College of Engineering
University of California, Berkeley
Spring 2020
Volume 17

**Learning to learn**
AI and self-taught robots

**Super sand**
Cleaning up stormwater

# Berkeley ENGINEER

## Reinventing cybersecurity

Privacy, potential and the new data economy

# Rising to the challenge

This will not be a short-lived crisis, and it will require everyone to come together as citizens, innovators and problem-solvers.

As I write this in early April, our world is in the midst of a public health emergency and economic crisis unlike anything I've seen in my lifetime. Like millions of people around the globe, I'm distressed as I see countries, communities and families struggling as the number of COVID-19 cases continues to grow.

Although the predictions of how this might unfold are continuously changing, it is clear that, as United Nations Secretary-General Antonio Guterres has said, the coronavirus pandemic is the greatest global challenge since World War II. This will not be a short-lived crisis, and it will require everyone to come together as citizens, innovators and problem-solvers.

It gives me hope that we're seeing heroic efforts in abundance: doctors, nurses and other healthcare professionals treating the sickest of patients; truck drivers ferrying needed supplies; grocery clerks keeping stores running; cleaners sanitizing public spaces.

As engineers, this is our fight, too. Using our knowledge and technical skills, we can help to address the myriad challenges that arise during this pandemic, and we can also have an enormous impact on alleviating the suffering and hardships that this crisis brings.

I'm already witnessing impressive efforts from the Berkeley Engineering community: Bin Yu, professor of electrical engineering and computer sciences and of statistics, is creating algorithms to track medical supplies as well as public health data; mechanical engineering associate professor Grace O'Connell is exploring how to convert machines used to treat sleep apnea into ventilators; bioengineering professor Amy Herr is evaluating methods to sterilize N95 masks; and electrical engineering and computer sciences professor Michel Maharbiz is developing software tools to enable remote operation of ventilators to reduce healthcare workers' exposure to the virus.

Those are just a few of the projects underway that illustrate the spirit of public service and societal impact so ingrained in our DNA at Berkeley.

All of us — including our students — are experiencing tremendous disruption to our work and increasing uncertainty in our lives. But amid these challenges, I see enormous opportunities for doing good. Whether we're collaborating with others to innovate ways to mitigate the effects of COVID-19, or supporting the professors, students, researchers and staff within our college community, each one of us can make a positive difference. Now more than ever, society needs engineers to design and implement solutions for the benefit of our globally interconnected society.

—*Tsu-Jae King Liu*
DEAN AND ROY W. CARLSON PROFESSOR OF ENGINEERING

Noah Berger

# in this issue

Berkeley**ENGINEER** **SPRING** 2020



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*Berkeley Engineer* is published twice yearly to showcase the excellence of Berkeley Engineering faculty, alumni and students.

**Published by:** UC Berkeley College of Engineering, Office of Marketing & Communications, 201 McLaughlin Hall #1704, Berkeley, CA 94720-1704, phone: 510-642-2024, website: engineering.berkeley.edu/magazine

**Reach editors:** berkeleyengineer@berkeley.edu

**Change of address? Send to:** engineerupdates@berkeley.edu **or submit at:** engineering.berkeley.edu/update

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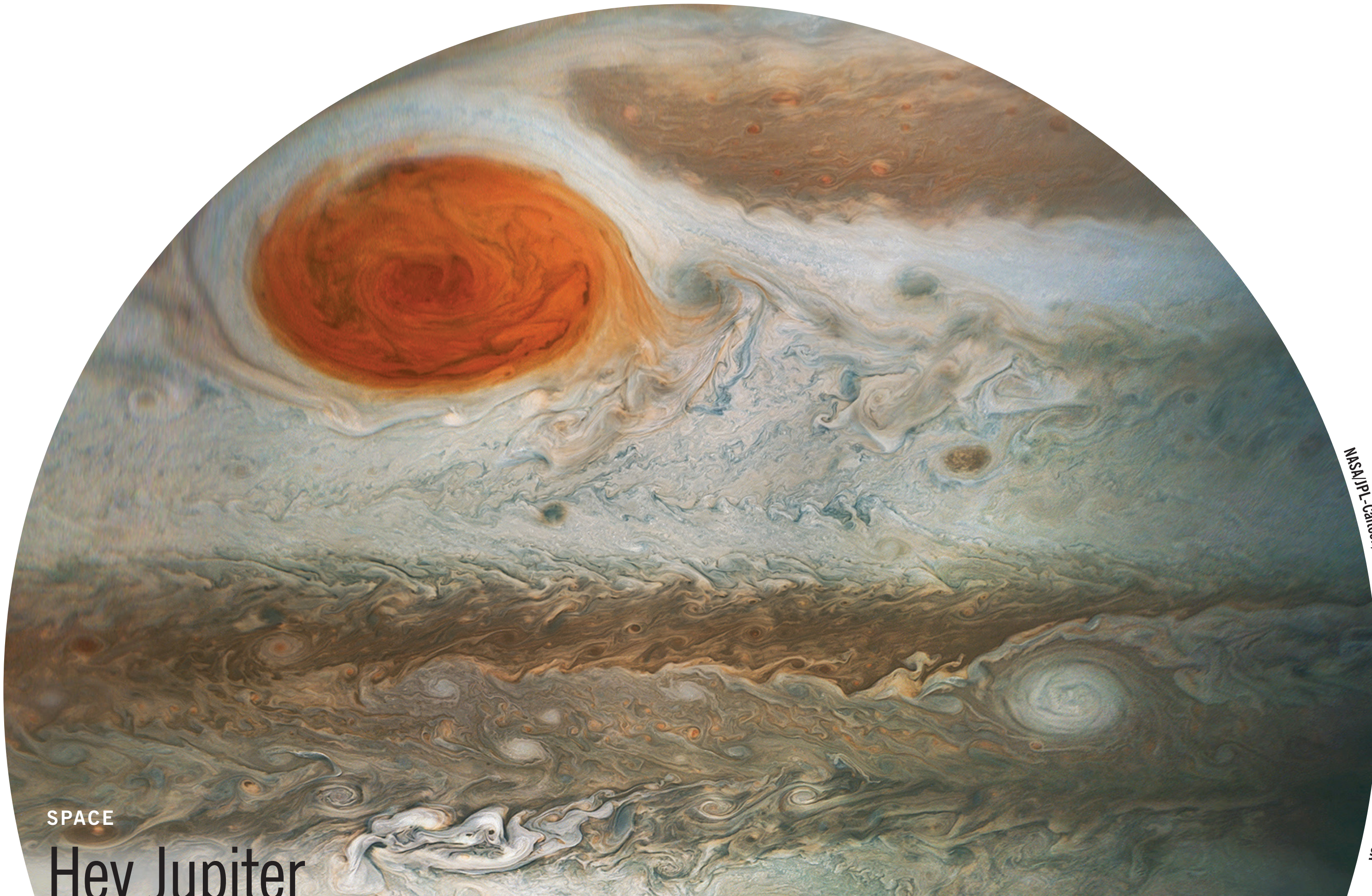

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SPACE

## Hey Jupiter

It would appear that reports of the death of Jupiter's Great Red Spot have been exaggerated. After extensive computer simulation of the giant storm, Berkeley scientists say that it is not dying. The research, led by mechanical engineering professor **Philip Marcus** and graduate student **Aidi Zhang** with undergrad **Finn Boire,** refutes implications that either the observed shrinkage of the spot's associated clouds or its recent, violent shedding of small, red "flakes" means that the underlying vortex is not healthy.

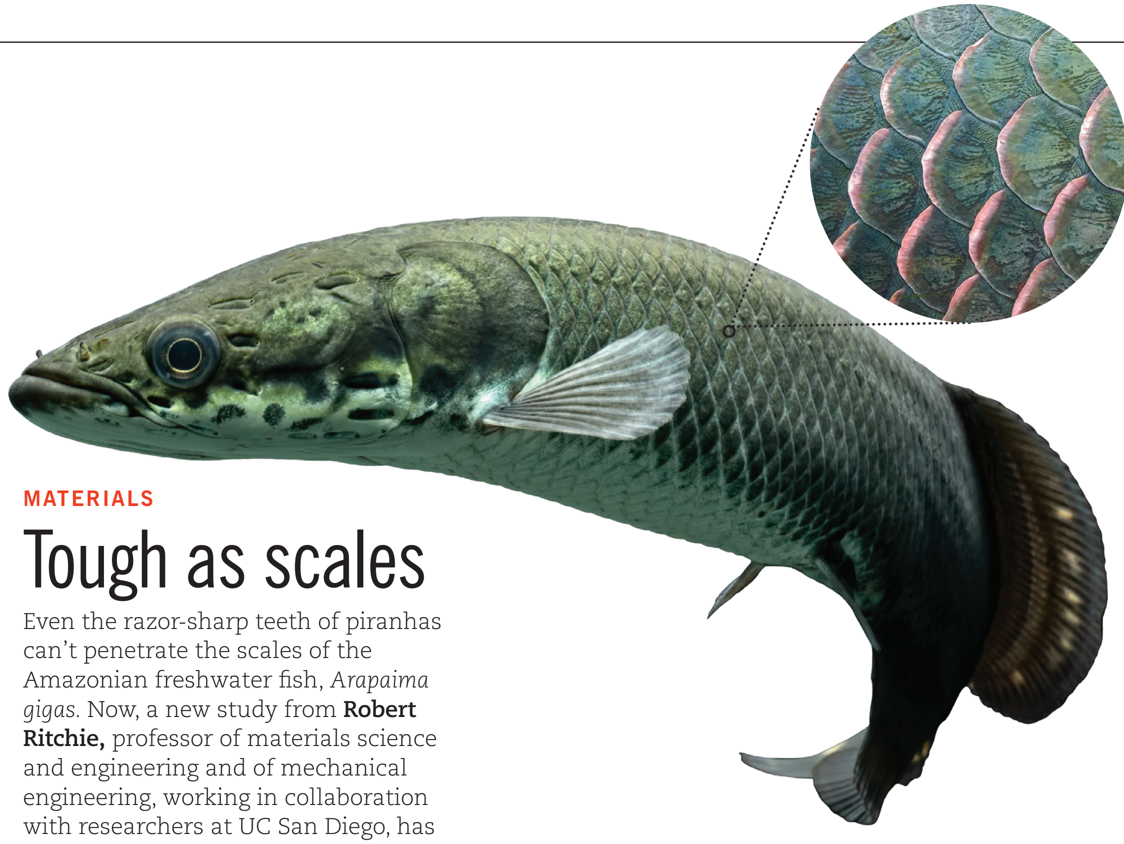
Marilyn Chung/ Lawrence Berkeley National Laboratory

PUBLIC HEALTH

## Double duty

Gadolinium is a metallic element widely used in MRI contrast dyes to improve the clarity of images and help with diagnostic accuracy. But some patients have reported odd symptoms following scans in which these contrast dyes were used, and studies have found gadolinium deposits in the bones and brains of MRI patients. Now, a pill originally developed by nuclear engineering professor **Rebecca Abergel** and her Berkeley Lab colleagues to treat radiation poisoning may also be effective in protecting patients from the potentially toxic effects of gadolinium.

