Parallel computing institute

continued from front page

Center and the Institute for Advanced Computation and Applications Technology. Illinois is also an important participant in projects such as the DOE's Exascale Software Stack and the DARPA Ubiquitous High-Performance Computing program.

Today's programmers often lack the skills necessary to write code for many-core systems. One of PCI's early thrusts will be research and education that make it easier to program on parallel platforms.

PCI will also focus on extreme scale, high-end computing for compute-heavy applications, such as those that will utilize resources like Blue Waters, which will boast a peak performance of 10 quadrillion calculations per second when it goes online. Research areas include building compilers for single-chip parallelism, designing new architectures for massively parallel systems and creating new algorithms to solve complex problems.

"The Parallel Computing Institute provides the strong base of infrastructure and expertise needed to transform the way we design and interact with massively parallel computing systems," said Ilesanmi Adesida, dean of Illinois' College of Engineering.

The institute intends to capitalize on growing industry interest in parallelism, says Wen-mei Hwu, PCI Chief Scientist, CSL Researcher and AMD-Jerry Sanders Chair of Electrical and Computer Engineering.

"Many commercial developers and software vendors are beginning to tackle parallel programming issues," Hwu said. "We want to be the place where they come for help."

"In the tradition of CSL initiatives, the Parallel Computing Institute will look at how parallel computing innovations can be created for platforms ranging from embedded devices to the largest supercomputers, and for a diverse set of applications," said William H. Sanders, director of the Coordinated Science Laboratory. "With a comprehensive, multi-faceted approach, we will develop software and hardware solutions needed to advance technology for the future."

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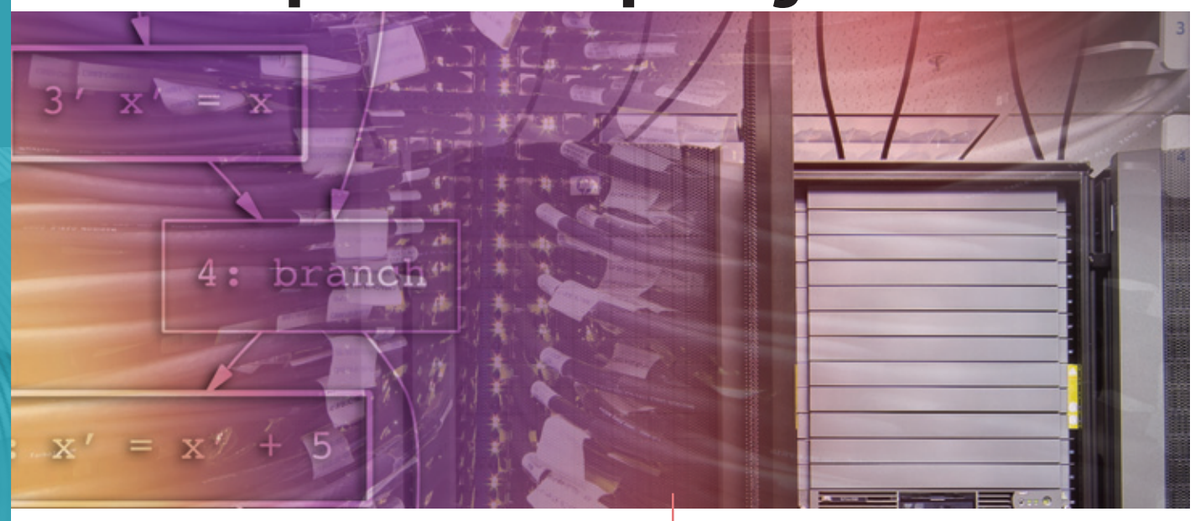
NEWSLETTER OF THE COORDINATED SCIENCE LABORATORY VOL. TWO, NO. 2 | 2011

CSL to accelerate performance with new parallel computing institute



The Coordinated Science Laboratory has launched a new interdisciplinary institute that will provide the resources to enable breakthroughs in parallel computing.

The Parallel Computing Institute will arm researchers and educators with the support they need to address major computational challenges in science, engineering, health and business, among other areas. PCI will serve as an incubator for parallel initiatives by:

- expanding access to resources and infrastructure,
- teaching critical skills to graduate and undergraduate students,
- creating more opportunities for funding and establishing key external partnerships,
- sharing center creation expertise with research teams who want to do high-impact work in parallel computing.

