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The Magazine of the Carnegie Mellon University School of Computer Science

### **Smashing the stereotypes**

WE LOOK AT WAYS TO MAKE WOMEN AND OTHER UNDER-REPRESENTED GROUPS FEEL MORE WELCOME IN THE WORLD OF COMPUTER SCIENCE

#### also inside:

CLASS OF '79 ALUMNA SHARES 2012 TURING AWARD DOES YOUR TYPING RHYTHM HOLD CLUES TO YOUR HEALTH? RESEARCH NOTEBOOK: LOW-LITERACY COMMUNITIES CONNECT VIA SOCIAL MEDIA

**Carnegie Mellon University** 



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The Link provides a mosaic of the School of Computer Science: presenting issues, analyzing problems, offering occasional answers, giving exposure to faculty, students, researchers, staff and interdisciplinary partners. The Link strives to encourage better understanding of, and involvement in, the computer science community.

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on the cover Cover illustration by Jordan Bush; photography by Tim Kaulen



Dean Randal E. Bryant

#### Reflecting on the Cohon Era

Jared Cohon will be stepping down as president of Carnegie Mellon on June 30 after 16 years of service.

It's remarkable how the School of Computer Science has flourished during that time period. Our total student enrollment, including undergraduate, masters and Ph.D.'s, has almost doubled to its current level of 1,600. Our research budget has nearly tripled, to its current level of \$110 million.

We have greatly expanded our physical footprint as well with the opening of Newell-Simon Hall, the Gates and Hillman Centers, and several renovated office buildings near the Pittsburgh campus on Craig Street. President Cohon has been an enthusiastic supporter of computer science throughout his tenure.

By all indications, Subra Suresh will be a strong supporter of computer science. Suresh comes to us with impressive credentials, including his current position as director of the National Science Foundation, and before that dean of the College of Engineering at MIT. We look forward to welcoming him as the ninth president of Carnegie Mellon University on July 1.

andy Bru

Randal E. Bryant Dean and University Professor School of Computer Science



The university's new president received an enthusiastic welcome on Feb. 21. Among those greeting Subra Suresh and his family in the University Center's Rangos Hall was the Home Exploring Robot Butler, or "HERB," a Robotics Institute creation designed to help people with physical challenges live independently at home.

Suresh is former dean of engineering at MIT and currently serves as director of the National

Science Foundation. Ray Lane, chairman of CMU's board of trustees (far right), calls Suresh "uniquely qualified" to lead the university in part because of his commitment to technology research and education.

Also shown are Suresh's wife, Mary Delmar, the former director of public health for the town of Wellesley, Mass., and their daughters Meera and Nina.

## New CSD head had role in program's design

#### By Byron Spice

Frank Pfenning (S '81, '87), a professor of computer science who played a key role in the recent update of Carnegie Mellon University's introductory computer science curriculum, is the new head of the Computer Science Department.

He succeeds Jeannette Wing, who stepped down to become head of Microsoft Research International. SCS Dean Randy Bryant said Pfenning has been heavily involved in the school's educational activities and has shown great care for the welfare of students.

As head of the Computer Science Department, Pfenning will lead a distinguished faculty of more than 70 members. Established in 1965, CSD was one of the world's first computer science departments.

"At the undergraduate level, Frank has taught an amazing array of courses, from the very theoretical, such as mathematical logic, to the very applied, such as computer systems and computer graphics," Bryant said. "At the graduate level, he served as director of the computer science Ph.D. program, keeping track of the progress of around 150 Ph.D. students. He also served on the committee that designed our recently introduced computer science master's program."

Pfenning's research focuses on applications of mathematical logic in computer science. This includes the design of programming languages, systems for reasoning about computer programs and logics for ensuring computer security.

Pfenning developed a new course, Principles of Imperative Computation, that is part of CSD's updated introductory computer science curriculum. This and other new courses, which have been implemented over the past several years, reflect a more rigorous approach to developing reliable software. They place greater emphasis on parallel computation and incorporate concepts of computational thinking—the idea that computer scientists have developed unique ways of formulating and solving problems.



Born in Rüsselsheim, Germany, Pfenning studied mathematics and computer science at the Technical University Darmstadt. With the support of a Fulbright Scholarship, he attended Carnegie Mellon, where he earned a master's degree

Frank Pfenning

in mathematics in 1981 and a Ph.D. in mathematics in 1987. He subsequently joined CSD as a research scientist, receiving an appointment as associate professor in 1999 and full professor in 2002. He served as CSD director of graduate programs from 2004 to 2008 and as associate dean of graduate education for the School of Computer Science from 2009 to 2010. He also holds an adjunct appointment in the Department of Philosophy.

Pfenning has been a visiting scientist at the Max-Planck-Institute for Computer Science in Saarbrücken, an Alexander-von-Humboldt Fellow at the Technical University Darmstadt, and a visiting professor at École Polytechnique and INRIA-Futurs. He won the Herbert A. Simon Award for Teaching Excellence in the School of Computer Science in 2002.

He has served on numerous boards of international professional organizations, research journals and academic conferences. →

*—Byron Spice is director of media relations for the School of Computer Science.* 

# All in good time

Traffic-sensitive signals developed at the Robotics Institute are saving fuel, time and drivers' nerves

#### By Linda K. Schmitmeyer

Gregory Barlow knows a lot about traffic, and not just how long it takes to commute from his home in Squirrel Hill to his office in Newell-Simon Hall, where he works with CMU research professor Stephen Smith on tackling traffic congestion in urban areas.

Barlow (CS'11), a post-doctoral researcher in the Robotics Institute, knows traffic problems are nothing new: The early Romans wrestled with them two millennia ago by banning wagons on their roads during certain times of the day. He also knows they're costly: In 2009, drivers in 439 urban areas in the United States traveled 4.8 billion hours longer and purchased 3.9 billion more gallons of fuel because of traffic snarls, for a total congestion cost of \$115 billion.

And all this comes from Barlow, a man who admits, "I don't really like to drive."

Maybe that's why he's working to improve the driving experience in Pittsburgh, along with CMU colleagues Xiao-Feng Xie, a research associate, and Zachary B. Rubinstein, a senior systems scientist. They are part of a team led by Smith, director of the Intelligent Coordination and Logistics Laboratory in the Robotics Institute, where they developed a "smart" traffic signal that works in realtime. Smith has dubbed the project Scalable Urban Traffic Control (SURTRAC).

Today, most signals operate by pre-setting the timing on the green light for several different periods throughout the day, depending on the number of vehicles expected to travel through an intersection. As part of the Traffic21 Initiative in Carnegie Mellon's H. John Heinz III College, the researchers developed software that allows a signal to respond to traffic as it is happening. Last spring, they installed adaptive signaling systems at nine intersections in Pittsburgh's East Liberty neighborhood.

"Our system watches actual traffic flow through the cameras at each intersection and dynamically adjusts the green timing periods on a second-by-second basis," Smith says. According to Smith, similar software is already being used to manage traffic flow onto along arterial roadways surface roads with a strong traffic flow in one direction and some side streets. With these systems, though, information is typically collected and sent to a central location, where data are analyzed and adjustments to the signaling are determined.



"It can take anywhere from five to 15 minutes (to reprogram the signals), depending on the system being used," Smith says. "The beauty of our approach is that it is decentralized, which makes it inherently scalable, in principle."

There also are decentralized systems used on arterial roads, says Smith, but they operate on the assumption that there is a dominant flow

of traffic that does not change.

SURTRAC, in contrast, is designed to discover the dominant flow of vehicles through an intersection and automatically adjust the signaling. It is designed to operate within urban grids, where the volume and direction of traffic can change throughout the day.

At the East Liberty intersections, cameras take continuous shots of the traffic, which allows SURTRAC to create a schedule for moving vehicles through the intersections in the most efficient way possible. Each intersection also communicates via a fiber optic cable (or, in the case of one East Liberty intersection, a wireless signal) to its downstream neighbors as to what the projected outflow from its signal will be. The neighboring signals do the same thing, and together they create a communications network that's akin to having the watchful eyes of traffic police at every intersection.

More impressive, though, are the net results. At the East Liberty intersections, the research team found that the wait time for people driving through the grid was reduced by 40 percent. Travel time was reduced by 26 percent and projected vehicle emission by 21 percent. The researchers obtained the results by completing "before" and "after" drives along 12 predetermined routes through the nine intersections. They did the drives during four set times throughout the day; GPS tracers on their cell phones allowed them to gather the data necessary to calculate the differences.

Smith says the methodology is based on a model used frequently by the Southwestern Pennsylvania Commission, a regional planning agency that administers state and federal transportation and economic development funds.

"When I saw the results, I was really shocked that they were as good as they were," says Allen Biehler, executive director of CMU's University Transportation Center and former secretary of the Pennsylvania Department of Transportation.

Although Biehler says that more "robust testing needs to be done" by expanding the pilot grid in an effort to obtain more data, he expects other cities throughout the United States will be interested in SURTRAC. In November, during the annual meeting of the American Association of State Highway Transportation Officials, Florida Transportation Secretary Ananth Prasad invited Biehler and Smith to discuss SURTRAC with his state's Department of Transportation. "This (technology) will have far-reaching implications," Biehler says.

Nate Cunningham, director of real estate for East Liberty Development Inc., sees the ease in congestion at the East Liberty intersections as a boost to the local economy. "There is no more important thing to make a community competitive than being able to move people easily from place to place," Cunningham says. "I can see how (the ease in traffic flow) will have an impact on real estate in East Liberty."

Another advantage, says Cunningham, is that municipalities can implement the technology incrementally. Once an intersection has been upgraded to include detection equipment, a SURTRAC system can be installed to monitor traffic in real time. "What's exciting is that this is so powerful and so cheap. Cities can bite off little chunks at a time, as funds become available."

Amanda Purcell, municipal traffic engineer for the City of Pittsburgh, says that the pilot project in East Liberty "is working fine" and will help "establish a baseline for how the signals operate."

She says talks are under way to expand the project,





which has already received approval to install SURTRACsupported signals eastward from East Liberty along Penn Avenue to Fifth Avenue. Nine more intersections will be added to the grid during 2013. Adaptive signaling is also being considered along Baum and Center avenues to Craig Street in Oakland, creating what Smith likes to call "a virtual corridor to Downtown."

A computer-enhanced corridor into Pittsburgh may not match the Roman accomplishment of "all roads leading to Rome," but a faster way into town should please many drivers.

Traffic21 was launched in 2009 with funding from the Henry L. Hillman Foundation. Grants to Traffic21 from The Heinz Endowments' Breathe Project and from the Richard King Mellon Foundation provided the funding for the pilot.  $\rightarrow$ 

*—Linda K. Schmitmeyer is a writer and editor in Valencia, Pa. This is her first Link byline.* 

# Decoding a cyber-fingerprint

Your typing rhythm holds clues to your identity, and maybe even your future health

#### By Mary Lynn Mack

The blink of an eye takes 300 to 400 milliseconds. It takes less time than that—about 90 milliseconds, on average to press a computer key while typing.

Individual keystrokes as well as the "rhythm" of typing a word, sentence or document are forming the basis of a cyber equivalent to handwriting or fingerprint analysis.

In a small laboratory on the eighth floor of CMU's Gates Center for Computer Science, Dr. Roy Maxion and his team have developed the ability to capture and analyze those 90-millisecond keystrokes and read the clues encoded in them. Called "keystroke dynamics," Maxion believes the research may have the potential to not only change the world of cybersecurity, but also to identify individuals with musculoskeletal diseases, neurological disorders, cognitive decline and acute stress.

Maxion, a research professor in the School of Computer Science, became interested in keystroke dynamics about five years ago when he was asked to review a journal article on the subject. Although research into keystroke dynamics began 30 years ago, some of the most significant progress has been made in the last decade or so. The topic was new to Maxion, and it interested him. Within a short time, Maxion was working on a National Science Foundationfunded project to determine if someone could be identified from his or her typing style.

"My position is that no one has demonstrated that it isn't possible," he says.

Cybersecurity is Maxion's speciality. A member of the National Academies' Committee on Future Research Goals and Directions for Foundational Science in Cybersecurity, Maxion serves as vice chair of Professionals for Cyber Defense and director of CMU's Dependable Systems Laboratory, and has also studied intrusion detection. His early interest in keystroke dynamics focused on ways of lowering the error rate when analyzing keystrokes in applications such as Web-based financial transactions— Maxion's group was able to improve the accuracy to 99.97 percent in 10 keystrokes.

Maxion's lab is now able to measure typing rhythms on a scale far more precise than any other known system available. In addition to capturing the length of time the keys are pressed, the lab also collects information about user demographics, hand geometry, hand and body posture, and movement.

#### Could your password be customized?

As a result, his team is close to determining what password they could assign to someone that could be distinguished not just because of the mix of numbers, letters and punctuation marks, but because of the way the user types the password—their individual typing rhythm. In other words, "can we customize your password so that your typing style would be best conveyed by that particular password?" Maxion says. For instance, for someone with short, thin fingers, a password with characters that span the keyboard would be more difficult to type than one that had characters grouped together. Conversely, for an individual with thick fingers, a combination of characters clustered in the center of the keyboard would require more effort and deliberate attention.

There are "lots of thorny little problems" that can affect a person's typing pattern, such as stress, fatigue, illness, injury or substance use, Maxion says. But just as a person can be identified by his or her gait, even when they're carrying a heavy object or wearing different shoes, Maxion says that someday, software may be able to identify someone's core typing rhythm despite a slight deviation from the norm. Finding that core typing rhythm, he says, may unlock the doors to reliable, real-world applications.