The pill, designed to remove radioactive contaminants from the body, has an ingredient that is nontoxic and highly effective at clearing gadolinium deposits. In a study, the team was able to show this drug — if given right before or after an MRI — could prevent up to 96% of the gadolinium from depositing. It was also shown to be much more selective for gadolinium than similar drugs, which means it won't deplete the body of important minerals. The researchers hope to pursue further investigations into how gadolinium interacts with the human body.



- The scale has **a hard outer layer of mineral and collagen** — similar to bone, but even harder. This highly mineralized surface is the initial line of protection.
- The scale's **soft, thick inner layer** is composed of parallel collagen fibrils arranged in a twisted spiral pattern. If the outer layer is cracked, these fibrils deform, containing the crack and preventing the scale from breaking.
- The outer and inner layers of the scales are **bound by collagen** and grow together as a graded structure in one solid piece, which further strengthens the scales.
- After subjecting the scales to force, the researchers found the *A. gigas* scales to be **one of the toughest flexible materials in nature.** They hope their study can be used to develop improved lightweight armor.

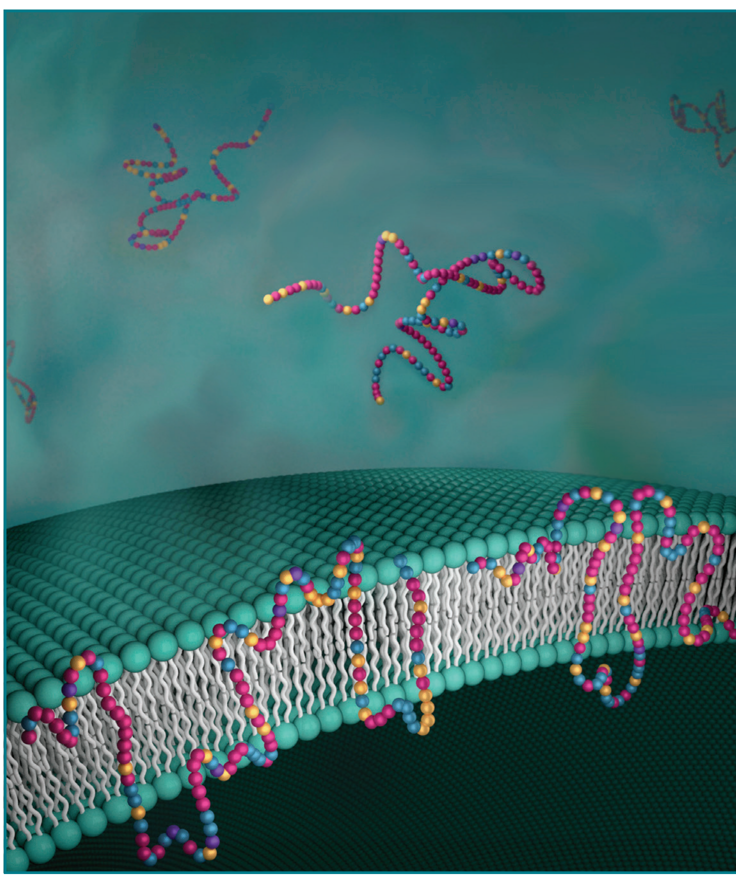
MATERIALS

# Tough as scales

Even the razor-sharp teeth of piranhas can't penetrate the scales of the Amazonian freshwater fish, *Arapaima gigas.* Now, a new study from **Robert Ritchie,** professor of materials science and engineering and of mechanical engineering, working in collaboration with researchers at UC San Diego, has determined exactly what makes these scales so incredibly tough, yet still lightweight and flexible.

CHEMISTRY

# Grand designs



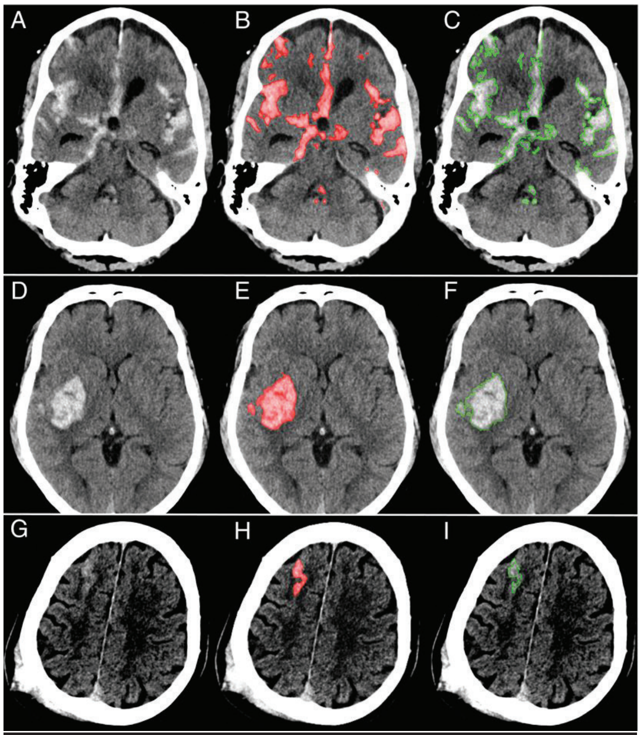
Jill D. Hemman, Oak Ridge National Laboratory

Researchers led by **Ting Xu,** professor of materials science and engineering and of chemistry, have created a synthetic material that is as effective as naturally occurring proteins in transporting molecules through membranes, a major milestone that could have applications in water desalination, batteries, pharmaceutical and biofuels research. Mimicking transmembrane proteins, which act as gatekeepers in living cells, has been a key goal — and a significant bottleneck — in synthetic membrane development, but this new achievement could alleviate that jam. The team of researchers designed a polymer that selectively transported protons, or charged subatomic particles, across an acrylic film at a rate similar to those of natural proton channels while successfully filtering out other types of cations.

The scientists also provided a solution to a long-standing challenge in designing synthetic proteins that worked like their natural counterparts. For decades, scientists believed that they had to copy an exact monomer sequence to create a synthetic polymer that would function as well as naturally occurring proteins. But Xu and her collaborators found that the monomers don't have to line up nor match exactly to function like a protein. Rather, their design only requires researchers to statistically control the sequence of four types of monomers for the polymer to perform as well as a naturally occurring protein. The monomers can be grouped into segments like Lego pieces to construct functional protein-mimics.

DIAGNOSTICS

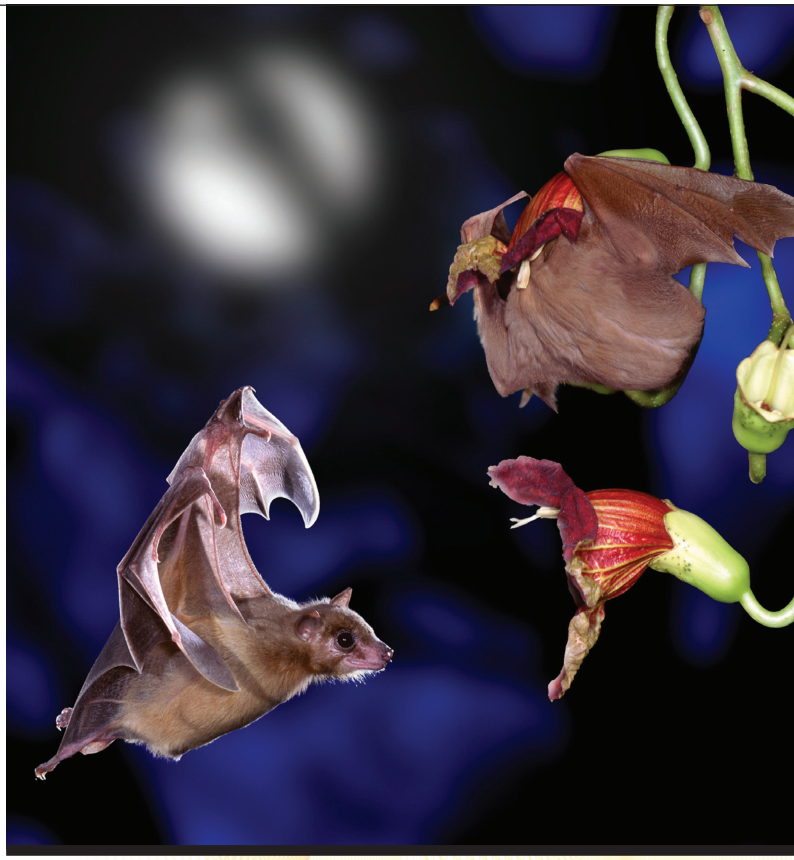
# Good for the image




Courtesy UCSF

Images A, D and G are the original brain scans. The red shading on scans B, E and H indicates hemorrhages as recognized by the algorithm; the green outline on images C, F and I shows hemorrhages as determined by neuroradiologists.

Radiologists can review thousands of brain images each day, searching for minute signs of traumatic brain injuries, strokes and aneurysms. Now, Berkeley researchers, working with scientists at UCSF, have developed a computer algorithm that could help radiologists focus on the most important images and examine them more closely. Using artificial intelligence to more efficiently and accurately recognize abnormal CT scans, the team's algorithm took just one second to identify head scans with signs of hemorrhage — even some that experts missed. For each abnormality, the algorithm also provided a detailed outline, location and subtype, which could help physicians quickly determine the appropriate treatment. According to study co-author **Jitendra Malik,** Berkeley professor of electrical engineering and computer sciences, the researchers were able to use a small number of images to train the algorithm by using a type of deep learning known as a fully convolutional neural network, or FCN. In these training images, each small abnormality was manually delineated at the pixel level, helping to create an extremely accurate algorithm.



PHYSICS

# Quantum weirdness

Upending a basic tenet of classical physics, a study by Berkeley researchers has shown that heat energy, in the form of molecular vibrations, can travel across a few hundred nanometers of a complete vacuum, thanks to a quantum mechanical phenomenon called the Casimir interaction. The discovery, led by mechanical engineering professor **Xiang Zhang,** could have profound implications for the design of computer chips and other nanoscale electronic components where heat dissipation is key.