Parallel computing provides the most powerful and efficient infrastructure for computation-heavy applications. It is a key element of modern computing, ranging from multi-core processors in commodity electronics to supercomputers with nearly a million processing elements.

"Illinois is already a leader in parallel computing, with tremendous depth and breadth in this area," said PCI Director Bill Gropp, CSL researcher and the Paul and Cynthia Saylor Professor of Computer Science. "What PCI aims to do is to provide researchers in different disciplines the opportunity to collaborate in an innovative, resource-rich environment. By approaching problems in a strategic, interdisciplinary way, we can develop solutions with greater impact."

The center will leverage Illinois' strength in parallel computing. Illinois is already the home to the NSF Blue Waters Petascale Computer, the CUDA Center of Excellence, the Intel/Microsoft Universal Parallel Computing Research

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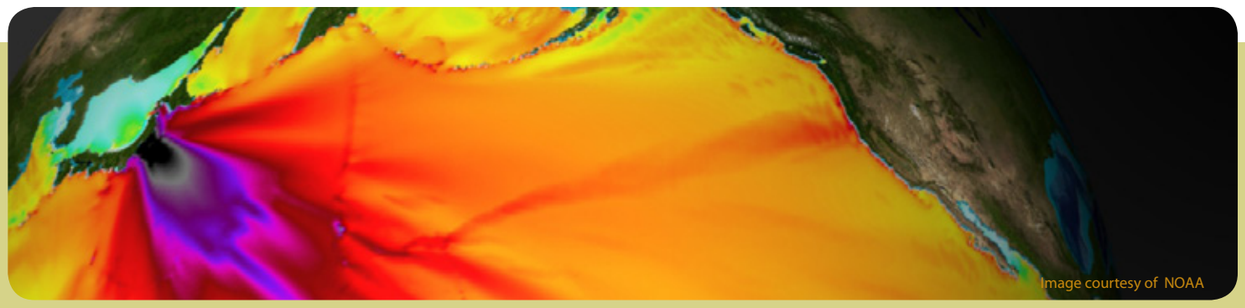
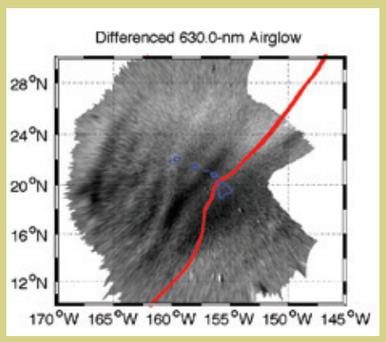


Image courtesy of NOAA

Illinois researchers capture images of first tsunami-related airglow signature

Researchers at the University of Illinois have become the first to record an airglow signature in the upper atmosphere produced by a tsunami. The activity was observed using a camera system based in Maui, Hawaii.

The signature, caused by the March 11 earthquake that devastated Japan, was observed in an airglow layer 250 kilometers above the earth's surface. It preceded the tsunami by one hour, suggesting that the technology could be used as an early-warning system in the future.



The observation confirms a theory developed in the 1970s that the signature of tsunamis could be observed in the upper atmosphere, specifically the ionosphere. But until now, it had only been demonstrated using radio signals broadcast by satellites.

"Imaging the response using the airglow is much more difficult because the window of opportunity for making the observations is so narrow, and had never been achieved before," said Jonathan Makela, an Illinois professor of electrical and computer engineering and researcher in the Coordinated Science Laboratory. "Our camera happened to be in the right place at the right time."

Tsunamis can generate appreciable wave amplitudes in the upper atmosphere – in this case, the airglow layer. As a tsunami moves across the ocean, it produces atmospheric gravity waves forced by centimeter-level surface undulations. The amplitude of the waves can reach several kilometers where the neutral atmosphere coexists with the plasma in the ionosphere, causing perturbations that can be imaged.

On the night of the tsunami, conditions above Hawaii for viewing the airglow signature were optimal. It was approaching dawn (nearly 2 am local time) with no sun, moon or clouds obstructing the view of the night sky.

Along with graduate student Thomas Gehrels, Makela analyzed the images and was able to isolate specific wave periods and orientations. In collaboration with researchers at the Institut de Physique du Globe de Paris, CEA-DAM-DIF in France, Instituto Nacional de Pesquisais Espaciais (INPE) in Brazil, Cornell University in Ithaca, NY, and NOVELTIS in France, the researchers found that the wave properties matched those in the ocean-level tsunami measurements, confirming that the pattern originated from the tsunami. The team also cross-checked their data against theoretical models and measurements made using GPS receivers.

