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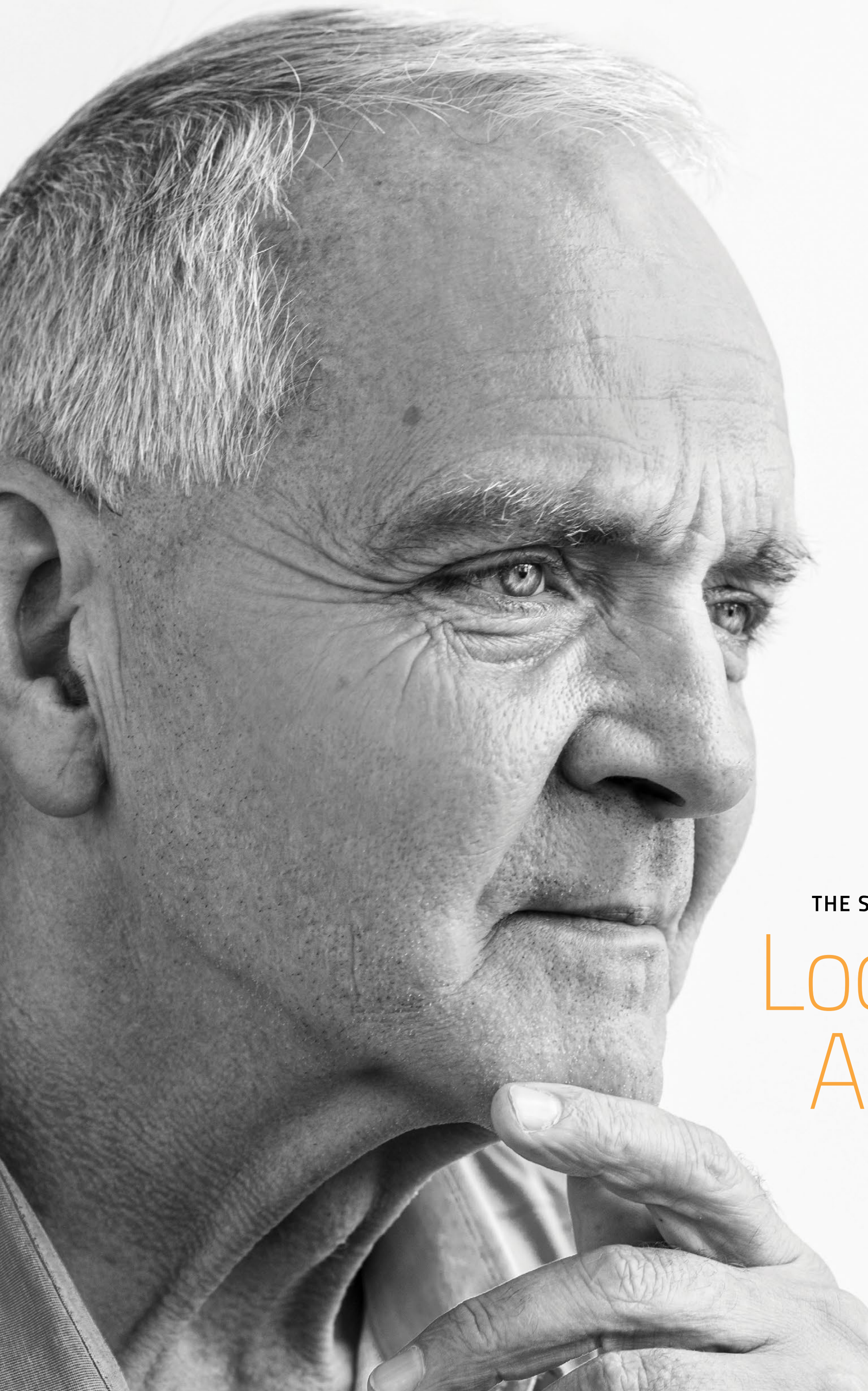
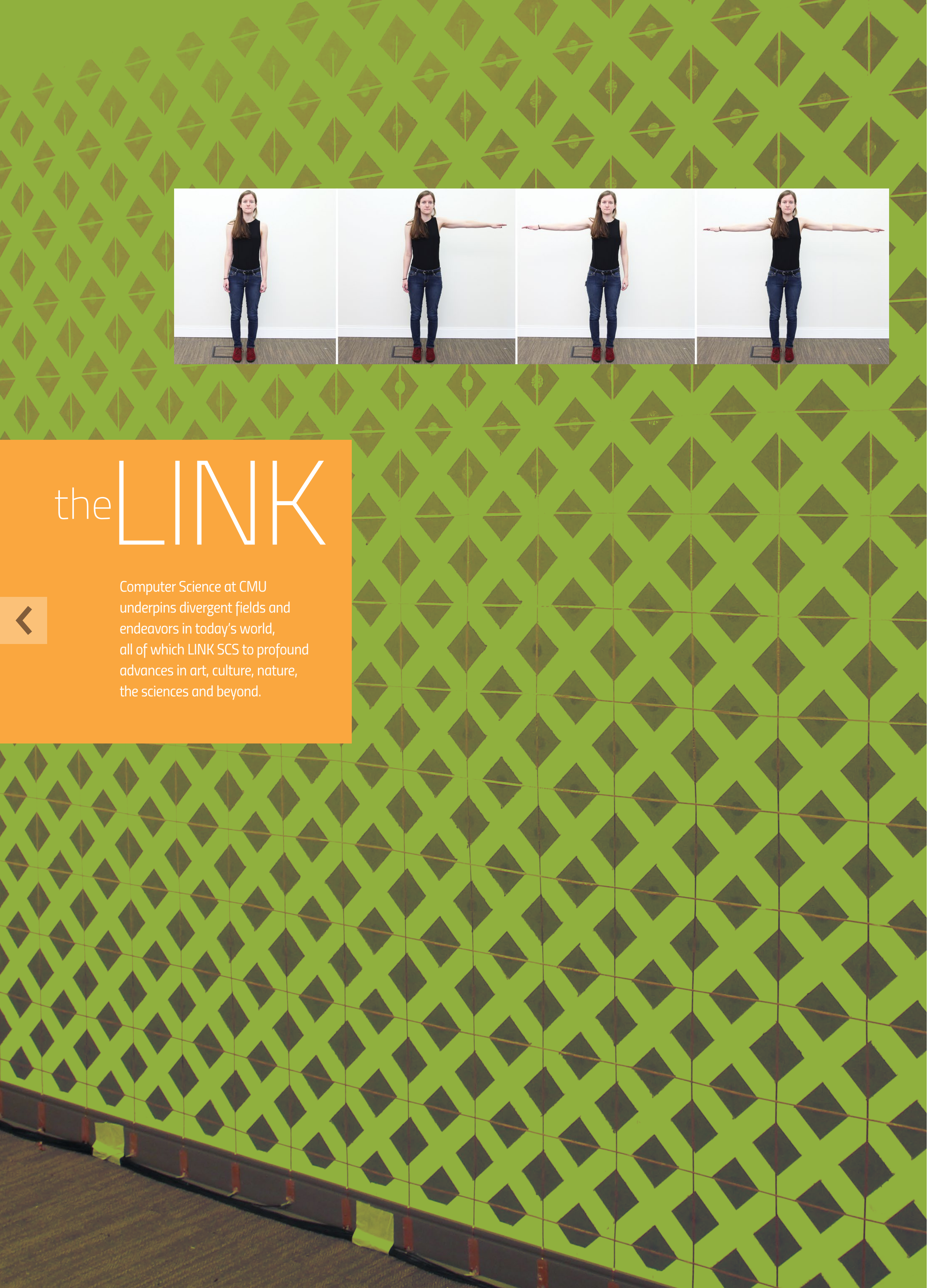


WINTER 2019
ISSUE 13.2

MARTIAL HEBERT
THE SIXTH DEAN OF SCS

Looking Ahead



the LINK

Computer Science at CMU underpins divergent fields and endeavors in today's world, all of which LINK SCS to profound advances in art, culture, nature, the sciences and beyond.

If these walls could talk...

With the transformation of many everyday objects into smart appliances, more and more space in our homes is being taken over by specialized gadgetry and wall fixtures. We currently choose between form and function. But what if we could seamlessly blend all of these smart technologies into our environment?

Researchers at Carnegie Mellon University's Human-Computer Interaction Institute (HCII) along with Disney Research Pittsburgh have found one potential solution in a ubiquitous but often-overlooked feature — the standard wall.

"Walls are usually the largest surface area in a room," said Chris Harrison, assistant professor in the HCII, "yet we don't make much use of them other than to separate spaces, and perhaps hold up pictures and shelves." This new smart wall technology, dubbed Wall++, takes advantage of necessary infrastructure by creating a single high-tech installation.

To create smart walls, researchers in the HCII attached a lattice of thin copper wire to ordinary walls and coated them with a diamond grid of a common, nickel-based conductive paint. They connected both a mutual capacitance-sensing circuit board and radio frequency-sensing circuit board to these conductives, allowing users to interact with Wall++ in two distinct modes.

The mutual capacitance mode detects a user's hands and body pose, similar to the multifinger touchscreen technology found in tablets and phones, which could allow gestures over Wall++ to seamlessly close blinds, dim lights or turn up music. In the second mode, Wall++ senses electro-magnetic signals from electrical appliances within the room to map their location and on/off state, which could eventually provide real-time data from devices such as heart monitors and insulin pumps.

"Walls are large, so we knew that whatever technique we invented for smart walls would have to be low cost," said Yang Zhang, a Ph.D. student in the HCII. Overall, the cost is $20 per square meter, more than a regular paint job but modest compared to other integrated smart technologies like the smart board, which retail for around $1,500.

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Publisher
Martial Hebert

Editor
Kevin O'Connell

Contributing Writers
Susie Cribbs (DC 2000, 2006),
Melissa Curtis (DC 2020),
Niki Kapsambelis, Kevin O'Connell,
Chris Quirk, Mark Roth,
Cristina Rouvalis, Byron Spice

Photography
Jessica Bernstein-Wax,
Michael Henninger, Rebecca Kiger,
Elan Mizrahi, Kevin O'Connell, Matt Wein

Design
Vicki Crowley (A 1996)

Office of the Dean
Gates Center for Computer Science
Carnegie Mellon University
5000 Forbes Avenue
Pittsburgh, PA 15213
cs.cmu.edu

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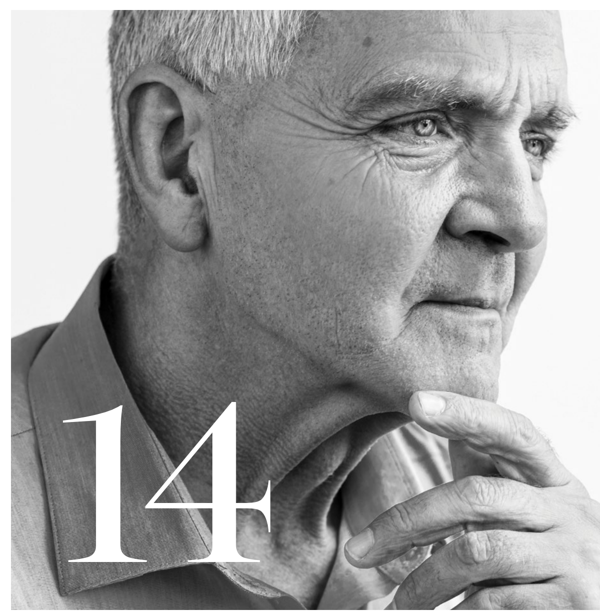

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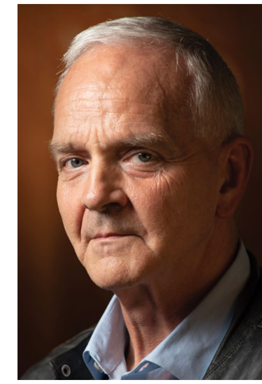
It's Always Interesting



This year marks my 34th at CMU. And I am very pleased to now be serving as the Dean of SCS. In some ways, I feel like I've just had my first day all over again.