"Heat is usually conducted in a solid through the vibrations of atoms or molecules, or so-called phonons — but in a vacuum, there is no physical medium. So, for many years, textbooks told us that phonons cannot travel through a vacuum," said Zhang. "What we discovered, surprisingly, is that phonons can indeed be transferred across a vacuum by invisible quantum fluctuations."

BRAIN RESEARCH

# In sync

Humans aren't the only species capable of getting on the same wavelength with each other. Research from Berkeley scientists shows that bats have synchronized brain activity when engaging in social behaviors, such as grooming, fighting or sniffing each other. Led by **Michael Yartsev,** assistant professor of bioengineering and of neurobiology, the study is the first to show neural correlation during social interactions by a non-human species.

In the study, Yartsev and postdoctoral scholar **Wujie Zhang** used wireless neural recording devices to measure the brain activity of bats interacting in a chamber. These devices captured signals that included the bats' higher frequency brain waves, as well as electrical activity from individual neurons. The researchers found surprisingly strong correlations between the bats' brains, especially for brain waves in the high frequency band. These correlations were present whenever the bats shared a social environment and increased before and during their social interactions.

To better understand these correlations, a team of undergraduate students went through hours of high-speed video of the bats, characterizing behavior in each frame. The lead researchers then analyzed the relationship between bat behavior and inter-brain correlation, allowing them to rule out other possible explanations for the synced-up brain activity, such as that the bats' brains were simply reacting to the same environment, or that the bats were engaging in the same behavior. The researchers hope this work will help future studies on how brains process social interactions.

SENSOR-ACTUATORS

# In touch with reality

Today's augmented and virtual reality (AR/VR) technologies simulate a vivid interactive experience by altering what users see and hear. But what if users could also feel their way through an experience?

A new flexible, wearable device developed by Berkeley researchers, led by mechanical engineering professor **Liwei Lin,** could make this a reality. Their piezoelectret-based device, about 150 micrometers thick, is both a sensor and an actuator. Under mechanical deformation caused by human movements, the device's sensor can generate electrical outputs without a power supply. These electrical outputs can then help turn on the actuator via electrostatic force to generate vibrations that can be felt by human skin. Currently, the device's actuating mode can generate up to 20 meganewtons, comparable to the vibrations of a cellphone, and sense objects as light as a dandelion seed.

"There are many applications for this technology that can sense motion and give haptic feedback," said Lin. "One application is AR/VR. Right now, if you are playing a game and hitting a wall, you only hear a sound. With our device, the sensor can detect if you are going to hit something, and the actuator can vibrate to simulate a physical impact." Because the vibrations can be customized, this technology could also be used to help people with visual or hearing impairments interact with the world around them.

Adam Lau

HOW DO I FIND OUT MORE? Find links to source articles and expanded coverage at **engineering.berkeley.edu/magazine.**

# Super sand

As regions like California face more extreme weather patterns and unpredictable water supplies, cities are **looking to save some rain for a sunny day.** Stormwater, an abundant but underused water source, could serve as an inexpensive, local supply during the dry season. But this resource has gone mostly untapped because stormwater picks up toxic chemicals as it runs through streets and gutters.

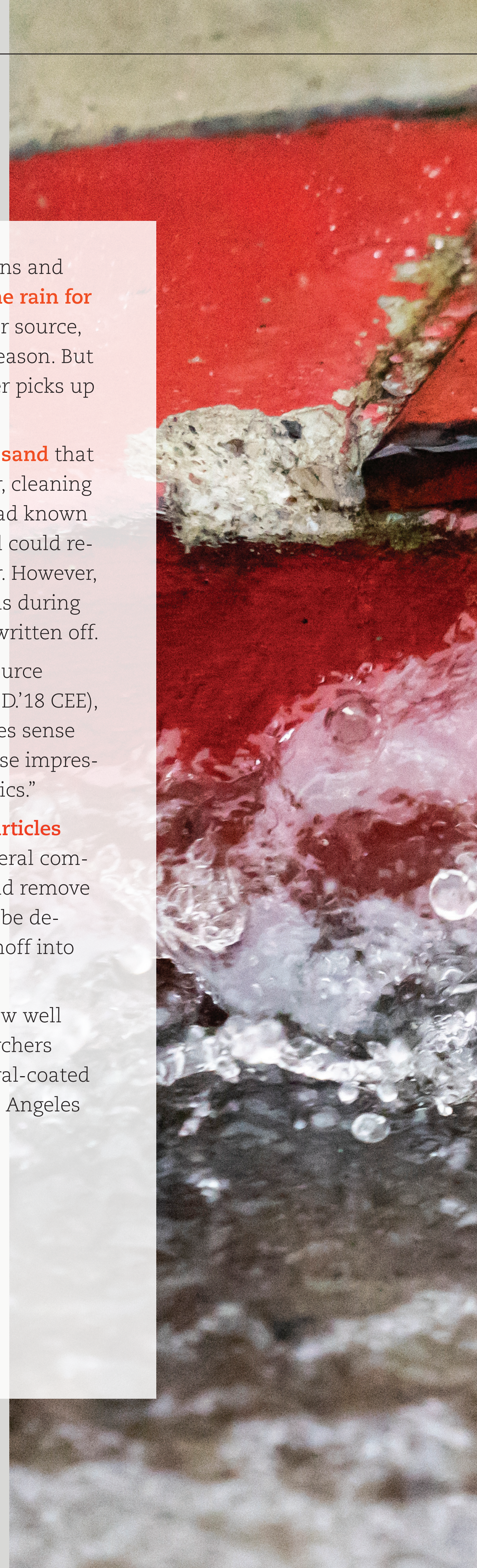
Now, **Berkeley engineers have developed a mineral-coated sand** that can soak up toxic metals like lead and cadmium from water, cleaning up the stormwater as it replenishes aquifers. Researchers had known that the naturally occurring minerals they coated onto sand could react with organic contaminants like pesticides in stormwater. However, the ability of this coated sand to also remove harmful metals during filtration could unlock urban water supplies that had been written off.

"The pollutants that hold back the potential of this water source rarely come one at a time," said **Joe Charbonnet** (M.S.'13, Ph.D.'18 CEE), who conducted this research as a graduate student. "It makes sense that we fight back with a treatment technology that has these impressive double abilities to take out both toxic metals and organics."

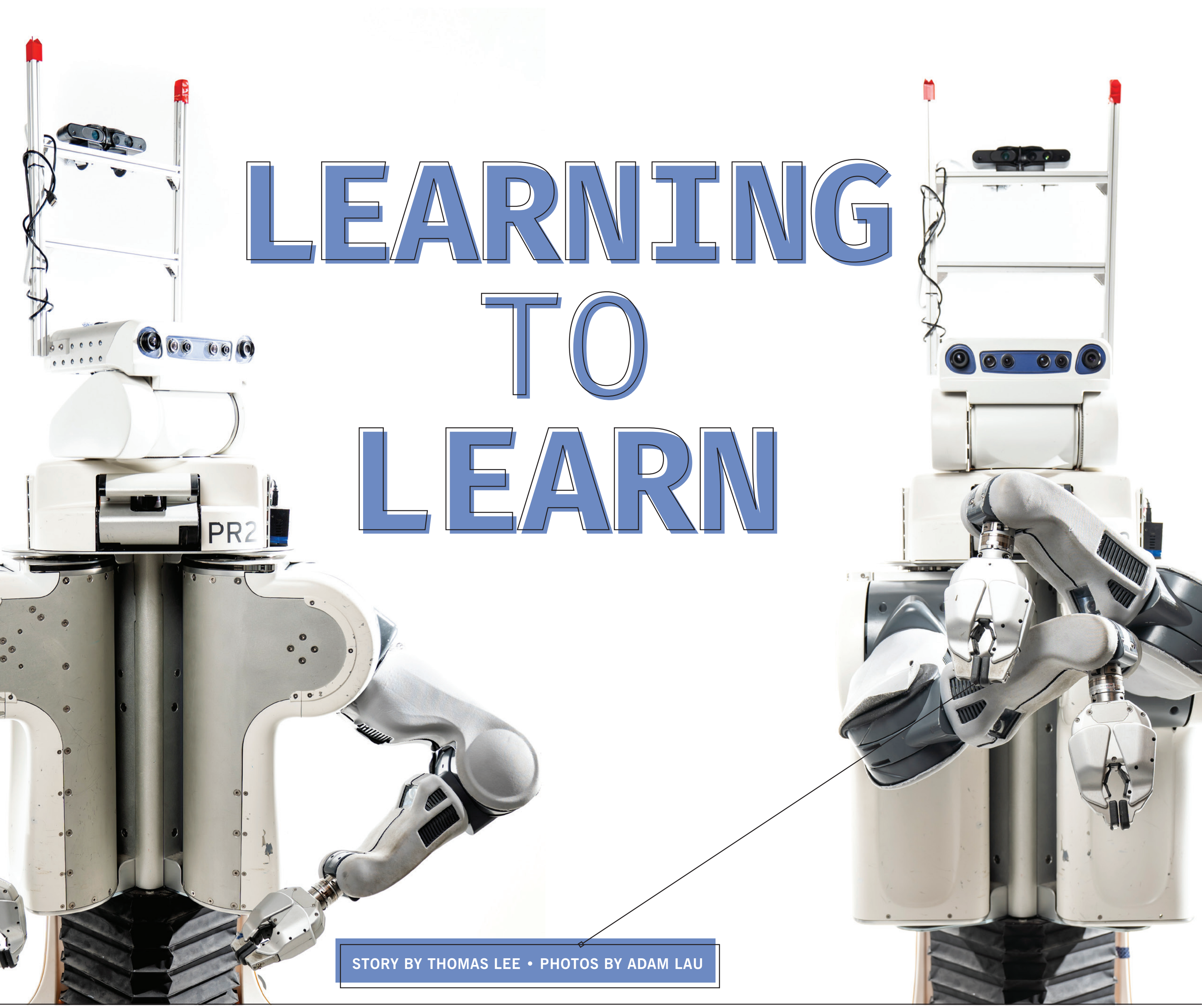
**To make the filtration media, the scientists coated sand particles with manganese oxide**, a naturally occurring nontoxic mineral commonly found in soil. They estimate that this material could remove metals from stormwater for over a decade. It could be deployed in infiltration systems that convey runoff into underground aquifers.

**Work has already begun** to investigate how well this material performs in the field. Researchers have deployed test columns of the mineral-coated sands to treat stormwater at sites in Los Angeles and Sonoma, California.

PHOTOS BY ADAM LAU



Coated sand can remove two major classes of contaminants that threaten groundwater quality during stormwater infiltration.