Makela believes that camera systems could be a significant aid in creating an early warning system for tsunamis. Currently, scientists rely on ocean-based buoys and models to track and predict the path of a tsunami. Previous upper atmospheric measurements of the tsunami signature relied on GPS measurements, which are limited by the number of data points that can be obtained, making it difficult to create an image. It would take more than 1,000 GPS receivers to capture comparable data to that of one camera system. In addition, some areas, such as Hawaii, don't have enough landmass to accumulate the number of GPS units it would take to image horizon to horizon.

In contrast, one camera can image the entire sky. However, the sun, moon and clouds can limit the utility of camera measurements from the ground. By flying a camera system on a geo-stationary satellite in space, scientists would be able to avoid these limitations while simultaneously imaging a much larger region of the earth.

To create a reliable system, Makela says that scientists would have to develop algorithms that could analyze and filter data in real-time. And the best solution would also include a network of ground-based cameras and GPS receivers working with the satellite-based system to combine the individual strengths of each measurement technique.

"This is a reminder of how interconnected our environment is," Makela said. "This technique provides a powerful new tool to study the coupling of the ocean and atmosphere and how tsunamis propagate across the open ocean."

From the Director

In recent years, parallel computing has opened up possibilities previously unimagined – and we've only scratched the surface.

Over the next decades, parallel computing will provide the backbone for breakthroughs in critical areas such as medicine (reading MRIs in real time), bioengineering (DNA sequencing) and astronomy (understanding how the cosmos formed), among others. It will also transform the way we work and play by enabling interactive, immersive virtual realities.

With its strong roots in high-performance computing, the University of Illinois is well poised to lead this technology revolution. That's why the Coordinated Science Laboratory, with the participation of Illinois faculty from many academic departments, has launched the Parallel Computing Institute, an interdisciplinary center that will provide support to researchers who are tackling these complex problems.

Why is CSL leading this endeavor? From our historical contributions to our present-day strengths, we have the experience and tools necessary to help guide the effort.

CSL researchers have been involved in high-performance computing since the days of the ILLIAC machines. For example, CSL research engineer W.J. Bouknight helped develop the ILLIAC IV array-based supercomputer, one of the earliest massively parallel systems, in the 1960s and '70s.

Since then, CSL researchers have:

- **Invented cube-connected cycles, an architecture for massively parallel processing.**
- **Built the first multiprocessor using microprocessors, AMP-1.**
- **Developed the Illinois Protocol, used today by most cache coherent multi-core processors.**
- **Invented optimal pipeline scheduling with delay insertions, which led to the development of software pipelining in compilers.**
- **Created Superblocks, a compiler innovation that extended the applicability of software pipelining from Fortran loops to general C programs, leading to the HP-Intel Itanium platform that now plays an important role in the server market.**
- **Contributed to the development of the Cedar machine and helped pioneer parallelizing FORTRAN Compilers.**
- **Used predicated or guarded instructions to improve instruction-level parallelism.**
- **Created influential tools such the IMPACT compiler, which has contributed to the foundation of compilers for Intel's line of IA-64 microchips as well as VLIW processors, used in many DSP and GPU chips today.**

More recently, CSL has been involved in the development of the National Center for Supercomputing Applications' Blue Waters, a petascale computer; the CUDA Center for Excellence, which pursues advances in many-core computing research; the EcoG Supercomputer that earned Illinois the #3 spot on the November 2010 Green 500 most energy-efficient computers in the world; and the Institute for Advanced Computing Applications and Technologies, which transfers high performance computing to the larger research community.

CSL researchers – who hail from computer science, electrical and computer engineering and many other disciplines – continue to tackle hardware, software and middleware problems related to parallel computing in a strategic, multidisciplinary way.

Our goal is to enable researchers to connect with resources and to bridge the outstanding efforts currently underway at Illinois. Together with our partners, we aim to harness the power of computing and enhance life for future generations.

William H. Sanders

Managing Editor: Kim Gudeman
Contributing Writers: April Dahlquist, CSL; Rick Kubetz, College of Engineering; Jennifer La Montagne, Computer Science; and Tom Moone, Electrical & Computer Engineering.