I keep telling people that even though I've been here a long time, I still have an enormous amount to learn. CMU truly is an amazing place in terms of the variety of research and work we do. From the most fundamental to the most applied — our work transforms a staggering breadth of topics.

Down one hallway we have people doing incredible work on the theoretical foundations of AI, alongside people doing the technical and mechanical — designing working physical systems. In between, we have people working with social scientists and psychologists to better understand human interaction. All of this — an incredible spectrum of ideas — working independently and yet also together.

It may sound a bit utopian, but it's much deeper than that. And it's very unusual.

This issue of The Link features articles on our people working on topics that range from the theoretical potential of quantum computing to the development of physical systems in computer vision capable of seeing the unseeable around corners. It's fantastic. We show how applying algorithms in medicine helps match organ donors in ways never before conceived, and we demonstrate how we continue to lead the world in robotics — this time underground — by designing and constructing robots using the newest and most innovative techniques in the world.

One thing remains clear: We have always been allergic to people putting themselves in boxes.

This kind of siloed view of the world really doesn't exist here. I'm not entirely sure why, but it's simply not part of our culture. We attract the opposite. We bring together the collaborators and multidisciplinary minds to create a high level of intellectual freedom that is truly exceptional. The excellence of our students is unmatched, but even with all these incredible minds, things would not work as they do if we did not have this culture of being interested in many different things — especially outside of our own areas of expertise.

So even though I'm not starting anew, technically, there's a lot for me to learn here. You always need to know what you don't know.

And it's always interesting.

Martial Hebert
Dean, School of Computer Science

The Explorer team's wheeled ground robot navigated the mine shaft on its way to victory in phase 1 of DARPA's Sub-T Challenge.

Explorer

Mining the Power of Autonomous Robots

Mark Roth

In the end, it wasn't even close.

After the first leg of the Defense Advanced Research Projects Agency's (DARPA) Subterranean (Sub-T) Challenge, the team from Carnegie Mellon and Oregon State universities blew away the competition.

The CMU-Oregon State team, Explorer, used wheeled ground robots and aerial drones to perform a simulated search-and-rescue mission inside two coal mine shafts just south of Pittsburgh. The team racked up 25 points, more than twice that of its closest competitor, CoStar, led by California's Jet Propulsion Laboratory.

The event, called the Tunnel Circuit, was the first of three missions the teams will undertake over the next two years. The next leg, slated for February 2020, will be a simulated urban rescue scenario at a location yet to be chosen, which could involve such obstacles as steps and shafts. The third competition will be a simulated cave rescue. The challenge culminates in a final event in August 2021, when the winner will receive DARPA's $2 million grand prize.

Kevin Pluckter (CS 2019) helped design the interface that connected him to the machines.

The Tunnel Circuit took place this past August at two experimental coal mines run by the National Institute for Occupational Safety and Health. The teams performed two runs through each tunnel and could spend an hour on each run. During that time, the robots not only had to find their way through the mineshafts, but also had to identify five objects — a cellphone, drill, backpack, fire extinguisher and a human dummy (dubbed Rescue Randy). Each team was allowed one human operator communicating with the robots. In CMU's case, that human was Kevin Pluckter (CS 2019), who helped design the interface that connected him to the machines.

So how did Explorer outperform the other 10 teams so decisively?

For starters, the team broke from earlier tradition and designed its robots to be as independent as possible, anticipating the day when humans would have only intermittent contact with robots roaming through dangerous spaces.

Team leader Sebastian Scherer (CS 2004, 2007, 2011), an associate research professor in the Robotics Institute, pointed to two additional key factors in their success.

First, the Explorer team made the risky decision to custom design their robots rather than adapt existing ones, as most of their competitors did. For the ground robots, that meant outfitting them with the largest wheels possible on a robot that had to fit through a one-meter-by-one-meter space. The large wheels turned out to be a valuable advantage, because they could slog through deep mud and climb over pipes or other objects. Scherer also noted that the team designed the aerial drones to have extra strong thrust, so they could overcome turbulence in the mineshaft. "We also overlapped the props to get a lot of motor packed into a smaller area," he said.

The Explorer team made the risky decision to custom design their robots rather than adapt existing ones, as most of their competitors did.

The second factor that gave the Explorer team an edge was practice. For eight hours each day in the month leading up to the competition, the Explorer team tested its robots in a tourist coal mine northeast of Pittsburgh. And that was after nine months of running tests once or twice a week in the same mine.

Now, the Explorer team will have to decide how much to further customize their robots for the next legs of the Sub-T Challenge.

Team member Geoff Hollinger (CS 2007, 2010), an assistant professor of mechanical engineering at Oregon State and a graduate of CMU's robotics program, said that he believes the aerial drones will be especially important in the upcoming urban and cave-rescue challenges.

"My guess is that in future challenges, there will be more 3D structures, and drone robots may have a particular advantage," he said. "If I have a ground vehicle on the floor, it's going to be limited in what it can see, whereas a drone can get up and see what is going on. In caves, if there are vertical shafts, drones will function in spots where ground robots can't."

Unlike the 2018 rescue of a soccer team from caves in Thailand, the DARPA cave challenge won't have any submerged spaces, although DARPA program manager Timothy Chung said that "technologies spawned by this challenge might be relevant for submerged rescues in the future."

Carnegie Mellon entered the Sub-T competition with a well-deserved reputation as one of world's leaders in creating groundbreaking robots, from a snakelike robot that can look for earthquake survivors to a robotic arm that can obey brain signals.

More than 30 years ago, CMU's William "Red" Whittaker designed the robots used to explore and take samples in the damaged Three Mile Island nuclear reactor. And, of course, in 2007 a CMU team won DARPA's Urban Challenge — the autonomous vehicle challenge. It maneuvered its robot across the finish line 19 minutes ahead of the next challenger, kick-starting the now thriving autonomous vehicle industry and bringing a fresh infusion of applicants to CMU's robotics programs. Winning the Sub-T Challenge could provide the same boost.

The Sub-T Challenge hopes to create technologies with applications in many other areas of society. DARPA's Chung said autonomous drones might one day inspect and repair bridges, roads and tunnels. The challenge robots' 3D mapping abilities also could be useful in construction and architecture.

At the technical level, Scherer said the challenge has helped his team develop ways to keep the robots running even when they encounter unexpected difficulties. For example, the Explorer team

The Explorer team designed its ground robot with the largest wheels possible to still fit through a one-meter-by-one-meter space, allowing it to slog through deep mud and over unforeseen objects.

The Explorer team practices with an aerial drone robot to help the team gain its best advantage.

put its perception hardware into modules that were designed to be easily swapped from one robot to another if one becomes stuck or disabled. The modules also simultaneously run several route-finding algorithms so the robot can use whichever one works best.

They also found ways to work around problems created by mist or dust, which can clog sensors and make the robot think it was hemmed in.

"Traditionally, the robot would say 'I'm surrounded by obstacles, I can't move,'" Scherer said. "But part of our strategy was to sometimes turn off the sensors." The robot would drive forward blindly, relying on its internal gyroscope-based navigation instruments to get out of the jam. Sometimes, driving blind meant the ground robots would start to drive up the side of a wall, but when that happened, its gyroscopes helped prevent it from tipping over. When the robot was out of the jam, the human would turn its sensors on again.

The team also had to create a way for the robots to communicate with each other when thick mine walls stymied outside Wi-Fi signals. To solve that problem, the robots dropped communications nodes inside the tunnel to create an instantaneous Wi-Fi network.

For eight hours each day in the month leading up to the competition, the Explorer team tested its robots in a tourist coal mine northeast of Pittsburgh.

While there may be completely autonomous robots one day, Scherer said that's not the current goal. Instead, the Explorer team wants to use the human coordinator in the smartest way possible.

"The human can bring a lot of creativity to a situation and it's impossible for the system to do everything. So you have to have the right tools to interact with the robots. We want to use the human's best abilities to help the robots get the job done," he said.

One broad benefit from the DARPA challenges is that they help train the next generation of robotics experts. For example, members of CMU's victorious autonomous vehicle team went on to shape the emerging driverless car industry.

Chris Urmson (CS 2005), the technical lead for CMU's DARPA Urban Challenge team, went on to run Google's self-driving car program and now has launched his own startup, Aurora Innovation. Raj Rajkumar, professor in ECE and the Robotics Institute, who was an engineering faculty member on the team, created a spinoff called Ottomatika, which was purchased by Delphi Automotive and is now part of its self-driving car subsidiary, Aptiv. Bryan Salesky, who was the software lead, started Argo AI, another self-driving company.

In a similar way, CMU team members who worked on Google's Lunar XPrize for trips to the moon started the spinoff Astrobotic, which now has NASA contracts to deliver payloads to the moon.

Oregon State Explorer team member Geoff Hollinger says, the DARPA challenges have, in a way, become this generation's space race.

"My wife and I often go to science museums with our daughter," he said. "We see exhibits on the Manhattan Project and the Space Race, and I say to her, 'If I had been alive then, that's what I would have wanted to work on.' I think in today's world, robotics has the same kind of potential." ■

To learn more or for partnership opportunities, visit subt-explorer.com. To contribute to the effort, visit giving.cmu.edu/explorer.

CS Idea Triggers First Kidney-Liver Transplant Swap

Multi-Organ Exchanges Could Boost Transplants

Byron Spice

Aliana Deveza was desperate. Her mother's health was failing after years of fighting a hereditary kidney disease. Aliana wasn't a good donor candidate for her mother because she eventually might face the same disease herself.

But what if she donated part of her liver instead? Specifically, what if she donated part of her liver to a patient who needed it and then a loved one of that patient donated a kidney to her mother?

It wasn't Aliana's idea, but one she gleaned from a research paper by Tuomas Sandholm, the Angel Jordan Professor of Computer Science, and one of his former students, John Dickerson (CS 2014, 2016). The result is what many believe to be the world's first kidney-liver swap.

In July 2017 at UCSF Medical Center in San Francisco, Aliana, of Gilroy, California, donated a little more than half of her liver to Connie Saragoza de Salinas of Sacramento. Saragoza's sister, Annie Simmons, of Boise, Idaho, donated one of her kidneys to Aliana's mother, Erosalyn Deveza.

"Everyone's doing well now," said Aliana, now 23 and a psychology major at the University of California, Santa Cruz, though her mother subsequently was treated for breast cancer. "Things were a little rough for her for a while," Aliana acknowledged. In her own case, her liver rapidly regenerated and she considers herself in good health.

Neither Sandholm nor Dickerson, now an assistant professor of computer science at the University of Maryland, had any idea the kidney-liver swap they inspired had taken place until this past April. That's when a case report by the UCSF surgeons describing the historic transplant was published in the American Journal of Transplantation.

"Multi-organ exchange is something I thought would be really cool," Sandholm said of the research paper he and Dickerson wrote, which explored the potential for kidney-liver swaps to increase U.S. organ transplants overall. "I didn't anticipate it would be performed anytime soon because there are so few live donors for livers."

Sandholm already has played a key role in the expansion of kidney paired-donation (KPD) transplants. In these cases, mismatched donor-recipients — a donor who is willing to donate a kidney, but is biologically incompatible with the recipient — are matched with other donor-recipients in the same situation. The first donor donates to the second recipient, while the second donor donates to the first recipient, thereby enabling two transplants.

Sandholm, his students and collaborators devised computer algorithms that made it possible to make KPD matches using a national pool of candidates, making matches more likely and enabled chains of kidney swaps that involve multiple donor-recipient pairs.

The first kidney swaps resulting from his algorithms took place in 2006. The United Network for Organ Sharing (UNOS), the nonprofit organization that manages the U.S. organ transplant system, adopted his algorithms for a national kidney exchange that began in 2010. Thousands of donor-recipient pairs have been matched, resulting in hundreds of kidney transplants, Sandholm noted. About 70 percent of U.S. transplant centers now participate in the UNOS national kidney exchange.