Although cybersecurity continues to be a major focus, Maxion says the research has implications in health care. Would it be possible, for instance, to detect whether someone's typing rhythm is changing because of illness or injury? Maxion's research suggests that changes in typing rhythm could provide early warning signs when someone is beginning to suffer from musculoskeletal problems such as carpal tunnel syndrome, digital flexor tendonitis and arthritis.

Maxion recently partnered with Nancy Baker, an associate professor of occupational therapy at the University of Pittsburgh's School of Health and Rehabilitation Sciences. Baker has been conducting research on detecting musculoskeletal disorders through keyboard use since 2008.

"In my experience, as people develop illness of or injuries to the soft tissue, the way they perform certain tasks changes, as they adapt and respond to changes in the tissues," Baker says. For example, subjects with rheumatoid arthritis are more likely to use high-force keystrokes, not use a wrist rest, move their hands to strike keys, maintain their wrists and fingers in a fixed position, and use only one finger on each hand to type.

#### **Testing typing to predict illness**

By pairing Maxion's precise measurements with Baker's studies, which include visual observations as well as measurements to determine the location of joints in space at specific moments (kinematics), the two hope to be able to determine which postures, angles and positions put a user at risk of developing a musculoskeletal disorder.

Early detection of such disorders can improve treatment and prevent further damage. The longer a patient has a disorder, Baker says, the more difficult it is to treat or reverse. Work-related musculoskeletal disorders are both common and costly. In 2010, according to the Centers for Disease Control and Prevention, an estimated 3.1 percent of U.S. adults aged 18 to 64 reported suffering from carpal tunnel syndrome at some point during the previous 12 months. A 2001 report from the National Research Council and the Institute of Medicine estimated the cost to the U.S. economy of such disorders, including lost wages and productivity, at between \$45 billion and \$54 billion per year. "If by using our technology we could make even a 1 percent difference, it would be a substantial savings," Maxion says.

The CMU team also is looking at connections between keystroke dynamics and neurological issues. During one recent test, the researchers identified a subject who had a very unusual, distinctive typing pattern, Maxion says. Additionally, the subject held his keystrokes for just 46 milliseconds, about half the average of other subjects. With more investigation, the team learned that the subject had recently been diagnosed with right temporal lobe epilepsy.

Maxion sees a similarity between those findings and the type of results generated by the Halstead-Reitan Finger Tapping Test, which assesses motor speed and motor control, and which is part of a battery of tests used to help identify neurological disorders. There also are some indications that early signs of Alzheimer's disease and dementia can be detected through changes in typing rhythm, which suggests keystroke dynamics could one day be used as part of the diagnostic process for these diseases. As with musculoskeletal disorders, early detection and diagnosis could give patients a better chance to benefit from early treatment. "If we obtain baseline information on enough people with and without specific diseases or disorders, then we are going to be able to separate the characteristics of the keystroke rhythms that correspond to those diseases and disorders," Maxion says.

He notes that while it's too early to know what those characteristics might be, learning those signs could lead to the development of software that can determine, by the way an individual types, if they have a susceptibility to a particular disease or disorder.

#### Precise, careful data collection

Maxion says that CMU has advanced the field of keystroke dynamics because of its specific research methods. His team built its own timing mechanism that can measure the time it takes to press keys at speeds not previously available sub-millisecond levels. And they standardized the collection of their data to incorporate tight experimental control. During the initial studies, 51 subjects were asked to sit in the same room, at the same desk, using the same keyboard and computer, and type the same 10-character password 400 times over eight sessions.

The controlled, standardized setting is possibly the most important thing that distinguishes the research being done by Maxion's team. Many other studies of keystroke dynamics, he says, have gathered data under real-world conditions without controlling for the many variables—keyboard type, typing posture, language fluency—that may or may not affect someone's typing rhythm. Maxion likens that to doing chemistry experiments with dirty test tubes, and says the resulting datasets are "all over the map." Maxion's team has published its standardized dataset online for other researchers to download and use in their own work.

"When you first approach keystroke dynamics, it looks pretty simple," he says. "The key goes down, and some milliseconds later, it goes back up. But when you start to get into it, there are a lot of subtleties that need to be recognized and dealt with. That's what makes it hard and interesting." →

*—Mary Lynn Mack is a Washington, Pa.-based freelance writer. This is her second Link byline.* 

# Sweating the details

"When people think of

language technology and

translation, most people

(think) of free services, like Google, that are basically

designed to support a very

broad range of individual

says Alon Lavie, research

users who might want

to translate anything,"

SCS startup Safaba develops smarter translations for specialized clients

#### By Meghan Holohan

Say a marketing executive at a large company needs to translate new product information on her company website from English to French within a few hours. She's not fluent enough in French to do it herself, so she has several options—she can hire a human translator or a translation agency. She can also use a readily available online translation program, such as those offered by Google and Microsoft's Bing.

Translating an entire website using human translators would be time-consuming and costly, and the commonly available free online translation services have drawbacks.



Alon Lavie

professor at CMU's Language Technologies Institute and president and CEO of the startup Safaba Translation Solutions, which provides specialized computer-based machine translation software for global corporations.

"What Google and Microsoft are trying to do is build systems that generate the best possible translation without knowing anything specific about your company and the specific terminology and other language characteristics that you and your company typically use," Lavie says. While those translations are often understandable, he says they're not quite good enough for representing your company in another market.

To cover their bases as broadly as possible, Lavie says, free translation services build their translations from a wide range of different resources. The resulting quality can vary from one sentence to the next. Anyone who has translated a webpage from another language to English, using a free online service, is familiar with awkward translations. Sure, a native English speaker may be able to figure out the gist of a computer-generated translation phrase such as "from now officially Cologne," but it doesn't sound right.

The company exec who used an online, mass-market translation program to translate her website from English to French could end up with text using either slang (informal language instead of formal) or terms from the wrong domain or industry. Lavie uses the example of the English word "tablet." Imagine translating "tablet" on the website of a computer company as if it were a medicine "tablet" or pill, he says.

Unlike free services that aim for very broad audiences but provide somewhat crude translations, Safaba targets large organizations—such as companies in the Fortune 500—that need fast but high-quality translations of high volumes of documents, often incorporating very specific corporate language.

"We use machine-learning to give them what they need," Lavie says.

The global market for translation services is estimated at \$30 billion annually, with machine translation currently accounting for a fraction of this market. As demand for large volumes of content translation increases and the technology improves, experts believe that demand for machine translation will continue to expand.

"The industry itself is growing," says Olga Beregovaya, a vice president at Welocalize Inc., which is using Safaba's translation engine to provide specialized, on-demand translation services to major clients with global audiences, such as Dell and PayPal.

While working on research projects as a faculty member at the Language Technologies Institute, Lavie became involved in the Association for Machine Translation in the Americas, or AMTA. Through AMTA, Lavie saw that the machine translation market needed programs that better captured certain specialized nuances of language.

Lavie teamed up with his former Ph.D. classmate Bob Olszewski (CS'01), who was working at the time at a different LTI spin-off company that creates software for language tutoring. The two began collaborating on a system that businesses could use to translate content into multiple languages.

With support from the SCS-based entrepreneurship program Project Olympus and CMU's Center for Technology Transfer and Enterprise Creation, Safaba was launched in summer 2009 with just Olszewski and Lavie. Since then, it's grown to include 11 employees. (Project Olympus recently merged with the similar Don Jones Center for Entrepreneurship in CMU's Tepper School of Business to create the Carnegie Mellon University TRANSLATION Center for Innovation and OPTIMIZATION Entrepreneurship.)

To create custom translation programs, companies provide Safaba with source materials that they've already had translated by humans-the same documents in, for example, English and French. Those documents already contain approved translations of specialized language such as technical descriptions or trademarked corporate slogans. Safaba's software then analyzes the materials, sentence-by-sentence, creating highly reliable statistical models used to generate translations of new documents and adapt the generated translations to respect the individual company's unique language.

Safaba's software can handle multiple languages and the company hopes to eventually incorporate its services directly into content management systems and other backend authoring technologies, allowing businesses to generate live translations as the original texts are being written.

Only a relatively small amount of material is needed to train Safaba's programs on how to adapt its language to the specific nuances of a particular company quickly and accurately, Lavie says. And because Safaba's software is learning from professionally translated documents, the translations it generates include fewer of those awkward phrases that confuse native speakers.

However, the reliance on a company's own translations can lead to problems of its own. If the translated materials include errors, the program's models will "learn" those errors, too. "There often isn't a single

> translation that is correct in all possible contexts," Lavie says.

To prevent errors from going public, human translators still have to get final approval before content goes live, says Beregovaya of Welocalize. "We always edit Safaba output," she says. "The benefit here is that post-editing is faster than human translation, and cheaper. Safaba output is good, but (it) doesn't read as human."

Beregovaya says having access to machine-learning models developed at Carnegie Mellon gives Safaba an

edge over competitors. "Initially, we went with them because of CMU's name recognition," she says. Welocalize then held a "technology bake-off" between Safaba and two competing translation services, and

OPTIMIZATION

Safaba was the clear victor.

Welocalize is currently bidding on a project where Safaba's engine would provide translations between 35 different languages.

"We are pragmatic," Beregovaya says. "If it works better, our clients save money and we also save money." →

—Meghan Holohan is a Pittsburgh-based freelance writer and a frequent contributor to The Link.

# Speaking of security

Voiceprint authentication a la "Star Trek" could be poised to become reality

#### By Ken Chiacchia

Now, what was that password? This was the system that needed eight digits, right? Did it require symbols, or just letters and numbers?

Today's password-driven electronic security systems have a face only a system security administrator could love. Better to use some kind of biometric—something physically a part of us, marking us as ourselves. Some systems already use fingerprints. What about a voiceprint? Wouldn't it be great if our computers could recognize us, the way the Enterprise recognized Captain Kirk saying, "Zero-zero-zero destruct zero?"

Simply recognizing human speech isn't all that hard for today's computers. Take Apple's voice-activated Siri assistant, for example. Matching voiceprints is possible, too, and is already being done by commercially available software from companies such as Nuance and Auraya.

The problem is making the voiceprints themselves secure and difficult to steal, says Bhiksha Raj, associate professor and non-tenured faculty chair at the School of Computer Science's Language Technologies Institute. But Raj and his colleagues may have found the way forward.

"Where (the work) really began was when we realized that every time we use our voice to authenticate (ourselves), we put ourselves at risk," Raj explains. "Your voice is supposed to be a viable biometric, but once you've given it away it becomes just another bit of data out there."

Just as a stolen password can leave your email or financial data wide open, a cracker could potentially steal your voiceprint from a database and take over part of your life, at least as effectively as if he'd stolen your social security number.

The question that stumped Raj and his colleagues was: Could they somehow get "Siri" to respond to voice commands without sending the actual voiceprint over the network and into the cloud, where it would be vulnerable to theft?



#### **Old-school encryption**

The obvious answer to the problem was to encrypt the voice recording. A system would store an encrypted version of your voice, identifying you without actually having access to your voice. Each system would have its own encrypted version, impossible to connect with each other or with your original voiceprint.

To accomplish this, Raj and his colleagues had to solve two problems. The first was authentication itself.

"Speech is a noisy signal," says Shanatu Rane, a principal research scientist at Mitsubishi Electric Research Laboratories, who collaborated with Raj on his early work. "If you say something now, and then say it again five minutes later, the two signals are not going to be identical." There's simply no way to make a person's voice input completely stable in the same way as a typed password.

To solve this issue, the voice authentication process employed by Raj's team used Gaussian mixture models, or GMMs. GMMs are a way to statistically match up a given pattern to a standard sample. In this case, Raj says, the researchers used the parameters of the GMMs they calculated from individual voice recordings to represent the actual recordings. Using GMMs, their system achieved excellent results both in terms of recall (the ability to recognize a matching voice sample) and precision (the ability to avoid accepting a nonmatching sample). The second problem was more of an obstacle. Encrypting and decrypting voice samples is straightforward—if you have plenty of time to burn.

"When you encrypt data, the size of the data increases," says Rane. "With the thousand-bit keys typically considered suitable for encrypted-domain processing, the overhead for storage, communication and computation increases a thousand-fold."

Unlike text passwords, voice samples are complex, and encrypting them generates huge amounts of data. Just moving it back and forth from machine to machine becomes time-prohibitive. In one experiment, Raj, then-CMU graduate student Manas Pathak and colleagues from Portugal's Instituto de Engenharia de Sistemas e Computadores Investigação e Desenvolvimento tried encrypting, exchanging and decoding a 4.4-second voice recording, using a 1024-bit security key. It took more than 14 hours.

That wasn't going to work—so how could they get around the limitations of encrypted data?

#### Taking a trick from text passwords

The answer, ironically, was to make voiceprints behave more like text-only passwords.

Most laypeople don't realize that when they type in a password, their computer does not transmit the password to the system. Instead, it uses the password to generate a "hash"—essentially, a mathematically devised "password for your password" that only one particular system possesses and uses. It's almost impossible for someone intercepting the hashed password to decode it. Hashes are as secure as encrypted data, but far smaller, and easy to transmit quickly.