Comments and suggestions are welcome. Please send them to kgudeman@illinois.edu.

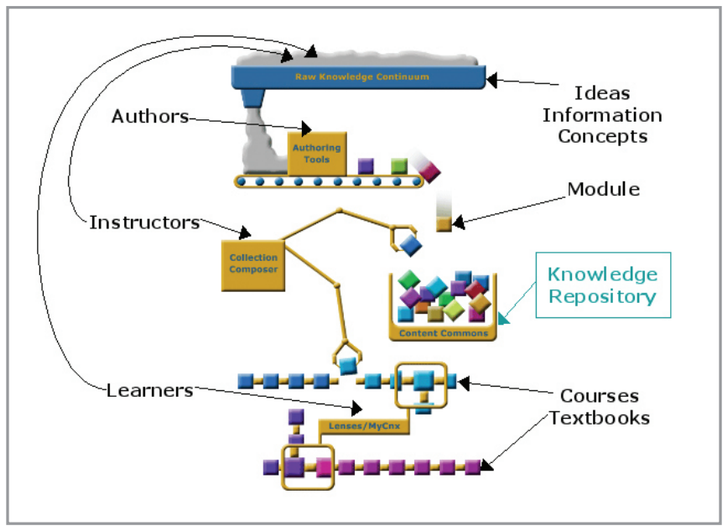
Baraniuk's platform connects educators, custom textbooks

By April Dahlquist

As a graduate student in the Coordinated Science Laboratory, Richard Baraniuk made the connection between research and education.

After receiving his PhD in electrical and computer engineering from Illinois in '92, Baraniuk continued his educational pursuits at Rice University in Texas, where he founded Connexions, or CNX.org. Connexions is an educational platform where anyone can submit materials, and professors can then select the information they want to build their perfect textbook, customized for each class.

"This takes the pressure off students having to buy increasingly expensive textbooks, and makes the textbooks even better," Baraniuk said. "Instructors can customize the book so it is just right for everyone at Illinois… or wherever."



After the instructor builds the textbook from the information available on the site, students can either electronically use the textbook for free or buy it at an extremely low cost. For example, a conventional publisher charges $129 for a 600-page statistics textbook, while a comparable version from Connexions would cost $29.

"I think it is a part of the future of education," said CSL researcher Doug Jones, Baraniuk's previous advisor and professor of electrical and computer engineering.

These types of textbooks are especially advantageous for subjects where new research rapidly changes the field of study. Instead of using an outdated textbook, professors can build a textbook with the most up-to-date information.

In fact, a similar situation inspired Baraniuk to create Connexions in 1999. At Rice, he became frustrated by a lack of textbooks appropriate for his undergraduate students. In the last couple of years, the website has really taken off, he says. He attributes this recent increase in use to the recession and the rising costs of textbooks.

The site is not-for-profit and is sponsored by the Hewlett Foundation, the Maxfield Foundation, the National Science Foundation and other contributors. Now that Connexions has achieved the initial hurdle of lowering operating costs to zero, the next goal is to not only have textbooks customized for each classroom, but for each student. Baraniuk wants to create a textbook that "learns about you, while you are learning from it." Meaning, the textbook figures out how each student learns best, knows the student's motivations and interests and can give the student information that best suits him or her.

Baraniuk's research at Illinois helped set the foundation for Connexions. While in the signal processing group under Jones, he worked on a time-frequency analysis project that represented signals and data like a musical score.

"[My time at Illinois] really provided me with a great, solid foundation for what I've done with my career," Baraniuk said.

In addition, while Baraniuk was at Illinois he was involved with the computer-based education research lab under former ECE professor Don Bitzer.

"I think it helped spark an interest in novel ways of thinking of educational technology," Jones said.

Baraniuk still has many Illinois ties, as he is currently working on a five year Department of Defense grant with CSL researchers Tom Huang, Mark Hasegawa-Johnson and Tamer Başar. They are researching opportunistic sensing.

Baraniuk, who is still at Rice, looks at unique ways to represent and process massive data sets when not consumed by his Connexions "hobby."

Baraniuk is extremely grateful for the opportunity he had to explore signal processing in great depths at the CSL.

"CSL in particular and U of I in general is such a diverse place and there are so many opportunities for learning about ideas outside your exact PhD topic. You can become a really well versed person in a whole bunch of different ideas," Baraniuk said. "I would have never done things like Connexions if I had not learned to look beyond my field of study."

