the new center.

"The focus on using technology to meet security challenges has implications on both private and public organizations, and that's why our research is a collaborative effort," said Khosla.

"In order for the Software Engineering Institute program in network survivable systems, including CERT/CC, to stay on the cutting edge, it is absolutely mandatory that we collaborate with leading researchers in the world," said Stephen E. Cross, director and chief executive officer of the Software Engineering Institute. "Those researchers are in C3S, and this grant is further proof of their preeminence."

One of the center's latest research tasks includes developmentof "self-securing systems," computer components such as hard disk drives and network cards that will defend themselves, and ultimately each other, from attack.

Carnegie Mellon researchers say one advantage of making components self-securing is that each one can closely monitor itself, finding clues about intruders that go unnoticed by firewall devices, which must handle a large flow of information into a local network

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AM I REALLY WHO I SAY I AM?

Ph.D. student Marius Savvides (top, at computer) has been developing face recognition technology that will play an important role in computer security (see Faces are Fluid, p. 12). Looking on (from L to R) are Professor Kumar (Savvides' advisor), Carnegie Mellon President Jared Cohon, Pradeep Khosla and Congressman Mike Doyle.

Doyle then has his turn mugging for the camera mounted on top of the screen to create the variety of facial images that are necessary to enroll him as a user.

Carnegie Mellon Hosts White House Town Meeting on Cybersecurity

Howard Schmidt, vice chair of The President's Critical Infrastructure Protection Board (CIPB), led a town hall meeting at Carnegie Mellon in late October to stress securing the nation's critical infrastructure and discuss The National Strategy to Secure Cyberspace, released last September by the Bush Administration.

The standing-room-only crowd in McConomy Auditorium included representatives from industry, the university and local government. Participants took part in an interactive two-hour discussion to learn more about the national strategy and what they can do to protect our nation's infrastructure.

During his visit, Schmidt toured Carnegie Mellon's new Center for Communications and Computer Security (C3S), led by Pradeep Khosla, Department of Electrical and Computer Engineering (ECE) Head.

Déjà Vu

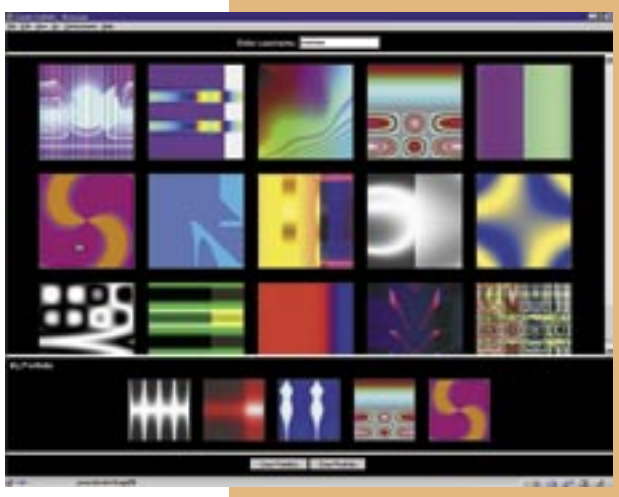
Adrian Perrig (left), assistant professor of ECE and EPP, is demonstrating one of his security research programs to Congressman Mike Doyle (right).

"Current security systems suffer because they neglect the importance of human factors in security," says Perrig. "With Déjà Vu, we address a fundamental weakness of knowledge-based authentication schemes, which is the human limitation to remember secure passwords."

Relying on recognition-based, rather than recall-based authentication, Déjà Vu authenticates a user through his ability to recognize previously seen images. Déjà Vu is more reliable and easier to use than traditional recall-based schemes, which require the user to precisely recall passwords or PINs. Furthermore, it has the advantage that it prevents users from choosing weak passwords and makes it difficult to write down or share passwords with others.

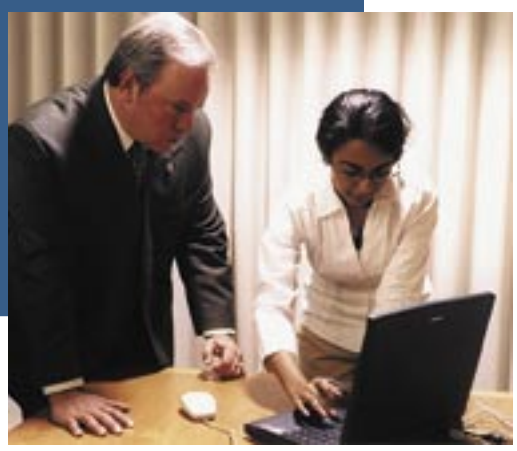
Shown here is a prototype of the Déjà Vu login screen. Using the prototype, Perrig and his research group conducted a user study that compares it to traditional password and PIN authentication.

The user study shows that 90% of all participants succeeded in the authentication tests using Déjà Vu while only about 70% succeeded using passwords and PINS. Findings indicate that Déjà Vu has potential applications, especially where text input is hard (e.g., PDAs or ATMs), or in situations where passwords are infrequently used (e.g., web site passwords).



The Magic Touch

Because it is difficult to compromise biometrics like face, finger, iris, etc., fingerprint recognition via digital live-scan devices is being investigated by researchers in the Security Center. For her master's project, Krithika Venkataramani (below right) looks at the applicability of correlation filters for fingerprint verification. Correlation filters have several attractive features such as shift-invariance, ability to accommodate in-class image variability, and closed form expressions. Venkataramani is also exploring other aspects of the verification process such as tampering prevention and reducing algorithmic complexity.



Department & Faculty Development News

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from the larger Internet.

A prototype of a self-securing disk drive has been developed and will be tested in a variety of industry sectors. Other research includes developing security for wireless broadcasting and remote sensor networks.

Because of the fast rate of innovation in the technology sector, there is a shortage of network security professionals.

In addition to research, the new center will coordinate a 16-month graduate degree program culminating in a master of science in information security technology and management that will be managed by the Information Networking Institute (INI), a designated National Security Agency center of excellence. The program, slated to begin in the fall of 2003, emulates the highly successful master of science in information networking in which students find careers in telecommunications and the wireless and mobile computing sectors.

Carnegie Mellon was identified as a center of excellence in cybersecurity in June 2002. The designation gives Carnegie Mellon the green light to participate in the Federal Cyber Service Scholarships for Service Program. Participating students obtain scholarships from designated schools, such as Carnegie Mellon, in return for working in government-related cybersecurity jobs.

