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Auto Pilot

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On the cover: *A startup company launched by a UCI alumnus competes in Silicon Valley's hottest race: to develop and market autonomous vehicle navigation systems.*

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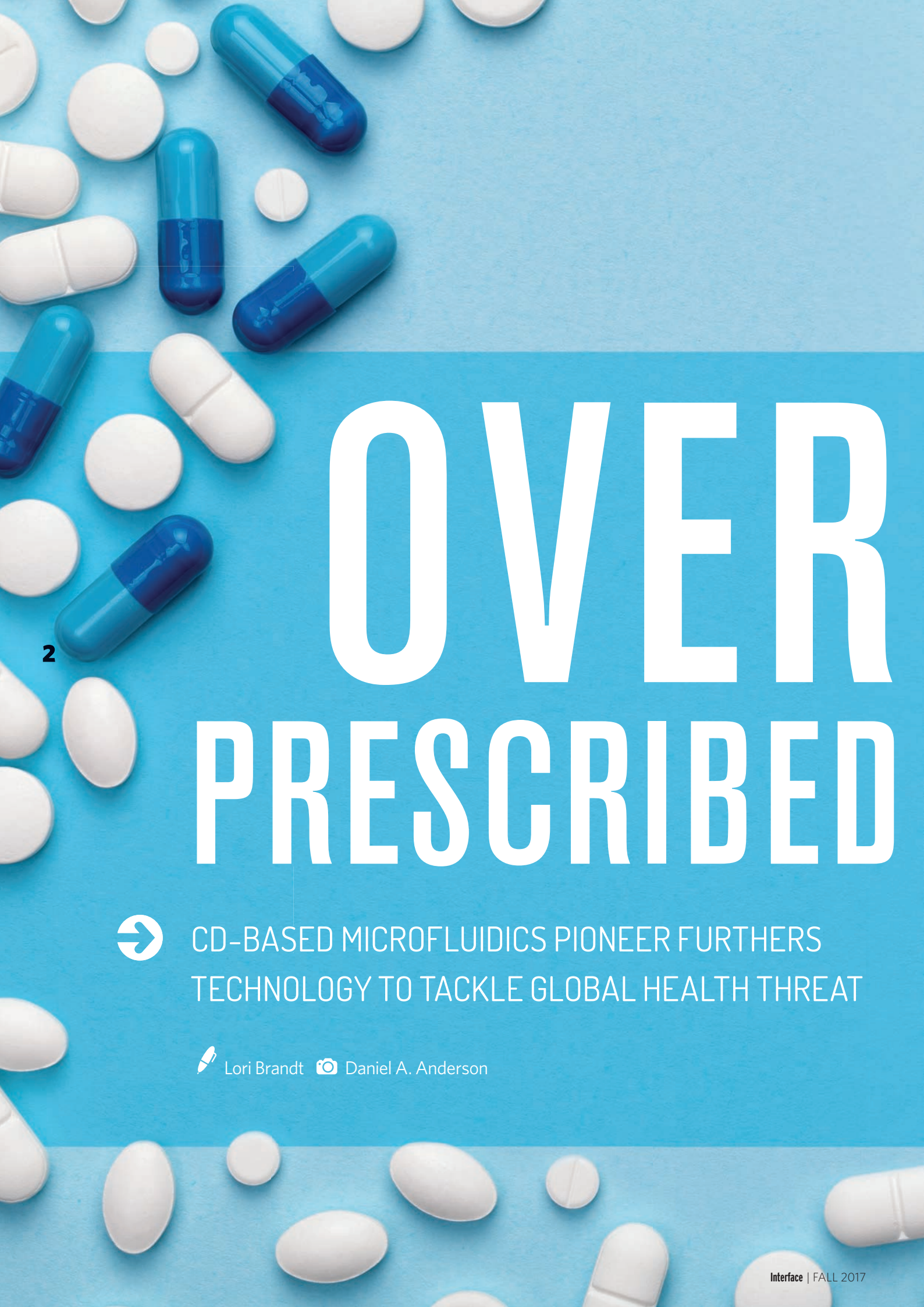


OVER PRESCRIBED

CD-BASED MICROFLUIDICS PIONEER FURTHERS TECHNOLOGY TO TACKLE GLOBAL HEALTH THREAT

Lori Brandt Daniel A. Anderson

76%

of people mistakenly think antibiotic resistance occurs when the body becomes resistant.