Raj and his colleagues developed "secure binary embeddings," or SBEs, to convert key features of complex voice signals into simplified hashes. The hashes of a given recording can then be compared with the original voiceprint's hashes in a way that maintains recall and precision without any way for the hashes to be used to reconstruct the original voiceprints. In a paper written with Jose Portelo of INESC-ID/IST, Raj and colleagues showed that an SBE system could deliver recall and precision in voice authentication of over 93 percent—slightly under that of encryption-based authentication. Since then, they have improved this performance further.

"You can actually achieve more or less the same performance that you get with a conventional (encrypted) system, with a fraction of a percent error," Raj says. They've already achieved recall and precision with less than 0.18 percent error—a level that suggests SBE is a workable identification system for comparing voiceprint information through the cloud.

Rane, who was not involved in the SBE research, says the results Raj and his colleagues are reporting are "much faster" than encryption. "You take a small hit in accuracy in return for a very large increase in speed," he says.

A few questions need to be resolved before SBE can be deployed, Raj says. Importantly, they need to decide how much of the conversion is performed on the user's device and how much is done in the system. The more of the conversion done in the end-user's device, the easier it would be for an intruder to use that device to simply reset everything for his or her purposes—for example, if you lost a smart phone. On the other hand, the more that resides in the system, the more the user is at the mercy of that system's security and goodwill.

Possibly, different levels of voice authentication would be best served by different formulations of conversion.

Once these issues are decided, Raj says, voiceauthentication passwords are "computationally feasible and plausible, and can be implemented today." →

—Ken Chiacchia is a freelance writer of both science fiction and science fact. He recently joined the Pittsburgh Supercomputing Center as senior science writer.

## Is the end near?

Daniel H. Wilson's "Robopocalypse" plots a robot uprising in the near future, but (so far) the science is still fiction

#### By Meghan Holohan

It starts out slowly—so slowly people don't realize what's happening. One robot malfunctions, attacking a human. Soon more robots fail, turning on humans, hunting them down and slaughtering them. Some of the survivors are forced into labor camps, where they undergo bizarre cyborg experiments. Others fight the robots.

Daniel Wilson's book "Robopocalypse" paints a bleak picture of the near future when robots work together to crush humans and take over the world. Wilson's books, which include "How to Survive a Robot Uprising: Tips on Defending Yourself Against the Coming Rebellion," focus on the dark side of technology—what happens when good robots go bad, what occurs when we become trapped by our own creations.

His work, like that of so many other science fiction writers, speaks to our fear of technology, and that fear resonates with readers—including Steven Spielberg, who's currently working on the movie version of "Robopocalypse." Anne Hathaway and Chris Hemsworth are slated to star in the film, which is tentatively scheduled for 2014 release. (Recent reports in Hollywood trade papers suggest the film is being delayed.)

In "Robopocalypse," a highly intelligent robot named Archos infects the world's other robots—companions, domestic helpers, smart homes, boxy drones, manufacturing robots and cars—with a virus that causes them to seek out humans and kill them. Many of these robots resemble existing robots in our real-life world; the self-driving cars bear an eerie resemblance to driverless vehicles developed at CMU, Google and elsewhere, while the humanoid robots sound like a more advanced version of the Wabian robots at Japan's Waseda University. "There isn't anything inherently scary about robots," says Matt Mason, professor of computer science and director of CMU's Robotics Institute. Sometimes they're bad, other times they're good.

Indeed, asks Mason, "Isn't the reason that we're interested in robots because they're so much like us?"

Robots have played important roles in literature, TV and movies for generations—centuries, if you count Homer's description in the "Iliad" of Hephaestus using an army of metal men to build his armor. Fictional robots fulfill different roles in our imaginations. They have to solve problems and move in the physical world, like humans. They're helpers such as RoboCop, or Rosie, the Jetsons' maid, and they're killers like the Cybermen of "Doctor Who" or the Cylons of "Battlestar Galactica."

But Mason says robots do possess an essential quality that makes them perfect villains: "If you want to write a scary book ... you need a smart enemy." Robots are certainly smart, and getting smarter. The most interesting part about Wilson's book—and what makes it different from many other sci-fi books—is that Wilson makes a distinction between mere intelligence and actual human consciousness, Mason says.

But he notes that according to Moravec's Paradox—named for Hans Moravec, an adjunct faculty member at the RI it's easier to create a fast-thinking robot than one that can master complex locomotion. (Mason jokes that "maybe there are already evil robots out there who just have found [human] minions to carry out their plans.")

Put another way, machines may be able to process information quicker or better than humans, but it's harder to train a robot to fold a towel than it is to train a robot to think through chess moves like a grandmaster. That's one of the ways that Wilson's book differs from many other sci-fi adventures. Wilson, an SCS alumnus, doesn't create a dystopia where the evil robots are humanoids, like those depicted in "Battlestar Galactica" or Philip K. Dick's "Do Androids Dream of Electric Sheep?" Instead, in Wilson's world, boxy hunks of metal perched on insect-like legs lead the bloody revolution, while smart cars weed out the human population.

In other words, Wilson's robots are only a bit more advanced than our current technology, making it seem as if there could be monsters in labs and even in our homes. It makes a robot like Archos—seemingly limited in his mobility a more realistic threat than an army of murderous humanoid robots yet to be devised.

Are robots currently as smart as those depicted in Wilson's books? Self-driving cars and automated drones are certainly sophisticated, says Chris Atkeson, a professor of robotics and human-computer interaction at CMU. He also served



Daniel H. Wilson

as Wilson's Ph.D. advisor at CMU. "Google has cars that drive themselves and those cars have to make tough decisions on their own," Atkeson says. "That takes pretty subtle thinking." But he adds a caveat: "I think there is a greater cognitive capacity in (Wilson's) robots than what we have now, in that they are thinking like people. And we haven't achieved that yet."

Wilson says his fiction is informed and inspired by his education at CMU. Growing up, he enjoyed science fiction "like a lot of scientists do," he says in an interview. "Ultimately, I learned how to program as a kid and that gave me a real creative release ... I was able to program computers to do creative stuff. Then when I learned there was such a thing as (artificial intelligence), I got really excited."

But Wilson didn't really feel that his science fiction resonated until he started studying real computer science and robotics. He was still in CMU's Ph.D. program when he began writing the semi-serious book that became "How to Survive a Robot Uprising," which was released in 2005 and won Wired magazine's "Rave" award the following year. "Technology and robotics are having more and more of an impact on people's lives," Wilson says. "We're afraid of machines because we're afraid of them becoming too powerful." But he adds that fear of robots varies by country. In Japan, for instance, people embrace robots and one of its most popular heroes is Astro Boy, an animated robot who saves the world. What makes so many people so terrified of robots? "I am going to play psychoanalyst," says Atkeson, noting that robots "act like children. A critical part of growing up and becoming independent is rejecting your parents and going off and doing your own thing." Robots are stronger and smarter than humans. Combine this with the idea that many believe humans would mistreat robots making them second-class citizens—and it's easy to imagine a resulting horrible revolution as robots "grow up," reject their human "parents" and seek vengeance.

Wilson's latest book, "Amped," takes place at Pittsburgh's Taylor Allderdice High School and explores what happens when people become inseparable from their technology. In "Amped," some of the characters have neural implants that were originally intended to help people overcome handicaps. But these neural implants are making people smarter—superior to other humans. "It's another techno-thriller, a story of a civil-rights movement that is sparked when people with disabilities use neural implants to become smarter," Wilson says. "It's really the difference between us fighting the robots and us becoming the robots."

Wilson is now at work on a sequel to "Robopocalypse" and plans to continue exploring technology and the power it holds over us. "I am pro-technology—the more power the better," he says, "but the more technology we have, the more our lives depend on it." →

### in the loop: john c. reynolds



John C. Reynolds has been a professor of computer science at Carnegie Mellon University since 1986. He retired from active teaching Jan. 1. A graduate of Purdue University, Reynolds earned his Ph.D. in theoretical physics from Harvard University.

His main research interests have been the design and definition of programming languages and the specification of program behavior.

A past editor of the Communications of the ACM and the Journal of the ACM, Reynolds was appointed a fellow of the ACM in 2001 and won the ACM SIGPLAN Programming Language Achievement Award in 2003. Reynolds was honored with the Lovelace Medal of the British Computer Society in 2010.

He spoke to Link Editor Jason Togyer.

#### What made you decide to retire?

I'm suffering from some health problems and I wasn't sure I would be able to teach in the spring. But now that I've found out how much work it is to retire—you'd think that if there was one thing that would be made simple, it would be retirement—it's a little scary!

#### Where did you grow up, and how did you get interested in science?

I grew up in the Chicago suburbs, in Glen Ellyn, III. My mother had been a schoolteacher and my father was in advertising. It was apparent by the time I got to school that my first love was music, and I thought I might become a musician—I played piano and trumpet. But somehow, science became more and more interesting. I wound up being one of the winners of the annual Westinghouse Science Talent Search, went to Purdue and did my graduate work at Harvard in theoretical physics.

#### One of your teachers at Purdue was Alan Perlis?

Yes—he left Purdue for Carnegie Tech in 1956, at the same time I graduated. While he was there he taught the one and only course in computing. It was half a semester on how to build them, and half on how to program them. One day, he walked into class and said, "I'm going to show you how to build a divider." He started sketching this long equation on the board. Finally, one student said, "Professor, that won't work with a negative quotient." So he made some changes, and another student said, "Professor, now it won't work with a positive quotient." He made some more changes, and someone said, "It won't work with a positive divisor!" Perlis said, "Well, that just goes to prove that you cannot design a divider on a Monday morning. Class dismissed!"

#### What was the state-of-the-art then?

Strictly machine language. This was before even Fortran. Perlis at that time was working on one of the first compilers.

#### When you got to Harvard, was it more up-to-date than Purdue?

Harvard at the time was under the spell of Howard Aiken, which means its computer system was completely obsolete. Fortunately, IBM had set up an installation at MIT that could be used by a consortium of other universities, and I had access to that.

#### How does one go from theoretical physics to computing?

Well, my Ph.D. was called "Surface Properties of Nuclear Matter," but it was actually a big number-crunching program. I think I was the first person in theoretical physics at Harvard who used a computer to do his thesis, and that probably impressed the faculty more than they should have been impressed. I describe it as "an uninteresting computation of an unimportant quantity in a bad approximation"!

#### Where was your first stop after Harvard?

From 1961 to 1970 I worked at Argonne National Laboratory. While in grad school, I had worked at Argonne during the summers, because it was close to my home, and I went to Argonne after Harvard because they would have been happy with me to either stay in physics or move to computing. By that time, I had gotten very interested in compilers and programming languages, and one of the first things I designed was a compiler—actually, a compiler for compilers called COGENT, because the kinds of programming languages that we had then were not suitable for symbolic manipulation.

#### What eventually brought you to CMU?

Initially, what attracted me were the reputation and the high quality research I saw here. You have to have people with whom you share common goals on the one hand, but on the other you have to have people who bring different skills and talents and complement each other. At CMU, many of the people were working on functional programming languages, while I tended to work on imperative programming languages. I think that's made my research stronger in that I haven't limited myself to one side or the other.

#### What attracted you to working on the semantics of programming languages?

The fact that I could design the rules of the language based on a few essential principles that were very easy to implement and learn. Looking back, I think I have a terrible memory, and probably the big thing that excited me about math was that there were general principles by which you could derive things, and it didn't have the ad-hoc nature of, say, history.

#### Along with Jean-Yves Girard, you're credited with inventing polymorphic lambda calculus. How did you come to be working on the same thing at the same time in different places?

Jean-Yves is a first-rate logician. He took that concept and explained it much more deeply than I could have from a theoretical standpoint. He proved that every program you could write in the calculus will always finish, but some such programs will take an incredibly long time to finishwhich doesn't sound that unusual now, but was unheard of then. My contribution was to show that it could be useful to pass types around as parameters, and my real discovery was that you could type-check a polymorphic language statically, in other words, catching errors between different types of data.

#### Polymorphism—the ability to handle many different data types with the same programming language—has become ubiquitous, and your work, along with Girard's, has been credited with leading to most of the modern computer languages. Would you agree with that?

Oh, I'm not sure I've had all that much influence on polymorphism. The idea of polymorphism was really conceived by Christopher Strachey back in 1967, that if you have a sorting program and it will work for any "something," it is polymorphic, and he's the reason that Britain is still the leader in the field. In the latest James Bond film, there is a point at which a computer displays some kind of a graph that suddenly gets three times larger, and the "geek" character says, "Good heavens, it's gone polymorphic!" When we saw that, my wife and I burst out laughing! So maybe I've had a tremendous influence on pop culture?

#### Where do you think your work has been influential?

Polymorphism, to some extent, but also my work on definitional interpreters—defining the limits of a programming language by writing an easy-to-understand interpreter—and defunctionalization, which has been useful in reducing higher-order functions to simpler abstractions. Those have had a fair amount of influence. And third, separation logic—which is an extension of the normal predicate calculus that you use in Hoare logic to determine the correctness of a program.

#### What advice would you have for a student just starting out in computer science?

There are so many things that need to be said! One is that many grad students feel they have to completely master their field before they can do anything. Quite apart from the amount of time that would take, it's stultifying. It shouldn't be your goal to learn everything. It should be your goal to discover things that other people have to learn.