Error-free hardware? GoldMine guarantees it

By Kim Gudeman

CSL researcher Shobha Vasudevan has developed a tool that makes it easier to detect hardware errors during the verification stage of the semiconductor design cycle.

GoldMine is an automatic assertion-generation tool that integrates formal verification and data mining to guarantee reliable, fault-free hardware. The methodology was presented at the DATE 2010 and 2011 conferences and, more recently, at this spring's DVCon 2011 conference, where EDA journalists selected it as one of the most interesting tools.

"When you don't have enough coverage in your design validation, you could be making hardware that has flaws in it," said Vasudevan, an assistant professor of electrical and computer engineering. "It could cost millions of dollars if you're a semiconductor company and have to recall your hardware. If you're an airline or car company and your hardware fails, it could cost lives."

GoldMine is a one-of-a-kind tool that uses both formal verification and data mining to generate assertions. Formal verification provides content for the design that helps guide the data mining, which infers patterns from simulation data.

It proffers a solution to the troublesome coverage closure problem faced by designers and verification engineers, who often don't know how many tests to run to ensure that a design is bug-free. It can be used for formal verification, simulation-based verification or even post-silicon verification.

"When the formal verification says that something is false, it gives us a reason why it's false," said Vasudevan, who received a CAREER Award for GoldMine in 2010. "We plug these counterexamples back into GoldMine, which adjusts for the new information. As we do this iteratively, we reach a point where there's no more counterexamples and we have reached a complete test set."

Vasudevan and her student David Sheridan initially developed GoldMine in 2009, when they used the Rigel multicore architecture developed by CSL researcher Sanjay Patel as a test bed for the tool. Subsequently, Vasudevan's team, which consists of four graduate students, managed to scale GoldMine to the open source UltraSparc processor.

Several companies are already using the technology, for which the University is currently seeking licensing.

In addition to verification, GoldMine could be used for other phases of the design cycle, such as reliability and fault detection. That would open up applications in security, including monitoring and detecting hardware trojans.

For Vasudevan's team, the next step is to apply GoldMine's techniques to software. Vasudevan believes that by using data mining to create likely assertions in software systems, GoldMine can give developers a high level of confidence in their products.

"The idea of using data mining with formal tools is something that hasn't been explored before," she said. "As a result, the net effect is very powerful, evidenced by the interest the tool has received from companies."

3D PRINTING METHOD ADVANCES ELECTRICALLY SMALL ANTENNA DESIGN

While most electronic components benefit from decreased size, antennas—whether in a cell phone or on an aircraft—suffer limitations in gain, efficiency, system range, and bandwidth when their size is reduced below a quarter-wavelength.

CSL researcher Jennifer Truman Bernhard, a professor of electrical and computer engineering, has proposed a way to overcome these limitations through omnidirectional printing of metallic nanoparticle inks. She is collaborating on the research with Jennifer A. Lewis, the Hans Thurnauer Professor of Materials Science and Engineering.

The research findings and fabrication methods developed by Bernhard, Lewis, and their colleagues are featured in the cover article, "Illinois Calling" of the March 18 issue of Advanced Materials ("Conformal Printing of Electrically Small Antennas on Three-Dimensional Surfaces").

According to Bernhard, these antennas are electrically small relative to a wavelength (typically a twelfth of a wavelength or less) and exhibit performance metrics that are an order of magnitude better than those realized by monopole antenna designs. Conformal printing allows the antenna's meander lines to be printed on the outside or inside of hemispherical substrates, adding to its flexibility.

The design can be rapidly adapted to new specifications, including other operating frequencies, device sizes, or encapsulated designs that offer enhanced mechanical robustness.

CSL researchers receive CAREER Awards

By Jenny Applequist, ITI, and April Dahlquist, CSL

Matthew Caesar, Negar Kiyavash and **Sayan Mitra** all won NSF CAREER awards this spring.

Caesar (Computer Science) won for his proposal to design the first interactive debugging system for modern networked systems. Kiyavash (Industrial & Enterprise Systems Engineering) won for her work on the impact of timing in network security. Mitra (Electrical and Computer Engineering) was awarded the grant for his research on algorithms and verification for reliable distributed cyber-physical systems.

The CAREER award, given to the most promising young researchers, provides funding for scientists to continue and expand their work.