WHEN MOST PEOPLE LOOK AT A COMPACT DISC PLAYER, THEY THINK MUSIC.

Not Marc Madou. He contemplates using centrifugal force to channel microliters of body fluids – urine or blood – from point to point to identify a disease or an infection. He sees a CD-based microfluidic medical diagnostic device.

A UC Irvine Chancellor's Professor of mechanical and aerospace engineering, Madou pioneered the technology about 18 years ago. A powerful, affordable and potent medical diagnostic tool, it has since been commercialized by half a dozen companies.

Now, Madou is putting it to work on one of today's biggest threats to global health: antibiotic resistance.

According to the World Health Organization, "antibiotic resistance is rising to dangerously high levels" in all parts of the world. New resistance mechanisms are emerging and spreading, threatening our ability to treat common infectious diseases. A growing list of infections – pneumonia, tuberculosis, blood poisoning and gonorrhea – are becoming harder, and sometimes impossible, to treat as antibiotics become less effective.

The threat is heightened in countries without standard treatment guidelines, where antibiotics are often over-prescribed and overused, and in places where they can be purchased without a prescription. WHO warns that without urgent action, we are heading toward a post-antibiotic era, in which common infections and minor injuries can once again kill.

"Antibiotic resistance is a huge public health problem," says UCLA pediatric urologist Dr. Bernard Churchill, who, along with UCLA infectious disease specialist Dr. David Haake, has spent the past 15 years tackling the issue. They formed medical device company MicrobeDX and have turned to Madou to help take their idea to the next level.

Currently, the conventional process of detecting and identifying potential bacteria strains in patients with a possible urinary tract infection, for instance, takes 48 to 72 hours. That's not counting transportation time for the sample to go from doctor's office to laboratory. So in the majority of cases, physicians make an educated guess as to which antibiotic drug to prescribe – before the lab identifies the actual bacterium. According to Churchill, in the U.S. last year, 50 percent of these scrips were unnecessary, inappropriate or incorrect, contributing greatly to the development of antibiotic resistance.

Churchill and Haake created a diagnostic assay that more quickly detects and identifies the type of bacterium and then screens it for antibody sensitivity. "We wanted to completely revolutionize the field of diagnostic microbiology," says Churchill. "It was too slow, big and cumbersome."

This new assay uses ribosomal ribonucleic acid (rRNA) and a biosensor, giving the medical community the information it needs for evidence-based antibiotic therapy in less than three hours. However, it is still performed in a laboratory. The next challenge is to affordably scale up the process and reduce the time it takes to transport samples. That's where Madou and his 10-member team of graduate students come in. Turns out his spin stand and microfluidic CD design capabilities are a perfect match for this bacteria identification and antibody sensitivity test.

"This is a fantastic assay," says Madou. "We've put all the steps on our

Marc Madou, a fellow of the National Academy of Inventors, is a leading expert in scalable nanomanufacturing technologies. He hopes to apply his CD-based microfluidic technology to health problems in remote areas of developing nations around the world.

> **"I AM ENDLESSLY CURIOUS. RIGHT NOW, I'M THINKING ALL ABOUT HOW TO USE THIS TECHNOLOGY WORLDWIDE TO SOLVE HEALTH PROBLEMS; IT WOULD BE TREMENDOUS."**

platform, and we not only automate it but can make it better, faster and more reproducible. And the entire test can take place in the doctor's office or health clinic, wherever the specimen has been collected."

Alexandra "Sasha" Perebikovsky, a Ph.D. student in physics and lead researcher in Madou's bioMEMS lab, explains that the original benchtop assay, conducted manually, involved 88 steps and huge preparation. "We were able to drastically simplify the process by condensing it to five basic steps. We also cut the time needed for the bacteria to grow by improving the incubation with oscillation and a heated chamber."