"I am pleased to have been able to secure the necessary federal funds for C3S, and I continue to be an advocate for its mission," said Congressman Mike Doyle, D-18th District. "Homeland security is a top priority in Washington, D.C., right now, and the center will be vitally important to our security efforts because of its concentrated focus on developingtechnologiesforcombating cyberterrorism. These efforts at Carnegie Mellon began even before terrorism and security took center stage, and the opening of the new center comes at the right time now that protecting cyberspace is a crucial element to our security, an element in which Pittsburgh and Carnegie Mellon will lead the way."

C3S Works to Shrink Shortage of Info-Security Workers

Our country will require more than 1.3M new highly skilled information technology workers between 1996 and 2006, estimates the U.S. Department of Commerce.

In order to help fill that great need, the Center for Computer and Communications Security (C3S) is working with historically black colleges and universities and Hispanic-serving institutions to create the next generation of Internet-security experts. Partners in the effort, funded by the National Science Foundation (NSF), include Howard University, Morgan State University and the University of Texas at El Paso.

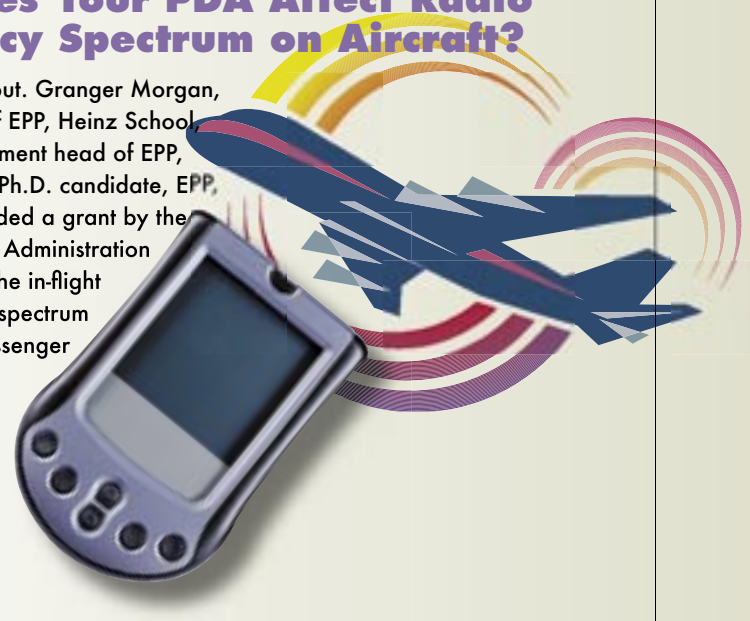
Carnegie Mellon is providing educational resources that will enable Ph.D. computer scientists to teach survey-level courses in information security to advanced undergraduate and first-year graduate students at their universities.

This summer, the initiative began with a four-week program by the ECE Department, the Software Engineering Institute (SEI) and its CERT® Coordination Center, the H. John Heinz III School of Public Policy and Management and the School of Computer Science.

An Image Is Worth A Thousand Words

A medieval castle is used by Greg Ganger, associate professor of ECE and CS, to illustrate the devices needed to protect computer data, even after intruders have hacked through traditional perimeters like firewalls. Ganger says these "self-securing devices" will erect their own security perimeters and defend their own critical resources just the way distinct parts of medieval castles formed distinct protective barriers, such as moats, inner sanctums and strategically placed guard towers.

How Does Your PDA Affect Radio Frequency Spectrum on Aircraft?



We'll soon find out. Granger Morgan, Lord Professor of EPP, Heinz School, and ECE; department head of EPP, and Bill Strauss, Ph.D. candidate, EPP, have been awarded a grant by the Federal Aviation Administration to characterize the in-flight radio frequency spectrum produced by passenger electronics on commercial aircraft.

Successful Practices in Engineering Education Survey

Carnegie Mellon and nine other leading technical schools in Europe and the United States have released a survey that identifies key features of successful engineering education. Entitled "Successful Practices in International Engineering Education," the survey includes interviews with more than 1,000 professors, company managers and graduate engineers with five to 10 years of work experience.

At Carnegie Mellon, the survey revealed that both female enrollment and retention of engineering students, in general, increased because of a more flexible engineering curriculum. The number of women enrolled at Carnegie Mellon for engineering rose to 22 percent in 2002. Ninety percent of the students who entered engineering in 2001 remained in the program, compared with only 70 percent prior to 1990.

Bryant Elected to National Academy of Engineering

Randy Bryant, President's Professor of Computer Science, head of Computer Science Department and professor of ECE, has been elected as a member of the National Academy of Engineering "for contributions to symbolic simulation and logic verification."

Among the highest professional distinctions accorded an engineer, NAE membership honors those who have made "important contributions to engineering theory and practice, including significant contributions to the literature of engineering theory and practice," and those who have demonstrated accomplishment in "the pioneering of new fields of engineering, making major advancements in traditional fields of engineering, or developing/implementing innovative approaches to engineering education."

Randal E. Bryant received the B.S. degree in applied mathematics from the University of Michigan in 1973, and the S.M., E.E. and Ph.D. degrees in electrical engineering and computer science from MIT in 1977, 1978 and 1981, respectively. He was on the faculty at the California Institute of Technology from 1981 to 1984. He has been at Carnegie Mellon since September 1984 and has been head of the Computer Science Department since 1999.

Bryant's research and teaching interests include digital system design and verification, as well as algorithms, computer architecture and computer systems. He and Prof. David O'Hallaron have co-authored the book "Computer Systems: A Programmer's Perspective," published by Prentice-Hall. This book is now used as a textbook for introductory computer systems courses at more than 30 institutions.

Bryant's election to the NAE was preceded by numerous other career honors. He received the 1987 CAD Transactions Best Paper Award, and the 1989 Baker Prize from the IEEE. He was an associate editor for IEEE Transactions on Computer-Aided Design for Integrated Circuits and Systems from 1989 to 1995 and editor-in-chief from 1995 to 1997. He was elected a Fellow of the IEEE in 1990 and the ACM in 1999.

Bryant has received several awards from the Semiconductor Research Corporation: Inventor recognition awards in 1989 and 1990, as well as a technical excellence award (shared with Edmund M. Clarke and Ken McMillan) in 1996.

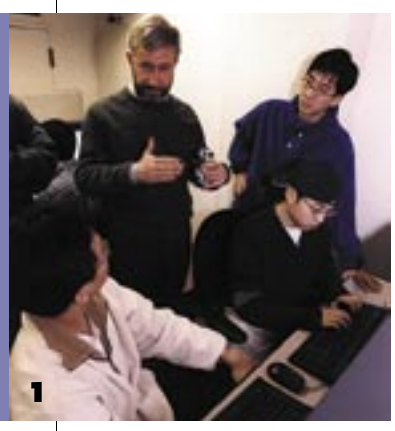
He received the 1997 ACM Kanellakis Theory and Practice Award (shared with Edmund M. Clarke, Ken McMillan and Allen Emerson) for contributing to the development of symbolic model checking.

