FACULTY AND STUDENTS ARE MELDING PROGRAMMING SKILLS WITH NEW MANUFACTURING TECHNIQUES TO POWER COMPUTING AND ROBOTICS INNOVATIONS

Maker culture: Bringing research to life

also inside:

WHO SHARES YOUR DATA—AND WHY YOU SHOULD CARE IN THE LOOP WITH DAVID GARLAN ANKI: ROBOTS THAT AREN’T JUST PLAYING GAMES
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
Illustration by
Nora Thompson
Maker culture and Mr. Waseleski

This issue highlights the rise of “maker culture,” and how new technology, such as 3-D printing, makes the path from concept to physical reality much simpler and shorter than traditional construction techniques and tools.

I wonder what Mr. Waseleski, my eighth grade shop teacher, would think about these trends and technologies? Back then, all boys were required to take two years of shop class. (Girls took home economics.) The underlying assumption—even in a suburban school—was that we were all in training to become tradesmen. Mr. Waseleski viewed his job as training us to become skilled factory workers.

We learned how to use a few tools, but mostly I remember spending hours sanding things by hand, using each piece of sandpaper until there was hardly any grit left. The concepts of “being creative” and “rapid prototyping” were certainly not among Mr. Waseleski’s priorities!

In the intervening years, shop classes have largely disappeared, at least as a requirement. Children grow up using their hands mainly to type on keyboards and to operate game controllers.

But we are seeing a growing interest in constructing tangible objects, where participants do things not because they have to, but because they want to. We can make objects at the push of a button that traditionally would have taken hours of cutting, drilling and (of course) sanding.

Consider how programmable smartphones have enabled developers to create and disseminate applications that perform a huge variety of tasks. Now: Imagine what creative people will be able to do with these new manufacturing technologies.

Randal E. Bryant
Dean and University Professor
School of Computer Science
Who shares your data?

By Jason Togyer

In a way, our daily computing experience is a lot like the old song, “Dem Bones.” The app is connected to the operating system, the operating system’s connected to the platform, the platform’s connected to the provider, and the provider is connected to the advertising network.

All of those connections, sharing our personal information—do we ever really wonder where it’s going, who might be using it, and for what purposes?

“In the old days, you bought a computer from Dell, Microsoft made the operating system, and Intuit made the accounting software,” says Travis Breaux, assistant professor in CMU’s Institute for Software Research. “These were all big companies, and you paid something for the software you used.”

Today, software—increasingly in the form of “apps”—is often free. Think of Facebook, or Google’s Gmail. But often, in exchange for using a free “app,” we give up some of our privacy, in the form of personal information that can be traded among companies that hope to market their products or services to us.

Whether it’s through the apps they access from their smartphones, or their browsing activities on the Web, people are leaking information to a variety of players, often with very little understanding of what’s being collected, says Norman Sadeh, professor of computer science and director of CMU’s Mobile Commerce Laboratory.

“Our studies have repeatedly shown that people are concerned about these practices, yet feel helpless when it comes to understanding what’s really happening, and what they can do to regain control over their information,” he says. (Editor’s Note: For more information on the same topic, see “Research Notebook” in this issue of The Link.)

Sadeh is leading a 42-month, $3.75 million research project to develop computer systems that can semi-automatically read website privacy policies and highlight their most important aspects. Ultimately, it could provide something like easy-to-understand letter grades for various aspects of privacy policies—sort of the way that Consumer Reports reviews cars and appliances.

Sponsored by the National Science Foundation through its Secure and Trustworthy Cyberspace program, the

SCS associate professor Lorrie Cranor, assistant professor Travis Breaux and professor Norman Sadeh are part of a new $3.75 million research project to develop systems that can semi-automatically read website privacy policies and highlight their most important features.
“Usable Privacy Policy Project” also includes Breaux; Noah Smith, CMU associate professor of language technologies and machine learning; Lorrie Cranor, CMU associate professor of computer science and engineering and public policy; Alessandro Acquisti, CMU associate professor of information technology and public policy; and law school researchers at Stanford and Fordham.

Prior research by Sadeh and his colleagues has shown that—although user privacy preferences can be fairly complex—there is often a relatively small number of considerations that matter most to them. Rather than attempt to automatically read and understand the full content of each website's privacy policy, the research team will look for text relevant to those issues that people care the most about. Then, it will develop algorithms that can automatically or semi-automatically understand the assurances (or lack thereof) given by those privacy policies, and summarize their findings in a short, easy-to-digest format—possibly something as simple as a letter grade.

The Internet has made it possible to collect data about individuals on an unprecedented scale. Let’s say you use an app that helps you find restaurants. Things such as your location, your name, maybe even your phone book and email addresses, might go into that app’s database. Your location helps pinpoint nearby restaurants, while your contact list provides the app with the names of restaurants your friends also liked. From that data, the app can construct a pretty good profile of your tastes and recommend restaurants you’re likely to enjoy.

A 42-month, $3.75 million research project could provide something like easy-to-understand letter grades for various aspects of privacy policies—sort of the way that Consumer Reports reviews cars and appliances.
“Users are not willing to invest a lot of time learning how to use their privacy settings,” Sadeh says. “We need to empower them to make more informed decisions.”

It seems innocuous. But someone with bad intentions—a burglar intent on breaking into your house, or a stalker trying to harass or harm you—could use the same information to figure out where you’re likely to be at any given time.

And even if you sign into applications using a throwaway email address, or don’t give your real name, it isn’t necessarily difficult to figure out your real identity; former SCS professor Latanya Sweeney, now at Harvard, proved in 2010 that the names of supposedly anonymous participants in medical research studies could be determined by comparing details of their treatments with publicly available data such as voter registration lists.

Corporations that run large app stores, such as Google’s Play or Apple’s iTunes, have detailed data-collection policies in place, but many independent developers lack the time, ability or interest to worry about user privacy. Even if they do, conflicting policies at different levels can lead to privacy leaks where information is shared without consent from users. “A single Facebook window could have three or more different privacy policies at work,” says Ashwini Rao, a Ph.D. student in CMU’s Institute for Software Research. “Individually, they may be OK, but when you put them together, you start seeing conflicts.”

Work recently done at Carnegie Mellon by Breaux and Rao illustrates the perils of conflicts between privacy policies. In a paper presented in July at the 21st IEEE International Requirements Engineering Conference in Rio de Janeiro, Breaux and Rao reported on their research into the privacy policies of Facebook, game developer Zynga and AOL, which places ads within Zynga games.

They found, for example, that Facebook’s policies tell app developers they cannot share user data with third party advertisers, even if the user consents, but Zynga’s policies allow them to share user data with the user’s permission. And, Rao says, they found a hidden data flow between Zynga and AOL’s advertisers over which the user has little or no control.

To compare the privacy policies of Facebook, Zynga and AOL, Breaux and Rao manually mapped them from natural language to formal logic, then compared them using proofs. “We applied conventional techniques from programming to privacy policies,” Breaux says. “Our results show that developers can check their data practices for conflicts with third-party privacy requirements.”

Theoretically, developers could adapt Breaux and Rao’s technique to identify potential data leaks and privacy risks and mitigate them before releasing a new app to the public. But in practice, Breaux envisions that developers will someday use lightweight tools—perhaps similar to those being designed by the Usable Privacy Policy Project—to express their data practices while designing an application.

The goal isn’t to put roadblocks in the path of developers who want to roll out the “next big app.” Instead, it’s to give them—and end users—the tools they need to intelligently understand the implications of privacy policies. “Users are not willing to invest a lot of time learning how to use their privacy settings,” Sadeh says. “We need to empower them to make more informed decisions.”

—Jason Togyer (DC’96) is editor of The Link. He still doesn’t own a smartphone.
Life, death and software

With no margin for mistakes, control systems for surgical robots must be as error-proof as possible

By Nick Keppler

In the field of medical devices, the da Vinci Surgical System has been a breakthrough. It allows a surgeon at a remote console, viewing a 3-D image of a surgical area, to operate on a patient using four small robotic limbs.

It’s similar to surgery performed with the aid of a laparoscope—a thin, lighted tube, connected to a camera, which can be inserted into a patient. But it’s also much, much more.

“The depth perception is so much better than it is in a traditional laparoscopy,” says Dr. Michael J. Bonidie, who utilizes the da Vinci for hysterectomies at Magee-Womens Hospital of UPMC in Pittsburgh. Conventional laparoscopes can only move forward and backward through an incision; the da Vinci allows a view from several different angles.

“It essentially gives you a neck,” Bonidie says.

Other surgical robots preceded the da Vinci, yet none has been as heralded or widely used. Its maker, Intuitive Surgical, has sold more than 2,500 units since 2000, and the robot participated in 367,000 operations in the United States last year, up 34 percent from 2011. Intuitive claims use of the da Vinci decreases scarring, shortens hospital stays and lowers the risk of complications versus conventional laparoscopy. The da Vinci’s success has made it a kind of status symbol, with hospitals touting their use of the high-tech tool in their advertising.

Yet complications can arise in any kind of surgery, and surgery performed by the da Vinci is no exception. There have been more than 20 lawsuits filed against Intuitive by patients who claim they were harmed by the robot, and so far this year, the U.S. Food and Drug Administration has logged 455 incident reports involving da Vinci surgical robots. (For its part, Intuitive says the company has won every suit that’s been heard in court.)

Many robots have mission-critical applications, but in the case of surgical robots, software must not just be reliable—it has to be practically flawless.

That’s why the developers of the next generation of game-changing surgical robots have enlisted the expertise of André Platzer. A 34-year-old assistant professor of computer science at CMU, Platzer has developed a reputation as the man to turn to when you need a piece of software that can never, ever, fail when it’s put into everyday use. He and his team have created error-proofing techniques for air-traffic control software, as well as for the embedded systems that could control the much-discussed self-driving cars of the future.

“It’s the question I ask most days: How do we create a system that we can bet lives on?” Platzer says.

Platzer’s work isn’t very dramatic—at least not visually. Peek in on him and his team on any given day and you would see people feeding information into a set of computers. In fact, they’re coding scenarios to testing different systems’ reactions to a variety of potentially life-threatening dilemmas, and trying to remove them before they can hurt anyone.

For his first foray into surgical robots, Platzer analyzed a Johns Hopkins University-developed system—a cousin of the da Vinci—that would literally guide a surgeon’s scalpel during brain surgery to remove a cancerous tumor. The instrument would be wired to a computer containing a magnetic-resonance image, or MRI, scan that would act as a map of the patient’s brain. The job of the robot would be to guide the scalpel to the cancerous area in the least destructive way, then keep the blade within the confines of the tumor zone, which may be no larger than a dime. The robot would provide feedback to the surgeon’s hand in the form of force, to keep the scalpel from going astray.

André Platzer
Checking a computer program or electrical circuit for errors using formal logic relies on mathematical proofs. But classical error-checking techniques study simpler computer programs by making a smart enumeration of all cases, because those programs have clearly defined boundaries—a finite number of states. Air-traffic control systems, self-driving cars and surgical robots are all hybrids: systems that contain both digital components as well as physical parts that move in space and time—a practically infinite number of states. A traditional enumeration of all states would be impossible to complete.

To cope with these hybrid systems, Platzer and former doctoral student David Renshaw (CS’12) developed an automated theorem prover called KeYmaeraD. KeYmaeraD is a formal verification tool that relies on quantified differential-dynamic logic. To account for factors happening in the physical world, it calculates a range of safe parameters for a given system’s operations, rather than focusing on just one parameter.