# LEARNING TO LEARN

STORY BY THOMAS LEE • PHOTOS BY ADAM LAU

When children play with toys, they learn about the world around them — and today's robots aren't all that different. At UC Berkeley's Robot Learning Lab, groups of robots are working to master the same kinds of tasks that kids do: placing wood blocks in the correct slot of a shape-sorting cube, connecting one plastic Lego brick to another, attaching stray parts to a toy airplane.

Yet the real innovation here is not what these robots are accomplishing, but rather how they are doing it, says Pieter Abbeel, professor of electrical engineering and computer sciences and director of the Robot Learning Lab.

Taking inspiration from the way that children instinctively learn and adapt to a wide range of unpredictable environments, Abbeel and assistant professor Sergey Levine are developing algorithms that enable robots to learn from past experiences — and even from other robots. Based on a principle called deep reinforcement learning, their work is bringing robots past a crucial threshold in demonstrating human-like intelligence, with the ability to independently solve problems and master new tasks in a quicker, more efficient manner.

"If you see a robot do something through reinforcement learning, it means it actually knows how to acquire a new skill from its own trial and error," Abbeel says. "That's a much more important accomplishment than the specific task it completed."

And while today's most advanced robots still can't match the brain power of a toddler, these researchers are poised to equip robots with cutting-edge artificial intelligence (AI) capabilities, allowing them to generalize between tasks, improvise with objects and manage unexpected challenges in the world around them.

## MAKING "GOOD" DECISIONS

Over the past 80 years, seemingly unrelated innovations in mathematics, economic theory and AI have converged to push robots tantalizingly close to something approaching human intelligence.

In 1947, mathematician John von Neumann and economist Oskar Morgenstern developed a theorem that formed the basis of something called expected utility theory. In a nutshell, the theory holds that when given a set of choices left to chance, a person will choose the option that produces an outcome with the maximum level of individual satisfaction. Moreover, we can represent that desired outcome, the "reward," with a numeric value.

"That number represents what they want," Abbeel says. "So the theorem shows that having a reward is fully universal. The only thing you need is a number."

Researchers then applied this theory to computers by giving them numerical incentives to learn how to play board games.

Take chess. If the computer's goal is to checkmate its opponent as quickly as it can, that outcome is assigned the highest number in the game. The computer explores which moves to make to achieve checkmate: a "good" move earns the computer a high number while a "bad" move produces a low number.

Since choices that represent higher numbers mean the computer will reach its goal more quickly, the computer becomes proficient at chess by systematically learning, through trial and error, to make "good" decisions while avoiding "bad" ones.

Using this reinforcement learning technique, researchers created computers that could defeat human champions in checkers, chess and even Atari video games. In 2017, AlphaGo, an AI program invented by Google, beat the world's best player at Go, an abstract strategy game much more complicated than chess and checkers — cracking a new threshold in AI.

## NEURAL NETWORKS

Teaching a computer to win a video game is one thing. Teaching a robot to perform a physical action is much harder.

For one thing, software code exists in the virtual world, which means AI programs enjoy unlimited space to explore and learn. Robots, however, are physical objects operating in physical space. Training a robot to grasp and manipulate objects or navigate spaces without crashing into a filing cabinet requires painstaking and tedious programming work.

Researchers must feed the robot with a vast database of images and train it to recognize patterns so that it can distinguish pictures of chairs from pictures of cats. That way, when a robot rolls into a room, its sensors, or "eyes," can detect an object blocking its path. The robot compares the visual data to similar images in its database before it can successfully conclude that object is indeed a chair.

"Such trial and error takes a long time," Levine says.

But the use of artificial neural networks has allowed robots to process and analyze information at much faster rates. These networks consist of connected units or nodes that resemble the neurons in human brains. Each node can signal other nodes to connect to it, allowing the robots to establish relationships between different types of data.

Using this approach, Berkeley researchers have been able to do things like teach robots how to run, both in computer simulations and in real life. The robot learns the optimal neural connections it must make to apply the right amount of force to the motors in its arms, hips and legs.

**SERGEY LEVINE**
Assistant professor, electrical engineering and computer sciences

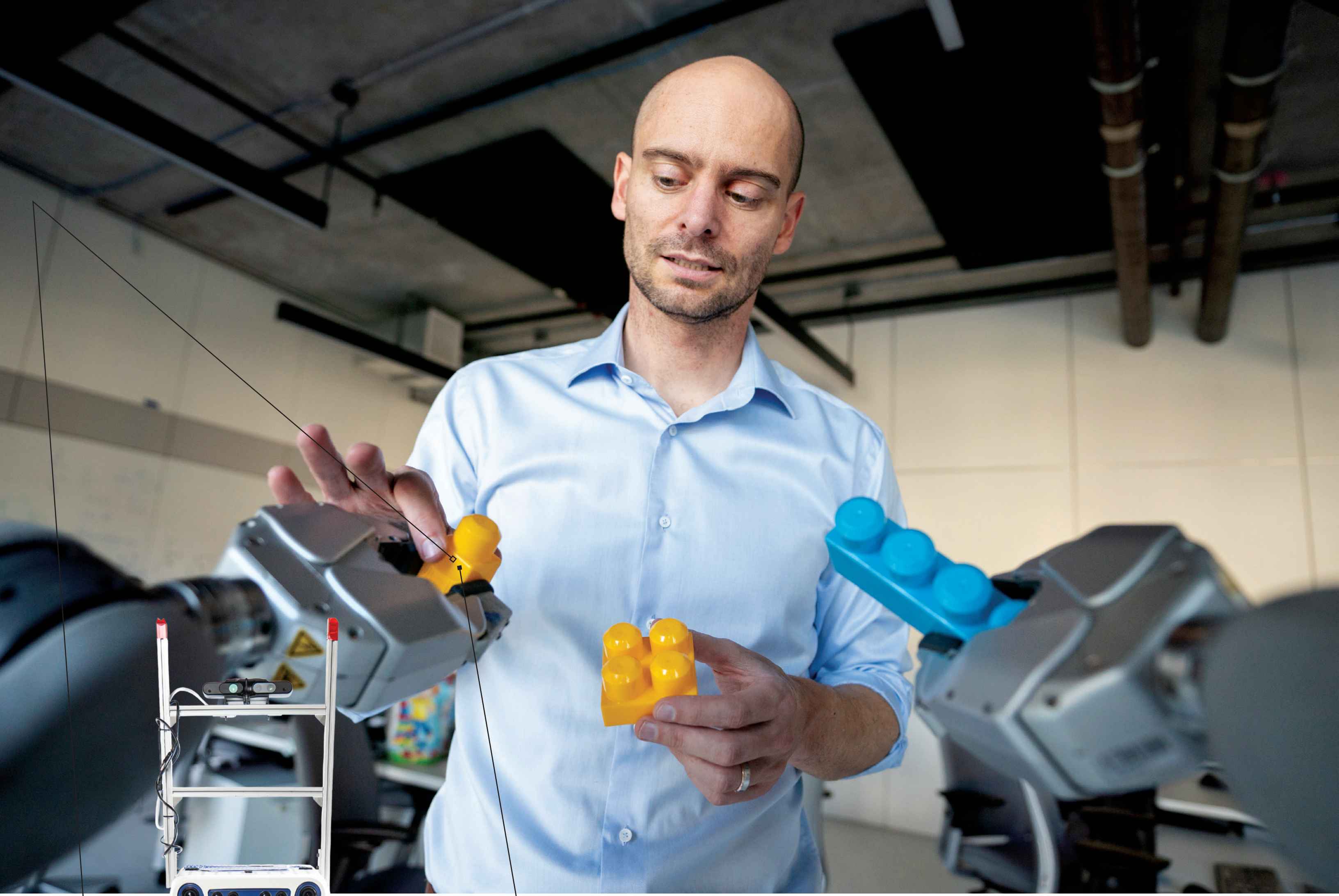
**PIETER ABBEEL**
Professor, electrical engineering and computer sciences

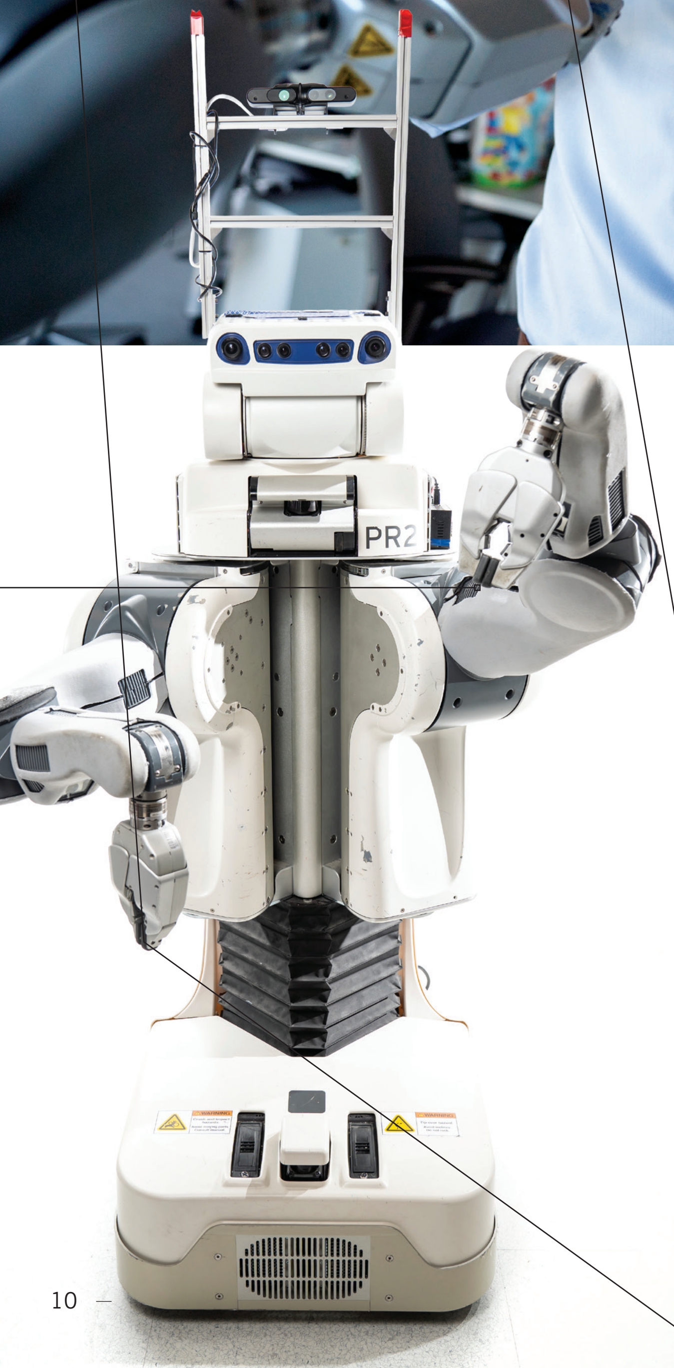
"Through different runs, the robot tries different strengths of connections between the neurons," Abbeel says. "And if one connection pattern is better than the others, the robot might retain it and do a variation on that connection, and then repeat, repeat, repeat."