#### Are you pursuing any hobbies in retirement?

I still play piano from time to time. But it's a problem because if you reach some level of technique and then you let it go, it's really painful to get it back. It's a bit of an uphill struggle, but I would like to start playing again. Both my wife and I also love going to musical and dance performances, and I'm doing a pretty good job catching up with my reading. →

# Smashing the stereotypes B

Computer science's future depends on attracting people who aren't white male gamers—and making women and other under-represented groups feel less alone

#### By Jason Togyer

It's a Monday night at the Raj Reddy Conference Room in the Hillman Center. Groups of squirming middle-school girls are sitting cross-legged on the floor. In the middle of each group there's an old desktop computer, donated by the School of Computer Science's IT team. Each computer is about to give its life for science.

This is one of the weekly Creative Technology nights, or "TechNights," for girls presented by CMU's Women@SCS program. Natalie Hildebrandt, a senior computer science major and undergraduate student organizer, puts a slide on the screen listing cookie ingredients. "I have a pop quiz for you," she says. "One of these ingredients is the wrong amount. Do you know which one?" Hands shoot up. One girl says too many chocolate chips. Another says "too much butter." Finally, one gets the right answer—too much salt.

"Right!" Hildebrandt says. "A half-cup of salt is way too much! And what would those cookies taste like?" Really nasty, the girls say.

"You just did something called 'Reverse Engineering," Hildebrandt says. "You took apart something and figured out how to make it better by changing the ingredients.

"Tonight," she adds, "you are going to reverseengineer a computer." After Hildebrandt reviews safety rules, the girls are tearing apart their computers—first with prying fingers, then screwdrivers, wrenches and pliers.

"We tend not to let girls do things like this, or we tell them 'be careful, don't hurt yourself,' and then we complain because they won't take risks," says Carol Frieze, director of Women@SCS, watching cautiously from a corner. "As you can tell, this is not like a regular classroom, and it's not meant to be."

Each girl is expected to find the hard drive, CD drive, memory chips, processor, fan and power supply. They aren't being dainty and delicate. One girl is jumping up and down on a stubborn subassembly to loosen it. Soon, boards, parts and cables are stacked in neat piles on the floor. By the end of the night, the girls are listing features they liked about their computers, and things they didn't like. ("Our computer needs more USB things," one girl says, "and our power supply was on top of the motherboard and it was insanely hard to get open.")

#### Drawing more women (and men) into CS

"TechNights," held Mondays on the Pittsburgh campus, let these young women experience the "nuts and bolts" (literally, in this case) of computer science. It's a part of an ongoing, multifaceted effort by Women@SCS to boost the stagnant percentages of women seeking careers in computer science and information technology, and to diversify the pool of men entering the field beyond white and Asian male gamers and hackers.

In fact, an increasing number of male students now volunteer to help Women@SCS outreach programs, including "roadshows," where CMU computer science students visit Pittsburgh-area middle- and high-school students and talk to them about computing and robotics. "And many of the men involved are minorities," Frieze says. "They 'get it'—they understand what it's like to not be represented in a field."

Several Women@SCS volunteers also are involved in an organization called ScottyLabs that's helping spread "maker" culture among CMU undergrads, and its related effort called TartanHacks, which is designed to broaden the appeal of "hackathons."

There are abstract reasons—moral, ethical, cultural—for wanting to encourage women and other under-represented groups to pursue careers in science, technology, engineering and math, or "STEM" fields. But there are practical reasons as well. According to 2011 data from the U.S. Department of Commerce, people in STEM fields earn about 21 percent more per hour than people in non-STEM jobs. Women in STEM jobs earn 33 percent more than women in comparable non-STEM jobs, the same data indicate. In February, the National Center for Women & Information Technology announced that 20 universities and 14 companies had signed onto "Pacesetters," a two-year program that encourages senior executives to recruit women for technical careers from previously unused talent pools, and develop strategies to retain women who are at risk of leaving computing and IT careers. CMU has been a member of NCWIT's Academic Alliance since 2004 and is a partner in Pacesetters.

Having a more diverse pool of people working in the field will pay off in innovations, argues Lenore Blum, CMU distinguished career professor of computer science and founding director of Women@SCS. She currently serves as the group's faculty advisor. "When you increase the variety of the people involved, they start paying attention to more different kinds of things," Blum says, "and there's a bigger potential for some big disruptive technology breakthroughs."

#### Networking, leadership, outreach

Women@SCS is not a club, department or office. It's an advisory council and a collection of student-led working groups (with assistance from faculty and staff) that focus on sharing information about women in computer science both on campus and in the wider community; promoting opportunities for women to contribute research and ideas; and connecting female students to mentors. The program has its roots in the late 1990s, when the School of Computer Science, under then-Dean Raj Reddy, made a concerted effort to encourage female high school students to apply and create a support structure to keep those students enrolled. It was launched with money provided by CMU President Jared Cohon and received continued funding from SCS deans Raj Reddy, Jim Morris (CS'63) and Randy Bryant, Blum says.

In fact, she says CMU may be unique in that its computer science outreach to under-represented groups has a dedicated, continual funding stream. "In other places, with other programs, they're funded by grants—and when the grants go away, the programs go away," Blum says.

At the same time Women@SCS was created, CMU also received a National Science Foundation grant to fund outreach to high school computer science teachers. In a single year, the percentage of women entering the SCS undergraduate program shot from single digits to near 40 percent. In 2002, then-SCS Associate Dean Allan Fisher (CS'81, '85) and Jane Margolis, a senior researcher at UCLA, published "Unlocking the Clubhouse," a much-discussed book about the barriers faced by women pursuing CS degrees and ways to overcome them. (Much of their research was influenced by work being done at CMU, though Blum, Frieze and others say "Clubhouse" does not necessarily reflect current or past SCS practice.)

But the short-lived increase in women applicants couldn't be sustained; along with the end of the NSF outreach grant came the early 2000s dot-com bust, and the numbers declined. Today, the percentage of female computer science undergrads at CMU is about 25 percent. Yet Carnegie Mellon is still doing better than peer institutions, many of which have percentages near 10 or 15 percent.

#### 'Paint it pink'

Throughout the U.S. and Europe, women remain a distinct minority in computer science programs, and faculty such as Blum say some universities took the wrong lessons from the work done by Fisher and Margolis: They watered down curricula in attempts to get women to enroll in computer science programs. Blum calls it the "paint it pink" mentality—trying to attract women by emphasizing the uses of computer applications rather than the fundamentals of programming, systems and operation. "If you want to know how to create computer programs rather than just use them, that's not good," she says.

Blum has been working to increase the numbers of women in science and technology careers since she was a faculty member at California's Mills College in the early 1970s, where she helped launch the first computer science department at an all-women's college, and served as codirector of Mills' "Expanding Your Horizons" math and science conferences for high school girls. "In some ways, progress hasn't been as fast as I would have hoped," Blum says.

The reasons for the lack of progress are complicated and have social and political overtones. The American feminist movement of the 1970s was followed by a backlash in the 1980s from people who considered it a threat to traditional nuclear families. Dwindling budgets for social programs meant that funding for some early efforts to encourage women to pursue science and technology (such as federal resources made available through the Women's Educational Equity Act) faded away.



#### High-school CS classes fading, too

For that matter, few American high school students-male or female-are getting any formal education in computer science these days. As the 2010 study "Running on Empty" (The Link, Spring 2011) pointed out, public school systems facing budgetary pressures have focused on improving math and reading scores to the exclusion of programs that aren't subject to mandatory standardized testing. Computer science is treated as an elective, and along with art, music, social studies and foreign languages, it's among programs being de-emphasized. Elizabeth Davis, a junior CS major, says her high school in southern Maryland listed computing classes under "business technology"-as if computer science were a vocational course, like typing. She knew of only one girl that took the class. "I also remember expressing my desire to pursue something in the computing industry as a career path," Davis says. One teacher "looked at me like I was insane," she says, adding that she got the feeling that computer programming was viewed as "menial" work.

"When I was in sixth grade, I was good at math, but I didn't know that math was useful," jokes Amy Quispe, a CMU senior majoring in computer science. The Queens native was fortunate enough to attend New York City's Stuyvesant High School, which offers accelerated programs in math, science and technology. "It wasn't until then that I found out there was such a thing as computer science," Quispe says. "A lot of kids don't realize that it's even an option." Consequently, most middle- and high-school-age students are unlikely to learn much about computer science unless they explore it outside the classroom, where many of the people held up as tech pioneers or heroes-Facebook's Mark Zuckerberg, Microsoft's Bill Gates, Apple's Steve Jobs and Steve Wozniak-are white males. The lack of visible computer science role models for women and people of color is a serious problem, Jocelyn Goldfein, director of engineering for Facebook, told The Huffington Post. "I've come to basically believe this is a self-fulfilling prophecy," Goldfein told the website. "The reason there aren't more women in computer science is that there aren't very many women in computer science. You look into a computer science classroom and see mostly men and think, 'Oh, this classroom is not for me. I'm going to go find a class that has more people that look more like me."

It's true that all "STEM" fields have more men than women. According to "Women in STEM: A Gender Gap in Innovation," a 2011 report by the U.S. Commerce Department, although women make up 48 percent of the U.S. workforce, they hold only 24 percent of STEM jobs. But the problem in computer science is particularly acute and going in the wrong direction. Between 2000 and 2009, the number of women in STEM fields such as engineering and physical and life sciences went up slightly, while in computer science, math and information technology, the number of jobs held by women fell 3 percent.

link

And the problem in computer science is also odd because it's among the youngest of the scientific disciplines, and because there wasn't always such a big gender gap. Women such as Ada Lovelace and Grace Hopper are among computing's earliest pioneers. All of the programmers of the original ENIAC at the University of Pennsylvania were women.

Blum notes that those women made in-roads during World War II; following the war, there was a concerted effort to force women out so that male veterans could return to those jobs. Nathan Ensmenger, a professor of informatics at Indiana University who has researched historical reasons for the gender imbalance, says a variety of other factors also combined to discourage women from careers in computer science.

#### The roots of disparity

Many early computer programmers were recruited into "data processing" departments from secretarial pools, which were overwhelmingly comprised of women, Ensmenger says. As computers became more important, programming jobs grew in status and salary, attracting more interest from men. In attempts to professionalize the field, businesses began recruiting people who had four-year college degrees in science and engineering; in the 1960s, that favored men. And some male managers simply didn't want to trust their increasingly crucial computer operations to women, so they didn't hire them. "There is in computer science a kind of sexism and misogyny that's not deeply hidden under the surface," says Ensmenger, who has expanded his research into a book about the phenomenon called "The Computer Boys Take Over" (MIT Press).

There were other factors as well. In the '60s and '70s, programmers often were only allowed access to computers after the day's data processing was done—in the late evening and early morning. But because some colleges and corporations didn't allow women on the premises overnight by themselves (supposedly for "safety" reasons), the programmers were mainly young, single men. Working in isolated computer rooms away from other professionals, programmers cultivated images as rebels—unshaven, unshowered, uncouth, anti-social—spending time alone in dimly lit labs, fueled by junk food and rejecting anyone unwilling to live under those conditions as not dedicated to the craft. By the 1980s, the stereotype would be known as the "computer nerd" or "hacker." The stereotype continued long after it had any basis in reality, Ensmenger says. "Take other professions that we recognize as taking a lot of time commitment—medical students, for instance, work long hours and pride themselves on hard work, but they don't think being scruffy or nerdy is one of the required attributes for proving that you're smart or competent," he says.

#### Persevering in a 'very male culture'

That image of the stereotypical computer nerd, reinforced by movies and T.V., has attracted like-minded people while simultaneously discouraging women and many men from computer science careers. Gabriela Marcu, now a Ph.D. student in CMU's Human-Computer Interaction Institute, has first-hand experience with the stereotypes from high school and college. With encouragement from her mother (an engineer), Marcu took AP computer science in high school, "but almost nobody else took the class," she says. "At first, I thought they were a bunch of nerds, and I didn't want anything to do with it."

Later, when she got to college, she can remember the "atmosphere of male competitiveness." "Some of these guys had been programming since they were five," Marcu says. "Every class, every assignment, they had to prove everything they knew." Her early interactions with her mostly male classmates filled her with apprehension. "As a new student, that made an impact," she says. "I felt like, 'No matter how smart I am or how hard I work, I'll never catch up, they have so much more knowledge."

With encouragement from faculty, Marcu persevered. "I found out that computer science isn't just about programming, and those people who are super-duper technically and want to impress you with their technical skills generally have very limited knowledge in a certain area, and don't have great social skills," she says. Still, it took time for Marcu to shake the feeling that she was an outsider in the world of computer science. "It was a very male culture," she says. "It's not that I doubted my ability, but I felt like maybe it wasn't the place for me."

That feeling of being an "outsider" can become, as Goldfein put it, a self-fulfilling prophecy. "Numbers make a difference—people need to be able to see themselves in the field," Frieze says. The ratio of male to female computer science faculty also has a "subtle, not deliberate" effect, she argues. "Some women can go through an entire CS undergraduate program without ever having a female faculty member" as an instructor, Frieze says. As computers became more important in the 1960s and '70s, programming jobs grew in status and salary, attracting more interest from men. And some male managers simply didn't want to trust their increasingly crucial computer operations to women, so they didn't hire them.

#### Providing a visible support network

Raising the visibility of female and non-white computer scientists is an important goal of Women@SCS. At social and research events, students are encouraged to meet and collaborate with female faculty and alumni. Faculty and alumni also participate in OurCS, an annual three-day workshop sponsored by Women@SCS that allows female undergraduates to work together on problems in computer science, explore research opportunities and talk about graduate school. This year's workshop will be held Oct. 18– 20. Mary Ann Davidson, chief security officer for Oracle Corp., will be the keynote speaker, along with Manuela Veloso (CS'89, '92), CMU's Herbert Simon Professor of Computer Science.