Using KeYmaeraD, Platzer and his colleagues evaluated the control algorithm of the JHU robot, testing for any systemic errors in the feedback mechanism. They were able to find a few ways in which the robot could go wrong. In some cases, the system might not warn a surgeon he is veering off course until he has made a motion his wrist can’t take back. In other situations, it might warn a surgeon that she’s exiting the cancerous zone in good time, but not prevent her from jerking her hand backward into the no-go zone. This intense precision matters when the difference between life-saving surgery and debilitating brain damage might be a few millimeters.

Other robots are under development for a variety of medical circumstances, both ordinary and extraordinary. IBM is working on a version of Watson—the supercomputer that competed on “Jeopardy!”—which could diagnose rare diseases by analyzing a vast inventory of symptoms that doctors might otherwise overlook. NASA is offering a grant for a lab to develop a remote-control system in which an Earth-based surgeon could operate on someone in space using robotic arms.

But none of these systems can be wholeheartedly endorsed until they are absolutely error-proofed—and that’s the role played by teams such as Platzer’s.

This may seem like new territory for Platzer, whose work on planes and cars had him measuring miles and feet as opposed to millimeters, but he says all of his work comes down to the same principles of logic, math and physics.

“If you move in an object towards a boundary, you have to calculate how fast you are moving and when to angle it and where,” he says, “and it’s the same kind of thinking if it’s a ship moving in a harbor, or a scalpel moving into some skin.” —Nick Keppler is a Pittsburgh-based freelance writer who has contributed to Pittmed, the magazine of the University of Pittsburgh School of Medicine, as well as Pittsburgh City Paper and Nerve.com. This is his first Link byline.
A ‘killer app’ for teaching math, developed by an HCII Ph.D. student, draws heavily on large-scale data analysis

By Linda K. Schmitmeyer

Walking into the offices of Carnegie Mellon’s Project Olympus on Henry Street—a long, narrow brick building that once stabled Oakland’s many horses—feels like walking into the proverbial “garage” of one of the Silicon Valley’s great startup companies. (Think of Hewlett and Packard, or Steve Jobs and Steve Wozniak.)

Strewn across a dozen or so folding tables are cups of cold coffee and half-eaten lunches. Instead of huddling over drawing boards, though, these emerging entrepreneurs are pecking away on laptops while 3-D printers output prototypes of their ideas. They are hard at work on products and services that may one day change our lives.

Project Olympus, now part of CMU’s Center for Innovation and Entrepreneurship, supports faculty and students during the early stages of their entrepreneurial endeavors. One of those students was Derek Lomas, who is a Ph.D. candidate in CMU’s Human-Computer Interaction Institute. Lomas is studying how people learn while playing online educational games. In December 2011, he and Kishan Patel, then a CMU intern scholar, cofounded Playpower Labs, an educational research initiative that develops Web and mobile applications for students in kindergarten through eighth grade. Project Olympus supported their work by providing coaching, connections to experts in their fields and business advice.

“We’re studying how to maximize player learning and engagement in educational games,” says Patel, who holds a B. tech degree in information and communications technology from Dhirubhai Ambani Institute of Information and Communication Technology in India. For two summers, he worked alongside Lomas and Ken Koedinger, one of Lomas’ advisors and a professor in the HCII. Koedinger also is co-director of the Pittsburgh Science of Learning Center.

Playpower’s “killer app” is Fraction Planet, a suite of educational software that supplements traditional elementary school math curricula and provides instruction and assessment in more than 50 of the “Common Core” standards—the set of interstate educational benchmarks coordinated by the National Governors Association and the Council of Chief State School Officers. In a Playpower promotion video, Lomas describes Fraction Planet as “Angry Birds meets the Common Core.”

The games—Battleship Numberline, Bubble Pop and Party Time—are self-paced and progress from easy to difficult; they are designed to address concerns about math proficiency and help prepare students for careers in the STEM fields of science, technology, engineering and math. Fraction Planet is available now through a beta website (fractionplanet.com) and is scheduled for a full launch soon.

“Elementary (school) students have very strong misconceptions about fractions, which makes it difficult for them to learn algebra in high school and go on to pursue STEM education,” says Lomas, who earned a master’s degree in visual arts from University of California at San Diego, and a bachelor’s in cognitive science from Yale University.

“Fifty percent of eighth graders can’t order three fractions from least to greatest,” he says, citing a 2004 National Assessment of Education Progress study.

One thing that makes Lomas’ scholarship unique is that “his research is embedded in the games,” Koedinger says. “Derek can make infinitely subtle changes to these games—like whether there are four or five fractions involved, or how the players are rewarded. He’s looking hard at student motivation and is making changes (to the games) based on important educational and psychological hypotheses.”

The scale at which he conducts his research is also innovative. Kit Needham, entrepreneur-in-residence at Project Olympus, says that unlike many makers of educational games, who base their claims on “gut feelings,” Lomas has the data to prove that children do learn using Playpower’s software.

“We recently ran research that analyzed 14,000 experimental conditions,” Lomas says. “This scale allows us to systematically break down data and see how motivation occurs.”

“This blows my mind,” Koedinger says. “Derek’s large-scale data collection is a huge advantage in understanding how...
students learn. His research is cutting-edge and quite remarkable."

Lomas also works closely with the Pittsburgh area’s Propel charter schools, where he conducts randomized control trials. “I can talk with the teachers and observe students playing the games. It also allows me to conduct controlled pre- and post-testing of the students.”

Game design is instrumental in the success of Fraction Planet. By adjusting the games’ graphics—the color or size of the battleship, how points are scored, or the frequency of pop-ups with positive messaging—Lomas and his team can analyze how long participants play, at what point in each game they stop and how well they perform.

“The use of design as a factor in educational games is fairly new and not a lot of research has been done as to its efficacy,” says Jodi Forlizzi, Lomas’ other advisor and an associate professor in CMU’s HCII and the School of Design. One of the findings discussed in the paper “Optimizing Challenge in an Educational Game Using Large-Scale Design Experiments,” published in the journal ACM CHI, was surprising, Lomas says. “We found that the most engaging design conditions produced the slowest rates of learning.”

Forlizzi adds that Lomas is deeply devoted to understanding how children learn. “What touches me is that Derek is very committed towards developing high-quality educational games,” she says. “I think he is motivated, in part, by his own two children. He has such a passion for what he is doing.” Lomas is the father of two, Milo, 4, and Mia, 1.

Fraction Planet’s success is attracting the attention of others. Playpower has received numerous awards, including the CMU McGinnis Venture Competition Foundation, the Pittsburgh Sprout Fund and a Project Olympus Spark Grant, among others.

But it’s being accepted into the TechStars deep-immersion mentorship program that Lomas hopes will propel Fraction Planet into the educational marketplace. Lomas and Patel spent their summer in New York City along with nine other education startups for TechStars, which provides seed funding to companies from more than 75 top venture capital firms and angel investors. Only 1 percent of companies who apply to TechStars are accepted into the program, according to its website, and of the 223 startups that have completed it since 2007, 90 percent remain active or have been acquired by other companies.

“Getting basic research into the marketplace is difficult,” admits Lenore Blum, distinguished career professor of computer science at CMU and founding director of Project Olympus. “What Derek has going for him is extremely high-quality material that has been tested and evaluated.”

“Students come to Project Olympus with ideas ranging from a sketch on a napkin to actual prototypes,” Needham says. There they can obtain startup advice, business strategy planning and connections to industry experts, advisors and the business community. “Some are here “with the intention of making money,” says Needham, “but Derek has a product that he also hopes will make a difference.”

A native of Chagrin Falls, Ohio, Lomas said that it was Carnegie Mellon’s support of social entrepreneurship that prompted him to pursue his doctoral degree at CMU. “I liked their global social impact mindset.”

—Linda K. Schmitmeyer is a Butler County, Pa., based freelance writer and editor. Email her at lkschmitmeyer@gmail.com.
In a lab in the basement of Newell-Simon Hall, robotics doctoral student Matt Tesch grabs what looks like a PlayStation controller and begins quickly pressing buttons and moving the joysticks. A serpentine robot, about two-feet-long and with 16 distinct segments or modules, slithers across the floor like a snake. It stops for a moment and then begins crawling sideways, much like a sidewinder.

After the snakebot crawls on the floor for a bit, showing off all its moves, Tesch grabs a hollow plastic tube, wraps the snakebot around the pole and it rolls upward. After it reaches the top, he takes it off the tube and straightens it out. He feeds about half of it into the tube, and it inches down slowly.

“We control the motion by sending waves through the joints,” he says.

Tesch is demonstrating a snakebot’s means of locomotion. It can slither backward, crawl through tiny openings and navigate sharp bends, which comes in handy for inspecting pipes. In fact, one recently showed how well it crawls at a nuclear power plant in Austria.

In May, a snakebot slithered through pipes and vents in the never-activated Zwentendorf Nuclear Power Plant, west of Vienna on the south bank of the Danube River. The tests gave researchers an opportunity to access pipes and areas that would be restricted because of high radiation levels in working plants, allowing the robot to go where no robot has gone before.

“Think of how they could have been used at Fukushima,” says Howie Choset, director of the CMU Biorobotics Lab, referring to the Japanese nuclear power plant that melted down in 2011 following an earthquake and tsunami. Radiation levels in much of the plant remain so high that humans can’t enter, and the company that owns the Fukushima Daiichi plant has recently admitted that it doesn’t know where the melted fuel cores are.

But perhaps a snakebot could.

Choset has been developing snakebots for almost two decades. Over the past few years they’ve broken into the public consciousness—and in a big way. Videos of the amazing snakebots from Choset’s lab are going viral, capturing the attention of bloggers and journalists for Popular Science, Bloomberg Businessweek and NPR.

This year’s Austrian tests happened almost through a happy set of coincidences. The Zwentendorf nuclear plant was built in the 1970s. Public opposition to starting the plant meant that it was never commissioned, and instead it’s used for training and educational purposes. Florian Enner, a research associate and software engineer in the Biorobotics Lab, is from Salzburg, Austria, and following a conference in Germany, he asked officials if the snakebot team could do some research at Zwentendorf. To the team’s surprise, the power company that owns Zwentendorf agreed, giving the CMU group access for two entire days.

“In the lab we sort of know what to expect,” Enner says. “There, we didn’t know what we would find.” As the snakebots crawled through the pipes, they used LED lights and cameras to show the researchers where they were and what they saw. They encountered lost bolts that had lain undetected inside conduits for so long they were rusted to the sides. They found long-forgotten sensors protruding into the pipes.

The snakebots’ cameras are able to automatically correct the view presented—when they’re upside down, the cameras adjust the video to appear right side up. That feature impressed the power plant’s staff, the researchers say, but more impressive was the robots’ flexibility, which gives them a serious advantage over conventional equipment for inspecting the insides of pipes. Current pipe inspection tools cannot turn corners. When they encounter a sharp bend, workers have to cut a hole in the pipe and push the robot.
At the Zwentendorf Nuclear Power Plant, Chaohui Gong (E’12), a Mech.E. Ph.D. student, deployed the Biobotics Lab’s snake robot into the steam piping of a turbine room.

through. It’s awkward, causes damage to pipes and exposes workers to potentially dangerous situations.

A segmented snakebot can easily twist and turn up into inlets and through tight corners, allowing researchers to be far enough away from dangers such as radiation. (Tesch and Enner have pictures of themselves with the Zwentendorf plant’s steel containment vessel. If the plant were active, they’d never had been able to get so close.)

Inspecting power plants is only one of the many tasks Choset’s snakebots can perform. The robots are effective in search and rescue—snakebots can easily slither between fallen debris in crumbled buildings after a disaster. And snakebots can go places where ladders can’t be used. A rescuer, for instance, can throw the robot at a pole. It grabs the pole, coils around it and crawls upward. At a dangerous building, first responders could toss in a snakebot and have it send back images of the scene before humans risk their lives.