Department & Faculty Development News

New Labs Provide Real Experience

Carnegie Mellon's Hamburg Hall was originally designed by campus architect Henry Hornbostel to house the U.S. Bureau of Mines. Now nearly a century old, the building's ground floor is being transformed into state-of-the-art computing laboratories for ECE students.

The labs in networking, wireless and security – three major growth fields – are vital for keeping ECE at the educational forefront. Faculty members have been busy writing original curricula geared to the latest advances in each field (including a whole new master's program in security). And much of the new course material calls for experimentation in realistic settings, for as professor Ozan Tonguz notes, "Companies prefer people who have actually played with these things in the lab."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Network Design

"We're not just hacking here," says professor Peter Steenkiste. Unlike most networking courses, which are done via software simulation, the 500-level lab in Network Design and Evaluation gives students the chance to "send real packets, with real applications, over real networks that they build and configure."

Intel has provided 20 PCs plus network routers based on the firm's IXP1200 chipset. The students work in teams and "we give each team a router which they have to extend in some way, such as by adding security or quality-of-service functions," Steenkiste explains. The projects are complex. Each must include changes programmed into both the packet-forwarding side of the router and the control side. The team must give professional-quality status reports and the final presentation must include a live demo: "for instance, if it's a security project, you have to show that [a certain kind of attack or an unwanted app] won't work, just as you said it wouldn't."

Now in its third year, Network Design and Evaluation is a capstone course: the kind in which students build on previous learning with a design project or experiment of their own choice.


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'Major Capabilities' in Wireless

ECE's wireless instructional lab is the product of a global competition. Last year Intel, wishing to sponsor cutting-edge wireless curricula, invited proposals for new courses from 16 universities in the U.S. and abroad. The Carnegie Mellon proposal, drafted by ECE faculty, was one of five chosen for support.

"This is major in every sense," Ozan Tonguz says. "It signals that we are a major player in wireless. It gives us major new educational capabilities and it paves the way for a major [i.e., a specialty degree] in wireless." Intel's $250,000 startup grant is being used to buy test equipment along with PCs and laptops, 802.11a wireless cards and other gear. A high-level faculty team headed by Tonguz and Rohit Negi is now designing experiments and course materials for a launch in fall 2003.

The course will explore current hot topics in wireless, such as software-defined radio, ad hoc networking, multiple input/output (MIMO) wireless systems and ultrawideband. The slate of topics may change from term to term. Experiments will be highly structured and highly "layered." Students will approach each topic from the viewpoint of multiple network layers, studying the interplay of physical components, signal processing, transport, applications and so forth.


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Faculty members believe that seniors and early grad students who are interested in wireless must have a comprehensive, hands-on feel for this emerging world. The new wireless lab – combined with existing strong courses, like the wireless-oriented capstone course in digital communications and signal processing – should give ECE students a head start that few of their peers can match.

Security: New Master's, New Lab

It's a long acronym, but then again, it's a big package. The new MSISTM – Master of Science in Information Security Technology and Management – will be the first master's degree of its kind offered at a top-tier university. Starting in fall 2003, the MSISTM program will teach an integrated approach to digital security for design engineers and code writers, as well as for systems administrator types who want a strong technical grounding in the subject.

MSISTM program director Mike Reiter had the media's attention at the official kick-off for the Center for Computer and Communications Security. Reiter, who is also associate director of C3S, secured $100K in equipment from Intel to create the laboratory that is part of the new degree program.

Security issues range from confidentiality to damage control, and students will consider how to deal with them "at every system level from the individual device to the network," says professor Mike Reiter. "We hope to place a lot of our graduates on development teams at companies like Microsoft, Intel, Hewlett Packard and Cisco."

Reiter (pronounced "writer") was director of Secure Systems Research at Lucent before joining the ECE faculty. His own research interests include capture-resilient devices: he is studying ways to make a networked laptop or smart phone essentially "turn into a brick" if lost or stolen. As program director for MSISTM, he plans to use the new Intel-funded security lab in Hamburg for a variety of lifelike learning experiences.

"We've got a network, with PCs and a server, where we can simulate large-scale attacks like worms and viruses or propagation attacks. And we're going to have war games," Reiter says. The games could range from real-time exercises – "you're the network administrator; here's an attack coming in and you've got to diagnose what's going on and defend against it" – to longer-term assignments in which, for instance, "one team of students would design and build a system, and another team would try to break their design."

The lab is also equipped with PDAs for studying techniques such as device-based access, whereby a digital handheld can be used for a host of security-related functions: keyless entry to doors and vehicles, automated purchasing, and more.

MSISTM will be a 16-month, straight-through program. Core courses in computer security, network security, secure software and cryptology are being designed largely from scratch. "There aren't a lot of good textbooks," Reiter says. "There aren't the kinds of gaming software that we want. So it's going to take some work to fill out the big picture, but we have the expertise here to do it." Reiter notes that C3S, the new federally funded Center for Computer and Communications Security, will make Carnegie Mellon a world leader in security research – and this degree program will be expected to be of equivalent quality.

Photos 1–5 were taken during the final project in Professor Peter Steenkiste's Network Design and Evaluation lab last semester.

ECE Faculty Garner Four out of Five Annual College Awards

The Philip L. Dowd Fellowship Award

Vijayakumar Bhagavatula (a.k.a. Kumar)
Professor of ECE

Established in 1996 by Materials Science & Engineering alumnus Philip Dowd, the Dowd Fellowship is awarded to an engineering faculty member to recognize educational contributions and to encourage the undertaking of an educational project.

An often intimidating, sometimes boring mathematically oriented course in pattern recognition is about to become more palatable for the many juniors, seniors and first-year graduate students who find the course an important part of their education.

Kumar will use the Dowd Award to finish the textbook on Pattern Recognition Theory and Applications he has been drafting and to develop MATLAB-based demonstrations for 18-794: Pattern Recognition Theory.

The book will contain significant biotechnology applications, making it useful for students in the new Biomedical Engineering Department, and will also make the book appealing to a wider audience such as those students interested in robotics, machine learning and biometrics.

Kumar is proposing to develop MATLAB-based pattern recognition demonstration modules in biometric verification, blood cell identification and DNA sequence analysis and integrate them into the textbook.

Kumar has been a major contributor to the research and educational missions of the ECE Department for over two decades. He served from 1994–96 as associate department head during which time he developed curriculum materials for the web, introduced the department's Co-op Program and shepherded the introduction of the Integrated Master's-Bachelor's Program.