Tuomas Sandholm   John Dickerson

Liver recipient Connie Saragoza de Salinas, liver donor Aliana Deveza, kidney transplant surgeon Dr. Nancy Ascher, liver transplant surgeon Dr. John Roberts, kidney donor Annie Simmons and kidney recipient Erosalyn Deveza gathered at UCSF Medical Center several months following what is believed to be the world's first kidney-liver swap. (Photo courtesy of Jessica Bernstein-Wax/UCSF Health)

In their paper, published in the Journal of Artificial Intelligence Research, Dickerson and Sandholm calculated that combining the kidney exchange with a liver lobe exchange could match 20 to 30 more candidates a month than would be possible with separate liver and kidney exchanges. That would be an increase of about 10 percent.

Importantly, an increase in liver transplants would translate into lives saved. Though kidney dialysis can keep people with failing kidneys alive, no such life-saving treatment is available for someone with a failing liver.

When Aliana read the paper in 2015, she thought the computer scientists were describing an existing scheme for kidney-liver swaps.

"I didn't realize that it was just theoretical," she said. But it met her needs, so she began calling hospitals in California, trying to learn how she and her mother could join such an exchange. Most of the people she called had no idea what she was talking about, much less where to transfer her call. At UCSF Medical Center, however, Dr. John Roberts, a liver transplant surgeon, returned her call. "He said it was an interesting thought."

He referred her to a transplant coordinator and she and her mother were approved by the transplant program in January 2016. But finding a suitable exchange took 18 months, in part because Aliana's small physique meant they would need to find a recipient of similar size.

Saragoza, who had primary biliary cirrhosis, and Simmons ultimately were matched. Simmons had originally planned to donate part of her liver to her sister, but her liver wasn't of sufficient size.

According to the case study recently published by Roberts and kidney transplant surgeon Dr. Nancy Ascher, every indication was that the transplant recipients would have normal outcomes. The major concern prior to surgery was ethical; the risk Aliana was assuming as a liver donor was far greater than Simmons' risk as a kidney donor, and the life-enhancing benefits to her mother were less than the life-saving benefits to Simmons' sister.

"My parents and family were a little hesitant," Aliana said. "But I really wanted to push for the transplant because it was my mom. It was getting to the point where her condition was really painful. I wasn't too worried about myself; I was in good hands with the doctors at UCSF."

Sandholm said he's not sure whether multi-organ exchanges will catch on the same as KPD transplants. At this point, for instance, no system exists for pooling donor-recipient pairs and making matches. But he said it is heartening to see that an idea born in a computer science lab resulted in a first-of-its-kind operation that saved lives.

"Computer scientists have a lot of wild ideas, and this one just seemed so out there," Sandholm said. "It's just very cool that this turned out so well. We're happy for all of the patients." ■ ■

New SCS Dean Reflects on the Past, Looks to the Future

Kevin O'Connell

When Martial Hebert contemplates what has kept him at SCS these past 34 years, he thinks about what constitutes "CMU-ness."

"We often hear about the 'bottom-up' culture here," said Hebert, who was recently appointed dean of the School of Computer Science. "It's something that is not only inherent in the culture, but an important aspect for quality of life."

Hebert has served in a variety of roles during his time at CMU — faculty member; head of the Robotics Institute; and, now, the sixth dean of SCS. But Hebert remains stoic about his new position. "It's not a job I sought out, necessarily," he said. "But it is one I am happy about and very proud to take on."

FROM PARIS TO CMU

Born in the Paris suburbs, Hebert studied mathematics as a first-generation college student at the University of Paris. His computer science career began when he took an introductory CS course, which then led to internship opportunities at France's National Institute for Research in Computer Science (INRIA) — part of the first national robotics programs in the country. A postdoctoral fellowship with Takeo Kanade, now U.A. and Helen Whitaker University Professor in the Robotics Institute, brought him to CMU.

Three and a half decades later, he still hasn't left. In fact, he's inked a remarkable legacy.

> “More than ever, I think there is great opportunity to probe the reflexive relationship between AI and the discipline it’s being applied to — how one informs the other and how they can both be improved by the combination.”

A prestigious teaching career followed Hebert’s postdoc, and his research, centered primarily on computer vision, has helped define the field. In fact, he created the first degree program in computer vision. As an early researcher with the Autonomous Land Vehicles program, Hebert’s work on object recognition, environmental modeling and obstacle detection contributed to today’s research on self-driving vehicles.

Hebert attributes his long run at CMU to the freedom its professors and researchers have to investigate what interests them most, without being overly concerned with the work’s field or discipline.

“It’s a natural tendency to move toward one’s area — one’s view of the world,” Hebert said. “What I think we need to do in leadership is everything we can to resist that, and to maintain the culture we have established here.”

Hebert stressed the importance of reminding ourselves how unique this culture is in academia. “What works is to listen to the faculty and to understand how to facilitate their work. They are the ones who come up with the great ideas, not the leadership,” he said. Truly bottom-up thinking.

Of course, in an institution of SCS’ size and reputation, there have to be some rules — at least organizationally. Hebert bases his vision for this on allowing freedoms within the structural demands of a growing organization. As dean, Hebert said that he will always fight to protect the school’s culture, just as he did as the department head of the Robotics Institute.

“In a way,” he said, “it would be much easier to simply say that we have rules, ‘this is what you can work on, and this is what you can’t work on.’ But we must resist that.” Moreover, Hebert admitted, faculty and the school would never allow him to go in the direction of too much bureaucracy.

“They would come for me with pitchforks and torches,” he joked.

LOOKING AHEAD

When it comes to discussing any new direction for SCS, Hebert says he’s proud that the school’s already doing the right things. “The trick,” he said, “is to keep doing them as the organization continues to grow in both size and impact.”

An example of something SCS has done well, and that Hebert would like to see more of, is a concept he calls “AI + X” or “Computing + X.” This theory runs against the current notion in some circles outside CMU that sees computing (and particularly AI) as a powerful toolbox that should be applied to other fields. AI + X goes deeper than that notion, fully merging AI into other fields.

“This new combination completely transforms the original field and creates a brand new way of looking at it,” Hebert said. “It becomes, basically, a different field. And at the same time, it motivates new challenges and research areas on the computing side that did not exist before.”

He cites the example of AI and automated scientific discovery as a game-changer in that field. “It didn’t just tweak it, or make it faster or cheaper,” Hebert said. “It transformed how we think about it.” On the computing side, applying AI to scientific discovery essentially created the field of automated science, resulting in SCS developing an entirely new educational program: the Master of Science in Automated Science in the Computational Biology Department.

Hebert believes CMU can apply AI across many disciplines and fields, given our interdisciplinary culture. Finance, health care, education, sports — new fields await those willing to do the merging.

“More than ever, I think there is great opportunity to probe the reflexive relationship between AI and the discipline it’s being applied to — how one informs the other and how they can both be improved by the combination,” he said.

Hebert is also focused on broadening the view of what constitutes AI, whose current definition he finds far too narrow. He said our thinking on AI is too often limited to machine learning, which in turn is limited to deep learning. Such a narrow view restricts our capabilities.

“There is much more to AI that includes both the hardware and software aspects,” Hebert said. “For example, the world of software engineering. Being able to put together AI systems, all the toolboxes and infrastructure for deep learning that allows people to prototype their ideas very quickly, all those contributions come from software engineering. Completely new ideas from sensors that we develop here will be critical for intelligent systems, self-driving cars and much more. And it’s all AI.”

Hebert stressed that it is up to everyone in SCS to articulate the breadth of what AI actually is and what it can be.

“That’s the kind of thing those in this role before me have always done,” Hebert said. “Going back all the way to the founders, who had an expansive view of the field but could communicate it concisely.”

Of course, during Hebert’s tenure as dean, plenty of new focus areas and initiatives will arise. But it’s nice to think they might stem from what folks in the SCS community have been doing all along. ■

BACKWARD, FORWARD OR COSTUMED: SCS'S PRETTY GOOD RACE IS A TRADITION THAT ENDURES

Niki Kapsambelis

Once a year, through the winding, leafy trails of Schenley Park in the waning days of summer, a pack of runners from the School of Computer Science puffs and pants its way through a 5K race that has withstood nearly 40 years of evolution and still managed to stay true to its low-key roots.

Founded in 1981, the Pretty Good Race is one of the most beloved SCS traditions, a way of uniting faculty, students, staff and their families in an event that has endured despite (or possibly because of) the fact that it has never taken itself too seriously. Participants range from dedicated runners to casual strollers. What unites them is their affiliation with a program that, like the race, inspires a sense of deep loyalty.

It started as a way of blowing off steam at the end of what was then a six-week immersive course that introduced new Ph.D. students to SCS culture. Students sat in the windowless interior classrooms of Wean Hall listening to faculty describe their research interests.

"The grad students could sit back and get a picture of the absolute frontier of computer science from the people chopping the trees and building the log cabins," said Phil Miller, a former professor of computer science who founded the race.

"It's not quite like a jail, but it feels that way when you're sitting there," said Dirk Kalp (CS 1973), the race's current organizer.

Miller, an avid runner, thought a 5K was the perfect antidote to the grueling days in the classroom. The timing loosely coincided with Pittsburgh's annual 10K, The Great Race. So Miller's self-deprecatingly dubbed his project the "Pretty Good" Race, since it was half as long and nowhere near as prestigious.

Kalp recalls that roughly 40 to 50 people showed up the first year, including a sizeable number of Ph.D. students, as well as other faculty and staff. Participation swelled each year thereafter, reaching close to 100 for the first five or six years of the race. This year, unusually hot weather kept the field to a dedicated 62.

"It hit the spot," Miller said. "If you think about the backbone of computer science at the time, the real jewel was considered the Ph.D. program. We were family, and people really came to run…you saw everybody at the race."

In keeping with its humble beginnings, the Pretty Good Race was strictly a no-frills affair. Winners were determined by Mark Stehlik, now an assistant dean in SCS but then a young faculty member, who borrowed a starter pistol from someone on the track team and kept times on his digital watch.

"We did this as old-fashioned as we could," Stehlik said. "The problem was when a whole metric ton of people came across. It was hard to figure out times."

Stehlik solved that problem by asking runners to put their names on wooden Popsicle sticks, which they handed over as they crossed the line. Volunteers mapped times against the names on the sticks to determine places.

"The mapping part, that's a computer science concept," Stehlik said. "We've often solved problems in less technological but elegant ways. I think that's a hallmark of the Computer Science Department."

Now in its 39th year, the race remains a largely manual affair, run with clipboards and stopwatches, though runners do have bibs. Kalp, who has run the race backward 11 times — once while blowing bubbles — posts detailed instructions on the website, but few competitors read them. Often, he will send a postrace email to a few runners to ask them if they finished ahead of another person.

What also hasn't changed is the postrace beer, affectionately known as a "TG," from "TGIF."

Miller once ran the race in a homemade costume designed to mimic Karel the Robot, which was used to teach Pascal to students in the 1980s. It was a stunt he quickly regretted — the cardboard box proved oppressively hot once he started running.

"It was a horrible thing," he laughed.

After a decade, Miller wearied of organizing the race and tried to pull the plug on it. When it proved too popular to die, he handed the reins to James "Coach" Tomayko (DC 1971, 1980), a founder and director of the Master of Software Engineering program. Tomayko earned his nickname because he disliked being called "professor" or "doctor," so students and colleagues referred to him as "coach."

Joe Pane, John Pane and Theresa Pane (l to r) with a sampling of their trophies from the Pretty Good Race.