“They work well if you want to reach a great distance and thread through tight spaces,” Choset says. “Urban search and rescue use extends your sensory reach to find survivors while protecting first responders.”

Another version of the snakebot—much smaller—is being tested in cardiac heart operations. For many heart procedures, doctors must crack the sternum to access the heart. A simple test could mean a week’s stay in the hospital. But with a snake robot, the same procedures can become minimally invasive. The snakebot can enter a small incision, make a quarter-inch turn, and weave behind

the heart, where it can send photos back to physicians. The technology has already been successfully tested on animals. Choset believes that snakebots eventually could allow technicians to perform common procedures that currently require surgeons.

“What’s provocative is that we can have nonsurgeons deliver care, and, it may not require a hospital stay,” he says. “Snakebots could decrease the cost of surgery. And robots could create new jobs.”

These robots of the future have gone into the past, too. Prior to the recent Egyptian revolution, Choset took a snakebot to an archeological site near the Red Sea. Ancient Egyptians left their old boats in caves along the coast, but as the centuries passed the caves collapsed, making it impossible for archeologists to reach the sea vessels. One of Choset’s snakebots slipped through the rubble and sent back pictures for the researchers to analyze.

And are you ready for “snakebots on a plane”? It’s no science fiction spoof: Choset is currently working on a project with Boeing to develop snakebots that could work in manufacturing situations, applying paints and other coatings inside tight spaces, such as tanks. “Snake robots have tons of applications,” he says. “It’s the future of assembly.”

—Meghan Holohan is a Pittsburgh-based freelance writer and a frequent contributor to The Link. Her work also appears at NBCNews.com.
David Garlan (CS’83, 87) is a professor in the Institute for Software Research and the Computer Science Department, and director of SCS’s Professional Software Engineering Programs. A graduate of Amherst and Oxford, he is a fellow of the IEEE and a senior member of the ACM, and is considered one of the founders of the field of software architecture. In 2005, Garlan received a Stevens Award Citation for “fundamental contributions to the development and understanding of software architecture as a discipline in software engineering,” and in 2011 he received the Outstanding Research Award from ACM SIGSOFT for “significant and lasting software engineering research contributions through the development and promotion of software architecture.”

Garlan spoke to Link Editor Jason Togyer.

Why is your office decorated with items related to Frank Lloyd Wright?
I’ve always been inspired by Wright. There’s integrity to his designs, because they’re held together by consistent elements and themes, and they worry a lot about context. It’s not just the buildings themselves that he was concerned with, but how they fit into their surroundings. When Robert Allen and I created a language for specifying architecture, I decided to call it “Wright.”

How do Wright’s design principles apply to software architecture?
There are interesting parallels. I’m interested in systems whose design naturally matches the domain they attempt to serve—ones that fit neatly into their contexts without creating abrupt changes in experience for their developers or users. The world of software has become increasingly complex—we need to make sure that developers aren’t just creating nice stand-alone applications, but ones that also fit well into their environments. The iPhone is an interesting example: Apple created the ecosystem and maintained its consistency, so users have a seamless experience as they go from application to application.

What are the ingredients for good software architecture?
Good systems have clean, consistent structures that make them easy to understand, analyze and maintain over time. Sometimes what happens is that the software architect comes up with a good design and the programmers mess it up because they don’t understand the architectural principles; or simply because it’s easier for them to do it some other way.

What were your early computing experiences?
My father was a professor of philosophy at Reed College in Portland, Ore., and my stepmother was in charge of the computing lab there. They let me sneak in and play with the IBM equipment. Unfortunately, at that time, computers were not really mainstream at most colleges. When I got to Amherst, I did some programming for the Physics Department, but when I got to Oxford, I wasn’t exposed to any. Instead, I studied mathematics, later deciding I didn’t want to become a mathematician.

What did you do instead?
Many things: I worked in a bakery, I worked in a brewery, I played in a band, and I taught high school and community college. While I was at the community college, one of the other instructors got sick, and I was asked to come in and teach a Fortran class.

You must have enjoyed that.
I did! So much so, someone suggested I apply to grad school at Carnegie Mellon for computer science. I have no idea why I was accepted. Perhaps I was one of those high-risk, high-potential people they were open to accepting in the early days of the department? I was lucky to have Nico Habermann as my advisor.
What was he like?
Nico was inspirational in terms of his vision, his dedication to his students and his ability to nurture creative thought. It was a wonderful time, too, to be at CMU—a time when many people were thinking about how to support software development with good tools.

What was in the “toolbox” then?
A text editor, a compiler and a debugger, and that’s about it. Nico said, no, no, no, it should be much more. He felt that, along with the tools you needed, we should provide a rich environment to support the development of software, as well as the management of different groups of people who were working together on that software.

You didn’t stay at CMU, though.
No, when I finished my Ph.D., I went to Tektronix in Portland, where I discovered software architecture and the concept of reusing pieces of software as a way to reduce the complexity of systems. But you can’t reuse pieces of software without having a conceptual framework in which to place them. So I came back to CMU to pursue, along with my colleague Mary Shaw, this idea of architecture and help bring it into the mainstream.

Is the idea of software architecture more widely accepted now than it was then?
Yes, but for many people today, the architecture is constrained by the domain in which they’re working—a system for a bank, for instance—and there’s still a long way to go in the industry, because there’s a lot of the attitude, “I build it today the way I built it yesterday.” Moreover, people struggle with maintainability because they don’t think about the long-term evolvability of systems.

Has the need for software to work across multiple platforms improved architecture?
The agile movement has actually somewhat exacerbated the problem, because programmers are often focused on adding features without thinking about sustainability. If people want certain properties built into the bones of a system, then it has to come through a framework and a platform—an architecture—that can evolve over time. You don’t want to add them in later in an ad hoc way.

How do you predict what your later needs will be?
The design-time side of software was the traditional focus of software engineering. Over the past few years, there’s been a shift in thought because systems are deployed in ways that we didn’t expect. They need to work when things around them are breaking. We’re now shifting our focus from design-time to run-time.

How does that change software architecture?
New systems need to support much, much more capability for monitoring themselves and fixing problems without being taken off-line. Take security—you can build into the system defenses against all of the known security risks, but what you really want is the capability to deal with unknown attacks as they will necessarily arise. Engineers need to be asking themselves, do I have an adequate number of probes, looking for faults? Do I have enough run-time repair strategies? If I execute certain repairs, will it lead to loss of data or other bad results?

How are universities preparing software engineers for this new world?
Educating practitioners is one of the best ways to spread these new ideas. One of the things that makes our software engineering program unique is that many of our tenure-track faculty are involved not just in research but in creating our courses for professional master’s students that expose students to cutting-edge ideas.

How much reverse flow is there, from students to faculty?
A lot, actually. I once received a letter from a graduate who said, “your course in architecture taught me a lot, but it’s not helping me in my current job, because I’m working with existing systems that have lousy architecture, and your course didn’t teach me how to handle that.” That led to a whole new research area for me called architecture evolution.

What activities do you enjoy in your free time?
I enjoy Argentine tango dancing. I also do a lot of gardening. I like to create landscaped spaces—I think of this as the antithesis of what I do at work. When you’re gardening, the boundaries are very soft and the time frame is very long—you plant a tree without knowing fully what it will look like in 50 years. It’s very non-algorithmic. There’s also a constant adaptation process of evolving the garden itself to make it what you want it to be—you and your garden are having a dialogue over the course of many years.
Maker culture: Bringing research to life

By Meghan Holohan (with Jason Togyer)
Chris Harrison holds what looks like an X-Acto knife in his hand and drags it across a rectangle of glass. The tool leaves a faint scratch on the surface. He picks the glass up, flexes it, and it breaks neatly where the line was. It's my turn. He hands me the glass-cutting tool. I don't think I can do it. Unlike Harrison, I haven't taken a glass-working class, and I'm not really mechanically inclined. He gives me encouragement, just like a good teacher, explaining that it's as easy as using a pen.

I take a deep breath and place the edge of the tool on the glass, applying a bit of pressure and dragging it, rather crookedly, across it. I pick it up and snap it. It breaks cleanly, just like Harrison's piece.

Harrison, an assistant professor in CMU’s Human-Computer Interaction Institute, took a glass-cutting class a few years ago. He thought the skill would help him as he built prototypes of his projects. Over the years, he also learned how to use a 3-D printer and took classes in carpentry, welding and stained glass. It's unlikely that stained glass will play a role in much of Harrison's professional work. But he believes all these skills help him as he builds prototypes of future computing devices. His work doesn't always involve glass, or 3-D plastic models, or carpentry, but it does always involve ingenuity. "All of these skills are little tricks," he says, adding that understanding how to use a 3-D printer or build something out of wood or glass changes how he tackles a prototype.

Harrison, like others at the School of Computer Science, is embracing maker culture—a sort of “do-it-yourself” ethos for technology. People in maker culture use traditional mechanical skills such as machining or carpentry, but combine those skills with computers or electronics to create new devices. Maker spaces have sprung up in Pittsburgh and many other cities, some run by volunteers, and others run for profit, such as TechShop—a national chain of “public workshops” with a location in Pittsburgh Bakery Square near Google's offices. These maker spaces give everyone from computer scientists to weekend hobbyists a chance to use lathes, laser cutters, 3-D printers and other manufacturing tools.
Having the skills to build a prototype touchscreen, or make a unique part for a robot, can help faculty and students become more innovative, Harrison says. “It’s good to wrap our hands around something,” he says. “Being able to make prototypes, artifacts, it’s what humans do. Making things is a special human trait.”

Dave Touretzky, SCS research professor in computer science and robotics, has become one of the campus’ most ardent advocates for embracing the maker aesthetic. He says there’s another important element to the maker revolution that has nothing to do with inspiration in any abstract sense. Instead, it’s about how maker techniques are lowering real obstacles to scientific discovery.

As Touretzky points out, throughout the history of their fields, computer scientists and roboticists have had to make things out of necessity, but it’s slowed them down. Now, rather than waiting for others to manufacture parts for their projects, or learning machining skills so that they can make those parts themselves, researchers can design a part in a program such as SolidWorks and output those parts to a 3-D printer or laser cutter. They can go from design to prototype at a fraction of the cost and time that it used to take.

“People are going to use this in different ways,” Touretzky says. “If you already know how to make things, you’re going to use these technologies to make things better. But if you’re a researcher who doesn’t want to be in the fabrication business, it’s removing a barrier to your research.”

He compares maker technologies and techniques to the revolution in digital imaging that was wrought by Adobe’s wildly popular photo-editing software, Photoshop. “People who are graphic designers can do amazing things with Photoshop,” Touretzky says. “But many nonprofessionals now have basic Photoshop skills and can do simple things like crop or rescale a photo, or alter the background.”

The maker revolution is happening at a time when some are wondering if the United States is still the world leader in technological innovation. In a November 2011 opinion piece for the Washington Post, political commentator Harold Meyerson noted something curious about Walter Isaacson’s best-selling biography of Apple co-founder Steve Jobs. Although Isaacson’s book discussed the many innovative products, such as the iPod and the iPad, that were introduced by Apple after Jobs returned to the company in 1996, it didn’t spend much time examining how those products were manufactured.
“To read Isaacson’s book, it’s as if all Apple and Jobs did was innovate, and the products magically appeared,” Meyerson wrote. In fact, Apple set up factories in China employing some 700,000 workers—“massive undertakings,” Meyerson said. And where manufacturing goes, he argued, innovation follows. In Meyerson’s article, former Intel CEO Andy Grove said some of the company’s semiconductor breakthroughs came straight from the factory floors where those semiconductors were made.