The spin stand, or box, is custom designed for the assay. It includes a motor, an array of magnets, a small heater, laser valving and a camera for detection.

Once they hooked up with Madou, MicrobeDX made rapid progress. "It was really the ideal platform for operationalizing our assay," says Mazi Zarrehparvar, MicrobeDX president. "So many functions are doable in a CD format, and Marc came up with a cell lysis approach on a CD that outperformed anything that we'd ever seen, even with expensive machines and traditional approaches."

Madou envisions applying this technology to health challenges in the U.S. and around the world. He says that when scaled up, CD-based microfluidic technology could help solve many health problems in rural remote areas of developing nations and resource-constrained environments: places like India, Africa and Mexico, where people have scarce access to health care.

He calls it extreme point of care, or EPOC, and he is working with Dr. Satadal Saha and engineer Chandra Sharma on a plan to implement this idea in rural India, under an Indian government-funded multi-institutional research project called Impacting Research Innovation and Technology (IMPRINT).

"Currently, there is no provision of diagnostic facilities in rural areas in India. Whatever little is available is of very poor quality and unreliable," says Saha, a co-principal investigator on IMPRINT. Diagnostic and other technologies are either too expensive, making it unaffordable for the poor, or require sensitive environmental conditions and

skilled labor for operation – criteria often not available in rural environments. "Samples, when transported far for tests, deteriorate due to improper handling and storage. If patients travel far for tests, the consequent secondary expense (travel, food, lost daily wages) is enormous, thus acting as a detriment."

As a pilot endeavor, Saha and his team have established three rural health kiosks in remote villages in West Bengal, staffed by local women formally trained as health workers, who deliver very basic medical care. The workers use an innovative software system to share data with remote doctors who then decide on a clinical management plan. The health worker can communicate with the doctor over the phone to prescribe medication and give patients instructions.

"With Marc's ideas and MicrobeDX technology, we could enable the health workers to undertake diagnostic tests at the kiosks," says Saha. "The results will automatically feed into the software ecosystem and generate a comprehensive data set for the patient's management plan."

This technology could go a long way toward improving health care by identifying bacteria and testing for antibody sensitivity. It can also rule out diseases, preventing misdiagnoses and unnecessary prescriptions. In total, Madou has designed multiple assays for use with CD-based microfluidic diagnostics, and he's working on a next-generation version with a smartphone attachment.

In a recent TEDx talk, Madou explains what drives him: "For me, being a scientist and being curious are all the same thing. It's life. I am endlessly curious. Right now, I'm thinking all about how to use this technology worldwide to solve health problems; it would be tremendous."

> "CURRENTLY, THERE IS NO PROVISION OF DIAGNOSTIC FACILITIES IN RURAL AREAS IN INDIA. WHATEVER LITTLE IS AVAILABLE IS OF VERY POOR QUALITY AND UNRELIABLE."

CAUSES OF ANTIBIOTIC RESISTANCE

Antibiotic resistance happens when bacteria change and become resistant to the antibiotics used to treat the infection they cause.

CONTRIBUTING FACTORS

Over-prescribing of antibiotics

Overuse of antibiotics in livestock and fish farming

Lack of hygiene and poor sanitation

Patients not finishing their treatment

Poor infection control in hospitals and clinics

Lack of new antibiotics being developed

Source: World Health Organization

INTRO TO DRIVERLESS CARS

Sharon Henry

Among the technologies that make autonomous vehicles possible is a combination of hundreds of specialized sensors, and sophisticated algorithms and processors. These all work together to analyze information and issue commands.

In 2014, Google's sister company Waymo debuted **Firefly.** The hybrid, two-seat concept car had no pedals or steering wheel, and a maximum speed of 25 mph.

COMPUTER

Information from sensors is analyzed by a central computer that regulates steering, acceleration and braking.

CAMERA

Video camera feeds images to recognition software.

WHEEL SENSORS

Sensors detect wheel rotations to help mark the vehicle's precise location.