Kalp, who started running because he needed exercise and his dorm room overlooked the track, remembers finishing last in a race and Tomayko doubling back to finish with him. They became fast friends, and Kalp assumed race responsibilities when Tomayko fell ill, battling a rare neurological illness. Too ill to continue running, Tomayko raced for a while in a wheelchair. After he died in 2006, the race was renamed the Coach Tomayko Pretty Good Race, and the first-place men's trophy also bears his name.

Yufei Ye, a first-year Ph.D. student in the Robotics Institute, won this year's women's division with a time of 25:11 — not as fast as previous winners, but she said she got lucky because the race-day weather was hot enough to keep some of her tougher competition at home.

Having run in her native China, Ye returned to her hobby when she arrived at CMU as a way of combatting loneliness and finding her niche.

"It definitely helped," she said, adding that she typically runs the Pretty Good Race course on work days, which helps her reconnect with her roots.

Jeff Bigham, associate professor in the HCII and Language Technologies Institute finished first in the men's field — his third overall victory.

John Pane (E 1985, CS 1994, 2002), a senior scientist at RAND Corporation, hasn't run the Pretty Good Race since 1990, but he won the men's division seven times and proudly displays his trophy collection in his home. His sister, Theresa, joined him in the winner's circle in 1989 and their nephew, Joe, picked up the family tradition by winning in 2015 and 2018.

Philip Lehman, associate dean for advancement, noted that the race's perpetually relaxed atmosphere stands in contrast to the school's reputation as a crucible for prodigies.

"These are all overachievers," Lehman said, but the race, like the school, is not a place for cutthroats. "SCS is very much a collegial place. It's not, 'Can I do better than the other student?' It's 'Can I work with the other student?' Because that's how life is." ■

OUTWARD BOUNDS

Creating new tools for quantum computing and probing its theoretical limits

Chris Quirk

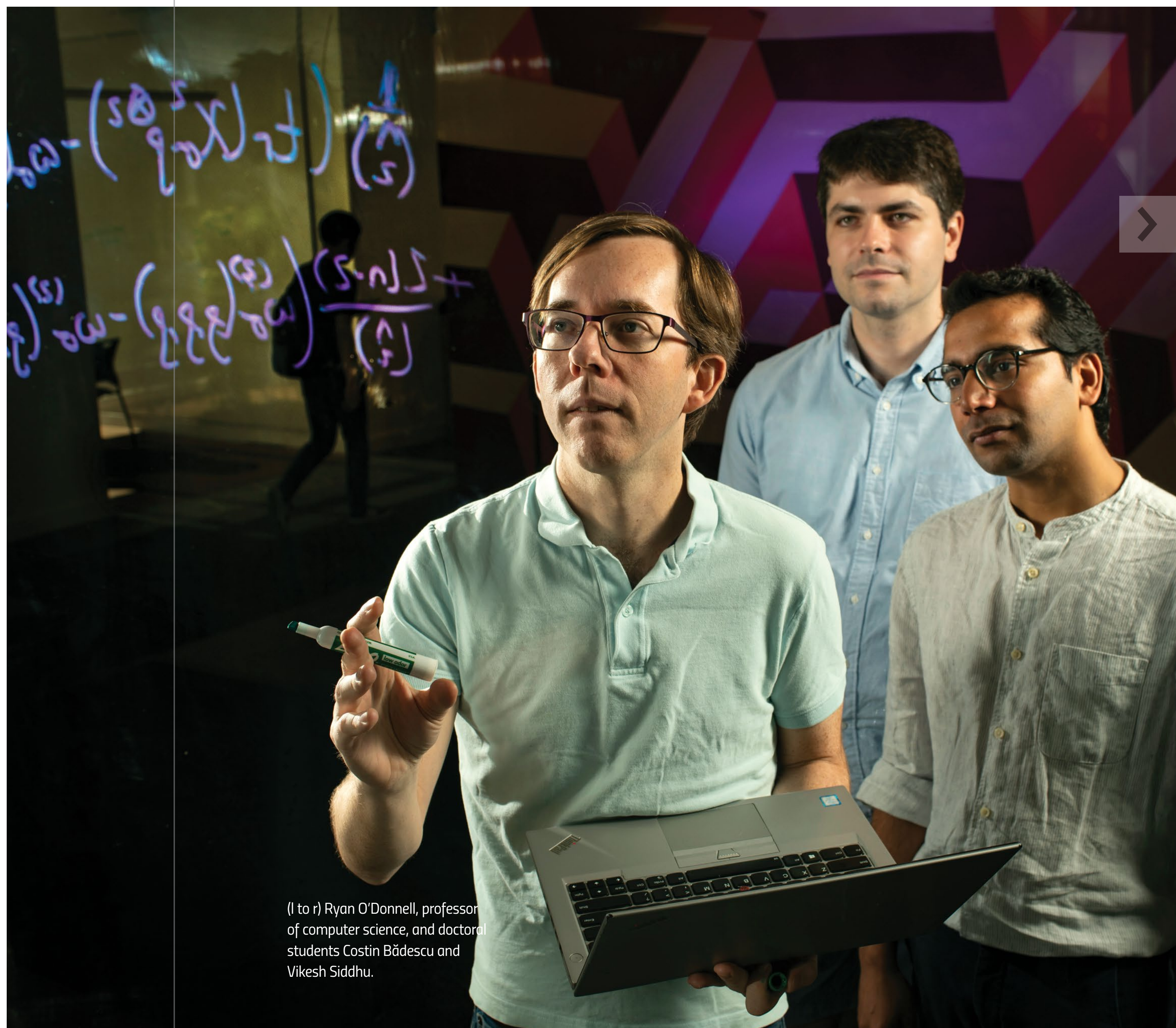
It's almost impossible to scan the science news without quickly coming across bold claims for the prospects of quantum computing, like speeding the development of life-saving drugs and radically enhancing machine learning. Governments and massive technology firms like Google, Microsoft and IBM are pouring billions into quantum computing research and development, with reports of new breakthroughs happening all the time. An era of virtually unlimited computational power feels imminent.

As experimentalists develop new ways to corral and control the wayward particles that are the meat and potatoes of quantum computers, researchers across Carnegie Mellon are creating tools that could aid their endeavors, while exploring the computational limits of what might be achieved. And though the overall outlook for quantum computing is upbeat, much remains unknown about its potential limitations, both theoretical and physical.

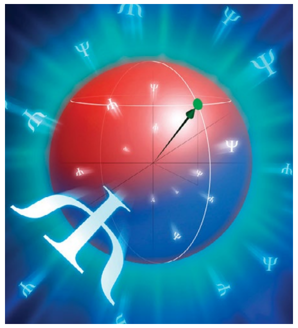
Ryan O'Donnell, professor of computer science, has devoted much of his recent research efforts to quantum information theory. "I'm inherently enthused about the nature of computation and what it means to compute things," he said. "Now it seems like there's this whole new method of computing. It's amazing, and it's incumbent on scientists to discover the power and limits of it that are allowed by the physical universe."

"Now it seems like there's this whole new method of computing. It's amazing, and it's incumbent on scientists to discover the power and limits of it that are allowed by the physical universe."

—Ryan O'Donnell



(l to r) Ryan O'Donnell, professor of computer science, and doctoral students Costin Bădescu and Vikesh Siddhu.



DEFINING QUANTUM COMPUTING

The difference between classical and quantum computing is the vastly expanded computational power that comes from taking advantage of the quantum states of atoms, particles or photons, which can serve as quantum bits (or qubits). Two important quantum characteristics integral to quantum computing are superposition and entanglement.

For a particle in superposition, its precise state remains unknown. For instance, one characteristic of an electron, spin, will always resolve to a value of 1 or 0 when measured, but prior to measurement you can't know its value — it's a combination of both 1 and 0 simultaneously. Compared to a classical bit, which will have a value of 1 or 0, the amount of information you can embed in a quantum system will be exponentially greater. If two particles are entangled — even if the particles are miles apart — when you measure one particle, the other immediately comes out of superposition, as if it had been measured, too.

Under the hood, a quantum computer will take an initial state of a set of qubits and perform a series of gate operations in a manner not dissimilar to classical computers. The difference is instead of sending charges into a circuit, the qubits are physically manipulated or rotated in a kind of synchronized dance, altering their quantum states and producing a result when the system is measured. It may sound like a tidy process, but the reality of quantum computing is full of engineering, software and theoretical obstacles.

O'Donnell, along with his former doctoral student John Wright (CS 2016), who is now a postdoc at the California Institute of Technology, has been examining possibilities for quantum tomography, a method for understanding the states of quantum particles. "Suppose you run an experiment, and at the end you get a quantum system of particles," Wright said. "The particles end up in a certain state, and you want to understand if that's the state they're supposed to be in. It's a fundamental fact about quantum mechanics that you can't learn the complete state of a particle — for instance, you can't simultaneously learn its position and velocity. But if you had identical particles, you could learn the position from one and the velocity from another." The problem is, what is the minimum number of particles required to do that?

It turns out that for an array of qubits, the number of proxy particles you need to verify the states of the original particles escalates rapidly. "A physical system can be assigned a dimension, which in the case of a quantum computer grows exponentially with the number of qubits available," said Costin Bădescu, a doctoral student in computer science working with O'Donnell. "The minimum number of copies you need scales linearly with regard to the dimension of the system."

QUANTUM INFORMATION THEORY

O'Donnell and Wright's analysis determined how to find the lower bound on that number. Their work could markedly increase the efficiency for calibrating a quantum computer. "Almost every quantum experimentalist is going to want to do a validation at the close of their experiment," O'Donnell said. Using an array of identical particles, experimentalists could check the gates on a quantum computer.

In a scenario where time is limited, efficiency is critical. O'Donnell described a recent quantum teleportation experiment, where the characteristics of one qubit are transmitted to a distant qubit. "In this case it was between a qubit on Earth and one on a satellite," O'Donnell said. "They had to check how close the state on the qubit on the satellite was to the qubit on Earth, but they only had about six minutes a day to do it because of interference from light from the moon and such. So in that case, you are really motivated to use as few copies as possible."

"Ryan and John are pretty much at the top of the game on the theoretical aspects of this," said Vikesh Siddhu, a doctoral student in physics. "One of the basic tenets of quantum computing, laid down by David DiVincenzo [in the DiVincenzo Criteria as they are known, published in 2000 and positing the minimum requirements for quantum computing], is that you must be able to initialize your computer in a simple state and then change that state as necessary. Quantum tomography can tell if you have achieved what you intended."

Part of quantum information theory is circumscribing the domain of the possible, Siddhu said. "We study theoretical limits that give upper and lower bounds on how well one can send information using quantum states." Siddhu's recent work looks at noisy quantum channels, whose ability to send information is not well understood. The problem here involves determining the capacities of quantum information transfers given the inherent instability of quantum elements. "Any channel that sends quantum information can be noisy. Knowing the limits of these channels would be vital for quantum computers and quantum memories," Siddhu said.

> "We have to be cognizant of how quantum information science and this technology is moving in a multidimensional way."
>
> —Jason Larkin (E 2013)

PUSHING BOUNDARIES

The theoretical work O'Donnell, his team and others are pursuing seems rarified at times, but is part and parcel of creating a foundation of knowledge that experimentalists and software developers can use as quantum computing becomes more viable, according to Siddhu. "We are creating some tools and studying the theoretical limits of what a quantum computer and a quantum communication device can do," he said.

"All these sorts of things come into play when we do our research," said Jason Larkin (E 2013), a researcher at the Software Engineering Institute's Emerging Technology Center who works with quantum computing. "We have to be cognizant of how quantum information science and this technology is moving in a multidimensional way. Ryan's work is looking far ahead and thinking about the ultimate scaling of things. Finding the bounds on the optimal, and answering questions like, 'Can you get me to 99% of the optimal, or 96% rather than the 93% of a classical computer?' can have huge consequences if you are looking at something like large-scale logistics."