Meyerson’s argument was that innovation isn’t strictly an ivory-tower pursuit, where new ideas are developed in isolation by deep-thinkers; instead, the development of new products must go hand-in-hand with knowing how those products are made and used. When a company—or a country—offshores or outsources the manufacture of its products, “the ability to devise new manufacturing processes is lost, and with it, the ability to devise new products,” Meyerson wrote, concluding, “absent manufacturing, innovation, even at its Jobsian heights, can’t do much for the U.S. economy.”

More recently, in March, a New York Times opinion piece by Eamonn Fingleton contended that American innovation has already stalled; most technological advances being pioneered in the United States, he said, aren’t happening in the creation of new devices, but in Internet applications and the financial sector.

Maker culture introduces thinkers to the techniques of manufacturing—the key ingredient people such as Meyerson and Grove believe is essential to invention. For his part, Harrison believes that having students actually make prototypes helps them think differently.

Some time ago, Harrison looked at a smartphone and wondered how he could make touchscreen devices easier to use. He designed prototype after prototype until he finally created a wearable system, OmniTouch, which allows cell phone users to turn anything from their hands to the table into a touch screen.

“My major body of work is making mobile devices better,” he says. “A big problem with a small screen is that our fingers are really big.”

He could have made the device larger. But Harrison thought a better solution was making screens respond differently to the pad of the fingertip versus the fingernail or the knuckle. By using the phone’s audio sensors to detect the sound of the touch as well as the pressure, he modified a phone so that it could tell the difference between different parts of the hand and cut down on user errors. Harrison calls it “FingerSense.” With FingerSense, a tap from a knuckle on a touchscreen might serve as a “right click,” and a tap from a fingernail might perform a different function. It could mean fewer mistakes from clumsy fingers and better human interaction.

Harrison even built a tiny keyboard for a smart watch, partly just to see if he could and partly to figure out “how small is too small?” The keyboard was about the size of a penny. “Smart watches are really too small,” he says, “but we need to be able to type on them.”

Harrison’s research involves a lot of hacking. Being able to take apart a phone and rebuild it with new features is essential to his research. As a doctoral student at CMU, traditional classes helped him gain the technical know-how he needed, but the extracurricular courses he took outside of computer science, in skills such as welding and glasswork, gave him a different perspective that he says enables him to innovate.

To try and determine “how small is too small,” Harrison and other researchers crafted a smart watch with a keyboard the size of a penny.

“People are going to use this in different ways,” Touretzky says. “If you already know how to make things, you’re going to use these technologies to make things better. But if you’re a researcher who doesn’t want to be in the fabrication business, it’s removing a barrier to your research.”
Perhaps the technology that is enabling the maker revolution more than any other is the 3-D printer. First developed in the mid-1980s, 3-D printers create objects by outputting thin layers of plastic, building up pieces in a honeycomb-type structure that gets stronger as the plastic hardens. The machines once cost tens of thousands of dollars, but in the past few years, prices have plummeted. Inexpensive machines geared to hobbyists can be purchased for less than a thousand dollars. As a result, 3-D printers have become a staple of maker culture.

“If’ ownership of the means of production’ determines the class structure of society, then 3-D printing and DIY culture threaten to annihilate archaic class distinctions,” Andrew Leonard argued this summer in Salon. “The means of production is about to get a lot cheaper.”

Touretzky says that's wrong—it's not production, but prototyping, that's gotten cheaper. “3-D printing is slow,” he says. “Mass production is still done more economically using techniques like injection molding.”

Last year, Touretzky proposed to Robotics Institute head Matt Mason and then-CS department head Jeannette Wing that SCS do an experiment, where he would teach people how to use SolidWorks, a 3-D printer and a laser cutter.

“Part of this was in my own self-interest, because I wanted to make robot parts, but part of this was about helping to build a maker culture at SCS,” Touretzky says. Wing and Mason agreed to pay for the printer, while SCS's computing facilities team acquired 50 unused site licenses for SolidWorks from CMU's Mechanical Engineering Department.

When the printer arrived on the ninth floor of the Gates Center, Touretzky offered a training session with space for 25 people. More than 80 signed up. He's since offered three more training sessions on 3-D printing, as well as instruction on using the laser cutter in Doherty Hall's Collaborative Machining Center. Greg Kesden, associate teaching professor and SCS director of educational computing, led the effort to put a second 3-D printer into the third-floor computer cluster.

Use of the 3-D printers is being governed by SCS’s time-honored “reasonable person principle”: If you’re going to print a lot of objects, you need to buy your own print cartridge for $50. Access to the laser cutter is also now available to SCS students; the Computer Science Department and Robotics Institute pay $10 per hour for their students to use the machine.

One of the people who took advantage of the first 3-D printer's arrival is Michael Taylor, a robotics doctoral

Tom Pope, an assistant systems manager in the Institute for Software Research, says trial and error is an important part of learning new techniques such as 3-D printing. Here, he designs a headphone hanger in SolidWorks (upper left), sends it to a 3-D printer in the Gates Center, and removes it from the printer’s carrier tray (bottom center). The final product—before being trimmed—is shown at lower right.
student and researcher in CMU's CREATE Lab. He had used a 3-D printer while an undergraduate at Olin College, where he created a mechanical fish that looked like a blue-fin tuna. It's not like there were a lot of off-the-shelf parts available for mechanical tuna fish, so he had little choice but to craft the pieces himself. When he was done, he had his tuna.

Soon after the 3-D printer's arrival at the Gates Center, Taylor designed little projects for it, like a cap for a bottle or a vintage rocket ship. These helped him become more comfortable with the software and equipment.

Taylor also received a more personal demonstration of the value of knowing how to "make" things, and its potential to spur innovation. In January, Taylor slipped on some ice and shattered his elbow. After a weeklong hospital stay, he faced some serious rehab time, which included wearing a monstrous brace. The brace, a metal tube with spokes sticking out of it, stretched his arm and put pressure on it.

After a few months, he didn't need to stretch it out anymore—he just needed the brace to hold pressure on his arm. When he learned he had to travel to Uganda for his research, he realized he had a problem. The brace was too bulky for travel. He did have a soft brace—more like a sling—and that set Taylor's mind to thinking: what if he could modify his portable sling so it would work like the bulky, metal one?

After some thought, he designed a turnbuckle of sorts, which allowed the soft brace to exert the pressure that he needed. It was only two inches long, but this little piece that Taylor designed and printed on a 3-D printer was exactly the elegant solution he needed to travel safely as his elbow healed.

As Taylor demonstrated, access to new tools and technologies inspires people to think about how to use them in creative ways, says Illah Nourbakhsh, professor of robotics and director of CMU's CREATE Lab, and even people who don't have a technical education can be inspired to find ways to make technology work better. “It’s all about the idea of empowerment,” he says. “It’s inverting the power relationship.”

CREATE stands for Community Robotics, Education and Technology Empowerment. Much of Nourbakhsh's work at the CREATE Lab encourages active participation in the creation of technology by end users—whether that user is a tech-savvy gadget lover, a child just becoming interested in robotics, or a graduate student in SCS. “We're making (the experience) relevant to what the user wants to learn,” he says.

Taylor worked with Nourbakhsh on a project to help improve air quality in homes in developing nations. People in poorer parts of the world often use indoor fires to cook their food, in part because stoves aren't easy to find or affordable, and also because cooking over an open fire is traditional in those cultures. Yet cooking over a fire leads to poor indoor air quality and experts are unsure of how big of a problem that is. Taylor and Nourbakhsh wanted to develop small, low-cost sensors to test indoor air quality, but those sensors were fragile and prone to being damaged once they were deployed.

Maker culture came to the rescue: Taylor was able to design a housing in SolidWorks and used the 3-D printer to produce them. “I think it's very valuable and a unique resource,” Taylor says. “We have access to something that allows people to implement ideas. That's very valuable.”

That ability to rapidly move from research to prototype is where maker techniques shine. Ellen Cappo, a master's student in the Robotics Institute, used the 3-D printer to help Prasanna Velagapudi (E’05, CS’09, ’12) and Pyry Matikainen (CS’10, ’12) build a prototype of a two-foot-tall humanoid robot for a competition. She's also used the laser cutter. "I really like that the School of Computer Science is making these tools available," Cappo says.

Marynel Vazquez, a third-year Ph.D. student in RI, used the 3-D printer to make a robotic judge for a game she created that encourages children to eat more fruits and vegetables. The robot gave people points based on how fast they responded. She's now working with Disney Research Pittsburgh on ways to help robots interact with children, and the ability to design something quickly in SolidWorks, and then send it to a 3-D printer, is spurring her creativity, Vazquez says. "It is an absolutely great opportunity for prototyping," she says. "In some cases, it's not until you have a physical model when you can say 'this might work' or 'this won't work.'”

Trial and error is an important part of the design and development process. Tom Pope, an assistant systems manager in the Institute for Software Research, has been using the 3-D printer to create everyday items for use around the department, like key fobs, business card holders, and smartphone stands. His first key fob was bit too bulky for comfortable use, while the second one was too small. But the process is helping him hone his design skills, Pope says. He envisions creating items that he can hand out to visitors to promote both the department and maker culture. It’s tangential to his job, Pope admits, “but it’s fun to do.”
Maker culture isn’t confined to faculty, staff and grad students. CMU’s makers include people such as undergraduate Julia Teitelbaum, a double major in information systems and human-computer interaction. Growing up, Teitelbaum sewed things and built projects in her father’s workshop, and the experience of “making something” using technology helped lead to her decision to pursue a degree in computing. “I got introduced to (making things) because I liked crafts, and because my grandmother sewed, and my dad had tools,” she says.

She recently interned at the Children’s Museum of Pittsburgh, where she got to see up close the first year of a long-term exhibit called “Makeshop.” The installation is designed to demystify technology by giving children the chance to take apart toys, electronic devices and small appliances, and to apply woodworking, wiring, sewing and other skills to their own inventions. Makeshop uses many materials from the Center for Creative Reuse, a Pittsburgh nonprofit dedicated to recycling and reusing.

“Knowing how things are made changes your mindset,” Teitelbaum says. “For example, at the Makeshop, I helped a group of kids take apart a printer. I couldn’t make a printer from scratch if you asked me to, but having had the experience of taking one apart makes it less of a ‘black box,’ inspires curiosity and makes it less intimidating to think about fixing one or trying to make one someday.”

Teitelbaum likes that the final project in the Fundamentals of Programming and Computer Science course requires that the students make something, such as an app, that forces them to test their skills in a tangible way.

On the surface, it would seem as if people interested in creating physical things would have a similar outlook on life as computer scientists, and that the School of Computer Science would be a natural place for doing-it-yourself to thrive. But in Teitelbaum’s opinion, that hasn’t always been the case, at least among undergraduates. “Maker culture is only just starting to catch on at SCS,” she says. “Across CMU and especially in computer science, people often know theory really well and do assignments,” but turning their theories into implementation “isn’t a skill that people necessarily have.”

If that skill doesn’t come naturally, maybe it can be taught: Teitelbaum is one of the students behind a group called ScottyLabs (see page 21), which is trying to nurture the hacking culture on the CMU campus by making it welcoming to newbies and outsiders.

ScottyLabs is taking steps to make sure that CMU’s maker culture isn’t insular. Indeed, one problem of technology development, according to Nourbakhsh, occurs when technology engineers become a “monoculture” of similarly minded people pursuing similar goals. That’s why so many projects at the CREATE Lab reach out into places where technologists don’t often go, such as inner-city elementary schools, scout troops, YMCAs, and hospitals and homes in developing nations.