He has authored or co-authored seven book chapters and is currently co-authoring a book on Correlation Filters which will be published by Cambridge University Press.

Kumar earned his Ph.D. here and joined our faculty in 1982. He has graduated 20 Ph.D. students and 22 M.S. students.

The George Tallman Ladd Research Award

Radu Marculescu
Assistant Professor of ECE

The Ladd Award is made to a faculty member in the college in the year of reappointment to assistant professor or the year after. It recognizes outstanding research and professional accomplishments and potential.

Marculescu's research is in the area of low power systems and system-level design methodologies, an area that complements the department's strengths in electronic design automation and embedded systems. A theme that cuts across his research is the integration of power and performance metrics and their formal modeling. This work is important in the context of small-embedded devices that have to deliver a level of performance while being severely limited in their ability to consume power.

In only two years Marculescu has established a productive research group of both graduate and undergraduate students. He and his students were one of the first to introduce formal methods for power/performance analysis and apply it to multimedia applications.

Since joining the department two years ago, Marculescu has won a best paper award at the International Design and Test Conference, an NSF CAREER Award, and two nominations for best paper at the IEEE/ACM Design Automation Conference.

Marculescu received his M.S. degree from the Technical University in Romania in 1985 and his Ph.D. from the University of Southern California in 1998. He was on the faculty of the University of Minnesota before joining our department in 2000.

Steven J. Fenves Award for Systems Engineering

from the Institute for Complex Engineered Systems

Sarosh Talukdar
Professor of ECE

"For his pioneering work on the introduction, analysis and use of autonomous asynchronous teams of computer agents (A-teams) to solve complex engineering problems, especially for the distributed control of power systems."

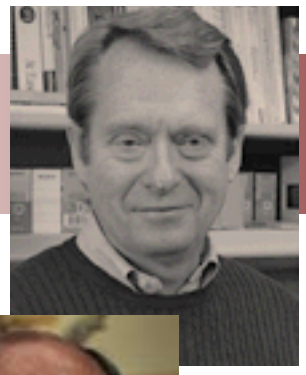
Talukdar was also cited for his many leadership roles in interdisciplinary engineering design: as a director of the original Design Research Center, PI of NSF funding for Engineering Design Research Center (EDRC), founding co-director of the EDRC, director of the EDRC Systems Lab and participant in numerous interdisciplinary research projects over his 29 years at Carnegie Mellon.

After joining our faculty in 1974, Talukdar ran the department's Power Engineering Program for a number of years. He was among the first to apply the Sequential Quadratic Programming algorithm, using it with his students to optimize the operation of electric networks.

Perhaps Talukdar's most significant contribution was his work on A-teams, first proposed in the early 1980s. Wondering why ant colonies do such extraordinary engineering, he proposed solving complex engineering problems by creating teams of automonous asynchronous computer agents – many of which are often very simple agents. This work demonstrated remarkable performance enhancements in the optimization of very large highly nonlinear systems. Now routinely used by many companies, this approach has given Talukdar a well-deserved reputation of being one of the most innovative researchers in that area.

On the educational front, Talukdar's ideas of a decade ago were the genesis of a popular course on design problem formulation that he team teaches with Professor Art Westerberg (Chemical Engineering) and Dr. Eswaran Subrahmanian (ICES). The basic approach of the course is to teach how to convert ill-posed design problems into well-posed problems. Now being taught with an international partner, Delft University, the course represents a very successful experiment in international teaching.

Outstanding Research Award



Awarded for an exceptional research contribution that has enhanced the reputation of the college in a global or national context.

Wojciech Maly,
Whitaker Professor of ECE

Andrzej Strojwas,
Keithley Professor of ECE

For the last two decades, the names of Maly and Strojwas have been recognized around the world for their work in design for manufacturability of integrated circuits.

In the chip manufacturing process, yield is defined as the percentage of working chips on a wafer. For a large semiconductor manufacturer, increasing the yield by just two percentage points can affect the bottom line by as much as $100M. And the ability of a company to increase the yield and predict the yield may be the difference between a company that survives and another one that goes under.

In the early days of chip manufacturing, the area of yield prediction was pretty much a black art. In 1982, Maly and Strojwas pioneered the use of statistical methods that transformed this area of analysis and modeling from black art to science.

In 1990, SEMATECH, a consortium of semiconductor manufacturers and the U.S. government, awarded Maly and Strojwas co-directorship of a research center for Rapid Yield Learning. One of only a few established at top U.S. universities, the goal of these centers was improving the competitiveness of the U.S. semiconductor industry, which was struggling to survive.

Maly and Strojwas have been highly sought after as consultants to industry and have received numerous awards from the Semiconductor Research Corporation and the IEEE. Perhaps the greatest indicator of the success of their research is the company they co-founded along with several former Ph.D. students to commercialize methodology and software developed at Carnegie Mellon. Over the past few years PDF Solutions, Inc. has emerged as an industry leader in the design for manufacturability area.

In nominating Maly and Strojwas, ECE department head Pradeep Khosla noted that in the past 20 years, he has seen only a handful of examples of research that made such a broad-based impact on both academia and industry. "Companies are heavily using the results of their research," wrote Khosla. "It is worth noting that the U.S. still has a major share of the high-end chip manufacturing business!"

Two Faculty Spin-offs Win Entrepreneur Awards

Rutenbar (L) and Carley

Thomas Beckley, the CEO of Neolinear, Inc. received Ernst & Young's 2002 Western PennsylvaniaEntrepreneur of the Year Award in the Emerging Entrepreneur category, and Lawrence Weidman, president of TimeSys Corporation, was also selected as a finalist in the same group.

Neolinear was founded in 1996 by **Rob Rutenbar**, Jatras professor of ECE and CS; director, Center for Circuits, Systems and Software and **Rick Carley**, ST Microelectronics Professor of ECE; director of CHIPS. Neolinear is a Pittsburgh-based technology company specializing in high-speed analog signal-processing circuits.

Rajkumar

Raj Rajkumar, associate professor of ECE and CS; director, Real-Time andMultimediaLaboratory, started TimeSys, which pioneers tools used to build Linux and Java embedded applications.

Koopman's Research Cited in MIT's Technology Review of Emerging Technologies; Elected to IFIP Working Group

The February 2003 issue of the MIT Technology Review names Philip Koopman, associate professor of ECE and CS, as a researcher in the area of mechatronics in an article anticipating "10 Emerging Technologies That Will Change The World." Koopman is noted for his research on fault tolerance in control software. Mechatronics involves the integration of mechanical systems, electronics and software control.