It is generally accepted that if quantum computers obtain the functionality foreseen for them, the computational increase over classical computers will be astronomical for some tasks. But hype aside, quantum computers created thus far are limited in their abilities, typically sporting qubits numbering only in the dozens. No small feat, but nowhere near able to fulfill the more extravagant of quantum computing's promises. There are also questions about the kinds of problems quantum computing might legitimately be able to tackle.

On this note, O'Donnell remains ambivalent. "While I'm not an expert on the experimental side of things, I do think they will be able to build large-scale quantum computers in 10-20 years. It's like building a space station on Mars. It would be very hard — requiring tremendous theoretical and engineering efforts — and a lot of money, but I believe it could be done.

"I'm less bullish on whether quantum computers will change the way we eat, sleep and play," he said. "It's expected there will be applications for things like quantum chemistry, but from a theory point of view, people have been thinking about what you can do with quantum computers for 25 years, and beyond things like Shor's or Grover's algorithms, we don't have a lot more examples. So while I'm cautious about whether they will revolutionize everything, I'm very interested in setting up the mathematical framework for what can be accomplished." ■

Computer Vision Looks Around the Bend

Cristina Rouvalis

The computer's view (left image) of the person on the right, taken from around a corner as the camera and pulsed laser measure the time photons take to bounce back to the lens.

SEEING AROUND CORNERS might sound like a super-power out of a sci-fi movie. But Carnegie Mellon researchers are using a high-powered laser to recreate the image of hidden objects with astonishingly accurate detail.

Ioannis Gkioulekas, an assistant professor in the Robotics Institute, demonstrated this breakthrough technology with a tabletop model in his laboratory. After hiding a coin around a corner, he pointed a camera and laser at the blank wall straight ahead of him. As the light scattered, his computer screen captured the coin's image, down to the contours of George Washington's face.

Re-creating minute details of a curved object is a major advance in this branch of computer vision known as non-line-of-sight (NLOS) research and could be useful in a wide range of applications. Imagine a self-driving car with a camera that can see around the corner to detect a child about to step into the street. Or a robot walking down a hospital corridor, mindful of gurneys about to cross its path.

NLOS view of two Quarters, as seen using Gkioulekas' algorithm.

Though these scenarios still seem futuristic, Gkioulekas' research — which won a best paper award at the 2019 Conference on Computer Vision and Pattern Recognition this past summer in Long Beach, California — brings them one step closer to reality.

"Our algorithm allows you to scan something in super high resolution, comparable to what you would get if the object were actually in front of your camera," Gkioulekas said. "But there is a big tradeoff. The more you increase this resolution, the smaller the area you can actually scan. So I can do this for a coin, but I can't achieve that resolution for an object like a laptop or a human face."

But how exactly does it work? Ordinarily the human eye sees an object when light reflects off that object and bounces back to the eye. But some of the reflected light also scatters around corners and into walls, and bounces off other objects out of view.

Using a camera and pulsed laser, the researchers establish a baseline by measuring the time it takes for photons — particles representing the smallest unit of light — to reach the wall and bounce back to the camera lens without a hidden object. They then compare that baseline to the time it takes for the light to bounce off a hidden object, scatter and return to the camera. Finally, they subtract the difference between the two times and graph individual points of the photons, recapturing the object's geometry.

Unlike earlier methods, Gkioulekas' process does not rely on light conditions to recapture the object's geometry, making it more reliable and less weather-dependent. This is just one of the many advances made by the research group, headed by Srinivasa Narasimhan, a professor and interim director of the Robotics Institute. The team also includes Matthew O'Toole, an associate professor in the Robotics Institute; Shumian Xin, a Ph.D. student in the Robotics Institute; Aswin Sankaranarayanan, an assistant professor in the Department of Electrical and Computer Engineering; Sotiris Nousias, a Ph.D. student in medical physics and bioengineering at University College London; and Kiriakos N. Kutulakos, a professor in the Department of Computer Science at the University of Toronto.

The researchers belong to a larger collaboration, which includes members from Stanford University, the University of Wisconsin Madison, the University of Zaragoza, Politecnico di Milano and the French-German Research Institute of Saint-Louis. The research is funded by the Defense Advanced Research Projects Agency, National Science Foundation, Office of Naval Research, and Natural Sciences and Engineering Research Council of Canada.

Before joining CMU, O'Toole was part of the Stanford team that developed a technique for capturing the hidden image in half a second instead of the hours it previously required.

"I really like the elegance and novelty associated with this research," O'Toole said. "It is how to model the way light bounces around, how to capture that light and process that information."

The technology involved in NLOS research is similar to that of Lidar, the surveying method used in autonomous cars. But while Lidar stops collecting information as soon as it receives the first signal, the CMU NLOS system keeps collecting information from scattered light. Researchers hope to eventually incorporate NLOS technology into existing systems for self-driving cars.

"Luckily, on the road there are lots of highly reflective objects, especially at night," O'Toole said. "The challenge during the day is that ambient sunlight can overpower the reflected light."

Moving forward, CMU researchers hope to improve upon their technology, allowing people to see objects around corners in constantly changing conditions outside the lab. And while it might not make us superheroes, it will certainly give us powers we once only dared to imagine. ■

DIRECTOR'S MESSAGE
OFFICE OF ANNUAL GIVING
AND STEWARDSHIP

SCS in Motion

It might sound cliché, but if anything in SCS is constant, it's change. And there's no better time to observe SCS in motion than the 2019 fall semester. We welcomed new students and faculty to campus, and said hello to our new dean, Martial Hebert (whom you met earlier in this issue). We celebrated the 10th anniversary of the Computational Biology Department, the 25th anniversary of the Human-Computer Interaction Institute and the 40th anniversary of the Robotics Institute. We sent robots into caves and worked on others that will go to the moon. Outside my window, the very nature of campus is changing before my eyes, with bike lanes on Forbes and more pedestrian crosswalks to ensure our students' safety. New buildings rise and old ones get facelifts.

Even with all this change, some things remain constant, including our commitment to training the best computer scientists in the world and collaborating across the university to create life-changing technologies. And, of course, the fact that nothing is possible without support from our alumni and friends.

Niccole Atwell,
Director of Annual Giving
and Stewardship

Case in point: Last fall, we announced our new bachelor's degree in artificial intelligence, which has been incredibly popular with our undergraduates. And we could only create this first-of-its-kind degree program through contributions to the Dean's Innovation Fund, which covered startup costs. That's pretty amazing.

The same holds true for other funds. Generous gifts to the Mark Stehlik SCS Alumni Undergraduate Impact Scholarship allowed us to award two scholarships to hardworking seniors last year instead of one. Likewise, support for the Scott Robert Krulcik Scholarship Fund in Computer Science, founded in memory of SCS alumnus Scott Krulcik (CS 2018), has been so strong that we've presented our first award this year.

Our dedication to students doesn't end with scholarships, though. This academic year, we've used gifts from the SCS Parents Fund to provide all incoming first-year students with PASS Kits — mental health first aid kits that include basic self-care items to help students deal with stress, and information about both on-campus and national mental health resources. In the same vein, we created an emergency fund for things no student can predict and that shouldn't derail their success — medical expenses, travel for a loss in the family, lock replacement or repair. Finally, we created a laptop loaner program to ensure students don't fail when their computers do. We couldn't have created any of these amazing support programs without your help.

There are countless other ways our success in SCS ties in to the people in our community. Our outreach initiatives — ranging from tutoring programs in classrooms to on-campus precollege summer camps — happen because of you. Crowdfunding initiatives have helped drive success in the DARPA Subterranean Challenge and the Project Olympus Spark Fund. Departments have also gotten into the crowdfunding action, with the Institute for Software Research raising money for its REUSE summer program, which helps provide research experience for students who are underrepresented in the field.

At the end of this issue, you'll find a list of all the people who have supported SCS this year. To all of you, I extend my sincere thanks. You're the unspoken heroes who support our students and research. And I, for one, am thankful that never changes.

Niccole Atwell
Director of Annual Giving
and Stewardship

"When I said I was going to be a programmer, people thought I was going to work for a radio station."

Peg Calder Puts Her Heart (and Harp) in the Work

Susie Cribbs (DC 2000, 2006)

PEG CALDER (MM 1966) has worn many hats in her lifetime. Student, mathematician, programmer, manager, advocate, fundraiser. But one of the most novel is "computress."

Anyone who's seen "Hidden Figures" knows that before machines did the heavy lifting, humans who computed things were called "computers." But when Calder took her first job — at Bettis Atomic Power Lab — the company decided that since she and other colleagues were females who computed, they should have the title "computress."

It's no surprise, then, that the Vandergrift, Pennsylvania, native went on to enroll at Carnegie Tech, studying mathematics in the mid-1960s, when computer software classes were new and nothing resembling computer science existed. In fact, most people didn't even know what a "programmer" was.

"When I said I was going to be a programmer, people thought I was going to work for a radio station," Calder said.

Calder studied on a campus populated with computing pioneers like Alan Perlis, Herbert Simon and Allen Newell, but it was also a campus that few current computer science students would recognize. (Or one her mother, who graduated in 1935, would know.) Sure, a few of her classes were in the "Potato Chip" building (Scaife Hall), which still stands, but her first programming class was in ALGOL, an algorithmic language created in the 1950s — not C or C++ or Python, which most students study now.

"It was the first class I took, and the very first day of class I felt like I had walked into the middle of the semester," she said. "I had no idea what anything they were talking about meant. And I ended up loving ALGOL!"

And forget completing a programming assignment by whipping a laptop out of your backpack and immediately compiling and checking your code. Instead, Calder and her classmates wrote their code on pieces of paper, then punched cards and gave them to an operator in Scaife. Two or three days later, they could pick up a printout of the program to see if it worked, or if a misplaced comma meant they had to do the same thing all over again.

As a bachelor of arts student, Calder belonged to Margaret Morrison Carnegie College. And as a female student, her campus life experiences varied greatly from the coed dorms on campus today. Women lived in Morewood Gardens and men were prohibited from going beyond the front desk. But while living conditions were strictly segregated, the same wasn't true in classrooms. It's tempting to

Peg Calder holds the medallion given to her mother, Emma Westbay (Class of 1935) on the 50th Anniversary of her graduation from Carnegie Tech.

"...my boss said that whoever I talked to at the Pentagon really liked me. He had thought they liked me as a cute girl, but then he learned that they really liked my work. And he acted surprised!"

assume that because it was decades ago, women experienced discrimination on campus, but Calder said she always felt on equal footing with her male peers. And there were plenty of women in her field.

"When I came back to campus for my 50th reunion, I looked in the yearbook and I couldn't believe how many female math majors there were!"

After graduation, Calder easily landed a job with the Johns Hopkins Applied Physics Lab, then moved on to MITRE Corporation. She remained with MITRE for 10 years, still programming with pencil and punch cards, and eventually moved to the company's headquarters outside Boston. She'd go on to management roles at GTE Sylvania Telephone, Apollo Computer (a hardware workstation manufacturer), Alliant Computer Systems and GE Aerospace, which Martin Marietta acquired before merging with Lockheed.

While she hadn't experienced sexism or discrimination at CMU, Calder definitely encountered it in the workplace. At her first two jobs, men were hired as members of technical staff, while women were associate members of technical staff unless they had a master's degree. After a few years at MITRE, Calder was promoted. "But that's five or six years of a lower salary because I was a woman," she said.

She also met managers who refused to give her assignments, which she worked around in true CMU problem-solving form. And sometimes she simply wasn't taken seriously because of her gender.

"One time, I had to go to the Pentagon to define some work. It was some time later that my boss said that whoever I talked to at the Pentagon really liked me," Calder said. "He had thought they liked me as a cute girl, but then he learned that they really liked my work. And he acted surprised!"

Calder's career contained twists and turns, but she's especially proud of a formal Defense Department contract protest she led when she worked at Alliant, which designed and manufactured parallel computing systems. The company wrote proposals for government agencies to buy their computers, and the Navy rejected one they had written for Naval Air Weapons Station China Lake. Calder protested the rejection before the Navy JAG and the company won.