Take Arts & Bots. This program introduces robots and computer science into grade and middle school classrooms, while assessing students’ ability in science, technology, engineering and math (STEM). CREATE Lab’s Project Hummingbird, for students age 11 and older, provides adolescents with the tools to transform a construction paper animal, for example, into a “kinetic sculpture” that uses sensors to respond to the changing environment.

CREATE Lab’s projects are designed to allow people to make their own products and innovate while also helping the economy, Nourbakhsh says. Things such as 3-D printers are similarly helping to democratize the process of creating technology by giving the public the tools they need to participate in research and innovation. “Everyone becomes a technologist,” he says. — Meghann Holohan is a contributor to NBC News and Today.com and frequent contributor to The Link. She wrote about Safaba Translation Systems and alumnus Daniel H. Wilson in the Spring 2013 issue. Jason Togyer is editor of The Link. In eighth grade, he tried to build a robotic arm out of balsa wood and brass tubing from Loreski’s hobby shop in Monroeville. It didn’t work very well.
You’re a first-year undergraduate in computer science. Your coding skills aren’t great (yet), but what you lack in knowledge, you make up for with hard work and enthusiasm. When you see posters advertising a “hackathon,” you decide to check it out.

You arrive to find small groups of students have already broken off into teams. They glance in your direction, and then turn back to their laptops. None introduce themselves. No one offers to help. You’re intimidated. You slink out, dejected, wondering if you’ve made a mistake in choosing your major.

That’s exactly the scenario that TartanHacks—a series of coding competitions run at CMU since 2012—is trying to avoid.

It’s also helping to push Carnegie Mellon students out of what recent graduate Amy Quispe (CS'13), a co-founder of ScottyLabs, TartanHacks’ parent organization, describes as “a rut in terms of how they think about building things.”

At CMU, argues Quispe, “there are certain ways that are viewed as ‘acceptable’ to how you use your time, like going to classes, TA’ing or doing research. It’s the way people at CMU are taught to think.” In that atmosphere, hanging out and experimenting to learn new tasks can seem as if you’re “fooling around” or wasting time.

Jeff Cooper, now a senior, noticed it when he joined CMU’s Robotics Club his freshman year. “There were a lot of people who had really cool ideas, and they would start on a project but then end up getting buried in their schoolwork and give up,” he says. “There was this reluctance to get involved in something that wasn’t grade- or academics-focused.”

The link.
That’s a barrier to innovation, Quispe argues. “How can you innovate if you don’t realize that you can solve the problems around you?” she says.

ScottyLabs was created for that reason—to solve one of the problems around students such as Quispe and her classmate, Vinay Vemuri (CS’13, E’13). They found CMU’s dining, housing, class scheduling and bookstore information scattered and difficult to use. In 2011, Vemuri returned from an internship at Google Boston with the idea to create APIs, or application-programming interfaces, that could pull these different data together into easy-to-use formats. “I don’t know when the brainstorming started, but pretty soon, we really got rolling,” says Cooper, who was recruited by Vemuri from the Robotics Club. “Our feeling was, ‘let’s do this right.’” The trio thought they could write some simple “scraping” scripts and launch “APIs@CMU” by the end of that year.

They were wrong. They hit their first brick wall—the data wasn’t in any format that lent itself to being easily imported. And another—one offices, worried about privacy or security backdoors, didn’t want to share their data with the students.

But as the late Randy Pausch (CS’88) famously said, “Brick walls are there to give us a chance to show how badly we want something.” Fighting administrative red tape only made the students more determined. Pretty soon, their hobby turned into a fully staffed technical project, attracted more students and had a name—“ScottyLabs,” after the university’s Scottish terrier mascot.

As work continued, Vemuri attended a “hackathon” at the University of Pennsylvania. He returned with the conviction that CMU needed to be in the hackathon business, too.

Hackathons—marathon programming sessions where students compete to make something from scratch before a deadline—weren’t unknown to CMU, but they tended to be sponsored by companies. They also tended to be a little cliquish, attracting the same people again and again—those with lots of previous coding experience. “Frankly, it was getting kind of boring,” says Cooper, now director of operations for ScottyLabs. “We started thinking, why not more women? Why not more freshmen?”

The stereotypical “hacker,” they decided, was something like Comic Book Guy from “The Simpsons”—smart but overconfident, and a little anti-social. In other words: Worst. Mentor. Ever.

The ScottyLabs crew decided that a CMU-run hackathon would be different. It would provide a more inviting environment; there would be a competition, sure, but one in which mastering skills, sharing ideas and having fun were as important as “winning.” They reached out and advertised not just to computer science students, but also to first-year students in other undergraduate departments, and to Women@SCS.

And they decided to train people up, providing two days of pre-hackathon sessions, called “Crash Courses,” to introduce “newbies” to techniques they might not already know, on subjects ranging from Ruby on Rails to user interface design, says Drew Inglis, a CSD senior who serves as director of technology for ScottyLabs. Students took turns giving talks. (The “Crash Courses” were popular enough to inspire a spinoff event of their own, called...
“SkillSwap Weekend,” held in fall 2012. When George Hotz, the first hacker to carrier-unlock Apple’s iPhone and now an SCS undergrad, spoke about security, more than 400 students showed up. “People camped out to hear his presentation,” Quispe says.)

The first 24-hour “TartanHacks” was held in February 2012, and 150 students turned out, many of them with little to no hacking experience. “We kind of nailed it on the first try,” Quispe says, a bit sheepishly. Volunteers—both students and IT professionals—circulated around the room, offering advice and encouragement. “We picked people smart enough to answer the complicated questions, but also people who liked to interact with other people,” Cooper says.

The second-annual TartanHacks, held this past February, was even more successful, attracting nearly 200 people plus support from companies like Dropbox, eBay, Facebook, Google, Microsoft and Yahoo!

With the graduation of ScottyLabs founders Quispe and Vemuri, the organization is in the hands of students such as Cooper, Inglis and current ScottyLabs Director Julia Teitelbaum, a senior majoring in information systems and human-computer interaction.

“Growing up, I always liked to make things,” Teitelbaum says, “and not software things, I’m talking like the Pinewood Derby car race—I owned that at our middle school!—and in high school, for example, I needed additional lighting in my room, so I built wall panels.”

What she couldn’t learn from her parents or friends about carpentry or wiring, she researched online.

“I was willing to learn what I needed to learn to remove the barriers I faced,” Teitelbaum says. ScottyLabs and TartanHacks help remove barriers other students may face that keep them from innovating, she says.

To that end, ScottyLabs recently absorbed Make CMU, an interdisciplinary space where students can get together to work on their personal projects. “Every week, we hold a hack session, where people can come and work on stuff for three hours—or more, if they want to,” Inglis says. “We’ve had people come and work on hardware, we’ve had people come and work on software. We had someone come and make a block puzzle using a laser cutter.”

Although student groups come and go, ScottyLabs has a core group of 10 people dedicated to keeping it sustainable. “I think we’re in good shape for the future,” Inglis says. The strong interest in maker culture at CMU and in Pittsburgh seems to work in ScottyLabs’ favor as well.

“There is a huge chunk of this campus that just wants to make something cool,” Cooper says. —Jason Togyer (DC’96) is editor of The Link. His hacks are mostly in the domains of ham radio, model trains and backyard car repair.
The quest for anonymity online

Concerns about Internet privacy are growing—but users don’t have a ‘one-size-fits-all’ mentality

Editor’s Note: This article was written by Link Editor Jason Togyer and is condensed, with permission, from the report “Anonymity, Privacy and Security Online,” written by Lee Rainie, director of the Pew Internet Project; Sara Kiesler, CMU’s Hillman Professor of Computer Science and Human-Computer Interaction; Ruogu Kang, Ph.D. student in the Human-Computer Interaction Institute; and Mary Madden, senior researcher at the Pew Internet Project.

The original report was published Sept. 5, 2013, and is copyright © 2013 by the Pew Internet & American Life Project. You may download the original report and the survey questions at www.pewinternet.org/Reports/2013/Anonymity-online.aspx.

Introduction

Most Internet users would like to be anonymous online at least occasionally, but many think it is not possible to be completely anonymous online. From July 11 to 14, 2013, researchers from Carnegie Mellon University and the Pew Internet & American Life Project surveyed 1,002 adults ages 18 and older. Telephone interviews were conducted in English by landline and cellphone. In this survey, 81 percent of adults are Internet users; 90 percent of adults are cell phone owners; and 53 percent of adults are smartphone owners.

Notable numbers of Internet users reported that they have experienced problems because others stole their personal information or otherwise took advantage of their visibility online—including hijacked email and social media accounts, stolen information such as Social Security numbers or credit card information, stalking or harassment, loss of reputation, or victimization by scammers.

Trying to stay anonymous—at least once in a while

In word and deed, most Americans would like the ability to be anonymous and untracked online at least once in a while. They may desire to avoid disclosing certain activities or political beliefs to particular groups of people, or to avoid certain people.

A clear majority—59 percent—says that people should have the ability to use the Internet completely anonymously. When Internet users are directly asked, 18 percent say they use the Internet in a way that hides or masks their identity. Yet when a broader battery of activities about masking behavior or content is asked of respondents, 81 percent say they do at least one of these obscuring activities.

And 81 percent of Internet users also have taken at least one step to try to mask their behavior or avoid being tracked. The most common strategy was to clear cookies and browser history (64 percent). Notable numbers have taken even more sophisticated steps, such as encrypting their email (done by 14 percent of Internet users) or using virtual personal networks (VPNs) or proxy servers that do not allow firms to track their online movements (also done by 14 percent of Internet users).

Other strategies included deleting or editing information they posted in the past, setting their browsers to disable or turnoff cookies, not using websites because they asked for real names, using temporary usernames or email addresses, asking someone to remove something posted about them, using public computers to browse anonymously, using false names, using services that permit anonymous web browsing, or giving inaccurate information.

The question of whether people should be allowed to use the Internet anonymously was asked of all adults (not just Internet users), and 34 percent of the general public (including 33 percent of Internet users) said they did not believe people should be allowed to use the Internet anonymously.
There are noteworthy demographic and political differences in the answers to this question. Those most likely to say that people should have the ability to go online anonymously include men; those under the age of 65; those who live in urban areas; and liberal Democrats. In addition, those who are employed are more likely than non-workers to believe Internet use should be allowed to be anonymous. Across the board, technology users were more likely than non-users to say this: that includes Internet users versus non-users, cell users versus non-users, and social media users versus non-users.

**Who has taken steps to mask their identity?**

Internet users and smartphone owners were asked a battery of questions about the strategies online Americans might use to hide their identity or otherwise mask them from others who might want to observe their online behavior.

In all, 81 percent of Internet users or smartphone owners said they had employed at least one of the eleven strategies we queried. Many had employed multiple strategies. The average anonymity seeker had used between three and four of these strategies at one time or another.

The most consistent differences in masking strategies are tied to age. The youngest adults (ages 18 to 29) are more likely than their elders to take steps to be hidden online, as Figure 1 shows. The one activity where stark differences were not observed was the encryption of email. Internet users of all ages under 65 were equally likely to have done that.

Other notable differences relate to educational attainment. Those who have a college or graduate education are more likely than those who have not gone to college to have cleared their cookie and browser history, disabled cookies, decided not to use a website because it asked for their name, encrypted their email, and used a proxy server or VPN.

**Age-related differences in habits**

When users post material online, they are more likely than not to attach their name or a recognizable screen name to their material: 49 percent of Internet users say they have used their real name, and 47 percent use a screen name or username that people associate with them.

At the same time, 25 percent of Internet users say that they have posted material without revealing who they are.