Koopman also has been elected to membership in the International Federation for Information Processing (IFIP) Working Group 10.4 on Dependable Computing and Fault Tolerance. The working group membership comprises 58 senior dependability researchers from 11 countries. Koopman had previously served for two years as the founding chair of the WG 10.4's special interest group on dependability benchmarking.

Kryder Wins Vectors Man of the Year Award

Vectors/Pittsburgh, an organization whose mission is to improve the quality of living for Pittsburgh citizens, has announced its Pittsburgh Men and Women of the Year. The 14 winners were honored at a gala dinner on Feb. 22 at the Westin Convention Center Hotel. Winners in three categories are associated with Carnegie Mellon.

Mark Kryder is the recipient of the David L. Lawrence Award (for promotion of Pittsburgh outside of our region);

Charles E. Thorpe, director of the Robotics Institute, is the recipient of the award for Technology;

Anthony DiGioia (E'72), adjunct professor of Civil and Environmental Engineering and director of the Institute for Computer Assisted Orthopedic Surgery at the Western Pennsylvania Hospital, is the recipient of the award for Science and Medicine.

Kryder is University Professor of ECE and founding director of the Data Storage Systems Center at Carnegie Mellon. He is also senior vice president and director of Research, Seagate Technology. In 1998 Seagate, the world's largest manufacturer of disk drives, recruited Kryder to head up their new research facility that would explore new technologies four to 10 years in the future. Kryder is credited with persuading Seagate to build the $40M facility in Pittsburgh.

Rutenbar is Recipient of Michigan Alumni Society Award

Rob Rutenbar, Jatras Professor of ECE and CS; director, Center for Circuits, Software, and Systems (C2S2) was the recipient of the University of Michigan's Engineering Alumni Society Merit Award in Electrical Engineering. He was recognized "for his outstanding professional achievements and contributions to society."

Rutenbar was presented with the honor at Michigan Engineering's annual Alumni Society Awards Dinner during Homecoming weekend in October.

Rutenbar is an internationally recognized researcher in computer-aided design and synthesis for analog integrated circuits. A key innovator in engineering education and a dedicated teacher, Rutenbar joined Carnegie Mellon in1984 after receiving his M.S.E. and Ph.D. in computer, information and control engineering from the University of Michigan.

The Semiconductor Research Corporation (SRC) honored Rutenbar last year with its Aristotle Award for outstanding achievement in teaching. Carnegie Mellon also recognized him with several awards for excellence in both teaching and research. A past NSF Presidential Young Investigator, he was elected a Fellow of the Institute of Electrical and Electronics Engineers, Inc., (IEEE) in 1998 for his contributions to CAD tools for the synthesis and layout of analog and mixed-signal integrated circuits.

Rutenbar is a former director of Carnegie Mellon's Center for Electronic Design Automation and co-founder of Neolinear, a Pittsburgh-based startup specializing in analog circuit synthesis tools. As the director of the MARCO Focus C2S2, he leads a consortium of 10 universities charged with developing the next generation of semiconductor systems, supported by the U.S. semiconductor industry and Department of Defense.

Left to right: Thomas A. Douglas (chair, Engineering Alumni Society Board of Governors); Stephen W. Director (Robert J. Vlasic Dean of Engineering); Rob Rutenbar; Professor Richard Brown (EE&CS, U. of Michigan). Rutenbar earned an M.S.E. (1979) and Ph.D. (1984) from the University of Michigan.

Department & Faculty Development News

Faces Are Fluid:

The challenge of biometric security

Why are most of us nervous about having our pictures taken? Because we never know what we are going to look like. We know that even subtle changes in expression, pose and lighting can make us appear entirely different: Did you recognize the photo they put on your driver's license?

This phenomenon, called image variability, is a major problem in the field of biometric authentication. There is a vast emerging market for security systems that can identify valid users of a computer network, or help to screen people entering a secure area, by capturing faces, fingerprints or other "biometrics" on the spot and comparing them to records in a database or on a smart card. But it's very difficult to capture any personal feature in exactly the same way every time. Fingerprints are skewed by rotation and tilt of the finger; the patterns in the iris of the eye vary as the pupil dilates and contracts.

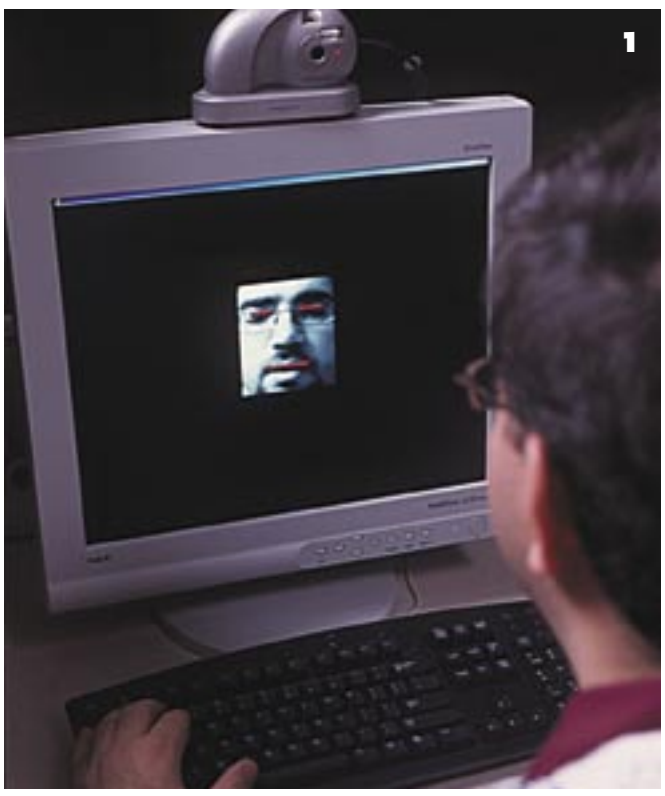
Thus present-day systems are often plagued by slow response times and false alarms. "If you put such systems in place, the security people turn them off, which has happened with some face recognition systems in airports," says professor Vijayakumar Bhagavatula.

The professor – known on campus simply as "Kumar" – is one of several ECE researchers developing better systems. Their work is part of the new Center for Computer and Communications Security (C3S) and it is close to commercialization, with one large firm deeply interested.

From Tanks to Smart Cards

Kumar's approach stems from previous Department of Defense research on automatic target recognition. ATR is likewise a game of detecting patterns amid variations: "Suppose you have to recognize a tank. They put kerosene barrels on the back [to change the profile]; they hide under a tree." The main difference, he says, is that "the military is willing to spend lots of money per device to make it work. For most commercial applications we have to keep the algorithms simple and fast."