"It wasn't the billions of dollars of a Lockheed or Boeing contract. It was maybe a million dollars. But it made a huge difference," she said.

Calder also never stopped learning. She took courses in networking, C and C++. She even enrolled in a Dale Carnegie course once, and years later taught the material to her GE Aerospace colleagues while they waited for their security clearances to be approved during the Martin Marietta takeover.

Calder technically retired in 2003, but she hasn't slowed down. "I always promised myself that when I retired, I was going to have a view," she said. So she worked with an architect to design and build the home of her dreams on Lake Champlain in Vermont.

When the house was finished, she encountered a situation that would change her life well into the next decade. A young acquaintance had a great job, kids and home, but her marriage dissolved and she became a serious alcoholic. She was in and out of jail, and lost her home and family. Calder worked with friends to secure a spot for the woman in a state rehab facility, furnish an apartment and get her back on her feet. Calder even went to live with the woman and take her to counseling sessions and other appointments.

"I entered this whole new world of counseling, probation, family services and food stamps. What I came away with is: They didn't know how to help her," Calder said. "I looked for an organization to join that was trying to find better medical treatment for alcoholism — like the American Cancer Society, but for alcoholism — and there wasn't one. So I started one."

Thus began the Foundation for Alcoholism Research, a nonprofit dedicated to finding better medical methods for prevention, prediction and treatment of the disease. Their grants have supported research on alcohol tolerance and its relationship to alcoholism; the medication naltrexone; and a pilot program testing the medication baclofen's ability to reduce cravings.

These days, Calder has a reduced role in the organization, and has traded in her Vermont lake house for a condo in downtown Pittsburgh. But she hasn't stopped learning and trying new things. Her next big adventure is taking harp lessons. She was even in a recital in CFA's Alumni Concert Hall, where she'd never set foot as student.

Next hat? Harpist. ■

Peg Calder at home with her harp.

Anniversary^3

2019 marks the anniversary year for three different SCS departments: Computational Biology celebrates its 10th, the HCII is 25 years young and the Robotics Institute is the elder statesman of the group at 40.

These photos represent a mere slice of the celebrating, roundtable discussions about the future, and reminiscing surrounding these landmark occasions.

ABOVE
Robert Murphy, head of the Computational Biology Department, discussed the future of the field with current and former students.

TOP LEFT
Former CMU assistant professor of Computational Biology and current lecturer at the University of Washington, Karen Thickman, offered historical reflections as part of her presentation.

HUMAN-COMPUTER INTERACTION INSTITUTE HCII
1994–2019
25 YEARS

TOP RIGHT
HCII professor Ken Koedinger asks a question from the audience.

MIDDLE
Lining Yao, assistant professor of HCII (center right) spoke as part of the panel discussion on Contemporary Perspectives on Human-Computer Interaction Today, along with (L to R) HCII professors Patrick Carrington, Thomas and Lydia Moran Professor of Learning Science Amy Ogan, and assistant professor of industrial design at TU Delft, Derek Lomas.

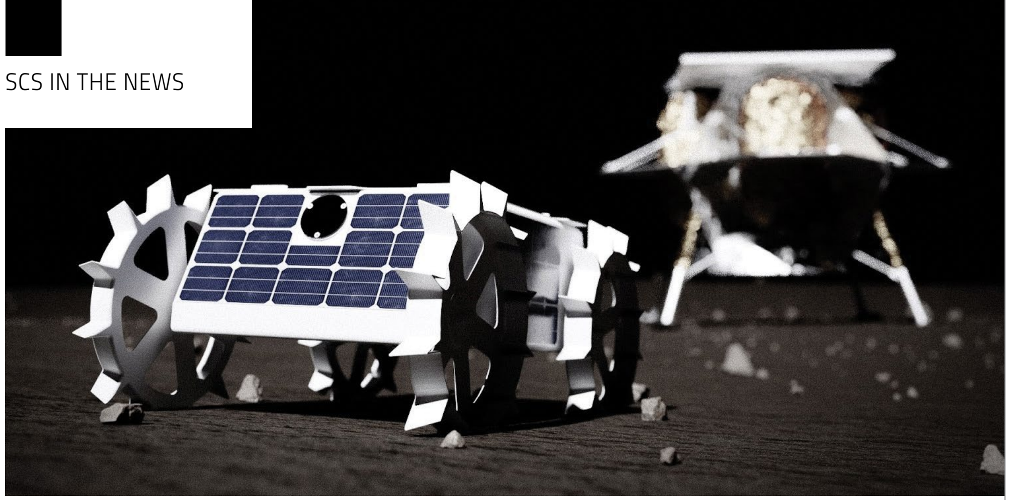
BOTTOM
John Zimmerman, Tang Family Professor of Artificial Intelligence and Human-Computer Interaction moderated the panel titled "The Future of Our Field."

RI40

TOP RIGHT
Takeo Kanade, U.A. and Helen Whitaker University Professor in the Robotics Institute in discussion at the RI40 reception.

MIDDLE
Ben Brown, project scientist in the Robotics Institute and Tom Lauwers (E'03, CS'06, CS'10) interacted with a robot photographer in the Rashid Foyer.

BOTTOM
William "Red" Whittaker, Founders University Research Professor (center-right), spoke both during his presentation on robots going to the moon and at the reception following (pictured here).



SCS Heads to the Moon

CMU is going to the moon, sending a robotic rover and an intricately designed arts package that will land in July 2021. The four-wheeled robot is being developed by a CMU team led by Robotics Institute Professor William "Red" Whittaker. Equipped with video cameras, it will be one of the first American rovers to explore the moon's surface. The arts package, MoonArk, is the creation of Lowry Burgess, space artist and professor emeritus in the School of Art. The eight-ounce MoonArk has four elaborate chambers that contain hundreds of images, poems, music, nano-objects, mechanisms and earthly samples intertwined through complex narratives that blur the boundaries between worlds seen and unseen. Both will be delivered on board a lander built and operated by CMU-spinoff Astrobotic Inc.

CMU received $2 million from NASA to develop technologies necessary for robots to explore pits on the moon — the lunar equivalent of sinkholes — which might provide access to shelter and resources that could sustain future lunar missions. And NASA selected CMU and Astrobotic to build another rover that will land on the moon as early as 2021. The rover, MoonRanger, will be about the size of a suitcase and weigh around 24 pounds on Earth.

"Carnegie Mellon is one of the world's leaders in robotics. It's natural that our university would expand its technological footprint to another world," said J. Michael McQuade, CMU's vice president of research. "We are excited to expand our knowledge of the moon and develop lunar technology that will assist NASA in its goal of landing astronauts on the lunar surface by 2024."

Researchers Unveil Latest Advances at CHI 2019

A smartwatch that detects what your hands are doing — for example, playing the piano — was one of many SCS technologies unveiled at CHI 2019, the Association for Computing Machinery's Conference on Human Factors in Computing Systems. The rundown: HCII researchers presented work that uses computationally controlled knitting machines to create plush toys and other knitted objects actuated by tendons. Robotics Institute researchers reported on a collaboration with the Pittsburgh International Airport to develop tools that help people with visual disabilities navigate airport terminals safely and independently (a smart rolling suitcase that sounds alarms when users are headed for a collision and a navigation app that provides turn-by-turn audio instructions for how to reach a departure gate, restroom or restaurant). Finally, CMU researchers are developing "Unremarkable AI," clinical AI tools designed so doctors don't need to think about them.

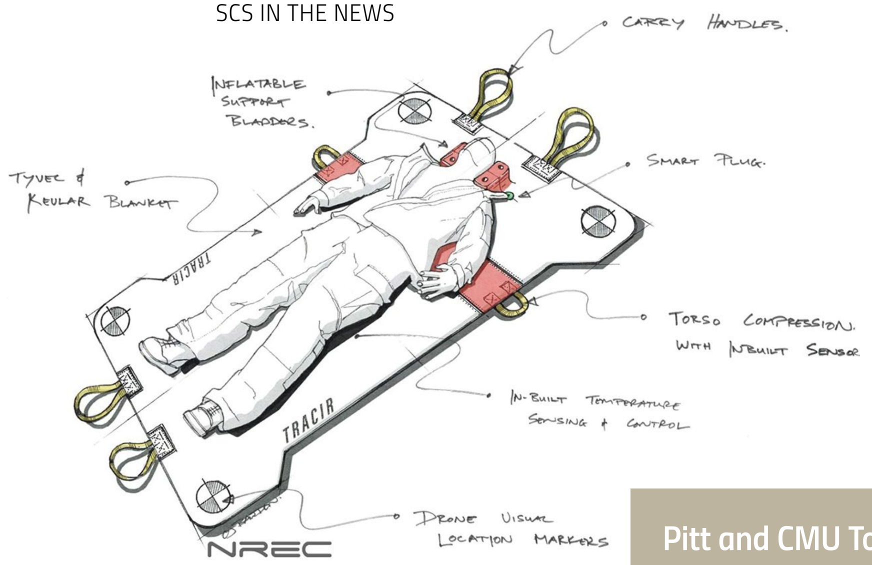
Bacteria Change Behavior To Tackle Tiny Obstacle Course

It's not exactly the set of "American Ninja Warrior," but a tiny obstacle course for bacteria has shown researchers how E. coli changes its behavior to rapidly clear obstructions to food. Scientists at CMU, the University of Pittsburgh and the Salk Institute for Biological Studies recently reported that the well-known "swim and tumble" behavior bacteria use to move toward food or away from poisons changes when bacteria encounter obstacles. Their work holds implications not only for biology and medicine, but also for robotic search-and-rescue. "Any type of insight we can get from biology to improve computation is important to us," said Ziv Bar-Joseph, a professor in the Computational Biology and Machine Learning departments.

CMU, ARGO AI FORM CENTER FOR AUTONOMOUS VEHICLE RESEARCH

CMU and Argo AI have announced a $15 million partnership to perform research into advanced perception and next-generation decision-making algorithms for autonomous vehicles. The partnership will establish the Carnegie Mellon University Argo AI Center for Autonomous Vehicle Research, which will pursue research to help overcome the hurdles that prevent self-driving vehicles from operating in a wide variety of real-world conditions, such as winter weather or construction zones. "This investment allows our researchers to continue to lead at the nexus of technology and society, and to solve society's most pressing problems," CMU President Farnam Jahanian said. "Together, Argo AI and CMU will accelerate critical research in autonomous vehicles while building on the momentum of CMU's culture of innovation."

Peter Rander, President of Argo AI, Rich Fitzgerald (E 1981), Allegheny County Executive, CMU President Farnam Jahanian, Bryan Salesky, CEO of Argo AI, Pittsburgh Mayor Bill Peduto

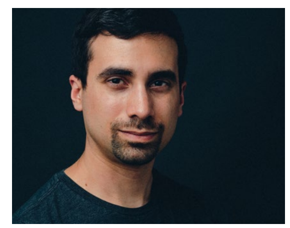


Educational Software Slated for Pilot Project in Zambia

CMU-based RoboTutor LLC, a finalist in the $15 million Global Learning XPRIZE, will use its educational technology to teach 10,000 children basic reading, writing and mathematical skills in Zambia. As part of the XPRIZE competition, the CMU team developed an educational app that allowed children to teach themselves basic literacy and numeracy without an adult's help. Now that the competition has ended, CMU researchers will use that app in Zambia, where they'll partner with Anchor of Hope Charities to perform a pilot study for a national education program for children. "Carnegie Mellon is all about using knowledge to solve big problems, and RoboTutor fits squarely within that CMU tradition," said Founders University Professor Tom Mitchell.