In other networking efforts, Women@SCS matches incoming undergraduate women with mentors in a "Little Sister/Big Sister" program; sponsors regularly scheduled social hours (some, for both men and women, are billed as "no faculty allowed," so that students discuss issues frankly); and provides financial support for students who want to attend conferences such as the annual Grace Hopper Celebration of Women in Computing.

"It's nice to have female friends who share many of my interests and are in the same classes as me, or have taken the same classes before," says Madeleine Clute, a CS junior from Concord, Mass., who chairs Women@SCS's outreach committee and also volunteers at TechNights. Clute, who came to CMU as a cognitive science major, wishes she had been exposed to a program like TechNights when she was in high school. "I was always under the impression that computers ran off of magic," Clute says. "Once I figured out that I could do this, too, I said, 'Hey, it's not magic, it's logic.""

Providing a network of people who share common experiences is important to professional development in ways difficult to quantify. As Blum points out, being in the majority in a group offers professional advantages not available to those in the minority. When she was deputy director of the Mathematical Sciences Research Institute at Berkeley, Blum remembers how on Monday mornings, her male colleagues would be excited about new findings, theories and gossip that female co-workers didn't know about. It wasn't that they were consciously excluding women; it's just that when they socialized together on the weekends, they shared information.

"If you're the only woman out of eight students, how do you find out about things?" Blum says. "If you're the only woman out of eight students in your class, who do you call up for help on a problem? ... The advantage of being in the majority is that you're part of a network, you have connections."

Some students say they've become inured to the gender imbalance and adapted. "It bothers me on a conceptual level, but it doesn't really bother me on a day-to-day basis," Clute says. "I had a lot of male friends growing up and I've never had a problem jumping in and making people pay attention to me." More importantly, she feels SCS provides a nurturing environment that allows her to assert herself.

She adds: "It might be at this point I'm just completely used to be surrounded by guys. When I go home I look around and say, 'Why are there so many women here?"

#### **Blum: No special treatment**

There has occasionally been a backlash against SCS's efforts to address the gender gap. When SCS first began its outreach efforts, Reddy asked admissions counselors to broaden the criteria for accepting undergraduates. In addition to high academic performance, he asked them to look for students with leadership potential. Because students who had developed coding skills on their own tended to be male, prospective students were told that no prior programming experience was necessary. "People were calling and complaining, 'All of these women are taking the place of my son," Blum says.

That's why it was important, she says, for SCS not to water down its curriculum to appeal to supposed gender differences. Some researchers, for instance, have suggested that women are more interested in applications and interface designs, while men



are more interested in coding and hardware. Blum says her own research, as well as 40 years' experience as an educator, disproves those theories.

"There are not intrinsic gender differences," she says. "There are internal differences within genders. There is a spectrum, where some men like coding, and others like applications, and some women like coding, and others like applications." Trying to target perceived gender differences is "counter-productive," Blum says.

Frieze, who has collaborated with Blum on research into gender imbalances in computing, surveys CMU undergraduates on a variety of topics, and says the differences between men and women are statistically insignificant. "We're up against this argument that 'Men are from Mars, women are from Venus.' I'm not in that camp at all," she says. Many perceived gender differences are the result of cultural and environmental conditioning, she maintains. "The good news is that if you're up against culture, culture can be changed. Sometimes it's very slow, but it can be changed."

#### Changing the culture

For volunteers in Women@SCS, one way to change the culture is by reaching out to younger children at elementary, middle and high schools in the Pittsburgh area through roadshows and TechNights. Blum calls it "proselytizing" for computer science. "Our students do a lot of outreach," she says. "So many of them say, 'I never realized computer science was so great, and I don't want these high school kids not thinking of it.' They feel a duty to go back and share it, because they don't want anyone else to miss out."

Getting kids excited about computer science means "showing off the magic," says Kenny Joseph, a Ph.D. student in the Institute for Software Research who volunteers through Women@SCS to work with students in grades six through eight at the Pittsburgh Science and Technology Academy, a public school not far from the CMU campus. That includes demonstrating computer science and robotics with experiential, hands-on methods, such as the Alice software developed at CMU.

One bit of "magic" that never fails to thrill middle schoolers was created by Blase Ur, a Ph.D. student in computer science, who put specially engineered Ardunio microcontrollers into a variety of household appliances that allow them to be operated remotely from the children's PCs using BYOB, a custom implementation of Scratch a programming tool developed at MIT for use by kids. "Tve never seen kids so excited as when they turn on a toaster oven from across the room and melt cheese," Joseph says, with a grin. "When I see the kids smiling and engaged, I know they're enjoying themselves."

With kids who aren't yet in high school, it's a little early to

discuss the merits of computer science as a career, he says. But it's not too early to demonstrate the benefits of solving problems using computational thinking, or to show kids that they have the power to invent and control technology, rather than just being passive consumers. "Part of it is just trying to push these kids who would otherwise not be exposed to this kind of thinking," Joseph says.

Yet even among preteen kids, it's hard to smash the perception that computer science is something for white folks. Joseph, who's researching social networks, has noticed among his middle schoolers less of a gender divide than a racial divide. "You can kind of see kids sometimes looking at an activity like they want to try it, but aren't sure they should," he says. "It sometimes comes down to, 'Are my friends doing that activity? No? Then I can't do it."

Joseph's observation is important, says Ensmenger, the IU professor. "There's a restricted range of masculinity for young African-American men," he says. "To be seen as a computer 'geek' is seen as behaving 'white." The cultural pressure closes off entire career paths to young men of color, Ensmenger says. "There's no job today that's not mediated by computers in some way, and therefore it's really important to change that," he says.

Joseph hopes the outreach helps chip away at stereotypes. "It boils down to the fact that there are lots of kids who would be really good at this, but if they don't have the perception that they should try it, they're never going to find out they enjoy it," he says.

#### Peer pressure a factor

If it hadn't been for a similar outreach program, Margaret Schervish wouldn't know that she enjoyed computer science. Schervish was encouraged by her father, Mark, a CMU statistics professor, to participate in Andrew's Leap, an SCS summer enrichment program for high school students. "I thought it was going to be nerd camp," Schervish says. But she thrived and made friends with one of the other girls in that summer's group. "She's now at CMU, too," says Schervish, a senior majoring in computer science and math.

Schervish, who was attending Pittsburgh's all-girls Ellis School, remembers experiencing some culture shock when she entered a co-educational setting. "Some of it was just high school boys being high school boys," she says: Loud, boisterous, pulling pranks and discussing video games. "To tell you the truth, it turned me off, but a group of women acting like that would have turned me off, too."

Later, when Schervish took a discrete math course at CMU as a pre-college student, "there were all of these guys in the class answering questions, and I just remember being shocked because I didn't remember that guys could be good at math, too."

Many of Schervish's high school classmates who pursued careers in science have gone into biology or chemistry, she says. The Ellis School offered computer science classes, she says, but "maybe four kids signed up every year. It was seen as kind of strange to take (computer science), like, 'Why are you interested in that?"

Schervish's story illustrates another reason that computer science can be a difficult place for women—female students feel pulled in different directions. On one side, they're pressured to conform to cultural stereotypes of femininity. On the other, they're pressured to conform to the perceived "nerd" culture and act less feminine.

For instance, Davis has heard women criticize other women for pursuing research in so-called soft areas of computer science, such as interface design. Men don't face that same criticism, she says. Davis compares it to an XKCD comic strip by cartoonist (and roboticist) Randall Munroe. In the first panel, two male stick figures are working on an equation. "Wow, you suck at math," one of the stick figures says when his partner makes a mistake. In the second panel, a male stick figure and a female stick figure on working on the same problem. "Wow, girls suck at math," the male figure says when the female figure makes the exact same mistake. Munroe's point? Things that escape notice when men do them are assumed to be "typical" female behavior when a woman does them.

"The only people I've felt discrimination from has been other females," Davis says. "I wonder how many women in technology feel the same way."

Female students feel pulled in different directions. On one side, they're pressured to conform to cultural stereotypes of femininity. On the other, they're pressured to conform to the perceived "nerd" culture and act less feminine.

she says. "It's almost easier to disregard people who are doing something malicious because they're trying to get to you, than to work with someone who you like, and try to tell them that something they intrinsically believe is messed up."

In computer science culture, women who wear makeup or seem "pretty" can be perceived as being less serious about their work—including among other women. "Even when women feel comfortable being feminine, the extra attention they get for looking different than the norm is still a reminder of that feeling they don't belong," Marcu says. "It's nice when people compliment me on my appearance, but it makes me feel like an alien sometimes. It's like you put on a decent set of heels and a skirt and everyone's like, 'Holy cow."

#### **Building on the positives**

As important as it may be to identify and root out gender or racial disparities, students say it's also important not to spend too much time looking for negatives. Marcu attended one conference for women in computer science in which participants told horror stories about sexual harassment, pay inequities and mistreatment. "It was just lots of negativity," Marcu says. "It felt like they were trying to scare women out of going into computer science."

Women@SCS "is not a support group for people to complain about sexism in computer science," Quispe says, "but it is definitely an outlet for me to feel better about being a woman in computer science."

Word about Women@SCS has spread, says Frieze, who has shared material developed at CMU with universities throughout the United States and around the world. "CMU has a reputation for paying attention to gender balance, but one of the things I have to always convince them of is that we don't do anything special for women," she says. That philosophy drew Marcu into the group in the first place. "I believe so strongly in what Carol is doing," says Marcu, who served as coordinator of SCS's Graduate Women's Mentoring Program and currently speaks at Women@ SCS roadshows. "Networking benefits women, not so that we can get together and talk about 'women's issues,' but because seeing people who look like you is very important." Hearing prominent female computer scientists talk about their experiences is important as well, she says: "It helps me envision someday being in their place."

For Schervish, Women@SCS is not just her link to female faculty and students—it's her link to her college and to the university. "There are so many people in SCS that I don't

know, but I feel so connected to it because of Women@ SCS," she says. "It's made me feel like I'm not an outsider."

Marcu says that through the activities promoted by Women@SCS, the group practices the inclusiveness it preaches. "Men are involved in Women@SCS—highly involved—in things we do," she says. "I'm not interested in having 'more women' in computer science, I'm interested in diversifying it overall."

#### What's the payoff?

Does diversity in both gender and race lead to smarter technologies and computing products? It's hard to say, although there's anecdotal evidence that the myopia caused by lack of diversity can lead to product flops. Some of the e-commerce shopping sites that went bust during the early 2000s dot-com boom were designed from the perspective of male engineers, Ensmenger says. "They were focused on creating the least difficult means possible of acquiring something, and that's not what shopping is for most people. It can be fun, it can be social. People wanted more out of (e-commerce) than just what a male engineer might want."

There are more recent examples: In 2009, reports circulated that cameras with face-detection technology were having a hard time detecting the faces of dark-skinned people. Last year, venture capitalist Marc Andreessen, co-creator of the Mosaic browser and co-founder of Netscape, told Fortune Magazine that he ignored the potential of Pinterest until a female researcher urged him to spend some time with the site. His firm then invested \$27 million. Too many computer technologies, Andreessen noted ruefully, have been "initially aimed primarily at men."

"If you're going to have successful social networking technologies, e-commerce, medical diagnostics, then we need to have systems designed for a broader perspective," Ensmenger says. "If we have systems designed not only by males, but by a particular kind of white male who defines himself in terms of his 'nerdiness,' we're going to have problems."

Computer scientists often talk of the potential of their work to change the world. If that's true, then, logically speaking, changing the population of computer scientists will eventually have a multiplier effect that will ripple through society. Women "need not only to be a part of the culture, but contribute to shaping the culture," Frieze says. "The idea is not simply diversity for diversity's sake or diversity for women's sake. It's become clear that diversity is important to the industry." →

-Jason Togyer (DC'96) is editor of The Link.

### Polly spreads the word: Delivering information to a low-literacy audience using viral methods

By Agha Ali Raza and Roni Rosenfeld, *Language Technologies Institute, CMU* and Farhan Ul Haq, Zain Tariq, Mansoor Pervaiz, Samia Razaq and Umar Saif, *Lahore University of Management Sciences, Lahore, Pakistan* 

Editor's Note: Portions of this article are adapted from the paper "Job Opportunities Through Entertainment: Virally Spread Speech-Based Services for Low-Literate Users," to be presented at the ACM SIGCHI Conference on Human Factors in Computing Systems, where it will receive a Best Paper Award.

The ACM SIGCHI Conference on Human Factors in Computing Systems will be held April 27 to May 2 in Paris, France (http://chi2013.acm.org).

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In 2011, we developed a simple-to-use, telephone-based entertainment service called Polly that allowed any caller to record a short message, choose from several entertaining voice manipulations, and forward the manipulated recording to their friends.