To enhance computer security, for example, you might want a PC or laptop with a small built-in camera that registers your face at log-in. The system would then keep checking periodically to be sure it's still you at the keyboard, rather than an intruder – "and I don't want my laptop to use all its power just to recognize me," says Kumar. Smart-card applications could be widespread as well. To use a computer, open a door or access any sort of online service, you might insert your card in a slot while presenting a finger to a print-reader or looking into an iris scanner. The sensor would feed the image to the card, where embedded firmware checks it against your pre-stored reference profile.



How the System Works

In Kumar's system, image variability is factored in from the start. When you are being "enrolled" as a user your face is photographed (or your fingerprints are taken) many times, with the poses, lighting, positions of the fingers and so forth purposely altered. From the resulting set of digital images the system creates a correlation filter – an array of numbers representing persistent patterns and their variations. The filter, not the image set, is what is stored for reference. It becomes your numeric signature. The values from any subsequent image taken by a security device are run through a fast Fourier transform,

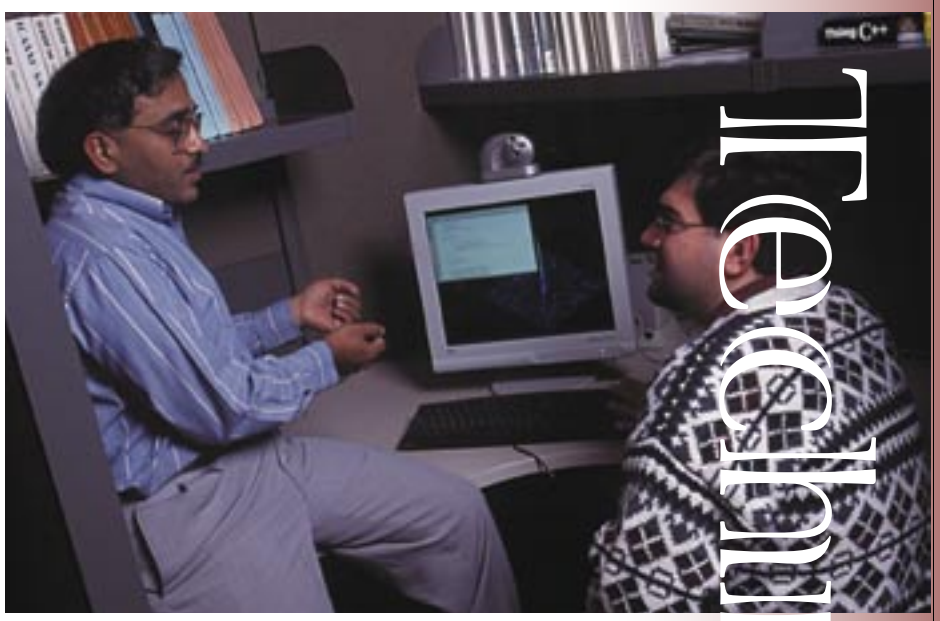
The problem of image variability in facial recognition technology is solved by photographing the user many times. A correlation filter is then created from the multiple images and stored in a computer—a numeric portrait.

In this series of photos, graduate student Marius Savvides demonstrates the system he is developing. (1) He tilts his head and makes various facial expressions while the digital camera mounted on top of the monitor takes multiple images and "enrolls" him as a user. When he wants to access the computer, the software compares his image with data it has stored. The peak in the output (2) shows that his image is found to be a close match and access is granted (3).

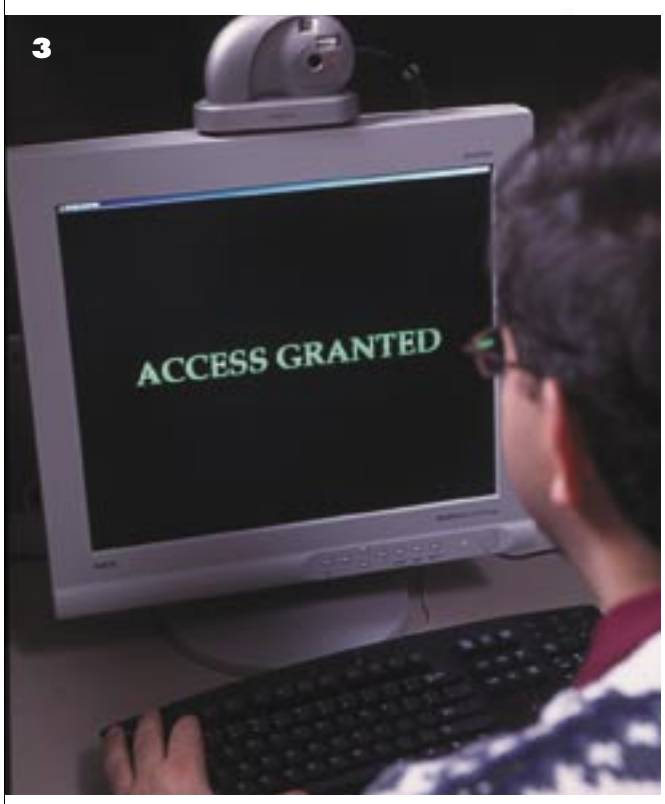
multiplied by the numbers in the filter array, and inverse-transformed. If the image is a close match the output will be distinctly large.

"Several people are doing correlation filters," says Kumar. "Our claim to fame is knowing how to do them well."

For testing, ECE researchers enlisted campus volunteers and built a facial expression database of 75 exposures per person. "We chose three images at random to make a filter for each person. Then we tested these against all 75 images for each of 13 people," Kumar explains. (Varied images of the original subject test the system's ability to avoid false rejections, while images of other people test its ability to screen out impostors.) The "equal error rate" – that is, with the system tuned so that false rejections and false acceptances were equally likely – was an impressively low 0.15 percent. Tests with fingerprints and iris patterns also have been encouraging.



The image recognition research of ECE professor Kumar (above, left) and graduate student Marius Savvides (right) is just one of the challenges being tackled by faculty and staff in the Center for Computer and Communications Security.



Further Possibilities

As Kumar's team refines the correlation filters, others in the Center for Computer and Communications Security are getting good results with a similar system that uses eigenflow algorithms. That system is based on the work of professor Tsuhan Chen, whose "face cam" research has been funded partly by General Motors and may have in-vehicle safety uses, such as monitoring a driver's eye movements to prod him when he looks drowsy.

"Someday we may find a way to combine correlation filters and eigenflows," Kumar says. "Right now, both work well and we are focused on the security applications. For instance, we want to make these systems fast enough to work with video streams. Video cameras are getting dirt cheap, so one idea is to put them everywhere – say, in an airport lobby. Then you can recognize people and track them in a crowd."