The robots understand that certain neural connections earn them rewards, so they continue along that path until achieving the objective, which is to run across a room without falling down or veering off in the wrong direction. The algorithms the Berkeley researchers ultimately produced allowed the robots to not only remember what they learned from trial and error but also to build upon their experiences.

"The strength of connections between the neurons, and which neurons are connected, is essentially how we internalize experience," Abbeel says. "You need algorithms that look at those experiences and rewires those connections in the network to make the robot perform better."

Eventually, Levine says, researchers might be able to create what he calls "lifelong robotics systems," in which robots improve themselves by continuously analyzing their previous individual triumphs and mistakes and those from other robots.






"When faced with complex tasks, robots will turn their observations into action," he says. "We provide them with the necessary ingredient for them to make those connections."

## MULTI-TASKING ROBOTS

Most robots today still require humans to set a reward. But what if robots could set their own goals, unsupervised, similar to the way children explore their environment?

Advances in unsupervised deep reinforcement learning could lead to gains not yet realized in supervised settings. Unlike in other areas of deep learning, robotics researchers lack the large data sets needed to train robots on a broad set of skills. But autonomous exploration could help robots learn a variety of tasks much more quickly.

Work coming out of Berkeley has shown what this might look like in robotic systems developed by Abbeel, Levine and Chelsea Finn (Ph.D.'18 EECS), now an assistant professor at Stanford University, as well as student researchers. Robots, drawing on their own data and human demos, can experiment independently with objects. Some of the skills mastered include pouring items from one cup to another, screwing a cap onto a bottle and using a spatula to lift an object into a bowl.

Robots even taught themselves to use an everyday object, such as a water bottle, as a tool to move other items across a surface, demonstrating that they can improvise. Further research by Finn and Levine, collaborating with researchers from the University of Pennsylvania, showed that robots could learn how to use tools by watching videos of humans using tools with their hands.

"What's significant is not the raw skills these robots can do," Finn says, "but the generality of these skills and how they can be applied to many different tasks."

One of the main challenges that researchers are contending with is how to fully automate self-supervised deep reinforcement learning. Robots might be learning like a toddler, but they don't have comparable motor skills.

"In practice, it's very difficult to set up a robotic learning system that can learn continually, in real-world settings, without extensive manual effort," Levine says. "This is not just because the underlying algorithms need to be improved, but because much of the scaffolding and machinery around robotic learning is manual."

For example, he says, if a robot is learning to adjust an object in its hand and drops that object, or if a robot is learning to walk and then falls down, a human needs to step in and fix that. But in the real world, humans are constantly learning on their own, and every mistake becomes a learning opportunity.

"Potentially, a multi-task view of learning could address this issue, where we might imagine the robot utilizing every mistake as an opportunity to instantiate and learn a new skill. If the coffee-delivery robot drops the coffee, it should use that chance to practice cleaning up spilled coffee," Levine says.

"If this is successful, then what we will see over the next few years is increasingly more and more autonomous learning, such that robots that are actually situated in real-world environments learn continually on the job."

## ENTERING THE REAL WORLD

Some of these advances in deep reinforcement learning for robotics are already making their way out of the lab and into the workplace.

Obeta, a German electronics parts manufacturer, is using the technology developed by Covariant.AI, a company co-founded by Abbeel, for robots to sort through bins of thousands of random gadgets and components that pass through the conveyor belt at its warehouse. The robot can pick and sort more than 10,000 different items it has never seen before with more than 99% accuracy, according to Covariant. There's no need to pre-sort items, making this technology a game-changer for manufacturing.

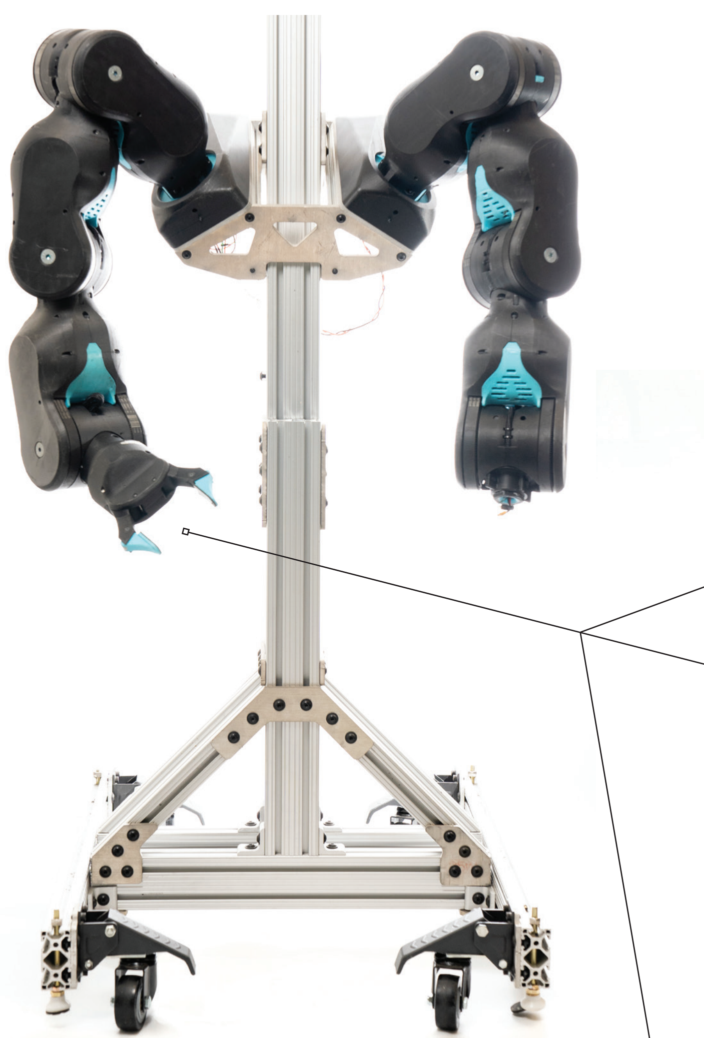
"I think we will likely see robots gradually permeating more and more real-world settings, but starting on the 'back end' of the commercial sector, and gradually radiating from there toward less and less structured environments," Levine says.

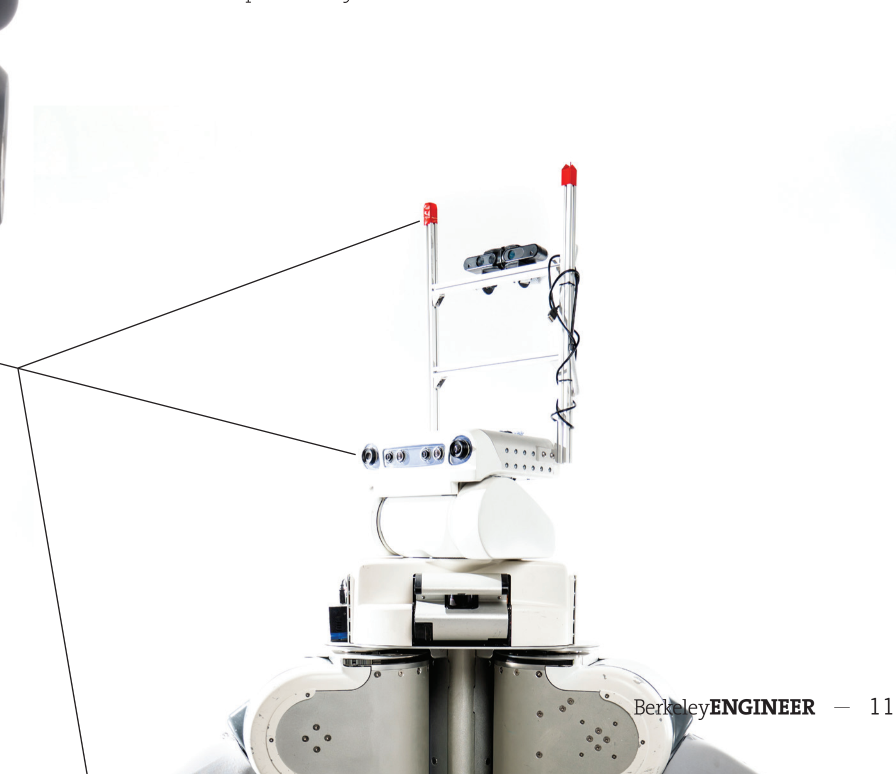
We might see robots transitioning from industrial settings like factories and warehouses to outdoor environments or retail shops. Imagine robots weeding, thinning and spraying crops on farms; stocking grocery store shelves; and making deliveries in hotels and hospitals. Eventually, robots could be deployed in more outward-facing roles, such as janitorial work in large commercial enterprises.

Levine says the fully consumer-facing home robot is some ways away, as robots must first master more complex domains with variability. This will also require a cadre of human experts, out in the field, before it can be fully realized.

Whatever the domain, these researchers aim to use robots to work collaboratively with people and enhance productivity, as opposed to displacing people from jobs. The attendant scientific, political and economic factors merit serious consideration and are integral to the work they do.

"Every technology has potential for both positive and negative outcomes, and as researchers it's critical for us to be cognizant of this," Levine says. "Ultimately, I believe that ever more capable robots have tremendous potential to make peoples' lives better, and that possibility makes the work worthwhile." BE





# REINVENTING CYBERSECURITY

## Privacy, potential and the new data economy

STORY BY ANN BRODY GUY • PHOTOS BY ADAM LAU

"If a service is free, you are the product," according to conventional wisdom about websites, apps and online services. That is, your *personal data* is the product. The truth is, whether or not we're paying for services, these cyber-businesses are tracking what we buy, where we go, what we're looking at and how long we look. And depending on the language behind that "I agree" button most of us click to get on with our tasks, they are likely selling our data to other businesses. Numerous large-scale hacks — affecting millions and even billions of users — have shown that we cannot trust these companies to keep our data safe.

The good news is that, as of January 1, 2020, the California Consumer Privacy Act joined other recent data protection laws in granting consumers new rights to know how our data is used, to have it deleted and to opt out of having it sold. Businesses are also now legally bound to protect our data throughout its life cycle, though many lack the technical capability to do so effectively.