Gropp named SIAM Fellow

Jennifer La Montagne, Computer Science

William Gropp, director of CSL's new Parallel Computing Institute, was named a Fellow of the Society for Industrial and Applied Mathematics (SIAM) this spring.

Gropp's development of algorithms and software for high performance computing, specifically the creation of the MPI, has earned him this title. MPI is the standard interprocessor communication interface for large-scale parallel computers.

Gunsalus named AAAS delegate

By April Dahlquist, CSL

CSL researcher **C.K. (Tina) Gunsalus** was elected to the American Association for the Advancement of Science (AAAS).

Gunsalus, who has been active in the organization for many years, will serve a three-year term as a delegate to the Societal Impacts of Science and Engineering Council, where she will be responsible for electing fellows and members to AAAS' board of directors.

Gunsalus is a professor emerita of business and director of CSL's National Center for Professional & Research Ethics (nationalethicscenter.org).

"AAAS is a very important organization and I'm so pleased to have a chance to work with others to further its worthy mission," Gunsalus said.

Yim scores gold

By April Dahlquist, CSL

CSL PhD student **Keun Soo Yim** (Computer Science) received the gold award in the Samsung Human-Tech Thesis Prize competition.

Under advisor Ravi Iyer (ECE), Yim designed software and hardware techniques that can detect and tolerate hardware faults in high performance machines, including Graphic Processing Units. Yim's new design can maximize fault detection with little overhead.

Rutenbar wins IEEE best paper award

By Jennifer La Montagne, Computer Science

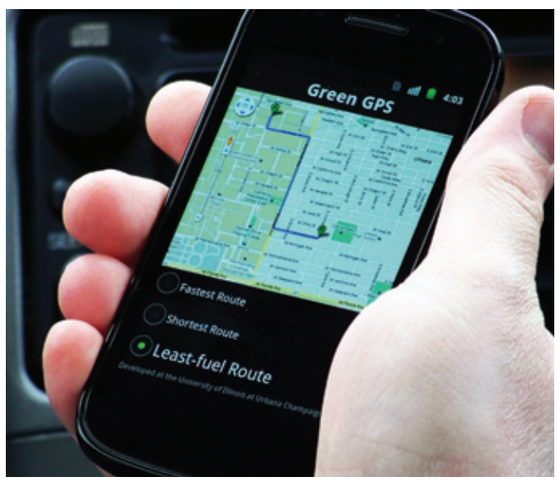
Rob Rutenbar and his former student, Dr. Amith Singhee (IBM) are the winners of the 2011 IEEE Transactions on Computer-Aided Design Donald O. Pederson Best Paper Award for their paper "Statistical Blockade: Very Fast Statistical Simulation and Modeling of Rare Circuit Events and Its Application to Memory Design," published originally in August 2009. The paper presented a radically new strategy for so-called "rare event" failure statistics in memory designs.

"Green GPS" calculates most fuel-efficient route

A new software interface reduces energy consumption in transportation systems.

Green GPS, developed by computer scientists at the University of Illinois at Urbana-Champaign, works like general GPS navigation, except that in addition to calculating the shortest and fastest routes, it also projects the most fuel-efficient route.

"Currently at least 30 percent of total energy in the United States is spent on cars," said Principal Investigator Tarek Abdelzaher, associate professor of computer science and researcher in the Coordinated Science Laboratory. "By saving even 5 percent of that cost, we can save the same amount of total energy spent on the nation's entire information technology infrastructure."



The technology runs on cell phones, which links to a car's computer using an inexpensive, off-the-shelf wireless adapter that works in all cars manufactured since 1996. The car's onboard diagnostics system uploads information about engine performance and fuel efficiency to the phone, which uses the data to compute the greenest route.

A grant through the National Science Foundation to Abdelzaher and Robin Kravets, also a member of Illinois' computer science faculty, is funding a large-scale deployment of the service via the University of Illinois' car fleet. The Office of Naval Research is funding research related to the technology's networking component. Researchers, including graduate student Hossein Ahmadi, also are collaborating with IBM through its "Smarter Planet" initiative.

Pete Varney, who oversees some of the approximately 500 vehicles used by the Urbana-Champaign campus, hopes research will help maximize fuel efficiency for the fleet. The units will be installed on up to 200 vehicles, including full-size vans that could be carrying 1,000 pounds or more in tools and equipment.