The most consistent pattern in these findings is that younger adults who use the Internet tend to do all three things at greater rates than those who are 30 or older—use their real names; use a recognizable screen name; and post without disclosing who they are. This undoubtedly relates to the fact that younger users tend to be more frequent users of the Internet and share more content than older users.

Beyond the differences tied to age, online women are more likely than online men to say they have used their real name when they post material (55 percent vs. 43 percent).

**Some believe they can be totally hidden**

Even though many wish to be anonymous and have taken steps to obscure their online activities at least occasionally, they do not necessarily think it is possible to be completely anonymous online.
All of the adults in the sample were asked: Considering everything you know and have heard about the Internet, do you think it is possible for someone to use the Internet completely anonymously—so that none of their online activities can be easily traced back to them? Just 37 percent of them said they thought it was possible to be completely anonymous and 59 percent said it was not possible.

The most striking differences on this question were between men and women. While majorities in both genders do not think it is possible to be completely anonymous online, women were more likely than men to say it is not possible to be completely anonymous online (64 percent vs. 54 percent).

The researchers also asked a specific question about anonymous posting online. Internet users were asked: Suppose you said something critical about a product online, and you didn’t use your real name. How easy do you think it would be for the company to find out who you are anyway? Most thought it would not be terribly hard for the company to track them down.

Those who had not taken any steps to obscure their online activities were much more likely to say it would be “very easy” for a company to track them (56 percent).

**A range of personal content online**

The CMU-Pew team asked Internet users about 11 kinds of personal information and whether that information was available online “for others to see.” They made clear that it did not matter if they posted or revealed the information, or if someone else did.

Users report that a wide range of their personal information is available online, but feel strongly about controlling who has access to certain kinds of behavioral data and communications content. Among the list of items queried, photos were the most commonly reported content posted online; 66 percent of Internet users reported that an image of them was available online. And half (50 percent) say that their birth date is available. Others reported that available online was their email address, their employment information, things they’ve written, their home address or their memberships in certain groups or organizations. More than 20 percent reported their cellphone number, home number or videos of them were online; 20 percent said their political party or affiliation could be found online.

The average user reported that they knew at least four of these details about them were available on the Internet. In several of the categories of personal information, young adults are more likely to have those details online, though young adults were the least likely online adults to say that their home address was available online. Similarly, these young adults were the least likely to say their home phone number was on the Internet—perhaps because this age group is among the least likely to have a landline telephone number. Finally, younger adults were no more or less likely than their elders to say that their political affiliations were available online.

It is important to note that significant numbers of respondents said they did not know if some personal information about them was available online. For instance: 30 percent of Internet users said they did not know if their email address was posted online; 22 percent said they didn’t know if their home address was posted; 17 percent said they didn’t know if their cellphone was posted; and 13 percent said they didn’t know if their political party, their writing and their birth date were available online.

**Whom are users trying to avoid?**

Sometimes, Internet users are not trying to be completely anonymous. They just want to stay unobserved or tracked by certain people or organizations.

Beyond their general hope that they can go online anonymously, the majority of Internet users (55 percent) have tried to avoid observation by certain people, groups, companies and government agencies. Hackers and criminals (33 percent) and advertisers (28 percent) are at the top of the list of groups people wish to avoid, followed by “certain friends” and “people from your past,” people who might harass or criticize them; family members or romantic partners; employers or co-workers; “the government;” and “law enforcement.”

It is worth noting that considerably more people take steps to avoid advertisers and unpleasant social observations than take steps to avoid detection by their employers (11 percent) or by government (5 percent) or law enforcement (4 percent).

Again, the most important, consistent differences in avoidance behaviors online are tied to age. Young adults (ages 18 to 29) are more likely to have tried to keep from being seen online by most of these potential observers than older users of the Internet.

While online, men are more likely than women to try to avoid detection by advertisers, to try to avoid observation by those who run the websites they visit, and avoid being observed by law enforcement. On the other hand, women are more likely to say they have used the Internet to keep from being observed by people from their past and by certain friends.
Certain kinds of data are more sensitive

Another set of questions that were asked focused on the “data exhaust” that is generated as a result of online communication, web surfing and application use. Respondents were asked how much they cared “that only you and those you authorize should have access” to certain kinds of behavioral data and communications content, and there was notable variance in the answers.

The content of email messages and the people with whom one communicates via email are considerably more sensitive pieces of information when compared with other online activities and associated data trails. (Figure 2)

There are also some differences on these questions between online women and men. Women who use the Internet are more likely than men to say it is very important that only they, or those they authorize, know who they are emailing (67 percent vs. 57 percent). Compared to men, women who use the Internet are more likely to say it is very important for them to control access to information about the place where they are located when they go online (60 percent vs. 49 percent).

Identity theft, security issues and reputational damage

An array of woes has struck some Internet users when personal information of theirs was compromised, or when some of their online activities put them in conflict with others. Twenty-one percent of Internet users have had an email or social networking account compromised or taken over without their permission; 12 percent have been stalked or harassed online; 11 percent have had important personal information stolen such as their Social Security number, credit card or bank account information.

Six percent have had their reputation damaged because of something that happened online, or been the victim of an online scam and lost money; while 4 percent have had something happen online that led them into physical danger.

In addition to those instances when personal information and personal identity have been at the center of a problem, 13 percent of Internet users report they have experienced trouble in a relationship with a family member or a friend because of something they posted online. And 1 percent say they have lost a job or educational opportunity because of something they posted online, or which someone posted about them online.

Online younger adults—those ages 18 to 29—are the most likely to have experienced some of these troubles, such as having an email or social media account hijacked; being stalked or harassed online; suffering reputational damage; or being in physical danger based on online events.

In addition to the age differences when it comes to these problems, there are also times when poorer Internet users are among the most likely to be victimized. For instance, Internet users who live in households earning less than $30,000 are particularly likely to have had an email or social media account compromised; experienced trouble in a relationship between themselves and others; been stalked or harassed online; had their reputation damaged; or been put in physical danger.
Conclusions

The team’s biggest surprise was discovering how many Internet users have tried to conceal their identity or their communications from certain other parties. Almost everyone has taken some action to avoid surveillance. And despite their knowing that anonymity is virtually impossible, most Internet users think they should have a right to anonymity for certain things, like hiding posts from certain people or groups.

Users clearly want the option of being anonymous online and increasingly worry that this is not possible. Their concerns apply to an entire ecosystem of surveillance. In fact, they are more intent on trying to mask their personal information from hackers, advertisers, friends and family members than they are trying to avoid observation by the government.

People would like control over their information, saying in many cases it is very important to them that only they or the people they authorize should be given access to such things as the content of their emails, the people to whom they are sending emails, the place where they are when they are online, and the content of the files they download.

Privacy is not an all-or-nothing proposition for Internet users. People choose different strategies for different activities, for different content, to mask themselves from different people, at different times in their lives. Key communications and content, such as emails, are relatively precious to Internet users, and information about the time of day when they are online is not nearly as important for users to control. Some of the strongest sentiments about controlling personal information are exhibited by those ages 30 to 49. Online Americans believe that different kinds of data trails have different value and they want control over some of the more personal material.

Internet users are more worried than they were in the past about the amount of information that is available about them online. Half (50 percent) of Internet users say they are worried, up from 33 percent who said that in September 2009. In late 2006, the figure stood at 40 percent.

There is consistent evidence that the level of concern is growing. It has increased among all groups, and is especially pronounced among Internet users ages 65 and older and those living in households earning less than $30,000.

Asked whether they think current privacy laws provide reasonable protections for people’s privacy on their online activities, 66 percent of all adults said the laws are “not good enough.” Some 24 percent said they provide reasonable protection.

Interestingly, there are not noteworthy differences in answers to this question associated with political or partisan points of view. Tea Party supporters, conservative Republicans, self-described moderates and liberal Democrats are not statistically significantly different in their answers.

Not surprisingly, those who say they are worried about the amount of information about them online are more likely to say that current laws are not good enough.

About this survey

This survey was underwritten by Carnegie Mellon University. The findings in this report are based on data from telephone interviews conducted by Princeton Survey Research Associates International from July 11 to 14, among a sample of 1,002 adults ages 18 and older. Telephone interviews were conducted in English by landline and cellphone. For results based on the total sample, one can say with 95 percent confidence that the error attributable to sampling is plus or minus 3.4 percentage points and for the results from 792 Internet and smartphone users in the sample, the margin of error is 3.8 percentage points.

Contributors to this study included Maeve Duggan, research assistant, Pew Internet Project; Stephanie Brown, research assistant, Human-Computer Interaction Institute, Carnegie Mellon University; and Laura Dabbish, associate professor of information technology and organizations, Heinz College, Carnegie Mellon University.

Users clearly want the option of being anonymous online and increasingly worry that this is not possible. Their concerns apply to an entire ecosystem of surveillance. In fact, they are more intent on trying to mask their personal information from hackers, advertisers, friends and family members than they are trying to avoid observation by the government.
Changes—for the better

By Tina M. Carr

We have some very exciting things to tell you about—including a new undergraduate scholarship and the 25th anniversary of the founding of the School of Computer Science—but let me first tell you about the last few months. It was a very busy summer. We had great, well-attended events for SCS and Electrical and Computer Engineering Department alumni and their families at the Boston Museum of Science and Seattle’s EMP Museum.

Yet nothing could have prepared us for July 27’s SCS/ECE event at San Francisco’s newly reopened Exploratorium. It was one of CMU’s largest regional alumni events this year, with more than 600 people in attendance. (See pages 30 and 31.)

Although we heard a lot of nice compliments about the San Francisco event and the venue, the evening couldn’t have happened without your support and enthusiasm.

Cèilidh—formerly known as homecoming and family weekend—came early this year (Sept. 27–29). One new wrinkle was a “TOBOM” race in the Gates Center for Computer Science. This was like our spring Mobot race on the mall in front of Wean Hall, but instead of going downhill, the autonomous robots navigated their way up the Gates Center’s helix.

I especially enjoyed spending time during Cèilidh with J. Renato Iturriaga (S’64, ’67) and his family. Renato was honored Sept. 27 as one of the university’s 2013 Distinguished Alumni.

As one of CMU’s first computer science Ph.D.s—his advisor was Alan Perlis—Renato is a living link to the early days of the CS department. He has gone onto a truly distinguished career in academia, government and private industry in his native Mexico, and was recently appointed as a liaison between Mexico’s Federal Ministry of Education and the state governor of Morelos.

Renato’s wife and daughters told me he’s been regaling them for years with stories about his days at Carnegie Mellon, but this was the first time they had visited Pittsburgh. It was an emotional and rewarding experience for all of us.

Network Nights Are Now CMU Connect: It seems like the only constant in CMU’s history has been change. What we’ve been calling “Network Nights” is now known as “CMU Connect.” It’s more than a new name—it’s a whole new philosophy.

Our goal is to expand both the quality and the quantity of the activities we offer for our alumni and students, so they can grow both their social and professional networks. We want our alumni to be able to share their experiences and expertise with students and parents, and our current students to help our alumni reconnect with the university.

Our first series of “CMU Connect” events was held in New York City Oct. 16–20, and included a technology and entrepreneurship workshop hosted by Facebook, a “women in business” networking breakfast, a career panel, alumni career counseling, a career fair and a reception hosted by PriceWaterhouseCoopers.

On Oct. 19, we tried something different, as alumni, students and friends of the university volunteered their time to help New York’s public schools during “New York Cares Day.”

Our next CMU Connect events will be held in February in Pittsburgh, followed by events in Washington, D.C., and San Francisco in March. Do you like the change? You’ll have to attend and let me know.

New Stehlik Scholarship Created: How about this new scholarship I mentioned? It’s the creation of our SCS Alumni Advisory Board, and it’s named for Mark Stehlik, longtime assistant dean for undergraduate education who now serves as associate dean of Carnegie Mellon University’s Qatar campus.