But all these new responsibilities — and liabilities — add to the likelihood that companies will simply lock up their private data, storing away potential value. Analyzing customer data can support business growth, for example, and collaborations can address societal problems, such as travel data from ride-sharing companies informing systemwide transportation improvements, or medical data being studied to compare treatment outcomes across large populations. So while the new legal landscape brings much-needed privacy protections, it also locks up a lot of potential.

"Data has fueled the modern-day economy," says electrical engineering and computer sciences professor Dawn Song (Ph.D.'02 EECS). Song made MIT Technology Review's "35 Innovators Under 35" list in 2009 for her advanced approaches to securing private data from attacks, and a year later was named a MacArthur Fellow. She says data informs business decisions that help grow the economy and can support discoveries that make society safer and healthier. She can enumerate better than most of us the importance of protecting sensitive data. "But if we silo the data to keep it secure," she says, "we don't get any benefit from it."

To access those benefits while protecting users' personal data, Song thinks we need to move beyond the ad hoc approach of simply adding security patches. Instead, she is reimagining what online security looks like, proposing a new paradigm she calls a "platform for a responsible data economy."

What does that mean, exactly? She ticks off several foundational ideas: We own our data; owners get to specify how we want our data to be used; and an individual's data is tracked throughout its life cycle, so how it's used is transparent.

Her research lab is developing security and privacy solutions based on these ideas. In 2018, she co-founded Oasis Labs, where she is chief executive, to commercialize this work. Oasis is building a secure platform to store, track and compute on private data, what Song calls "controlled use." The publicity materials for Oasis Labs put her goals more simply: She is building a "better internet" — one that can access data's value without compromising privacy. The work has earned her spots on Wired and Inc. magazines' top innovator lists.

## A MULTIFACETED DEFENSE

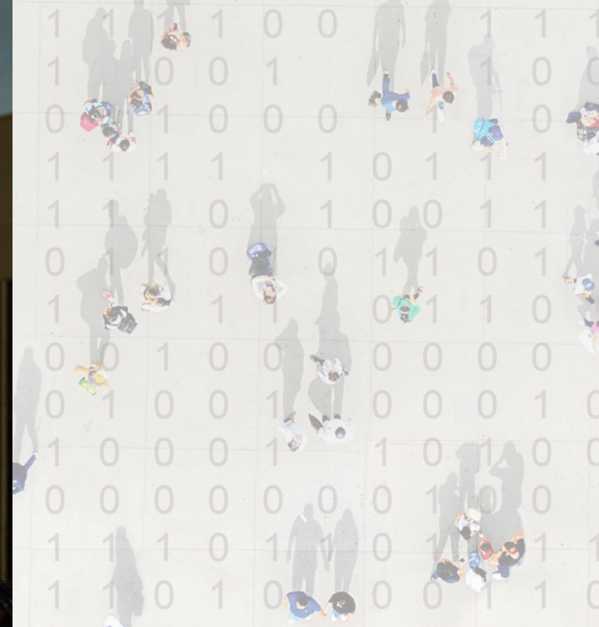
Song recently identified one particularly alarming privacy vulnerability: leaky programs. Language-prediction technology is everywhere now, deploying artificial intelligence to suggest our likely next words in texts, emails and search terms. These machine-learning models work by gobbling up huge quantities of data — some of it private, like emails and texts — to learn common speech patterns, then using that growing intelligence to predict what we're likely to say next.

The technology has brought some gentle relief to busy people and tired thumbs, but Song found that these language models have a nasty habit: They memorize the source data they learned from.

"We show that unintended memorization is a persistent, hard-to-avoid issue that can have serious consequences," reads the provocatively named 2018 study, "The Secret Sharer," which she co-authored in collaboration with Google Brain. Those consequences? Savvy attackers can query unique sequences — like credit card or Social Security numbers — then use the program's predictions to launch attacks.

Protecting data from this and other security vulnerabilities throughout its life cycle requires multiple lines of defense. Song's platform delivers a one-two-three punch.

To train language programs, the platform uses machine-learning models that employ cryptographic techniques such as inserting noise and duplications — a so-called "differential privacy" system that keeps nefarious queries from learning sensitive information. In addition, it runs data computations in a secured environment that combines hardware solutions and cryptographic techniques. For record-keeping, it uses a distributed ledger that deploys blockchain technology, the same decentralized ledger system used in cryptocurrency, where no single individual has control.



DAWN SONG
Professor, electrical engineering and computer sciences

Together, these innovations create a platform where organizations — like hospitals or ride-share companies — can share data to gain meaningful insights, without revealing an individual's personal information. This "blindfolded" secure-computing process, called "secure collaborative learning," can safely tap into data's potential.

Much of Song's work is open source, a free-access approach to programming that she says will speed the larger paradigm shift and help make the system more robust.

## JOINING THE DATA ECONOMY

A cornerstone of Song's vision is establishing data rights that align with basic property rights, allowing individuals to garner monetary value from their data. Does this mean you'll be able to rent out your 23andMe results like Airbnb and Uber let you unlock value from your home and vehicle? It's not so simple, she explains.

"People talk about data like it's the new oil. But data is actually crude oil. You need to process it to turn it into something that's useful and valuable."

That processing will require a whole new set of principles. She and colleagues are working on these ideas using a principle from game theory to determine exactly how much data is worth and what those transactions will look like. To train health-related models, for example, data pertaining to a rare disease would likely have more value than a ubiquitous data point like a common blood type.

Song's vision for a better internet is gaining traction. Last year, she advised the U.S. chief technology officer, and her research team's new approach to verifying differential privacy won the 2019 Distinguished Paper Award at OOPSLA, an influential software engineering conference.

"Both users and companies are suffering, but with our platform for a responsible data economy, we want to bring them into a win-win situation," Song says. Users can be assured that their data is safe and potentially even monetize it, and businesses can comply with their security and transparency obligations while realizing benefits from their data. "But," she adds, "in a privacy-preserving and responsible way."

## "SHARING WITHOUT SHOWING"

Electrical engineering and computer sciences assistant professor Raluca Ada Popa also believes that society can reap great benefits from private data if only we can learn how to use it securely. Popa, who counts a spot on MIT Technology Review's 2019 "35 Innovators under 35" list among the many honors for her work in secure cloud computing, focuses on secure collaborative learning to help organizations that have a lot of sensitive data unlock their potential to address big, important questions.

"We would love to learn from all this data," she says. What's the best cancer treatment across all hospitals, she wonders, and what are the indicators for a particular diagnosis? Illegal operations like drug dealing and human trafficking launder money by making small deposits across numerous banks and geographical locations, but banking data is, necessarily, private. "If these institutions could only put all this information together, they would learn a lot from it. They could produce much better cancer treatments, much better models for predicting money laundering and so on."

Encryption has been effective in securing data while it's in transit to the cloud or resting in cloud storage, but actually computing on sensitive cloud-based data has proven challenging — simply building firewalls around the cloud has not kept hackers out. Popa's work overcomes this hurdle by providing organizations a way to share and compute on their sensitive data without ever decrypting it.

"Essentially it's sharing without showing," Popa says. Secure collaborative learning has been around for three decades, she adds, but it's been too slow for practical

**Actually computing on sensitive cloud-based data has proven challenging — simply building firewalls around the cloud has not kept hackers out.**

applications. "My work makes it practical. For example, in our paper on Helen [Popa's encrypted machine-learning training system], we made training 1,000 times faster than existing technology. So instead of training a model in three months, it takes us under three hours."

Popa's technology is already helping organizations learn from shared data. An anti-money laundering pilot project with Canadian banks is just one of several trials that have proven the technology's potential and moved it a step closer to adoption. Secure auditing is another use case she's studying. Regulators can audit specific, agreed-upon activities at a country's nuclear power plants, for example, without violating private activities outside the scope of international agreements.

## COLLABORATING SECURELY

To begin a collaboration, organizations agree to run an algorithm on their collective data based on a specific shared goal. For example, to detect potential money laundering, banks may look for a single individual making deposits at different geographic locations at the same time. They agree on the data categories they need to include, such as customer IDs, deposit amounts and locations. They encrypt their data with Popa's systems, and then what she calls "the magic" happens: The banks run the algorithm on their joint data without ever decrypting it.

Finally, only the output is decrypted — in this case, suspicious accounts. "This is very powerful because banks don't have to share all their customer data with each other. They only share the results of their search," Popa says.

Decryption in her software works like nuclear launch codes, adding another layer of security against inadvertent leaks and human frailties. Employing blockchain's decentralized authorization process, each collaborator only has one piece of the key. To decrypt a computation result, all the parts must come together, a system that guards against even multiple points of corruption or error in the process.

Popa's company, PreVeil, makes this Berkeley-developed technology available for email and file sharing — applications that perform like Gmail and Dropbox. She has customers in security-critical fields like aerospace, defense and biotechnology.

But Popa's ambitions go beyond what her research and company can do alone. She is working on $MC^2$, an open-source version of her lab's secure collaborative learning platform that is accessible to non-technical users. Potential applications appear to be vast.

"People come to us from financial institutions, big internet companies, nuclear physics, the government, medical institutions.... We don't have the bandwidth to deploy our technology for every one of them, so we are creating a platform that anyone can use," she says. "You don't have to know cryptography or fancy engineering."

While Popa's lab works on about three use cases at a time, her students track the many inquiries they receive and integrate those questions into the open-source project. "Our goal is to bring secure collaborative learning to the masses — to the non-experts, to everyone," she says. "That's the vision we're working toward." BE

**RALUCA ADA POPA**
Assistant professor, electrical engineering and computer sciences

# Monteiro selected for elite engineering honor

**Paulo Monteiro** (M.S.'81, Ph.D.'85 CEE), professor of civil and environmental engineering, has been elected to the National Academy of Engineering for his "contributions to the science and nanotechnology of concrete for sustainable construction and durable structures." An expert in structural engineering, mechanics and materials, he has done extensive research into making concrete more environmentally sustainable. He joins Per Peterson (see page 18) as one of 78 Berkeley Engineering faculty members in the academy.

PHOTO BY ADAM LAU

**Rebecca Abergel,** assistant professor of nuclear engineering, and **David Schaffer,** professor of bioengineering and of chemical and biomolecular engineering, have been named fellows of the American Association for the Advancement of Science. They are among 443 members who were recognized for their scientifically or socially distinguished efforts to advance science or its applications.