Pitt and CMU To Create Autonomous Robotic Trauma Care System

CMU and the University of Pittsburgh School of Medicine have received more than $7 million from the U.S. Department of Defense to create an autonomous trauma care system that fits in a backpack and can treat and stabilize soldiers injured in remote locations. The goal of TRAuma Care in a Rucksack: TRACIR is to develop AI technologies that enable medical interventions that extend the timeframe for treating combat casualties and ensure an injured person's survival for long medical evacuations. "We see this as being an autonomous or nearly autonomous system — a backpack containing an inflatable vest or perhaps a collapsed stretcher that you might toss toward a wounded soldier," said Artur Dubrawski, a research professor in the Robotics Institute. "It would then open up, inflate, position itself and begin stabilizing the patient."



CMU, Facebook AI Create Technology That Beats Pros in Six-Player Poker

An AI program developed by CMU's Tuomas Sandholm and Noam Brown, in collaboration with Facebook AI, defeated leading pros in six-player No-Limit Texas Hold'em — the world's most popular form of poker. Each pro separately played 5,000 hands of poker against five copies of the AI called Pluribus. In another experiment involving 13 pros, all of whom have won more than $1 million playing poker, the AI played five pros at a time for a total of 10,000 hands and again emerged victorious. "Thus far, superhuman AI milestones in strategic reasoning have been limited to two-party competition. The ability to beat five other players in such a complicated game opens up new opportunities to use AI to solve a wide variety of real-world problems." Sandholm said.

ONLINE ATLAS OF AQUATIC INSECTS AIDS WATER-QUALITY MONITORING

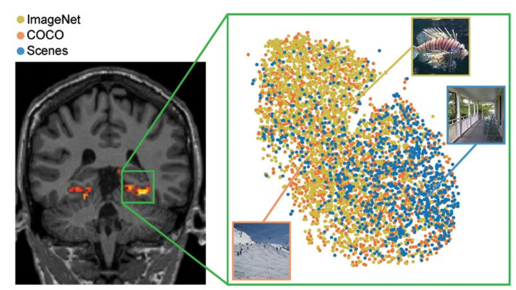
A new online field guide to aquatic insects in the eastern U.S., developed in part by CMU researchers, will help both volunteers and professionals identify insects in lakes, streams and rivers. CMU, working with Carnegie Museum of Natural History, the Stroud Water Research Center, the University of Pittsburgh, Clemson University and a set of volunteer biomonitoring organizations, led development of macroinvertebrates.org, a visual atlas and digital field guide that features highly detailed images of 150 common aquatic lifeforms. "One key goal is to make the task of accurately identifying aquatic insects easier for citizen scientists, which in turn will allow more people to engage and participate in water quality monitoring and stewardship of freshwater resources," said Marti Louw, director of the HCII's Learning Media Design Center, who led the effort.

#MeToo Media Coverage Sympathetic to but Not Necessarily Empowering for Women

Research by LTI Assistant Professor Yulia Tsvetkov shows that #MeToo media coverage portrays accusers as sympathetic, but with less power and agency than their alleged perpetrators. Tsvetkov's research team used natural language processing techniques to analyze online media coverage of #MeToo narratives, and their results show that the media consistently presents men as powerful, even after sexual harassment allegations. The team's analysis also showed that the people portrayed with the most positive sentiment in #MeToo stories were those not directly involved with allegations, like activists, journalists or celebrities commenting on the movement. "Bias can be unconscious, veiled and hidden in a seemingly positive narrative," Tsvetkov said. "Such subtle forms of biased language can be much harder to detect, and to date we have no systematic way of identifying them automatically. The goal of our research was to provide tools to analyze such biased framing."

Storytelling Bots Learn To Punch Up Their Last Lines

Most algorithms that automatically generate a story's end tend to favor generic sentences, such as "They had a great time." Those may be boring, but LTI Professor Alan Black said they aren't necessarily worse than a non sequitur such as "The UFO came and took them all away." In a paper presented in August, Black and his students presented a model for generating story endings that are both relevant and interesting. One trick to balancing these goals is to require the model to incorporate words into the ending that are related to those used early in the story. At the same time, the model is rewarded for using rare words in the ending, in hopes of choosing a conclusion that isn't totally predictable. "In a conversation, the human's questions and responses can help keep the computer's responses on track," Black said. "When the bot is telling a story, however, that means it has to remain coherent for far longer than it does in a conversation."



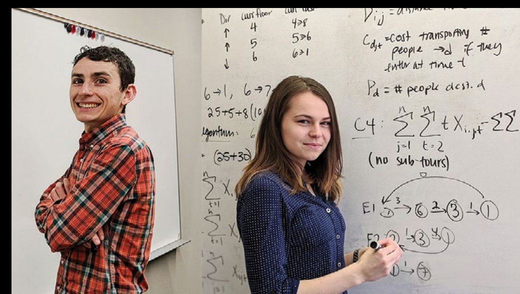
Dataset Bridges Human Vision and Machine Learning

Neuroscientists and computer vision scientists say a new dataset of unprecedented size — comprising brain scans of four volunteers who each viewed 5,000 images — will help researchers better understand how the brain processes images. Researchers at CMU and Fordham University, reporting in the journal Scientific Data, said acquiring functional magnetic resonance imaging (fMRI) scans at this scale presented unique challenges. Each volunteer participated in 20 or more hours of MRI scanning. The extreme design decision to run the same individuals over so many sessions was necessary for disentangling the neural responses associated with individual images. The resulting dataset, dubbed BOLD5000, allows cognitive neuroscientists to better leverage the deep learning models that have dramatically improved artificial vision systems.

Names in the News

Phillip Compeau and the Computational Biology precollege program

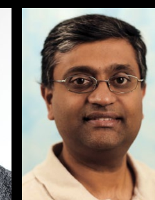
Kathleen M. Carley



Ben Eysenbach and Bailey Flanigan

The Girls of Steel

Srinivasa Narasimhan



James Herbsleb

Joy Arulraj

Tanvi Bajpai

Yonatan Bisk

Noam Brown

Computer Science Department alumnus Joy Arulraj (CS 2018) has received the 2019 Jim Gray Doctoral Dissertation Award from the ACM's Special Interest Group on the Management of Data.

Tanvi Bajpai (CS 2019) received the 2019 K&L Gates Prize, which recognizes a graduating senior who has inspired fellow students to love learning through a combination of intellect, high scholarly achievement, engagement with others and character.

Incoming LTI faculty member Yonatan Bisk co-wrote the AI installment of the YouTube series "Crash Course."

Ph.D. student Noam Brown has been named to MIT Technology Review's list of Innovators Under 35 in the Visionary category.

Kathleen M. Carley, a professor in the Institute for Software Research and the Engineering and Public Policy Department, has received an honorary doctorate from the University of Zurich's Faculty of Business, Economics and Informatics.

Phillip Compeau and Josh Kangas, both assistant teaching professors, co-directed the Computational Biology Department's first summer precollege program — the first of its kind in the nation.

CyLab director and SCS faculty member Lorrie Cranor has been named a 2019 Andrew Carnegie Fellow.

CSD Ph.D. students Ben Eysenbach and Bailey Flanigan have been named 2019 Hertz Fellows.

Alumnus Rayid Ghani joined the CMU faculty this fall as a Distinguished Career Professor in SCS and the Heinz College.

Lorrie Cranor

Rayid Ghani

The Girls of Steel, a robotics team sponsored by the Field Robotics Center, won two awards at the FIRST Robotics Competition Greater Pittsburgh Regional.

James Herbsleb and Srinivasa Narasimhan have been named interim directors of the Institute for Software Research and the Robotics Institute, respectively.

Jan Hoffmann, an assistant professor in the Computer Science Department, has received a Faculty Early Career Development (CAREER) Award.

Research Professor Roy Maxion received the 2019 Test of Time Award at the IEEE/International Federation for Information Processing Conference on Dependable Systems and Networks.

Roy Maxion

Kathryn Roeder

Founders University Professor Tom Mitchell and Hillman Professor of Computer Science Ken Koedinger will direct a new AI research lab made possible through a collaboration with Yixue Education Inc.

Kemal Oflazer, associate dean for research at Carnegie Mellon in Qatar, has authored "Turkish Natural Language Processing," a resource for understanding Turkish natural language and speech processing.

CMU's competitive hacking team, the Plaid Parliament of Pwning (PPP), won its fifth hacking world championship in seven years at this year's DefCon security conference.

UPMC Professor of Statistics and Life Sciences Kathryn Roeder, who holds an appointment in the Computational Biology Department, has been elected to the National Academy of Sciences.

Tom Mitchell

Ken Koedinger

Jan Hoffmann

Kemal Oflazer

Plaid Parliament of Pwning (PPP)

To make a year-end gift, visit **cs.cmu.edu/giving**

2019 Donor Recognition

July 1, 2018 – June 30, 2019

With 2019 soon coming to a close, we offer special thanks to our donors for their time, engagement with CMU and the School of Computer Science, volunteerism, and donations to SCS-related funds during fiscal year 2019. We've enjoyed connecting and reconnecting with many of you, and we sincerely appreciate your ongoing or first-time support.

Legend

(4) Member of CMU's Order of the May, recognizing individuals who demonstrate an extraordinary degree of loyalty and support by giving to Carnegie Mellon each fiscal year (July 1 – June 30); circled numeral indicates years of consecutive support

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Opposite: "It's Happening Here" mural on the 5th floor of the Gates-Hillman Centers

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Brighten Godfrey CS'02 ❷
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Shirley L. Goldstein ㉟ ■
Hannah Vera Gommerstadt CS'16 ❺ ■
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Lawrence E. Greenfield CS'01 ⓫
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& Lori Juergens Gross E'90, E'94 ❸
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Yady Guitana CS'05 ❹ ■
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Sajjan Gundapuneedi CS'14
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& Mengning Frank Zhou S'10 ❷ ■
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& Ady Gupta A'06, DC'06 ❹ ■
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Elora Gupta & Samir Gupta ❻ ■ ■
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& Raguvir Gurumurthy ■
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Yanran Hao CS'16 ■
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Franco Harris ■
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& Diana Hsien ❷
Goang-Tay Hsu CS'93 ❿ ■
Chen Hu CS'17 ■