The Stehlik Impact Scholarship is designed to address a concern—raised by some alumni and faculty—that students are too often focused on their grades and their future careers to the exclusion of exploring research and community service.

Continued on page 32
We capped off our summer alumni schedule with an amazing event in San Francisco on July 27. More than 600 people turned out at the recently reopened Exploratorium at Pier 15 on San Francisco’s Embarcadero.

The Exploratorium stresses hands-on, experiential learning, and it delivers, with a lot of very interactive exhibits. As a result, there was a huge “buzz” around this event, and it turned out to be one of the biggest regional alumni events not just for SCS and ECE, but across CMU this year.

It was a sprawling venue, but it worked. Here are a few of more than 1,500 photos that were taken that night!
The Stehlik scholarship will recognize SCS seniors who have demonstrated that they have interests beyond the classroom in research, entrepreneurship and outreach to others. The scholarship is designed as an incentive to help spark conversation and ultimately change the culture at SCS for the better. Students will be nominated by SCS faculty, and the ultimate selection will be made by the associate dean for undergraduate education. The guidelines for selection are intentionally broad, giving faculty wide latitude to nominate students based on their impact “in the field of computer science, in the community and in the world.” The alumni advisory board’s goal is to raise enough money to support a $10,000 annual scholarship. If you’d like to become part of the fundraising effort, please contact me.

SCS 25th Anniversary: Dec. 1, 2013 will mark the 25th anniversary of the appointment of A. Nico Habermann as the first dean of computer science at Carnegie Mellon University. The creation of the School of Computer Science was announced to the public on Jan. 2, 1989. We are planning a full slate of events later in 2014 to mark our first quarter century. You have played an important part in SCS’s journey so far—so we hope that you will be able to join us during the year as we mark this important milestone. Make sure you’re registered in our alumni database (alumni.cm.edu) so that you won’t miss an update. And we hope to see you soon!

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

By Philip L. Lehman

Thank you, 150 million times: thank you!

In June, the university wrapped up “Inspire Innovation—The Campaign for Carnegie Mellon University.” Our goals were to build awareness of the university, increase participation in (and by) our worldwide community and raise $1 billion.

It seemed like an enormous goal when it was first announced. Well, we’ve significantly exceeded it. Our alumni, students, faculty, staff and friends (almost 50,000 individuals and organizations overall) contributed more than $1.18 billion to Carnegie Mellon. Thank you!

Contributions to the School of Computer Science were nearly $150 million. More than 140 individuals, corporations and foundations each pledged in excess of $100,000. More than 270 separate areas of research, education and capital received pledges over that amount. More than 3,300 families of alumni, faculty, students, staff and friends contributed to SCS. Thank you!

Highlights included support for buildings (Gates Center for Computer Science and Hillman Center for Future-Generation Technologies); departments (the Lane Center for Computational Biology); faculty support, including chairs (such as the Charles M. Geschke Directorship for the Human-Computer Interaction Institute); research at all levels; graduate fellowships; and undergraduate support.

Donations through “Inspire Innovation” have strengthened our programs for outreach, including Women@SCS (now expanded into SCS4ALL), Girls of Steel, TechBridgeWorld, the Alice Project, Robot 250 and the ACM Programming Competition; entrepreneurship (Project Olympus, now helping lead the Carnegie Mellon Center for Innovation and Entrepreneurship); and other novel purposes (such as the Dean’s Innovation Fund). Thank you!

As we enter our second quarter century as a school, we are enormously gratified by this wide recognition of the importance of the work and contributions of our students, faculty and staff—and the impact that our interdisciplinary inspiration, innovation and hard work are having on the world.

We are much, much stronger for your support. Can I say it again? Thank you, thank you, thank you!

—Philip L. Lehman (CS’78, ’84) is associate dean for strategic initiatives in the School of Computer Science.
Mark Palatucci
B.S.E., computer science and engineering, University of Pennsylvania, 2000
M.S., robotics, Carnegie Mellon University, 2008
Ph.D., robotics, Carnegie Mellon University, 2011

Boris Sofman
B.S., electrical and computer engineering, Carnegie Mellon University, 2005
B.S., computer science, Carnegie Mellon University, 2005
M.S., robotics, Carnegie Mellon University, 2007
Ph.D., robotics, Carnegie Mellon University, 2010

Hanns Tappeiner
Dipl. Ing. Inf., Technische Universität Wien, Austria, 2004
M.S., robotics, Carnegie Mellon University, 2008

Anki Inc. made its high-profile debut on the world stage June 10 when the company’s first product, Anki Drive, was demonstrated during the keynote at Apple’s Worldwide Developers Conference.

Anki Drive runs on Apple’s iOS and allows users to control toy racecars from their iOS devices. It’s the first game where real, moving objects simultaneously interact with a virtual environment, their physical surroundings and one another.

Netscape co-founder and venture capitalist Marc Andreessen, who serves on the Anki board of directors, calls it “the best robotics startup I have ever seen.”

Anki’s three co-founders met at Carnegie Mellon in 2005. All of them grew up with an interest in technology—especially robotics. “As a kid, I was always interested in making things that could interact with the real world,” says Hanns Tappeiner, who was born in Germany and raised in northern Italy. “One time, I tried to build a machine that could steal candy out of a candy jar. It never really worked! Later, I took up building things in Lego and hooked my creations up to really, really early versions of microcontrollers.”

By the time Tappeiner completed his undergraduate work at Austria’s Technical University of Vienna, he’d been doing robotics “for a very long time,” both as a hobby and as a field of study.

Boris Sofman was born in Russia and immigrated to the United States as a child. His earliest computing experience was programming in Logo, the educational language that allowed users to program either an
on-screen turtle or a real-world robot. He came to CMU to earn degrees in both engineering and computer science.

“The idea of making things in the physical world was very exciting to me,” Sofman says. “As an undergrad, I got to participate in a couple of projects at the Field Robotics Center where people were working on autonomous navigation, with robots that could sense and avoid obstacles, and as I was applying to grad schools, I realized the kind of robotics I wanted to study was being done best at CMU.”

Mark Palatucci was just 5 years old when his dad brought an IBM PCjr—the family’s first personal computer—into their Philadelphia home. “I immediately fell in love with it,” he says. “By the time I was 6, I started learning BASIC, and by the time I was 10 years old, my aunt bought me my first robotics kit.” That kit, and others he assembled, are on his desk at Anki 25 years later.

He graduated from Penn, moved to Silicon Valley and started Copera, a company that developed software for handheld PCs and early smartphones. “I also started volunteering on Stanford’s DARPA Grand Challenge team in 2004 to help build the Stanley robot, and met a lot of really incredible people,” including former CMU professor Sebastian Thrun, Palatucci says. “They were all super-smart and they had all come from CMU’s Robotics Institute.” He applied and was accepted into the Ph.D. program.

Besides robotics, the three also shared an interest in consumer products. “Whenever we brainstormed things, it was never about, ‘What can we do in the lab?’” Tappeiner says. “Instead, it was always, ‘What can we do to make this a viable product?’”

The idea that evolved into Anki Drive can be described in four words, according to Sofman. “Real-world Sim City,” he says. “Sim City is an intelligent ecosystem. We wondered how we could make that environment possible in the real world. How could we make a physical object—a car—understand where it was located in its environment, very precisely? How could we make the algorithms efficient enough to do it, and how could we deliver it at a price point that people can afford?”

In laboratory research, Sofman says, it doesn’t matter if a robot needs a $5,000 sensor and “a crazy amount of computation,” but that simply won’t work for a consumer product.

Anki Drive solves the efficiency problem by separating higher-level functions—those that control game play—from less-complex functions. Although the remote cars each have an onboard 50 MHz microcontroller as well as navigational sensors, the artificial intelligence required to play a game is done completely on the user’s iPhone running the Anki Drive app. The cars communicate with the app and one another via Bluetooth LE.

Trying to offload all of the decision-making ability to the remote device wouldn’t work, Sofman says. “There’s too much latency, and the bandwidth also wouldn’t support it,” he says.

The separation of functions also ensures the long-term value of the system, Palatucci says. “The mechanical parts onboard the cars only control their basic functionality,” he says. “Over time, we not only can upgrade the software in the app, but we can also upgrade the software used by the microcontrollers in the cars.”

Apple’s iOS 6 ecosystem was the perfect platform for Anki Drive, Palatucci says, because it was one of the first consumer products to support Bluetooth LE, which was designed for low-power consumption and control of multiple devices at the same time.
Key to Anki’s development has been the continuing connection between the company and the School of Computer Science. At this writing, the company employs about four dozen people, one-fourth of whom have ties to the Robotics Institute. “It’s definitely a core part of what we’re doing here, and we’re very thankful for the experience we had at CMU,” says Tappeiner, adding that working with RI research professor Ralph Hollis helped to shape his own ideas.

Palatucci says Tom Mitchell, head of CMU’s Machine Learning Department, was a key influence, while Sofman says RI research professor Tony Stentz and associate professor Drew Bagnell had a big impact on his work.

“We had great advisors and great colleagues,” Sofman says. “What we’ve achieved at Anki on a technical scale was built on things we learned at the Robotics Institute.”

—Jason Togyer (DC’96)
A search committee has been named to recommend candidates to become the next dean of the School of Computer Science.

Guy Blelloch, professor of computer science, is leading the search for a replacement for Randal E. Bryant, who has announced that he will step down at the end of his term on June 30, 2014.

Bryant, dean since 2004, says he will resume teaching and research following a one-year sabbatical—his first ever.

“It’s been a wonderful experience for me to serve as dean,” says Bryant, who joined the CMU faculty in 1984 and also serves as a University Professor. “I’ve gotten to work with many creative and capable people on projects ranging from new research initiatives and new educational programs to improved outreach to our alumni and supporters. I’ve been able to ride in autonomous vehicles, walk around muddy construction sites, and meet with alumni and friends of SCS all around the world.

“I’ve especially enjoyed meeting the families of our students at graduation, sharing with them the excitement of our students’ achievements,” he says.

Called the “quintessential computer science professor” by former CMU president Jared Cohon, Bryant is a member of the National Academy of Engineering and the American Academy of Arts and Sciences, as well as a fellow of both the IEEE and ACM.

His research focuses on the development of computer-aided design tools that simulate and verify digital circuits, as well as on symbolic manipulation and large-scale parallel computation. He is the co-author, along with CMU Professor David O’Halloran, of “Computer Systems: A Programmer’s Perspective,” which is used by more than 130 colleges and universities worldwide, and has been translated into other languages, including Mandarin Chinese and Russian.

Bryant’s tenure as dean has seen the creation of two new degree-granting departments within the School of Computer Science—the Machine Learning Department and the Lane Center for Computational Biology. As SCS dean, Bryant also oversaw the relocation in 2008 of many classrooms and faculty offices to the Gates Center for Computer Science and the Hillman Center for Future Generation Technologies, establishing a new “SCS quad” on the east side of the Pittsburgh campus.

He serves on the Informational Technology Advisory Board of the Federal Bureau of Investigation; the Academic Research Council of the Singapore Ministry of Education; and as a council member of the Computing Community Consortium. He is a past member of the review committee for the federal Networking and Information Technology Research and Development program; the Computer and Information Science and Engineering Advisory Board of the National Science Foundation; and the board of directors of the Computing Research Association.

A graduate of the University of Michigan, Bryant earned his doctorate in electrical engineering and computer science from the Massachusetts Institute of Technology. He came to Carnegie Mellon from a faculty appointment at the California Institute of Technology.