This year, a sizeable contingent of Berkeley Engineering alumni was elected to the National Academy of Engineering, which is among the highest professional distinctions accorded to an engineer. **Eleanor Allen** (M.S.'07 CEE), **David Allstot** (Ph.D.'79 EECS), **Reginald DesRoches** (B.S.'90, M.S.'92, Ph.D.'97 CEE), **John Fan** (B.S.'66 EECS), **Susan Hubbard** (Ph.D.'98 CEE), **Ronald Klemencic** (M.S.'86 CEE), **Steven Kramer** (B.S.'77, MEng'79 CEE), **Chen-Ching Liu** (Ph.D.'83 EECS), **Lelio Mejia** (M.S.'78 CEE), **Rabab Ward** (M.S.'69 EECS) and **Deng Zhonghan** (Ph.D.'97 EECS) were all recognized by the academy.

**Alper Atamturk,** professor of industrial engineering and operations research, was named an INFORMS Fellow as well the next chair of the INFORMS Optimization Society.

Electrical engineering and computer sciences graduate student **Carlos Biaou** won a UC Berkeley Sather Gate Young Volunteer Award for giving his time and expertise to serve the Berkeley community. Biaou also won the Pillar of the Community Award from the Latino/a Association for Graduate Students in Engineering and Science at Berkeley (LAGSES) in 2019.

Bolt Threads — co-founded by **David Breslauer** (Ph.D.'10 BioE) — received an honorable mention in the 2019 Fast Company Innovation by Design awards for their new Mylo Driver Bag, a high fashion tote made from engineered mushroom mycelium cells.

Electrical engineering and computer sciences professors **Eric Brewer** (B.S.'89 EECS) and **David Wagner** (M.S.'99, Ph.D.'00 CS), along with **Ian Goldberg** (M.S.'98, Ph.D.'00 CS) and **Randi Thomas,** have won the 2019 USENIX Test of Time Award for their 1996 paper "A Secure Environment for Untrusted Helper Applications."

**Kevin Carter** (B.S.'86 CE) was appointed vice president and managing principal for Huitt-Zollars, Inc., a full-service consultant for all market sectors. Previously, he had worked for the city of Glendale for 16 years, as well as a design-build contractor.

Civil and environmental engineering professor emeritus **Anil Chopra** (M.S.'63, Ph.D.'66 CE) was awarded the Nigel Priestley International Prize by the Rose School at the University of Pavia, Italy. He was honored for his professional achievements and excellence in education in the field of earthquake engineering and engineering seismology.

Civil and environmental engineering professor **Matthew DeJong's** project on monitoring the health of aging railway infrastructure was honored with the New Civil Engineer TechFest Rail Visionary Award.

Electrical engineering and computer sciences professor **James Demmel** (Ph.D.'83 CS) and **Vasily Volkov** (Ph.D.'16 CS) have won the 2019 ACM/IEEE Supercomputing Conference Test of Time Award for their paper, "Benchmarking GPUs to Tune Dense Linear Algebra." The paper describes a first-of-its-kind vision of GPU architectures as a vector machine.

**Michelle DeRobertis** (B.S.'80, M.S.'82 CE) received a Ph.D. from the University of Brescia in Lombardy, Italy.

**Leslie Field** (M.S.'88, Ph.D.'91 EECS) gave a presentation at the inaugural Global Climate Restoration Forum at the United Nations. Field is the CEO and founder of ICE911 Research, a non-profit focused on developing materials to preserve and rebuild polar and glacial ice and polar habitats.

Civil and environmental engineering graduate students **Teddy Forscher, Alexandra Pan** and **Stephen Wong** all received prestigious Dwight David Eisenhower Transportation Fellowships. These fellowships are awarded to students pursuing degrees in transportation-related disciplines and aim to advance the transportation workforce.

**Suresh Garimella** (Ph.D.'89 ME) will become the new president at the University of Vermont in July. He is currently the executive vice president for research and partnerships and professor of mechanical engineering at Purdue University.

**Andres Gomez** (M.S.'14, Ph.D.'17 IEOR) and **Renyuan Xu** (M.S.'15, Ph.D.'19 IEOR) have joined the faculty of the University of Southern California's Department of Industrial and Systems Engineering as assistant professors.

**Sumit Gulwani** (Ph.D.'05 CS), **Susmit Jha** (M.S.'11, Ph.D.'11 EECS), electrical engineering and computer sciences professor **Sanjit Seshia** and **Ashish Tiwari** will receive the 2020 Most Influential Paper Award by the ACM/IEEE International Conference on Software Engineering, given to the paper judged to have had the most influence on the theory or practice of software engineering during the 10 years since its original publication.

**Bruce Hajek** (Ph.D.'79), professor at the University of Illinois at Urbana-Champaign (UIUC), has been named head of UIUC's Department of Electrical and Computer Engineering. He is an internationally renowned expert in the field of communications networks.

Bioengineering professor **Amy Herr** received the 2019 Faculty Award for Excellence in Postdoctoral Mentoring at UC Berkeley from the Visiting Scholar and Postdoc Affairs Program. Herr was also appointed to the National Advisory Council for Biomedical Imaging and Bioengineering, a high-level advisory and steering position at the national level.

Electrical engineering and computer sciences graduate student **Grant Ho** and his co-advisers, professors **Vern Paxson** (M.S.'91, Ph.D.'97 CS) and **David Wagner** (M.S.'99, Ph.D.'00 CS), were honored with a Distinguished Paper award at the 2019 USENIX Security Symposium for "Detecting and Characterizing Lateral Phishing at Scale."

**Feisal Jaffer** (B.S.'97 EECS) is the new global head for Hilton's luxury LXR Hotels and Resorts brand. Jaffer previously was the senior vice president of business development for Capella Hotel Group.

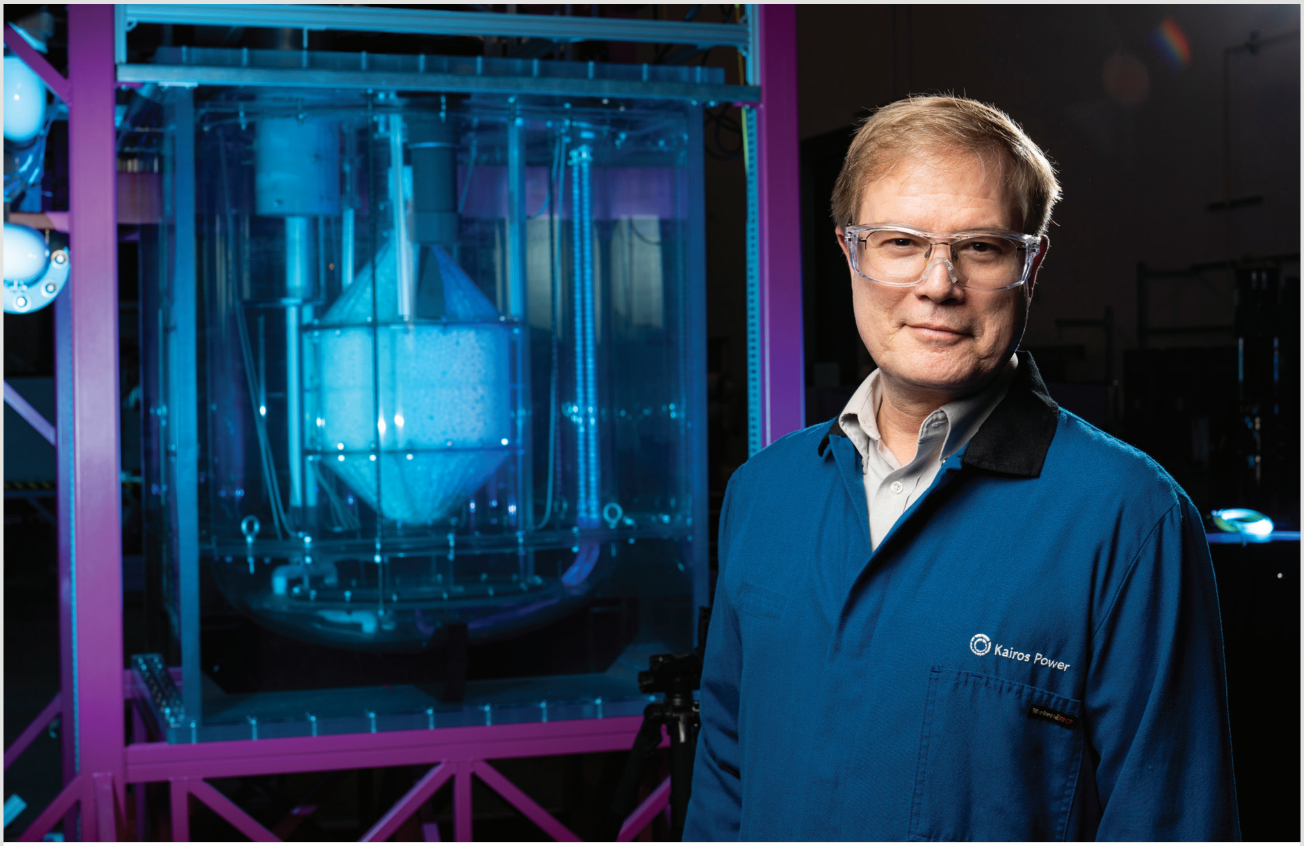
Electrical engineering and computer sciences professor **Michael I. Jordan** has won the distinguished John von Neumann Award from the Institute of Electrical and Electronics Engineers (IEEE). He was cited for "contributions to machine learning and data science."

**Jay Keasling,** professor of bioengineering and of chemical engineering, was awarded the Doing a World of Good Medal by the American Institute of Chemical Engineers for his achievements in advancing the social contributions of engineers.

Electrical engineering and computer sciences postdoctoral researcher **Pragya Kushwaha,** currently in the Berkeley Short-channel IGFET Model (BSIM) group, has won a prestigious 2019 IEEE Electron Devices Society Early Career Award.

**Darryll Pines** (B.S.'86 ME) has been named the next president of the University of Maryland, College Park. He is currently the dean of the university's A. James Clark School of Engineering, and he previously served as chair of the Department of Aerospace Engineering. A faculty member at the university since 1995, his research focuses on structural dynamics, including structural health monitoring and prognosis; smart sensors; adaptive, morphing and biologically inspired structures; and the guidance, navigation and control of aerospace vehicles.

PHOTO COURTESY UNIVERSITY OF MARYLAND




## Peterson honored as top engineer

Nuclear engineering professor **Per Peterson** (M.S.'86, Ph.D.'88 ME) has joined the ranks of National Academy of Engineering members. He manages Berkeley's Thermal Hydraulics Research Laboratory, and his expertise includes nuclear reactor design, radioactive waste and nuclear materials management. He was cited for "experimental and analytical research contributions for the design and development of passive safety systems for advanced nuclear reactors." Along with new member Paulo Monteiro (see page 16), he brings the total number of Berkeley Engineering faculty members in the academy to 78.