ON THE ROAD TO SELF-DRIVING

HIGHWAY OF THE FUTURE

In the 1950s, General Motors and RCA developed automated highway prototypes with radio control for speed and steering. A 1957 ad imagined, "One day your car may speed along an electric superhighway, its speed and steering automatically controlled by electronic devices embedded in the road."

Photo: The Everett Collection

LIDAR

The sweeping LiDAR (light detection and ranging) takes more than a million measurements per second to map a view of the car's surroundings.

RADAR

Radar sensors in the front and rear help determine the position and speed of distant objects.

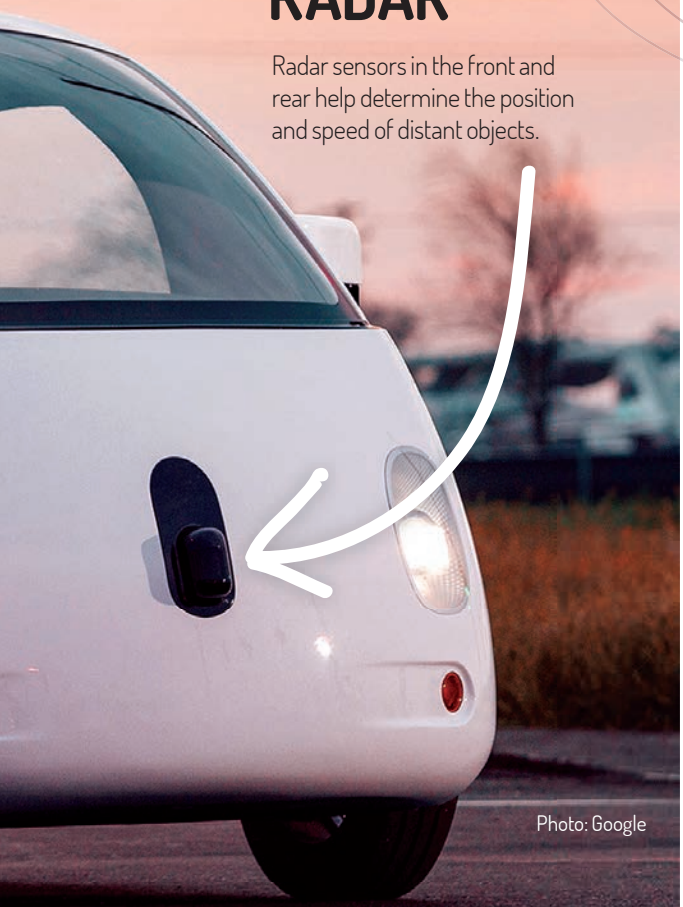


Photo: Google

After years of battling the high regulatory and societal hurdles of selling driverless vehicles, this past June the company announced it would retire the Firefly and shift to retrofitting commercially available vehicles with autonomous technology.

HOW A SELF-DRIVING CAR SEES

Information is collected simultaneously by the car's LiDAR, radar and camera, while an onboard computer manages the input to control navigation.

GPS

Car gets information from GPS satellite to pinpoint its location.

LIDAR

(Range: 230 feet)
A spinning laser beam generates 360-degree view to accurately detect the shape of objects, including other vehicles, pedestrians, curbs and structures.

FRONT-FACING CAMERA

High-definition video camera helps detect and read signs and traffic lights.

RADAR

(Range: 650 feet)
Identifies objects' position and speed.

NEW DIRECTION

Most driverless cars rely on LiDAR technology to map their surroundings, but not all. Turn the page to read about a disruptive autonomous vehicle technology developed in part at UCI.