Applications like this are, of course, becoming the subject of legal and ethical debate. Would the security benefits outweigh the privacy concerns? But the mere fact that the debate is occurring is a sign of one sure thing: the technology is coming along.

New Disk Research May 'Fingerprint' Computers

While the problem in biometrics is to recognize people, another research project in ECE tackles a related question: do individual computers leave fingerprints? The U.S. government's Technology Support Working Group, an inter-agency organization, would like to know if data on a floppy disk can be traced to the machine that recorded it.

Faculty members Vijayakumar Bhagavatula and Jim Bain — an ECE researcher with a Ph.D. in materials science — are inspecting the micro-surfaces of floppies to find out. Tiny variations in the disk drive motor and the write head, as well as emissions from the motherboard, can leave faint analog signatures behind the bits.

"It could be useful for an investigator or prosecutor just to narrow it down to something like 'This is a Seagate drive,'" says Kumar. "And we can do it. We can probably narrow it down to a model number. Can we narrow it down to serial number? The jury is out on that."

If research with floppies goes well, the next challenge would be extending the new science of disk forensics to CDs.

DIRECTING DIABETES DIGITALLY:
STUDENTS TEAM ENGINEERING AND MEDICINE

For many undergraduates, when finals are over, their textbooks close, and summer plans take them far from campus. Not so for ECE students Amy Smith, Katrin Ambroladze and Alan Wang. They continued working on their course project, improving the design of the Diabetes Management Assistant (DiMA), a Handspring™ personal digital assistant (PDA) that helps manage the disease discreetly and on-the-go, in a small carrying pouch.

Fifth-year senior Amy Smith (center) with graduate student Alan Wang (left) and junior Katrin Ambroladze (right) show an earlier version of the DiMA in its convenient carrying case. The case, which was designed by Mechanical Engineering senior Jason Fung, who worked on the DiMA project last academic year, has slots for accessories such as pedometer, glucose meter and insulin.

Under the guidance of two physicians and a nurse trainer from a local hospital, the classmates continued their research from the Rapid Prototyping of Computer Systems course they took during the spring 2002 semester. The project-oriented course is taught by Dan Siewiorek, Buhl University Professor of ECE and CS; director of the Human-Computer Interaction Institute and Asim Smailagic, senior research scientist, Institute for Complex Engineered System (ICES).

"[In planning the course] we did some brainstorming and decided we wanted to start a project that teamed engineering and medicine, focused on patient-centered care," Siewiorek said. Diabetes, with its broad scope of problems and treatment options, became the subject.

During the spring semester, 11 pupils from ECE, Computer Science, Industrial Design and Human-Computer Interaction created a new interface for the Handspring Visor, a popular hand-held organizer. With it, patients can run all of the applications they already operate for their job or personal use – including a calendar, games, phone book and expense reports – and customize the device to store and analyze information about their illness. Through a connector, they can add modules for a glucose meter for blood sugar readings, a pedometer to record each step of their exercise and a digital camera that snaps pictures of their meals.

"If the patient doesn't have time to write down what they ate, they can take a quick picture," explained Smith, adding that a photo could better communicate the size of their portions to medical staff than a verbal description.

The program includes a reminder system to keep track of appointments, when to take medication and a "tip of the day," such as, "Yogurt and granola bars are quick sources of energy."

Starting in the spring with a simplified date book they made themselves, over the summer the group adapted Handspring's Springboard™ module with Therasense's FreeStyle Tracker System™, which has a direct interface to the PDA. Each FreeStyle Tracker uses Handspring's familiar drop-down menus, icons and navigation, lessening the learning curve. The tool provides statistical analysis of data with charts and graphs, an optional entry for insulin, a 2,500-item food list with serving sizes and carbohydrate values, and a section for comments. TheraSense also manufactures FreeStyle™, the glucose monitoring system that plugs into the DiMA.

Siewiorek said their design goal was to integrate two triangles: managing the disease (medication, food and exercise) and communication across the treatment team.

"The data formats are designed to make each team member's access most effective for them – details for the patient, trends and summaries for the doctors, and focused details for the nurse trainer," he elaborated.

The students adapted the system to the patients' needs through the product development cycle, from the idea's conception to a working prototype. First, the nurse trainer evaluated the DiMA before the patients, to see the product and discern how it would best

The PDA currently being used for the DiMA project measures only about 3 in. x 5 in.

The DiMA with all accessories fits into a case measuring about 6 in. x 7 in. x 2 in.

help them. After incorporating her initial feedback, the students conducted two trials with two patients per trial, ensuring the hardware and software worked together, while matching the patients' preferences and making the system more robust. Each diabetic used the DiMA for a week, ranking it, and providing thoughts for future improvements. When they returned their questionnaires, the students learned more about the patients' interactions with DiMA via informal conversations.

Although Smith and Wang are adding new features to the DiMA, it won't be ready for the market until they incorporate functionality that Therasense hasn't considered and do more user-testing. Meanwhile, the two are enhancing the DiMA web site, an additional means of communication that allows patients to interact with their doctors and ask questions without an office appointment or email.

"In the future, we plan to be able to synchronize the patient's logbook information on the PDA with an online version of the logbook, so that the doctor will be up-to-date on the patient's status," Smith reported, continuing, "It's been really rewarding when the doctors tell us that they like the work that we've done and when patients ask, 'can I buy this?'"

The inventors showcased the product in October at the ICES open house and took it to Seattle for the International Symposium on Wearable Computers (ISWC). More funding sources are being pursued, and more extensive testing is on tap for the DiMA to justify broader research. New students will pick up the project in January.

By Jessica Kreger

Patients with diabetes either cannot produce or properly use insulin, resulting in abnormally high levels of glucose in the blood. The American Diabetes Association discloses that approximately 17 million people in the U.S., or 6.2% of the population, have diabetes. 800,000 new cases are diagnosed annually, ranking diabetes one of the most expensive health problems in America; medical treatment and loss of productivity totals $98 billion annually, according to the final project report of the students working on the DiMA.

With the help of these students and researchers, diabetics may soon no longer have to worry about writing down every item they eat, forgetting to take their medicine, making errors in insulin calculations or losing important records in the mail. By digitizing data that can be mailed, downloaded, saved, printed and shared on other computers, the all-in-one DiMA will generate less paperwork, reduce the chance of information getting lost and save money.

Zamora Connects to Industry Through an SRC Graduate Fellowship

ECE graduate student Nicholas Zamora's work is all about connections – electrical and otherwise. Whether connecting industry to academia through his Semiconductor Research Corporation (SRC) Graduate Fellowship, linking networks of embedded systems, or joining with his classmates in a course project, Zamora learns by reaching out to those around him.