PHOTO BY ADAM LAU

**Srinivasan Keshav** (M.S.'88, Ph.D.'91 CS) won a 2019 Indian Institute of Technology Delhi Distinguished Alumni Award. A professor at the University of Waterloo, Canada, he is known for his cutting-edge research in computer networking and energy informatics and for his current research on blockchains for transactive energy.

**Bill Kramer** (Ph.D.'08 CS) has been selected as the next director of the Pittsburgh Supercomputing Center, a joint research center of Carnegie Mellon University and the University of Pittsburgh.

Bioengineering assistant professor **Liana Lareau** received the 2019 Shurl and Kay Curci Foundation Faculty Scholars Program Award by the UC Berkeley Innovative Genomics Institute. Lareau will lead a new project using genome editing tools to understand how "silent" mutations lead to human disease and to predict which mutations have big effects on human health.

**Jack Moehle,** professor of civil and environmental engineering, is the recipient of the George W. Housner Medal, the Earthquake Engineering Research Institute's most prestigious award. The medal is awarded for extraordinary and lasting contributions to public earthquake safety.

**Shmuel Oren,** professor of industrial engineering and operations research, was selected as the key speaker at the first Felix Höffler Memorial Lecture, hosted by the EWI Energy Conference, held at the University of Cologne, Germany.

As part of an NVIDIA team, computer science Ph.D. student **Taesung Park, Ting-Chung Wang** (M.S.'15, Ph.D.'17 EECS) and **Jun-Yan Zhu** (Ph.D.'17 CS), as well as NVIDIA's **Ming-Yu Liu,** created a real-time AI art application, called GauGAN, that won two coveted awards — Best in Show and Audience Choice — at the SIGGRAPH 2019 Real-Time Live Competition.

**Stanley Qi** (Ph.D.'12 BioE) has been named to the annual "SN: Scientists to Watch" list by Science News.

Electrical engineering and computer sciences professor **Jaijeet Roychowdhury** (M.S.'89, Ph.D.'92 EECS) and Ph.D. student **Tianshi Wang** were awarded the Nokia Bell Labs Prize for their work on "A Classical Spin on Quantum Computing." Their innovation is a new type of processor element that will be significantly more efficient in computing the answers to discrete optimization problems.

Electrical engineering and computer sciences professor **Stuart Russell** has published a book, "Human Compatible: Artificial Intelligence and the Problem of Control," in which he explains why society needs to design artificial intelligence that is beneficial, not just smart, and presents a solution for doing so.

**Brian Salazar** (B.S.'15, M.S.'17 ME), now a mechanical engineering Ph.D. student, was honored with the Best Poster Presentation Award at the 2019 International Conference on Planarization/CMP Technology.

Electrical engineering and computer sciences professor **Ion Stoica** was honored with the ACM SIGOPS Mark Weiser Award.

**Valerie Taylor** (Ph.D.'91 EECS) has been named a 2019 Argonne Distinguished Fellow. She is currently the director of the Mathematics and Computer Science Division of Argonne National Laboratory.

**William Tarpeh** (Ph.D.'17 CEE) was selected by Chemistry and Engineering News as one of its "Talented 12: Young Scientists Tackling the World's Problems with Chemistry." His work consists of creating ways to extract resources from human waste to make valuable products, like fertilizers and cleaning products.

Mechanical engineering professor **Masayoshi Tomizuka** was recently awarded the American Society of Mechanical Engineers' Soichiro Honda Medal.

Assistant bioengineering professor **Moriel Vandsburger** was presented with the American Heart Association Transformational Project Award for his work on molecular MRI methods for integrative physiological imaging in gene therapy.

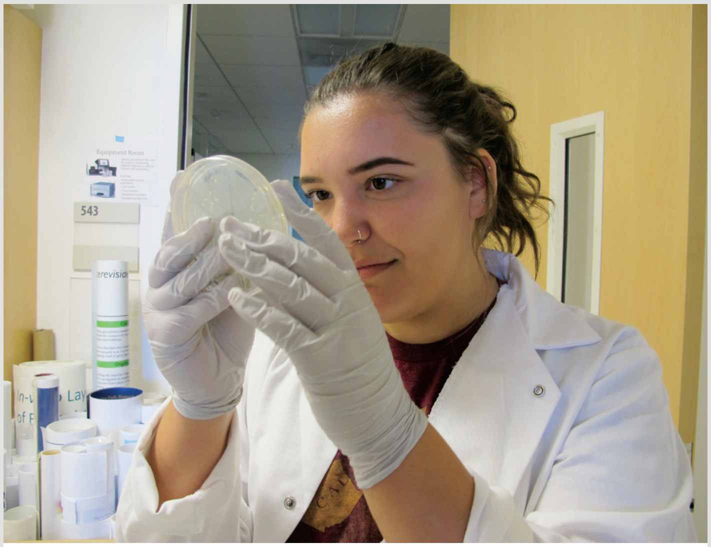
Electrical engineering and computer sciences professor **Ming Wu** (Ph.D.'88 EECS) has been named the 2020 recipient of the IEEE Electron Devices Society's Robert Bosch Micro and Nano Electro-Mechanical Systems (MEMS) Award for pioneering contributions in MEMS optical switches and optoelectronic tweezers.

**Michael Yartsev,** professor of bioengineering, was awarded a Jannett Rosenberg Trubatch Career Development Award from the Society for Neuroscience in recognition for his work in applying cutting-edge neural techniques to bats to understand how brain circuits mediate spatial and social behaviors.

**Yasuo Yoshikuni** (Ph.D.'07 BioE) and his colleagues at the Joint Genome Institute invented a genetic engineering tool, CRAGE, that will make studying secondary metabolites much easier and fill significant gaps in our understanding of how microbes interact with their surroundings and evolve.

**Chenming Hu,** electrical engineering and computer sciences professor emeritus, was awarded the IEEE Medal of Honor in recognition for "a distinguished career of developing and putting into practice semiconductor models, particularly 3D device structures, that have helped keep Moore's Law going over many decades." Hu was one of the researchers behind FinFET, a revolutionary 3D transistor structure that overcame physical barriers limiting device design and has been replacing the transistors used by industry for the past five decades.

PHOTO COURTESY CHENMING HU



# Transferring excellence

Seventy percent of California's community college students neither earn a two-year associate degree nor transfer to a four-year university after six years. In an effort to improve the transfer rate, a program called Transfer-to-Excellence Research Experiences for Undergraduates (TTE REU) offers California community college students an opportunity to work alongside Berkeley researchers.

For nine weeks every summer, 15 students join labs on campus to prepare themselves to transfer to a four-year university and ultimately complete a bachelor's degree in science and engineering. In addition to research, the students receive advising services, participate in seminars and go on field trips that expose them to different opportunities in a variety of areas in engineering and science.

"In the six years that the TTE REU program has been running, we have achieved a 93 percent transfer rate to a four-year school to major in a STEM degree," said **Nicole McIntyre,** associate director of education at the Center for Energy Efficient Electronics Science (E3S), which is headquartered at Berkeley Engineering.

She adds that the majority of these students have transferred to a University of California campus, and many choose to attend UC Berkeley.

"I did this program in 2017 before I transferred from community college, and I think this is one of the best things that I've done," said **Kimberly Ferry,** now a fourth-year bioengineering major at Berkeley. "As a community college student, it's hard to feel like you are in a real college. TTE helped me to feel like I belong here and that I can do this."

PHOTO COURTESY KIMBERLY FERRY

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Berkeley Engineer magazine, Berkeley Engineering, 201 McLaughlin Hall #1704, Berkeley, CA 94720-1704

**Myron "Jake" Jacobs** (B.S.'44 EE) died in October at the age of 96. After serving in the U.S. Navy, he worked for Pan American Airways on an Army contract. He then took a job as a bridge engineer with the state of California, which led to a 41-year career working on numerous bridge construction projects throughout the state.

**Neil Karpe** (B.S.'17 ME) died in October at the age of 23. He was a software and controls engineer at suitX, where he worked on exoskeleton technologies.

**Chuck Moran** (B.S.'48 CE) died in August at the age of 98. In World War II, he served as a first lieutenant in the Army Air Corps. Following graduation, he worked for Los Angeles County in structural engineering and then had a 20-year tenure at the Portland Cement Association. He later worked in business development at Kennedy Jenks Engineers and was the vice president of engineering at Hales Testing Laboratories.

**Andrew Packard** (M.S.'84, Ph.D.'88 ME), professor of mechanical engineering, died in September at the age of 59. He joined the Berkeley faculty in 1989 and was a major pioneer in the field of robust control theory. A passionate educator, he was renowned for his commitment to teaching and mentoring, receiving the department's best teaching award on numerous occasions as well as the university's Distinguished Teaching Award. He was also the recipient of many other professional honors, including the National Science Foundation Presidential Young Investigator Award, IEEE Fellow and the Berkeley Citation.

**Harry Pelton, Jr.** (B.S.'52 ME) died in January at the age of 94. After graduating, he attended the University of Southern California, where he earned a master's degree. He went on to work for several aerospace companies before joining the Aerospace Corporation, where he spent the remainder of his career.

**Eugene Serr** (B.S.'46 CE) died in September at the age of 94. Following graduation, he earned a master's degree in irrigation engineering at Colorado State University, then worked at the California Department of Water Resources in Sacramento and Red Bluff.

**Jerome Thomas,** professor emeritus of civil and environmental engineering, died in November at the age of 97. An expert in applied chemistry, he worked on a wide range of civil engineering problems, including corrosion, fire and explosions, plastics, hazardous waste, and water and wastewater treatment. He taught on the faculty for 39 years, held five patents, served as a consultant to the National Academy of Sciences and the National Science Foundation, and was an award-winning wood carver.

**George Trezek,** professor emeritus of mechanical engineering, died in December at the age of 82. A faculty member from 1966–90, he was an expert in energy science and technology, particularly in solid and hazardous waste treatment and disposal. Among his achievements, he established the Waste Processing Laboratory at the Richmond Field Station, authored more than 200 publications in research journals, held several patents and launched his own consulting company upon retirement.

**Doug Tygar,** professor of electrical engineering and computer sciences and at the School of Information, died in January at the age of 57. His research made significant contributions to the fields of usable computer security, cryptography, privacy and digital rights management. The co-founder of the Secure Machine Learning research group, he was a committed teacher and mentor, helping to create CS 161, the first undergraduate computer security class at Berkeley.


PHOTOS BY ADAM LAU

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