Introduced among lowskilled office workers in Lahore, Pakistan, within three weeks Polly had spread to 2,000 users and logged 10,000 calls. We eventually shut it down due to insufficient telephone capacity and unsustainable cost. In analyzing the traffic, we found that Polly was used not only for entertainment but also as voicemail and for group messaging, and that Polly's viral spread crossed gender and age boundaries—but not socio-economic ones. This experience demonstrated that it is possible to virally spread a speech-based service in a population with low literacy skills, using entertainment as a motivation. We then asked: can we leverage the power of entertainment to reach a large number of illiterate people with a speechbased service that offered a "payload"—a valuable service such as:

- Facilitating an efficient marketplace (a speech-based "Craigslist");
- Facilitating social and political activism (speech-based message boards and blogs);
- Sending and receiving group messages (speech-based mailing lists); and
- Citizen journalism

All of these services are available in written form via the web or text-messaging services. But very few such services are currently available to people with low literacy skills.

#### **Previous attempts**

Several attempts have been made to design user interfaces for users with limited reading and writing skills who are inexperienced with technology.

For instance, in 2007, some of the same researchers on the Polly team created Project HealthLine. Their goal was to provide telephone-based access to reliable spoken health information for low-literate community health workers in a rural province of Pakistan. The speech interface performed well but required training via human-guided tutorials.

Avaaj Otalo (2010) is another successful example of a speech interface serving users with limited literacy—in this case, farmers. Avaaj Otalo is a telephone-based system that offered an open forum where users could post and answer questions; a top-down announcement board; and an archive of previously broadcast radio shows. The most popular service turned out to be the open forum, constituting 60 percent of the total traffic. Users found other interesting but unintended uses for Avaaj Otala, such as business consulting and advertisements.

But such projects have typically required explicit user training. As a result, they're restricted to a moderate number of users. When dealing with a large user base, explicit training is not feasible. One alternative to such training is to rely on learning from peers, and on viral spread.

Voice-based media can also promote social inclusion among underserved communities. In 2012, Preeti Mudliar, Jonathan Donner and William Thies examined participation in citizen journalism among rural communities in India using CGNet Swara, an interactive voice forum. CGNet Swara enabled users to record and listen to messages of local interest and became popular among the target audience. With CGNet Swara, only an initial set of a few dozen users received training. The rest of the users learned about it by word of mouth.

### The viral loop, and the power of entertainment

Ed Baker, the co-founder and CEO of Friend.ly, has described what he calls the "viral loop." To spread virally, according to Baker, a technology must create a catchy call to action; create incentives for users to invite their friends; and maximize the average number of invites that users make to unlock those incentives.

A successful example of a cellphone-based service that has spread virally is SMS-all, a group text-messaging service in Pakistan. People use SMS-all to share information and discuss hobbies and other interests. As of last report, the service had more than 2 million users and 400,000 groups, and had delivered more than 3 billion messages.

In 2010, Thomas N. Smyth, Satish Kumar, Indrani Medhi and Kentaro Toyama provided a demonstration of the power of entertainment. In their paper "Where There's a Will, There's a Way: Mobile Media Sharing in Urban India," they describe a thriving black market in entertainment media on low-cost mobile phones, and highlight the remarkable ingenuity exhibited by users when they are motivated by the desire to be entertained.

Armed with these examples, we set out to develop an entertainment-driven telephone-based service that would spread virally among users with low-literacy skills.

#### Introducing Polly

Polly is a telephone-based, voice-based application that allows users to make a short recording of their voice, modify it and send the modified version to friends. In Urdu, Polly is called "Miyan Mithu," which has a meaning similar to "Polly the Parrot."

Manipulations offered by Polly include converting a voice from "male to female" or "female to male" by altering the pitch; a "chipmunk" effect, achieved with pitch and tempo modifications; an "I-have-to-run-to-the-bathroom" effect, achieved by a gradual pitch increase; converting the voice to a "whisper"; or adding background music. Polly is a telephone-based, voice-based application that allows users to make a short recording of their voice, modify it and send the modified version to friends. In Urdu, Polly is called "Miyan Mithu," which has a meaning similar to "Polly the Parrot."

The system we used in the current study was substantially upgraded from the one first deployed in 2011. Among other changes, we increased our telephone capacity to handle up to 30 concurrent phone calls; and concentrated the software on one server in Pakistan, reducing the cost of our outgoing call airtime from \$0.126 per minute to \$0.023 per minute. In addition, we allowed users to skip many of the menus. Extensive call logging and real-time monitoring capacity also were added.

The most important advance was the addition of a development-related application to Polly's menu—what we call "the payload." This was the option to browse audio descriptions of job openings suitable for low-skilled, low-literacy workers. We collected such job descriptions from Pakistani newspapers and recorded them in Urdu.

#### How Polly works

Calls to Polly can be made via a toll-free number or a caller-paid number. Early in the interaction, users are prompted to make short recordings of their voices. A funny voice transformation of the recording is immediately played back. The user is then offered the options to hear the recording again, re-record, try another effect, forward the recording to friends, give feedback about Polly or listen to the latest job ads. Those ads can be skipped, repeated, browsed and forwarded to friends.

The recipient of a message can record a reply, forward the recording to others, create their own recordings or listen to job ads. As an additional mechanism for viral spread, text messages containing Polly's contact information are sent to all of Polly's recipients on their first two interactions with the system. Polly's phone number is also played during the phone call itself.

#### The experiment

Polly was seeded on May 9, 2012, by placing automated calls to five of the most frequent callers from Polly's 2011 study. These calls briefly announced that Polly was back online. No attempt to further promote the system was ever made. Polly has been up continuously since then with minimal interruptions.

We studied 130 days of Polly operations between May 9 and Sept. 15, 2012. During that period, Polly had more than 495,000 telephone interactions with 85,000 users. Most users interacted with Polly only a few times over a few days. Average call duration was 160 seconds.

During this period, we recorded a total of 530 suitable job ads, an average of 28 ads per week. These ads were listened to 279,000 times—all by user initiative. That equates to more than 525 playbacks per ad, possibly more than the number of people who read that ad in a newspaper. Some ads were heard much more than others—the most popular ad was listened to more than 8,400 times, and 73 ads were listened to more than 1,000 times each.

A total of 23,288 requests were made to deliver a particular job ad to another user. Such job ads were delivered to 9,475 different users. Of such interactions, more than half requested only job ad delivery—that is, they didn't send a "fun" Polly message—indicating that the user probably called Polly specifically to interact with the job ad service.

With an outgoing airtime cost of \$0.023 per minute, and with average interactions lasting about three minutes, Polly during its peak cost us \$400 per day in airtime alone. We didn't want to eliminate the toll-free option because that would bias the user base away from the low-income people who are our prime target. So we experimented with limiting the number of times users could call the toll-free service per day. Each time we tightened the quota, usage of the caller-paid service spiked.

#### Surveying users

After the study period, we called 207 randomly chosen users of Polly to collect demographic information. Out of these calls, 106 resulted in useful information of some type. Although 57 percent of respondents browsed Polly's job ads, only a handful reported applying for those jobs. Two users claimed that their friends got jobs through Polly, but we were unable to verify this.

Respondents who described their primary use of Polly as "fun" gave examples such as making prank calls to friends, sending birthday greetings or hello messages, and browsing job ads as a pastime. Four sight-impaired users defined Polly as an "alternative to text messaging" and praised it profusely.

Among positive feedback for the job ad service, one man said (loosely translated) "after all that is going wrong with the country...well, at least we have Polly...God bless Polly and may the service continue forever."

#### Conclusion

This was our first attempt to add a development-focused service—a "payload"—to Polly's offering. We found that users took to the new offering in large numbers, and that many started calling Polly specifically for job information exactly the result we hoped for.

Why did only a handful of the users we interviewed apply for jobs? We attribute this to lack of trust or lack of interest. We believe we can correct the "lack of trust" by co-branding the ads with the names of familiar government organizations or newspapers. We believe we can correct the "lack of interest" by exploring more job types (e.g., jobs for the handicapped) to serve a wider selection of people.

Usage of Polly grew exponentially because every user, on average, spread the system to more than one new user. Since the target population is measured in the tens or hundreds of millions, volume will grow exponentially for quite a long time, limited only by the system's carrying capacity.

However, usage over time is marked by rapidly declining interest among most users. This was expected given the unchanging nature of the entertainment. In the short term, we are working to increase repeat usage by varying the entertainment content. In the long term, we believe that a diverse "payload" of useful services will retain users, with entertainment being used mainly to spread to new ones.

Is the service cost-effective? The jury is still out. Cost efficiency can be achieved not only by getting the users to pay for airtime, but also by the use of ads, carrier revenue-sharing and/or content sponsors (e.g., governments or NGOs). We are exploring all of these options. →

Usage of Polly grew exponentially because every user, on average, spread the system to more than one new user. Since the target population is measured in the tens or hundreds of millions, volume will grow exponentially for quite a long time, limited only by the system's carrying capacity.

# Building our legacy with you

#### By Tina M. Carr



The School of Computer Science

turns 25 this year. Although SCS is the youngest of CMU's seven colleges, its history stretches back to the 1950s, and is intertwined with our other colleges and schools, including CIT, MCS and Tepper.

As a result, our events for computer science alumni are an interesting

mix of people—many of the alumni who attend are undergraduate or graduate alumni from the 1990s and

2000s, but often we get people who graduated in the 1970s or '80s with a "math-CS" degree.

At our March 24 alumni brunch in Austin, Texas, I met a 1967 CIT electrical engineering alumnus from San Antonio who had been a member of what was then called the "digital circuits" group (as opposed to the "analog circuits" group).

The Computer Science Department was only two years old at that point, and it only granted graduate degrees. As our alum was recounting it, the "digital circuits" group was more "computer-y," and therefore he considers himself part of SCS. (The distinction between "digital circuits" and "analog circuits" was eliminated the following year, he told us.)



Left: SCS Dean Randy Bryant, alumni Derek Beatty (CS'93) and Larry Huang (E'91), and ECE professor Onur Mutlu

Right: About 60 people attended our SCS and ECE alumni luncheon on March 24 in Austin, Texas.



**It's really rewarding** to hear those kinds of stories. When our alumni get together, we hear a lot of different professional experiences as well as different life experiences. I've now been privileged to serve as the SCS alumni director for 13 years, and I've been fortunate to watch our alumni grow both professionally and personally. It's amazing to meet someone as a new undergraduate, see them wrap up a Ph.D., and then return to an alumni event with their spouse and children.

By the way: Most of our events are family-friendly. We've had events at science centers and art museums, as well as boat cruises and barbecues by the ocean.

Usually, both SCS dean Randy Bryant and ECE department head Ed Schlesinger attend our events, but we also have special faculty speakers. In Austin, we hosted Onur Mutlu, CMU's Dr. William D. and Nancy W. Strecker Early Career Professor of Electrical and Computer Engineering. Onur gave a very accessible talk about his current research in computer architecture and industry partnerships that was interesting and well received. Generally speaking, when our alumni attend events, they have a lot of questions—have there been changes in classes or courses? Do they still have 15-212 and 15-213? What new faculty have we added? Who's still there?

But other times, they really just want to enjoy some "face time" with one another and say, "Hey, how have you been, I haven't seen you since then." These days, they're likely to be connected through professional organizations or through social media networks such as LinkedIn, Twitter, Facebook, Tumblr, etc., but they're always looking to grow their connections. So many of them are working on startups or hiring people for their businesses that alumni connections are a fast way for them to reach out and find qualified people.

Incidentally, that's one of the reasons we invite and encourage current CMU students to attend our summer events. If they haven't graduated yet, students don't always understand why alumni associations are important. We like to get current students involved so that they can meet our graduates and say, "Hey, this is a really diverse group, a cool bunch of people, who do a lot of different things."



#### Alumni By Geography DOMESTIC\*—TOP TEN (by city)

#### INTERNATIONAL\*—TOP EIGHT (by country)



\*As of October 2012

\*As of October 2012

These days, we're also connecting alumni with prospective students who are thinking about attending CMU. For the past few years, we've held receptions in the San Francisco Bay area for high school students who have been accepted to CMU but haven't yet decided to attend. We encourage them to talk to recent graduates about what the student experience is like, and think about what it would be like to attend SCS. (Of course, we want them to choose CMU— if it's appropriate for them.)

We do the same thing for prospective graduate students connecting them to recent Ph.D. alums, encouraging them to ask questions such as what was CMU like, what faculty did you work with, and how did you choose your career path. (Incidentally, if you're looking for a way to volunteer for an alumni activity that's fun and mutually beneficial, this is a nice way to do it. Email me and we'll connect you with someone.)

As the School of Computer Science enters its second quarter-century, we're starting to develop "legacies" students who are now the second generation of their family to attend SCS. Fostering these legacies will be important to maintaining and expanding our tradition of excellence.

SCS Alumni At-A-Glance\*

Total Alumni: 6,346

**OK**, **so what's new?** By now, you should have received two installments of our new alumni e-newsletter, "Bytesize." If you haven't, make sure to register in CMU's online alumni community, or at least send me your current email address. We know you get a lot of email, so we're trying not to spam you—and that's why we've kept "Bytesize"... well, bite-size.

What else? By the time you read this, our LinkedIn community should be up and running. With this new addition, you'll be able to connect with the SCS community on four major media platforms—Facebook, Twitter, Google+ and LinkedIn. That should leave us pretty well covered (until one of our alumni invents another social media technology).

As always, your feedback makes a big difference when we're planning new events and services for our alumni. Do you have an idea, a suggestion or a comment? Please drop me a line. And I look forward to hearing your stories the next time we're in your town! →

Time m Car

Tina M. Carr (HNZ'02) Director of Alumni Relations tcarr@cs.cmu.edu



\*As of October 2012

## **giving back:** Pradeep Sindhu

#### By Mark Dorgan

As founder, vice chairman and chief technology officer of Juniper Networks, Pradeep Sindhu has his eyes on sustainable business models and the bottom line. But Sindhu (CS'83, '84) remains a computer scientist at heart, with an interest both in the design of complex systems and in the work of the School of Computer Science. Recipient of an alumni achievement award in 2008, Sindhu says he values the connections he maintains with SCS.