"Once I started working with him, I was impressed by his overall potential toward graduate studies and his abilities to work in a research team," said Radu Marculescu, assistant professor of ECE, Zamora's faculty advisor.

Following a national competition, Zamora received a fellowship this fall for outstanding achievement in microelectronics. His award includes tuition and fees, a stipend of $1,800/month, an annual gift of $2,000 to the department and travel expenses to the Graduate Fellowship Program (GFP) Annual Conference in Dallas, Texas. His two SRC industry advisors are George Cai of Intel Corporation and John Darringer from the T.J. Watson Research Center, IBM Corporation.

"It was clear when Nick first visited us that his technical breadth and communication skills would allow him to work across a wide variety of semiconductor EDA problems," reported Rob Rutenbar, Jatras Professor of ECE and CS; director, Center for Circuits, Systems and Software.

Zamora's eyes electrify with excitement as he describes a project examining code migration for embedded systems with fellow graduate student Phillip Stanley-Marbell. He beams while explaining that communication networks can be arranged in the context of acoustic beam forming, using sensors that "talk" to a master node and filter information about position based on sound. The "smart" system can detect when a sensor is low on power and use its remaining fuel to send the code to other sensors, preventing information from being lost or the system from crashing.

Although our great rankings, reputation and research opportunities appealed to Zamora, it was the personal connection that most attracted him to ECE.

"I wanted a lot more one-on-one interaction between myself and whomever I'd be interacting with in my research group. So, Radu is a great fit, because he was able to provide that personal contact," confirmed Zamora.

Enrolling in the fall of 2001, Zamora earned his master's in the spring of 2003 and expects to earn his Ph.D. in 2006. One of his most rewarding student experiences was presenting a poster in New Orleans at the GSRC workshop held in conjunction with the 39th Design Automation Conference (DAC) on exploiting symmetry through SAN (stochastic automata networks) analysis. The Treasurer and Sports Liaison for ECE's Engineering Graduate Organization (EGO), he rose to fame as the host of the 2002 and 2003 Winter Party entertainment shows with Tim Warneck and the Level G-Orchestra.

A graduate of the Electrical Engineering and Computer Science Department at U.C. Berkeley, he isn't a stranger to uniting corporations and classrooms; there, as the Eta Kappa Nu (HKN) president, he started a technology recruitment fair. Now in its third year, called "HooKiNg it up" after the technology and the honor society, the program drew 50 to 100 companies, raising funds for the department. Also a teaching assistant for an undergraduate signals and systems class at Berkeley, he took a venture design course and aspires to start his own technical company or join a start-up.

Photo by Ken Andreyo

Other ECE SRC Graduate Fellows, the dates their fellowships began, and their advisors include: Michelle Kruvczuk (2001), advised by L. Richard Carley, ST Microelectronics Professor of ECE and director of CHIPS; Benjamin Levine (2001), advised by Herman H. Schmit, associate professor of ECE; and Shipra Panda (1996), advised by Randal Bryant, President's Professor and department head of Computer Science and professor of ECE.

Aiming to improve educational opportunities and supply the semiconductor industry with educated employees, the SRC sponsors 54 doctoral fellowships, including 13 company-named fellowships and 3 research fellowships, and 14 master's scholarships. Since 1986, 186 Fellows have completed or are currently participating in the GFP.

The SRC is a university research management consortium based in Research Triangle Park, N.C., that sponsors research at universities worldwide; since its inception in 1982 it has funded more than $500 million in long-term semiconductor research contracts, according to the SRC.

Class Projects Students

Warner Hall Collapses in Earthquake: Seven People Trapped Inside

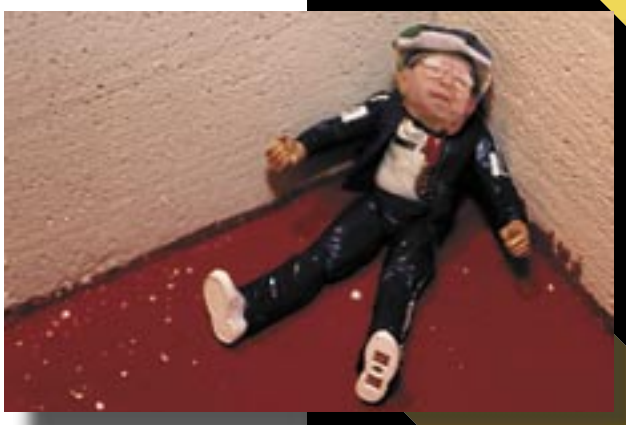
President Jared Cohon, MechE Department Head Adnan Akay and several other faculty are trapped in a collapsed Warner Hall.

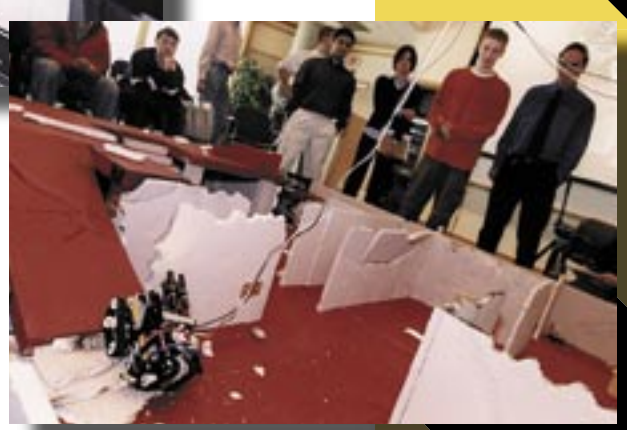
The first hours after the collapse are critical. Robots are sent in to search for victims. The robots' cameras send back images that enable rescue teams to guide the robots through the rubble piles to identify people in need of help.

In this instance, the scenario is a class project. Teams cheer each other on. They groan and then laugh when a robot runs over a 'victim.'

But, unfortunately, they also know that in the wake of the World Trade Center disaster and the Oklahoma City bombing, this kind of scenario may be all too real.

A team of instructors, led by Howie Choset, professor of Mechanical Engineering and Robotics, teaches 34–354 General Robotics each year. Much as they would in the real world, students work in interdisciplinary teams with an electrical engineer, a mechanical engineer and a computer scientist. Labs engage students in designing and building robots for such applications as urban search and rescue, Mars landings and fighting off those pesky Martians if they decide we're not welcome there.





PhotosbyKenAndreyo

Editor
Camela Miller

Writers
Mike Vargo, Features Writer
Jessica Kreger
Camela Miller

Photography
Ken Andreyo, Communications Design Group
Larry Rippel

Design
The Communications Design Group
Joseph P. Cancilla Design

Production
Rosemarie J. Szedula

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