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& Aurora Hsiao ❸
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Shanguang Huang & Ruiqing Li ❸ ■
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Xin Lyu Huang CS'17
Yu Huang & Yi Liu ■
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Kapisthalam Kumar & Katherine L. Kumar ❹ ■
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Guanjie Li CS'15 ❸
Hechao Li CS'16 ❷ ■
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Lucy Li CS'11 ❼
Ludi Li CS'16 ■
Mu Li CS'17 ■
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Peilun Li CS'17 ❷ ■
Shen Li CS'17
Tan Li CS'18 ❷
Wei Li & Xiaotian Zhong ■
Wendy Li ❷ ■ ■
Wenhui Li & Jinsheng Wang ■
Xiang Li CS'13
Yan Li CS'08
Yiheng Li CS'04 & Qi Jiang
Yu-Fang Li ❷ ■
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Yushan Li & Guanghao Liang ❸ ■
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Zhong-Qian Li & Hongwei Qi ■
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Guimin Lin CS'11
Patrick Lin CS'19
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Cong Liu CS'12 ❻ ■
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Jean Hyaejin Oh CS'09 ❸ ■
Kyung Chul Oh CS'03, CS'06 ❹ ■
Ronald Bert Ohlander CS'75 ❹
Koustubh D. Oka ⓬ ■
Yogesh K. Oka CS'04 & Ripple Sharma ⓭ ■
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Steven Tarek Osman CS'04
Erin O'Toole ■
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Daniel J. Paciulan CS'01 ⓯
Venkata Rama Karthik Paga CS'18 ■
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Scott Pakin CS'92 ❾
Muthukumaran Palanichamy ■
Sai Sandeep Reddy Pallerla ■
David Palmer & Edna Palmer ❹ ■
Shijia Pan E'18
Zhao Pan CS'17 ■
Sashank Mitra Pandem CS'18
Manish Pandey CS'95, CS'97 ■
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Michael Konstantinos Papamichael CS'15 ❹
Aparna Pappu ■
Sivaparamesh Parameswaran Ravindran CS'07 ■
Rebecca L. Paren CS'15 ❺ ■■
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Brian C. Parkison CS'00 ■
Rajash Patel ■
Richard Eric Pattis S'76 & Ellen F. Olshansky ❺ ■
Brad James Patton MET'07 & Ashley Williams Patton ❻ ■
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Matt Pavelle CS'98 ❽
Andrew Pavlo ❷ ■
John Edward Peabody CS'11 ❷ ■
Sarah K. Pearman ■
Brian T. Peck ❺ ■
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Sangeetha Pendyala ❷ ■
Chen Peng ❷ ■
Jacqueline Peng CS'19 ❷
David Penner ❾ ■
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Crispin Stone Perdue CS'77 ❿
Francisco Machado Aires Pereira CS'07 ❿ ■
Marko Petkovsek CS'91 ❾
Carol Phillips & Timothy Phillips ❸ ■
Satidchoke Phosaard CMU'03 ❸ ■
Serkan Piantino CS'04 ■■
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Swapnil Arvind Pimpale CS'15 ❷ ■
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Patrick G. Pinkerton CS'15 & Barclay Machika Kaku S'16
Mel Pirchesky TPR'92 ■
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Thad Anderson Polk CS'92 & Norma S. Polk A'89 ❺ ■
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Federico Ponte E'16 ❸
Vincent Ponzo ■
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Zania Susan Pothen CS'13 ❸
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Greg Price CS'06 & Margaret Barusch ❾
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William Robert Price CS'74 ❷ ■
Paige Pritchard CS'16 ❷ ■
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Liangsheng Qian CS'04 ⓫ ■
Long Qin CS'13, CS'13 & Yanan Chen ❷ ■
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Angela Qiu CS'18 ❹ ■
Shannon Qiu CS'99 & Howard R. Lee
Xianghua Qu & Heying Yang ■
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Siong Kar Quek CS'00, TPR'00 ❾ ■
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Faith Raida ■
Robert Raida TPR'15 ■
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Suresh Babu Rajasekaran E'10 & Deepa Koruturu
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Karthik Ramachandran CS'17
Sricharan Amand Ramanujapuram CMU'05 ⓫
Ramesh Ramiah CS'13 ❹ ■
Peyton J. Randolph CS'17 ■
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Qiang Rao E'99, CS'99 ■
Sanjay Gopinatha Rao CS'00, CS'04 ❷ ■
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Jamie Rausch & Jason Rausch ■
Karthik Ravi ■
Barbara J. Ray ⓱ ■
Scott Michael Raymond CS'98 ❷
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Rajesh C. Reddy CS'98 ❿ ■
Douglas Allen Reece CS'92 & Carole Warner Reece ❷ ■
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Paul Carl Rehmet CS'94 ■
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Theresa C. Richards S'90 & Charles H. Richards ❷ ■■
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Carolee Rowley ❷ ■
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Zack Rubinstein ❷ ■
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& Roy Richard Weil E'70 ㉟ ■
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& Gregory Kipp Shrack E'94 ❷
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& Stacey Lynne Jacobs TPR'90, TPR'93 ㉒
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& Murali Gopal
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& Mary L. Summers ❻ ■
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& Ramamurthy Sunder ❹ ■
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& Linda L. Ma Sung S'70 ⓯
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& Robert Sussman ❸ ■■
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Syahrul Nizar Syahabuddin CS'97 ❿ ■
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Desney Swee-Leong Tan CS'04 ❾
Prateek Tandon CS'13, CS'15 ■
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& Diane Marie Loviglio BHA'05 ❻
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Pucktada Treeratpituk CS'01, CS'06
& Atchara Mahatchavaroj CMU'03 ❷
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Raymond Sheung-Wan Tse CS'97 ❿ ■
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Ahmet Emre Unal CS'16
Vignan Uppugandla CMU'15 ❹
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& Tina Urso McDaniel DC'94 ❸
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Jean-Philippe Vidal CS'89 ❷ ■
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& Suresh Vishnubhatla ❸ ■
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& Laura H. Vives DC'97 ㉑ ■
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& Janice Lee Voigtmann E'13 ❿ ■
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& Skye C. Toor DC'17 ❷
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Naomi Aoki Waibel CS'95, CS'97 ❷ ■
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& Hui Boon Wan ⓰ ■
Bo Wang & Tao Yang ❷ ■
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Dennis H. Wang CS'19
Haohan Wang CS'14 ❷
Haoyu Wang CS'15 ❷ ■
Jianjun Wang & Xu Zhou ■
Jianwei Wang & Lin Wu ❷ ■
Jue Wang CS'05 ⓬
Kaipeng Wang CS'16
Lei Wang E'15, CS'15 ❹ ■
Mengzhi Wang CS'05 ❸
Phillip K. Wang CS'19 ❷ ■
Robert Y. Wang CS'04 ❾
Sen Wang E'17, CS'18
Sihan Wang CS'18
Wanjun Wang CS'03 & Lili Ma ❷ ■
William Wang CS'10, CS'11 ❸
Xiaohui Wang & Ling Yang ❷ ■
Ye-Yi Wang DC'92, CS'98 ❾
Yuchun Peter Wang E'04
& Abra Wang ⓮
Yufeng Wang & Ye Zhang ■
Yujun Wang CS'16 ❸
Yun Wang CS'12, CS'18 ❹
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John Lawrence Warwick CS'97 ❸ ■
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Wei Wei CS'12, CS'16
Yuanhao Wei ■
Zhengang Wei CMU'16
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Justin Blake Weinberg E'17 ■
Amy Lynn Weis ❷ ■
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& Susan Lawrenz-Smith ❺ ■
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Colin Robert Willson White CS'16, CS'18 ❸ ■
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Joseph Skeffington Wholey S'84, CS'89, CS'91 ❾ ■
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& Michael Widom ❸ ■
Jill Cherie Wieck & Vincent Wieck ❸ ■
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Philip Wildenhain
& Sarah Wildenhain ❷ ■
Shannon R. Williams CS'15

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CS'94, CS'98 2
Max Willsey CS'16 6 ■
Gail D. Wilson CS'16 6 ■
Scott Wilson ■
Eric Christopher Wise E'14, E'14 5 ■■
John David Wise E'84
& Tara Lee Wise DC'85 13 ■
Jake Witherell TPR'99 3 ■■
Lambert E. Wixson CS'88 9
Adam A. Wolbach CS'06, CS'08 11 ■
Benjamin Scott Wolf CS'10 2
Hao-Chi Wong CS'95, CS'00 7 ■
Theodore Ming-Tao Wong CS'01,
CS'04 13 ■
Wesley Sei-Ching Wong E'11
& Lara Wong 7
Richard R. Wongsonegoro CS'87 22 ■
Daniel Colin Wood CS'83 6
Gareth Wood CS'01
Tracey L. Wortham CS'00
James Mark Wright CS'81
& Pamela J. Wright DC'85 4 ■
Caroline Z. Wu CS'19 2
Jing Wu ■
Leejay Wu CS'98, CS'05 15
Pang Wu E'11 5
Franceska Xhakaj CS'17
Tian Xia CS'14, DC'14, S'14 4 ■
Alan Xiao ■
Jing Xiao CS'15
William Xiao CS'18 2
Yuzhou Xin CS'11, S'11 ■
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Yalin Xiong CS'93, CS'95 2 ■
Linqiu Xu & Lingling Zhai 2 ■
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Sheng Xu CS'19 ■
Victor Z. Xu CS'19
Yixun Xu CS'16 3 ■
Yunpeng Xu CS'17 & Ying Zhang
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& Constance R. Mennella CMU'06
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Dewey Yang CS'07 7 ■
Honghua Yang & Jin Yang ■
Jean Yang ■
Jeffrey SS Yang CS'94 4
Ke Yang CS'02, CS'04 6
Luona Yang CS'18
Rujia Yang CS'19 3
Shaoqian Yang E'17, CS'18 2
Ying Yang CS'16, DC'17

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Hong Ye & Wei Zhang ■
Hong Ye & Shuzhong Zhou ■
Jiacheng Ye CS'17 3
Ruijuan Ye & Huaqiang Zeng 2 ■
Zhan Ye CS'00 ■
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Chei Charles Yeh E'83
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& Patricia T. Yeksigian 13 ■
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Pengcheng Yin CS'18 2 ■
Yepeng Yin CS'16 3 ■
Yue Yin CS'19
John S. Yocca CS'87 6
Gary Dalton Young CS'98, S'98 2
Gregory C. Young 2 ■
Chenteh Yu & Pichin Yu ■
Donghan Yu ■
Haoran Yu E'16 3 ■
Hua Yu CS'98, CS'04 3 ■
Yu Yu CS'15 3
Zhe Yu CS'17
Chenxi Yuan CS'19 4
Haoyang Yuan INI'17
Yuehao Yuan INI'17 2
Yueran Yuan CS'13
Manzil Zaheer CS'16, CS'18 ■
John D. Zaientz CS'01 2
Gregory Zak CS'09 ■
Naveen Zalpuri E'11
AnnMarie Zanger 7 ■■
Hormoz Zarnani CS'09 4
Qianxu Zeng CS'16
Yiye Zeng CS'14 3
Zitong Zeng CS'17 & Han Zhang CS'17
Amelia Matzke Zgraggen CS'07, CS'11
& Guido Zgraggen CS'09 13
Chengxiang Zhai DC'95 4 ■
Amy X. Zhang DC'14, E'18 2 ■
Angela Zhang ■
Changjian Zhang CS'18 ■
Chiqun Zhang E'13, E'17, CS'17 2
Jimuyang Zhang CS'18
Jing Zhang CS'01
Shikun Zhang CS'14, CS'17 6
Tom C. Zhang CS'15 5 ■
Vida Zhang ■
Xunjie Zhang CS'17 ■

Yan Zhang E'17
Ying Zhang S'11, E'16, CS'16, S'16 3
Bing Zhao CS'03, CS'07 5
Chengguang Zhao CS'00 ■
Fuyao Zhao CS'12 5
Jiesi Zhao CS'15 ■
Kevin Zhao CS'11
Liang Zhao CS'98, CS'01 4 ■
Bo Zheng CS'10
Teng Zhong CS'17
Andy Zhou CS'00 & Debbie Fu ■
Bin Zhou CS'98 3 ■
Chunting Zhou CS'18
Jiali Zhou E'16 ■
Sisong Zhou ■
Wenqiang Zhou CS'16 ■
Xinyi Zhou CS'16 2 ■
Bofei Zhu CS'18 ■
Di Zhu E'17
Eric Zhu CS'18 5
Steve Zhu CS'13 2
Tiffany Zhu CS'18
Yan Zhu HNZ'99
& Yaohua Zou TPR'00 4 ■
Yangbo Zhu CS'08 & Betty Zhu 10 ■
Jing Zhuang CS'15 ■
Yi Zhuang CS'10
Andrew Leslie Zimdars CS'99,
DC'99, S'01
Todd Michael Zimnoch CS'98
Aldo Zini HNZ'85 2 ■
Daniel A. Zinzow E'06, CS'06
Joann Marie Zucofski CS'82
Monte Zweben CS'85 4 ■■

Carnegie Mellon University
School of Computer Science

OFFICE OF THE DEAN
5000 FORBES AVENUE
PITTSBURGH PA 15213-3890

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cs.cmu.edu

THE GOATS ARE BACK!
Allegheny GoatScape goats returned to campus for the third time this fall to munch down greenery on the hillside beneath the Pausch Bridge.

calendar of events

SPRING 2020

April 4 – 12
National Robotics Week

April 16–18
Spring Carnival

April 17
26th Annual Mobot Races

May 6
Meeting of the Minds Undergraduate Research Symposium

May 17
Commencement 2020

Summer 2020
Regional Alumni Events
Locations/Dates TBA