In his role as Juniper's CTO, Sindhu is responsible for outlining the company's technical needs and developing future projects. Among the most important benefits of his CMU education was the foundation it provided for his career—a solid grounding both in the fundamentals of computer science and the technologies behind computer systems.

His involvement runs deep at SCS, from supporting a graduate fellowship, to hosting CMU's Silicon Valley Network Night events at Juniper's Santa Clara facilities in 2012 and 2013, to speaking on campus and facilitating delivery of Juniper's networking equipment to the Gates and Hillman Centers.

Sindhu says his involvement is motivated by a desire to give back and share his experiences. That's been manifested in gifts such as the one that created the Pradeep Sindhu Graduate Fellowship to provide support to a graduate student in the Computer Science Department. "It's a great way to stay in touch with students who are experiencing the rewards and challenges of earning a Ph.D.," he says.

Severin Hacker, a recipient of the Sindhu fellowship, had the opportunity to meet Sindhu during his visit to campus in the fall of 2011. "Pradeep Sindhu stands not only for outstanding technological achievement, but also exceptional entrepreneurial achievement," Hacker says. "Given Pradeep's professional and technological accomplishments, I'm very grateful to receive the Sindhu Fellowship."

Hosting Network Nights provides Sindhu with a way to help CMU build its presence in Silicon Valley—where a large number of alumni work and live—and promote the university's Southern California campus. Juniper's



involvement for two consecutive years is a direct result of Sindhu's interest.

"CMU depends on its alumni for continued success," Sindhu says. "I feel strongly that alumni owe it to CMU and SCS to stay involved and provide philanthropic support."

Nearly 48,000 donors have made almost 222,000 individual gifts to the university as a part of Carnegie Mellon's "Inspire Innovation" Campaign, which has now raised \$1.11 billion. About \$560.3 million has gone into the university's endowment.

Until June 30, you can be a part of this historic milestone for CMU. To find out how you can help the School of Computer Science through scholarships, fellowships, faculty support or gifts to the Gates and Hillman Centers, please contact me at mdorgan@cmu.edu or call me at 412-268-8576. You can learn more about the Inspire Innovation campaign by visiting www.cmu.edu/ campaign. →

*—Mark Dorgan is executive director of major gifts and development liaison for the School of Computer Science.* 

### Stefanie Tomko

B.A., linguistics, University of Washington, 1996M.S., computer science, Carnegie Mellon University, 2001Ph.D., language technology, Carnegie Mellon University, 2007



Stefanie Tomko designs speech recognition systems. So it's a little bit surprising when she says, "You don't have to speech control everything." Do your ears deceive you? No, you heard right. Tomko, senior

Tomko, senior program manager in Microsoft's Windows Embedded

Connected Car Technology Group, says speech recognition, or voice-command, systems need to offer clear advantages over traditional knob-and-button interfaces. "Take your radio volume control," she says. "It's been around forever, and everyone knows how it works. You turn it one way to go up and the other way to go down. But volume control is a terrible thing to use speech for, because now you have to say something like, 'volume up' or 'volume down,' and you don't know exactly how much the system is going to increase it."

If you've ridden in a late-model Ford or Kia with voiceactivated controls for phones, music, navigation or climate control, you've seen and heard the work done by Tomko and her team. Their focus is making sure that the interaction is just right. "The more it's 'blabbering,' the less useful it is," Tomko says. "In a vehicle, speech recognition has to be designed to minimize distractions. We need to make sure it 'plays nice' with the visual user interface. It can't just be tacked on top."

Many of the problems of speech recognition—such as filtering ambient noise—have been "reasonably solved," she says, but difficult problems remain. "Right now, dealing with nonnative speakers of a language is a big challenge," Tomko says. "The other big challenge is making it intuitive—not necessarily that it understands everything I say, but that when it doesn't, the user doesn't fall off of a cliff." She describes a navigation system currently being beta tested. When a beta user said "cancel" to erase a destination, "it canceled the speech interaction, not the destination," Tomko says.

Anticipating those kinds of scenarios is a major focus of her team, she says: "When something goes wrong, we need to make it as minimally frustrating as possible."

Tomko came to computer science via linguistics. "I was an English major, and there was never any 'right' answer," she says. "As long as you made a coherent argument, it was OK. In linguistics, we had problem sets, and I had to work them out, and I thought: 'I like doing things where you work hard and solve a problem at the end." Tomko came to CMU to earn her master's and Ph.D. in the Language Technologies Institute, where she worked with Roni Rosenfeld, CMU professor of language technologies, machine learning and computer science, on a universal speech interface that could respond to user interactions and then shape the syntax of the user's input by varying the syntax of its own responses.

"Roni was a great adviser, because he always had challenging problems and interesting suggestions for ways of thinking about things," Tomko says. "He also was very good about providing networking opportunities, and as a student just getting into the field, it was good to have people to whom you could reach out and say, 'Roni introduced us.""

At Microsoft, Tomko works with many SCS and ECE alumni, including her husband, Dan Gaugel (E'01). The couple lives in suburban Seattle with their children Alex (3) and Theo (5). Tomko had a moment in the national spotlight in 2009, when she won more than \$43,000 as a two-day champion on the syndicated game show "Jeopardy!" And she recently took up running again a sport she enjoyed while at CMU, when she completed four marathons. Tomko did a half-marathon in November and is hoping to do a full marathon later this year. "Ideally, I'd like to run a marathon in every state," she says. It's one of the reasons Tomko misses Pittsburgh: "I had many more states that I could easily drive to." →

-Jason Togyer (DC'96)

the link.

# Séan Slattery

B.A., computer science, Trinity College, Dublin, 1993 M.S., computer science, Carnegie Mellon University, 1998 Ph.D., computer science, Carnegie Mellon University, 2001



A career in the financial sector? For a guy who grew up in the small city of Port Laoise in the Irish Midlands ("it was kind of like the U.S. Midwest—think Ohio") the idea left Séan Slattery cold. "It's got this kind of Hollywood reputation, and I had visions of people on these highpressure trading floors, shouting at one another," he says.

Instead, when Slattery finished his Ph.D. at CMU, he went to work at a startup in London that was developing a new search engine. "I hung on there for about two years, but when they started having redundancies, I decided it was time for me to start looking around," he says. He ended up in "The City"—London's financial sector—where he found a different environment than he'd envisioned. It appealed to his love of problem solving, and puzzles.

"When I was a kid, I used to go to the library, and when I was finally allowed to join the adult library, I discovered all of these books of puzzles by Martin Gardner from Scientific American," he says. "I loved them. I ended up tearing through them, and that's when I first realized I had an aptitude for that kind of thinking."

In his current role as head of emerging markets, commodities and FX quants, Americas, for Credit Suisse Group AG, the puzzles that Slattery's group is solving require deriving the fair prices for financial instruments known as derivatives, and then minimizing the exposure to risk for the company and its clients. "We're writing the core calculations that get slotted into other pieces of software," he says. "We're running these calculation engines by writing formulae that require a really deep understanding of how financial maths work. There's a lot of software in investment banking these days, and it requires a lot of attention to detail—to 'getting it right'. It also requires very strong programmers."

The basic skills that Slattery learned while working on his doctorate in computer science are the skills he uses every day, he says, adding that Tom Mitchell, CMU's Fredkin Professor of Artificial Intelligence and head of the Machine Learning Department, was an important influence. "One of the things I really admired about Tom is that he was very, very good at cutting to the core of any problem and defining what the important pieces were, and what the unimportant distractions were," Slattery says.

Slattery earned his undergraduate degree at Dublin's Trinity College and was attracted to CMU because one of his classmates, Joseph O'Sullivan (CS'97), had gone there. "I knew it was a tough school, but we didn't quite have the Web then, so I had written a letter asking for literature on the master's program," he says. "They wrote back and said, well, we don't have a stand-alone master's program right now, but why don't you apply for the Ph.D. program?"

He was glad he did. "Both Carnegie Mellon and Pittsburgh were good places to be," Slattery says. "Pittsburgh is a wonderful place. It's a proper city, but it's a very manageable scale, and then Carnegie Mellon had a family atmosphere that was very encouraging to my research."

Slattery's busy schedule doesn't leave a lot of room for hobbies, though he and his wife, Gordana, do have a passion for cinema. "My tastes range from classics like 'The Third Man' to the kinds of stuff that you would classify as 'bad movies," he says. →

—Jason Togyer (DC'96)

#### TWO WITH CMU TIES WIN TURING AWARD

Two researchers with ties to both Carnegie Mellon University and SCS professor Manuel Blum have received the A.M. Turing Award from the Association for Computing Machinery.

Shafi Goldwasser (CS'79) and Silvio Micali, both affiliated with MIT's Computer Science and Artificial Intelligence Laboratory, are co-recipients of the 2012 Turing Award for their work to take data encryption from theory to practice.

They will receive the award—sometimes called the "Nobel Prize of computing"—at the ACM's annual banquet June 15 in San Francisco. The Turing Award carries a \$250,000 prize, with financial support from Intel and Google.

Goldwasser is a 1979 graduate of Carnegie Mellon with a B.S. in mathematics who earned her M.S. and Ph.D. in computer science from the University of California at Berkeley.

With the win, Goldwasser becomes the 12th CMU affiliate—including faculty and alumni—to be honored with a Turing Award. Named for artificial intelligence pioneer Alan Turing, the very first Turing Award was presented in 1966 to Alan J. Perlis, founding head of the Computer Science Department at what was then the Carnegie Institute of Technology.

Micali is a graduate of the University of Rome who also earned a Ph.D. at Berkeley.

Goldwasser and Micali were advised at Berkeley by Blum, himself a Turing Award winner in 1995. Blum, formerly a professor of computer science at



Goldwasser and Micali

Berkeley, came to CMU in 1999 and currently serves as the university's Bruce Nelson Professor of Computer Science.

In honoring Micali and Goldwasser, the Turing Award committee said the pair "laid the foundations of modern theoretical cryptography, taking it from a field of heuristics and hopes to a mathematical science with careful definitions and security models."

The results they have achieved, working together and with others, "established the now-standard definitions of security" for encryption and digital signatures, the award committee said, adding that Goldwasser and Micali established the "tone and character of modern cryptographic research." Their work in collaboration with other researchers has "provided stunning innovations," the committee said.

Goldwasser is a two-time winner of the Gödel Prize presented by the

European Association for Theoretical Computer Science and the ACM's Special Interest Group on Algorithms and Computation Theory. Her 1993 Gödel was shared with a team that included Micali.

Micali has been a regular visitor to the CMU campus. In February 2000, Micali presented a paper on "certified email" as part of the SCS Distinguished Lecture Series, and in 2004 and 2011, Micali spoke at theory seminars held by CMU's Center for Algorithm Adaptation, Dissemination and Integration. He currently serves as Ford Professor of Electrical Engineering and Computer Science at MIT.

Goldwasser is the RSA Professor of Electrical Engineering and Computer Science at MIT and also a professor of computer science and applied mathematics at the Weizmann Institute of Science in Israel. →□

#### SCS, TEPPER CENTERS JOIN FORCES TO HELP ENTREPRENEURS

Two change agents on the CMU campus have joined forces to help students and faculty bring their ideas to market.

Project Olympus and the Donald H. Jones Center for Entrepreneurship are partnering to form a new Carnegie Mellon Center for Innovation and Entrepreneurship. Olympus was founded in January 2007 by Lenore Blum, professor of computer science, and operates as part of SCS. The Don Jones Center was created by CMU's Tepper School of Business.

"We want Carnegie Mellon to be the destination of choice for students and faculty who are interested in entrepreneurship," says Blum, who will co-direct CIE along with Tepper's Dave Mawhinney. "The knowledge and skills necessary to start a business don't come naturally, regardless of how gifted a person might be in their chosen discipline. The Center for Innovation *Continued on page* 38

#### CRAWLING CHIMP TAKES ON NEXT DARPA CHALLENGE

It looks like a primate, but crawls on tracks like a tank—the newest robot to take on a DARPA challenge is the CMU Highly Intelligent Mobile Platform, or CHIMP for short.

The Defense Advanced Research Project Agency Robotics Challenge seeks robots that can respond to search-andrescue situations such as the 2011 Fukushima nuclear plant disaster. The robots will need to be able to navigate stairs and ladders as well as operate equipment and vehicles designed for humans.

CHIMP is being developed by CMU's National Robotics Engineering Center, whose entry, Tartan Rescue Team, is one of seven selected by DARPA for "track A" of the challenge.

With four articulated limbs that incorporate hand-like claws, CHIMP does look something like a monkey or chimpanzee. But NREC scientists say its normal form of locomotion won't be walking on its legs, but rolling along tank-like tracks built into those four limbs.

"This type of robot has tremendous potential," says Tony Stentz, director of NREC and leader of Tartan Rescue Team. Although the human-size tasks required in this challenge would seem to favor a robot that can stand and walk like a person, he says the team is focused on simplicity and reliability, which favors tracked locomotion.

Walking and standing greatly increases the complexity of the processing power required by a robot, which in turn increases its power consumption, Stentz says. It also leaves the robot more vulnerable to energy or programming glitches, he says.