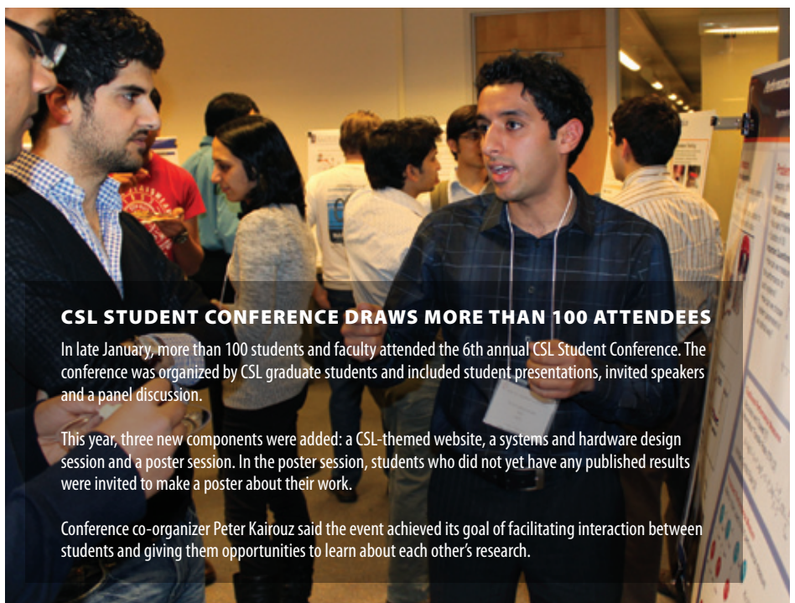
"The less money we can spend on fuel, the more money we can direct toward maintaining other things on campus," said Varney, director of Transportation & Automotive Services.

In addition, researchers are developing a social network of drivers who can share information about their cars. In the future, that would provide the basis for a community that allows drivers who don't have the technology to use the service based on data collected from cars with the same make, model and year.

In preliminary experiments, researchers were able to show that following the suggestion of Green GPS saves 13 percent more fuel over the fastest route and 6 percent over the shortest. The initial test was conducted on 16 cars of various types that collectively drove for 1,000 miles in Urbana-Champaign, a city of 170,000.

Abdelzaher hopes that the collaboration with IBM will open up opportunities to test the service in heavily urban areas with greater stop-and-go traffic.

"The preliminary results gave us hope that if we deploy it, it will be useful," he said. "If we can minimize brown energy and maximize green energy, we reduce our carbon footprint."



CSL STUDENT CONFERENCE DRAWS MORE THAN 100 ATTENDEES

In late January, more than 100 students and faculty attended the 6th annual CSL Student Conference. The conference was organized by CSL graduate students and included student presentations, invited speakers and a panel discussion.

This year, three new components were added: a CSL-themed website, a systems and hardware design session and a poster session. In the poster session, students who did not yet have any published results were invited to make a poster about their work.

Conference co-organizer Peter Kairouz said the event achieved its goal of facilitating interaction between students and giving them opportunities to learn about each other's research.

Economist touts Agha's bridge-monitoring research

If you can make a car smart enough to know it needs repairs, why couldn't you do the same for bridges? CSL researcher Gul Agha, a professor of computer science, and Civil Engineering Professor Bill Spencer are studying how to create such "superstructures," recently the topic of a feature in *The Economist*.

The resesarch team has created an inexpensive system for continuous, reliable structural health monitoring. The approach uses dense arrays of wireless smart sensors and concurrent and distributed real-time processing to overcome the limitations inherent in traditional systems. Already, researchers have produced a customizable software framework that simplifies development for smart sensor platforms.

In 2009, the team deployed the largest civil infrastructure monitoring system to date, and the only one using dense wireless arrays, on Jindo Bridge in South Korea.

For more information about Agha's research:
http://osl.cs.uiuc.edu/people
http://www.economist.com/node/17647603?story_id=17647603&fsrc=rss

Başar writes the book on network security

ECE Professor Tamer Başar, a researcher in the Coordinated Science Laboratory, and his co-author Tansu Alpcan (MSEE '01, PhD '06) are providing assistance to those who are fighting security threats with their new publication, "Network Security," which has just been published by Cambridge University Press.

Başar and Alpcan began the project more than seven years ago when Alpcan was a graduate student at Illinois. Their goal was to apply "a more systematic way of formulating network intrusion problems and network security problems in general," said Başar.