Blelloch says the search committee will seek input from different constituencies across the School of Computer Science to identify the “ideal characteristics” of the next dean. After identifying both internal and external candidates, the committee will meet privately with the finalists and make its recommendation to CMU President Subra Suresh and Provost Mark Kamlet.

Other members of the search committee include Kathleen Carley (ISR), Tom Cortina (assistant dean for undergraduate education), Kayvon Fatahalian (CS’03) (CSD), Martial Hebert (RI), Philip Lehman (CS’78, ’84) (associate dean for strategic initiatives), John Lehoczky (dean of Dietrich College), Roni Rosenfeld (CS’91, ’94) (LTI), Tuomas Sandholm (CSD), Russell Schwartz (Lane), Dan Siewiorek (HCI), Aarti Singh (MLD), Cheryl Wehrer (DC’90, TPR’96) (RI) and Edna Jackson (director, provost’s office).

ED CLARKE HONOURED WITH BOWER AWARD

Ed Clarke has been awarded one of the nation’s most prestigious science honors. Clarke, CMU’s FORE Systems University Professor of Computer Science, is the winner of the 2014 Bower Award and Prize for Achievement in Science from Philadelphia’s Franklin Institute.

Established in 1824, the Franklin Institute’s awards recognize people whose work has benefited humanity, advanced science and launched new fields. Past awards have gone to such legendary innovators as Alexander Graham Bell, Thomas Edison, Albert Einstein and Jane Goodall.

Also honored this year by the Franklin Institute was Mark H. Kryder, University Professor of Electrical and Computer Engineering, who will receive the 2014 Benjamin Franklin Medal in Electrical Engineering.

Clarke’s Bower Prize recognizes “his leading role in the conception and development of techniques...”
CMU and four major research universities have joined forces with the Army Research Lab to develop new computer systems that make smart decisions about their own security.

The five-year, $23.2 million project, called “Models for Enabling Continuous Reconfigurability of Secure Missions,” will enable future computing systems to respond to cyberattacks with or without human intervention.

Patrick D. McDaniel, professor of computer science and engineering at Penn State, is the principal investigator on the project, titled Models for Enabling Continuous Reconfigurability of Secure Missions.

The alliance will focus on: detecting adversaries and attacks in the cyberspace; measuring and managing risk; and altering the environment to achieve best results at the least cost. A fourth area, developing models of human behaviors and capabilities that enable understanding and predicting motivations and actions of users, defenders and attackers, will be integrated into the first three areas.

Lorrie Cranor, director of CMU’s CyLab, is leading the university’s part of the project, which focuses mainly on the psychosocial aspects.

“Humans are integral to maintaining cybersecurity and to breaches of security,” Cranor says. “Their behavior and cognitive and psychological biases have to be integrated as much as any other component of the system that one is trying to secure.”

Other CMU investigators include Lujo Bauer, associate research professor of electrical and computer engineering and CyLab; Nicolas Christin, assistant research professor of ECE and CyLab; and Coty Gonzalez, associate research professor of social and decision sciences and director of the Dynamic Decision Making Laboratory.

**ANSWER: IBM AND FOUR UNIVERSITIES, INCLUDING CMU**

And the question? Who’s working on a new collaborative research project to develop new question-answering systems, such as “Watson”?

In addition to CMU, MIT, New York University and Rensselaer Polytechnic Institute also are part of the IBM-led initiative, which will lay the groundwork for a “Cognitive Systems Institute.”

Like IBM’s “Watson,” which made its memorable worldwide TV debut defeating several human champions on “Jeopardy!,” these systems can learn, reason and help human experts make complex decisions involving extraordinary volumes of data.

Eric Nyberg (CS’92), a professor in CMU’s Language Technologies Institute, is a leading researcher in the field of question-answering systems and part of the new project. He says cognitive systems have the potential to support intelligent, natural interactions with “Big Data” to perform complex human tasks.

Personalized information agents will rapidly adapt and optimize their task performance based on direct interaction with the end user, he says.

Nyberg is a leading researcher in the field of question-answering systems. He pioneered the Open Advancement of Question Answering, an architecture and methodology for accelerating collaborative research in automatic question answering. OAQA supported the Watson system.
REYNOLDS, PIONEER IN SEPARATION LOGIC, DIES AT 77

John C. Reynolds, a longtime professor of computer science known for his incisive work on the logical foundations of programs and programming languages, died April 28. He was 77.

“We will always remember John for his cheerful spirit, his high ethical standards and his deep intellect,” said Randy Bryant, dean of SCS. “He will very much be missed.”

Peter O’Hearn, now at University College London, collaborated with Reynolds on the development of separation logic, which led to the creation of automated tools for program analysis that can run on parallel processors. “More than anybody I have ever met, John Reynolds went deep in his quest to understand,” O’Hearn said. “He was truly original—it is correct to say, a genius. And he was a gentle and wonderful man, a great friend.”

Colleagues and alumni also paid tribute to Reynolds’ skill and passion for mentoring students and junior faculty. “He cared sincerely for the well-being and career development of his students, continuing to provide guidance and advice for years after graduation,” said Stephen Brookes, professor of computer science.

Reynolds was profiled in the Spring 2013 issue of The Link. His death from cancer and congestive heart failure came as that issue was being delivered to mailboxes.

Reynolds is survived by his wife Mary and their sons Edward and Matthew. A memorial service was held May 11.

FORMER SCS COMPUTING FACILITIES DIRECTOR COSGROVE DIES AT 62

Bob Cosgrove, who retired in December 2012 after 11 years as SCS director of computing facilities, died suddenly near his home in Naples, Fla., on Oct. 9. He was 62.

Cosgrove first came to Carnegie Mellon in the 1980s as part of the Andrew Project, which created the world’s first wired campus. He later worked in the computer and information technology industry, filling a variety of leadership positions at such companies as Alcoa and NeXT Computer. He was later brought back as a consultant to the School of Computer Science to help improve the operations of the school’s computing facilities.

“We liked him so well that we recruited him to become director of computing facilities,” said Randal E. Bryant, SCS dean.

Cosgrove was honored at the SCS Founder’s Day ceremony on January 31, 2013, where he reminisced about his experiences as director.

Among other achievements as director, Cosgrove created a responsive help system, reduced needed customization of software and upgraded disk, email and backup systems to keep pace with changing technology and usage patterns. During a long and varied career, Cosgrove also taught philosophy at Drexel University and LaRoche College, and computer science at the University of Pittsburgh.

A native of Philadelphia, he earned a Ph.D. in philosophy at Temple University and a master’s degree in computer science at the University of Pittsburgh. Cosgrove is survived by his wife, Liz Hines, and his daughter, Kate Cosgrove.

Memorial contributions may be made to the Folds of Honor Foundation, 5800 N. Patriot Drive, Owasso, OK 74055.
It may not have the same cache as the Pittsburgh Marathon. But for 33 years, the “Pretty Good Race” has marked the end of the Immigration Course for incoming CSD doctoral students, and the beginning of another school year.

According to a history of the race written by Phil Miller, the PGR was created in 1981 from an idea by then-faculty member Phil Hayes, who had run a 10K that summer during an AAAI conference. The name was suggested by Bruce Lucas (CS’81,’84) as a spoof of Pittsburgh’s 10K “Great Race.”

The first PGR took contestants on a three-mile trek through Schenley Park, and it was won by Rich Korf (CS’80,’83) and then-assistant professor of computer science Elaine Kant.

The current race, now a 5K, has been renamed in honor of the late “Coach” Jim Tomayko (DC’71,’80), former director of the master’s in software engineering program and a one-time high school track coach. Open to more than just folks from the School of Computer Science, the SCS Coach Tomayko Pretty Good Race starts and finishes under the Panther Hollow Bridge, near Phipps Conservatory.

Nearly 70 people competed in this year’s PGR, held Sept. 6. Most runners took about a half hour to complete the course, while “race-walkers” took a little longer. This year, Jeff Bigham, associate professor of human-computer interaction, won the men’s category by completing the race in 17 minutes and 49 seconds, while in the women’s category, Jamie Morgenstern, a computer science Ph.D. student, won for the fourth consecutive year and set a new course record at 19 minutes and 40 seconds.

Most of us would probably agree that’s more than just “pretty good.”

—Jason Togyer (DC’96)
In 1989, “state of the art” computing for most of us meant software delivered on 5.25-inch floppy disks, files output to dot-matrix printers, and, if we were lucky, connection to a bulletin-board service via a 1,200-baud modem. But in Pittsburgh, IBM and Carnegie Mellon University were wrapping up work on The Andrew Project, which had begun in 1982. By the time these photos were taken in the spring of 1989 by photographers for The Thistle, CMU’s Pittsburgh campus was home to the world’s largest local area network. Andrew gave 7,000 students, faculty and staff access to multitasking, electronic mail, “what you see is what you get” word processing and graphics, and high-speed transfer of files between workstations, as well as a connection to what would soon be known as “the Internet.”

Something even bigger in computing was brewing at CMU in early 1989, though it lacked some of the “gee-whiz” appeal of Andrew. On Jan. 3, 1989, CMU announced creation of the world’s first “graduate School of Computer Science,” with A. Nico Habermann as its dean, 90 faculty members, 175 Ph.D. students and 17 research associates. The launch of SCS passed beneath the notice of Pittsburgh’s newspapers, who were pre-occupied with the firing by the Steelers of four assistant coaches. Even Carnegie Mellon Magazine relegated the announcement to page 32.

CMU’s computer science prowess was already well known in 1989, but few could have envisioned the growth in stature, or size, of the Carnegie Mellon School of Computer Science over the next 25 years. SCS will be celebrating its 25th anniversary—and looking ahead to its next quarter century—throughout 2014. And we’re sure that any announcements we make will get a bit more attention than they did back in 1989.

—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.

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Details</th>
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<tr>
<td>Nov. 27–29</td>
<td>Thanksgiving recess: No classes</td>
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<tr>
<td>Nov. 28–29</td>
<td>University closed</td>
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<tr>
<td>Dec. 4</td>
<td>CS faculty meeting 3:30 p.m., 6115 Gates and Hillman Centers</td>
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<td>Dec. 5</td>
<td>Detroit Alumni Holiday Party</td>
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<tr>
<td>Dec. 6</td>
<td>Last day of classes, fall semester</td>
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<td>Dec. 9</td>
<td>Final exams begin</td>
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<tr>
<td>Dec. 12</td>
<td>Black Friday: Systems 9:30 a.m., 6115 Gates and Hillman Centers</td>
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<td></td>
<td>Black Friday: AI/Theory 1 p.m., 6115 Gates and Hillman Centers</td>
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<tr>
<td>Dec. 13</td>
<td>Black Friday: General Meeting 6115 Gates and Hillman Centers</td>
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<td>Dec. 15</td>
<td>Alumni Yinz to Y’all Holiday Brunch Kaleidoscope Bistro, Atlanta</td>
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<tr>
<td>Dec. 18</td>
<td>Residence halls close</td>
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<td>Dec. 19</td>
<td>Final grades due</td>
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<tr>
<td>Dec. 24–25</td>
<td>University closed</td>
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Toward the next quarter century

The School of Computer Science formally began operations on Dec. 1, 1988. But we trace our history to the 1950s, when our founding faculty members, Alan Perlis (S’43), Herbert Simon (H’90) and Allen Newell (TPR’S7), defined “computer science” as “the theory and design of computers, as well as the study of the phenomena arising from them.”

Today, we continue and extend their vision by embracing all facets of computing, from the pursuit of elegant algorithms and novel applications, to the construction of rugged robots that explore the ocean and outer space.

Thank you for being a part of our first 25 years. We look forward to celebrating our silver anniversary with you in 2014!