CHIMP will be able to navigate through hazardous situations and maintain stability automatically, while a human operator working via remote control will make higher-level decisions. "This enables CHIMP to be highly capable without the complexity associated with a fully autonomous robot," Stentz says.

In addition to the Tartan Rescue Team, a second CMU team is also competing in this DARPA challenge. Team Steel is headed by Chris Atkeson, professor of robotics and human-computer interaction. Unlike Tartan Rescue, which is developing both hardware and software, Team Steel is developing software in a virtual competition that will run on a DARPA-provided humanoid Atlas robot.

Robots in the challenge will have to successfully perform tasks such as driving a vehicle, traveling across rubble, removing debris, opening doors, climbing ladders, and using tools to operate and replace components.



Events are planned for this June and December, with the final event scheduled for December 2014. The winner will receive \$2 million.

In 2007, Tartan Racing, a joint team fielded by Carnegie Mellon and General Motors, won the \$2 million DARPA Urban Challenge to develop a driverless vehicle that could successfully navigate an urban environment.

#### NREC'S ROBOT PAINT-STRIPPER AN EDISON AWARD FINALIST

A robotic system that would remove paint and other coatings from aircraft has been named a finalist for the internationally renowned Edison Awards.

The Advanced Robotic Laser Coating Removal System is being developed on behalf of the U.S. Air Force by CMU's National Robotics Engineering Center in conjunction with Concurrent Technologies Inc. It uses high-powered lasers mounted on mobile robotic platforms.

Named for inventor Thomas Edison, the Edison Awards are presented annually in 12 different categories and are voted on by more than 3,000 senior business executives and scientists from across the United States. First presented in 1987, the awards honor innovation and creativity in product and service design.



#### COGNITIVE TUTORING RESEARCHER RECEIVES SOCIETY'S HIGHEST HONOR

The researcher whose work led to creation of Carnegie Learning's first cognitive tutors has been awarded the highest honor of the Association for Psychological Science.

John R. Anderson, CMU's R.K. Mellon University Professor of Psychology and Computer Science, has been named this year's winner of the APS William James Lifetime Achievement Award for Basic Research.

Anderson, a member of the CMU faculty since 1978, combines research from both cognitive psychology and computer science to understand how the brain works, how people learn and how computer-based systems can be used as instructional aids.

In the 1990s, a team led by Anderson created a computer tutor that could teach algebra to high school students.

The program was so successful that Carnegie Learning was formed to bring it to market. More than a half-million students at 2,600 schools have now used software developed by Carnegie Learning.

"There have been a lot of well-intentioned but unsuccessful efforts at applying computer technology to education," says Randy Bryant, SCS dean, but Anderson's are "the real deal. By developing models of how students learn, his cognitive tutoring technology has been remarkably successful."

Anderson's research pointed the way to work such as that being done by the Pittsburgh Science of Learning Center, a joint project of CMU and the University of Pittsburgh, which is using tutoring software to both develop new methods of teaching and collect data from students in actual classrooms.



John R. Anderson

Anderson will receive the award in May at the APS's annual convention in Washington.

### TWO GRAD STUDENTS RECEIVE FACEBOOK FELLOWSHIPS

Two Ph.D. students have been awarded fellowships by Facebook that pay for their tuition, their travel to conferences and other fees.

Justin Cranshaw and Julian Shun also will each receive a \$30,000 stipend.

Facebook Graduate Fellowships support emerging research into ways to make the world more open and connected through technology, a company spokesman said.

Shun is a fourth-year doctoral student in the Computer Science Department whose research focuses on shared memory, multi-core computers. Shun is working on algorithms for large-scale parallel processing as well as techniques that simplify shared-memory programming.

Cranshaw, a fourth-year doctoral student in the Institute for Software



Julian Shun

Research, is working on research that harnesses social and mobile computing applications to improve the lives of people in densely populated cities.

Facebook awarded 12 graduate fellowships for the 2013–14 academic year. Other finalists from CMU included



Justin Cranshaw

Rebecca Balebako of the Department of Engineering and Public Policy, Alex Beutel of the Computer Science Department, Wang Ling of the Language Technologies Institute and Justin Meza of the Department of Electrical and Computer Engineering. →

#### CSD'S MILLER WINS 2013 KNUTH PRIZE



Gary L. Miller

Gary L. Miller has been honored with the 2013 Donald E. Knuth Prize for his contributions to the fields of cryptography, number theory, parallel computing, graph theory and related fields in theoretical computer science.

Miller received his Ph.D. from the University of California at Berkeley in 1975 under the direction of Manuel Blum. In a paper published that same year, Miller introduced the first efficient algorithm to test whether a number is prime. The generation of large prime numbers is an essential part of the RSA public key cryptosystem, on which much of today's Internet commerce depends.

In 1976, Michael O. Rabin showed how randomization could be used to turn Miller's algorithm into one whose efficiency did not rely on any unproven hypotheses. The resulting Miller-Rabin test is now the main method used in practice for RSA encryption keys.

Miller also made significant contributions to the theory of isomorphism testing—the problem of telling whether two structures are the same except for the labeling of their components. In 1984, Miller moved into the area of scientific computing. He set up the theoretical foundations for mesh generation, and his subsequent research with loannis Koutis and Richard Peng into solving "symmetric diagonally dominant" linear systems has had important applications in image processing, network algorithms, engineering and physical simulations.

Before coming to Carnegie Mellon, where he serves as professor of computer science, Miller held faculty positions at the University of Waterloo, the University of Rochester, Massachusetts Institute of Technology and the University of Southern California.

Miller was made a fellow of the Association for Computing Machinery in 2002 and in 2003 shared the ACM Paris Kanellakis Award with three other researchers for the Miller-Rabin test. Among his Ph.D. students are Susan Landau, Tom Leighton, Shang-Hua Teng and Jonathan Shewchuk.

The Knuth Prize is presented jointly by the ACM's Special Interest Group on Algorithms and Computation Theory and the IEEE's Computer Society Technical Committee on the Mathematical Foundations of Computing. The prize is named in honor of Donald Knuth of Stanford University, who has been called the father of the analysis of algorithms. It is given annually by SIGACT and TCMF, and includes a \$5,000 award.

Miller will be presented with the award when he delivers the annual Knuth Prize Lecture during the Symposium on Theory of Computing in Palo Alto, Calif., to be held June 1–4.

#### ENTREPRENEURS

Continued from page 35

and Entrepreneurship provides the missing pieces, benefitting not only our faculty and students, but the entire region."

Since its creation, Olympus has supported more than 100 projects developed by CMU students and faculty. More than 70 companies have been launched, attracting \$60 million in additional funding from university and outside sources.

Four of those companies received venture capital funding, and one— BlackLocus—raised \$35 million. Some 250 students have participated in product development supported in part by Olympus.

"The Don Jones Center and Project Olympus have been tremendously successful in helping students and faculty take the crucial first steps in transforming research findings into products and services that people want to buy," says Mark Kamlet, CMU provost and executive vice president. Kamlet will serve as head of CIE's new governing body.

CIE will continue successful programs from both the Don Jones Center and Project Olympus, including Olympus' seasonal Show & Tell events that connect campus researchers with local and national investors; the Open Field Entrepreneurs Fund; incubator space for fledgling companies; entrepreneurship workshops; and business competitions.

New this year is a program called "Launch CMU," a series of events that will bring top-tier venture capitalists together with the university's most promising researchers and entrepreneurs twice a year in both Pittsburgh and Silicon Valley. The first event is slated for May 21 in California's Silicon Valley. →

### SMART COOKIE



#### It takes a tough robot to disassemble a fragile cookie.

By now, you've probably seen the video, which has been viewed more than a quarterof-a-million times on YouTube. The makers of Oreo cookies recruited HERB, the Home Exploring Robot Butler developed at Pittsburgh's Quality of Life Technology Center, to separate the cookies from their cream filling as part of a national advertising campaign called "Cookie Vs. Creme."

There are many layers of science behind that video. HERB's programmers, including associate professor of robotics Siddhartha Srinivasa (CS'05) and project scientist Pras Velagapudi (E'05, CS'05, '09, '12), spent about an hour per day over a two-week period training the robot in the fine motor skills necessary to pry apart the delicate cookies. (That's Velagapudi in the photo.)

We all laughed at HERB's (staged) vexation when confronted with the task—in one part of the video that's staged as an "out-take," HERB tries unsuccessfully to separate the cookies first by stabbing at them with a butcher knife, and then by smacking them with a frying pan. The video had a serious side, too, showing how HERB's arms work as well as the cameras that allow HERB to perceive its visual world.

HERB also has a serious side. QoLT is a joint project of CMU and the University of Pittsburgh which develops technologies designed to help people with physical challenges including wounded veterans and older adults—to live independently in their homes. The Oreo challenge allowed researchers to validate the manipulation algorithms that explore how HERB or other robots could assist people at home, in ordinary kitchen environments, with everyday tasks. →

Learn more at HERB's website: www.cmu.edu/herb-robot/

And if you didn't see the video: www.youtube.com/watch?v=gBgfplOlclo

### then and now: \_\_\_\_\_\_computer science's female pioneers



Do you think women were always a minority in computer science? Think again.

You may already know about computing pioneers such as Grace Hopper and Ada Lovelace, but in the early days, women were highly visible at every level of computer programming—including entry-level coders.

In fact, the word "computer" originally applied to the people (mainly women) who computed, by hand, the answers to complicated mathematical equations. During World War II, more than 80 of these women "computers" were hired at the University of Pennsylvania to plot ballistic missile trajectories using differential equations.

When Penn began work on the world's first all-electronic digital computing machine, six of those women—Frances Bilas, Jean Jennings, Ruth Lichterman, Kathleen McNulty, Frances Snyder and Marlyn Wescoff—were asked to become its programmers. The machine was the Electronic Numerical Integrator and Computer, or ENIAC. Working in teams, the women programmed ENIAC by manually routing cables and setting switches and dials.

In this February 1946 photo from Penn's archives, Jennings and Bilas are shown preparing ENIAC for its public unveiling. After the war, Lichterman moved with ENIAC to the Army's Aberdeen Proving Ground in Maryland, where she taught programming, while Snyder and Jennings helped design and write code for the first UNIVAC. McNulty married John Mauchly, co-inventor of ENIAC and UNIVAC, and collaborated with him on program design.

Through the 1950s and 1960s, computer programming was a popular career path for women, but a variety of social, political and economic factors led the field to become increasingly dominated by men. Some of those same factors have also discouraged men and under-represented minorities from pursuing careers in computer science and information technology.

Since the 1990s, Carnegie Mellon University has made a concerted push to encourage young women and under-represented minorities to explore careers in computer science. In February, CMU joined 19 other universities and more than a dozen corporations to participate in the Pacesetters program recently launched by the National Center for Women & Information Technology. And every day, students and faculty are engaged in outreach and networking, both to attract people to computer science—and keep them engaged in the field.

Read more about Women@SCS on page 16.

—Jason Togyer (DC'96)

### calendar of events

All events to be held on the Carnegie Mellon University campus in Pittsburgh, unless otherwise noted. Dates and locations subject to change without notice. Visit calendar.cs.cmu.edu for a complete and current listing of events.

#### April 30

2013 Celebration of Education 4:30 p.m., Rangos 1 & 2, University Center

#### May 2

Senior Student Leadership Awards Reception, Qatar Campus 6 p.m., Assembly Area, Education City

#### May 3–5

Conference on Automated Personal Genome Analysis for Clinical Advisors: Challenges and Solutions Gates and Hillman Centers

#### May 6

Qatar Graduation Ceremony 2013 7 p.m., Qatar National Convention Centre

May 18–19 Commencement Weekend

May 19 University Commencement Ceremony 11 a.m., Gesling Stadium

#### May 19

SCS Diploma Ceremony 1:30 p.m., Carnegie Music Hall, 4400 Forbes Ave.

#### May 23-25

Workshop honoring Ravi Kannan's 60th birthday Various locations, Pittsburgh campus

#### June 14–15

Carnegie Mellon Alumni Volunteer Forum Pittsburgh

July 13 SCS/ECE Alumni Reception Seattle

July 27 SCS/ECE Alumni Reception San Francisco

Aug. 18–25 First-Year Orientation Various locations, Pittsburgh campus

Aug. 21 Qatar Convocation Class of 2017 6:30 p.m., Education City Aug. 26 Fall semester begins

**Sept. 2** Labor Day: No classes

Sept. 26–28 Ceilidh: Homecoming and Family Weekend Various locations

**Oct. 18** Mid-semester break: No classes

**Oct. 24** TechBridgeWorld Interactive 5 p.m., Perlis Atrium, Newell-Simon Hall

**Nov. 18–22** Spring 2014 registration week

**Nov. 27–29** Thanksgiving holiday: No classes

**Dec. 6** Fall semester: Last day of classes

**Dec. 9–17** Final exams

#### Carnegie Mellon University School of Computer Science

Office of the Dean 5000 Forbes Avenue Pittsburgh, PA 15213





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Thanks to all of you — nearly 50,000 alumni, faculty, students, parents and staff — who supported the Inspire Innovation campaign, we are in the homestretch of an historic effort that's already impacting everything from new research facilities to faculty and student support.

But we're not done yet. Help us continue the celebration as we prepare to cross the campaign finish line in June.



Celebrate with us at we.cmu.edu to add your gift today.