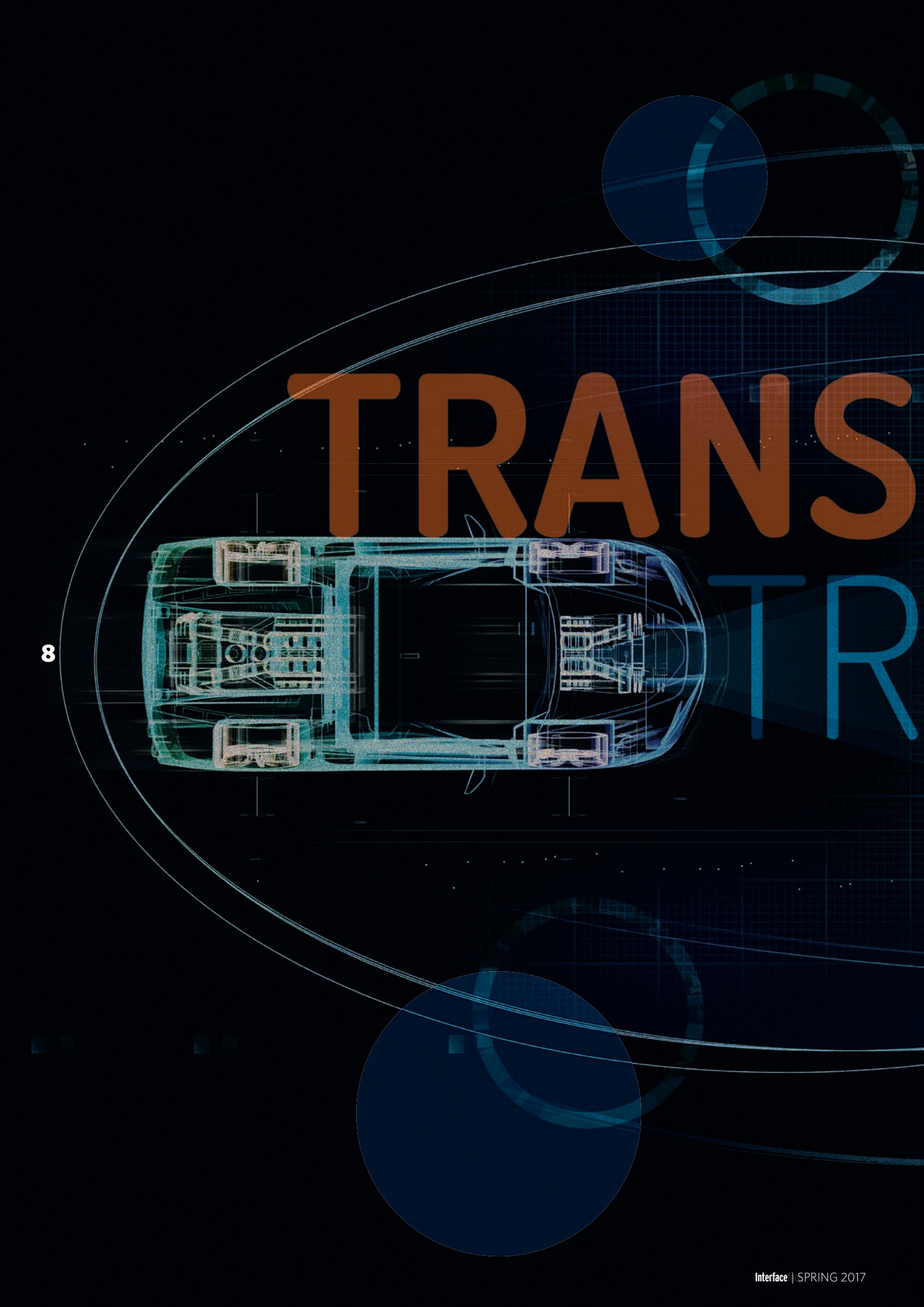
THE STANFORD CART

In 1961, Stanford University mechanical engineering doctoral student James L. Adams created a remotely controlled rover. The cart rode on four bicycle wheels and used artificial intelligence and machine vision to navigate. In the 1970s, the cart was fitted with a swiveling camera for obstacle avoidance.

DRIVERLESS CAR USER #1

Steve Mahan is reported to be the first person to ride in a driverless car without an engineer. In 2014, Mahan, who is legally blind, rode around Austin, Texas in Waymo's vehicle. The car "successfully navigated around everything from four-way stops, to a school bus, to a pedestrian with a stroller," said Nathaniel Fairfield, Waymo's principal engineer.

Photo: Google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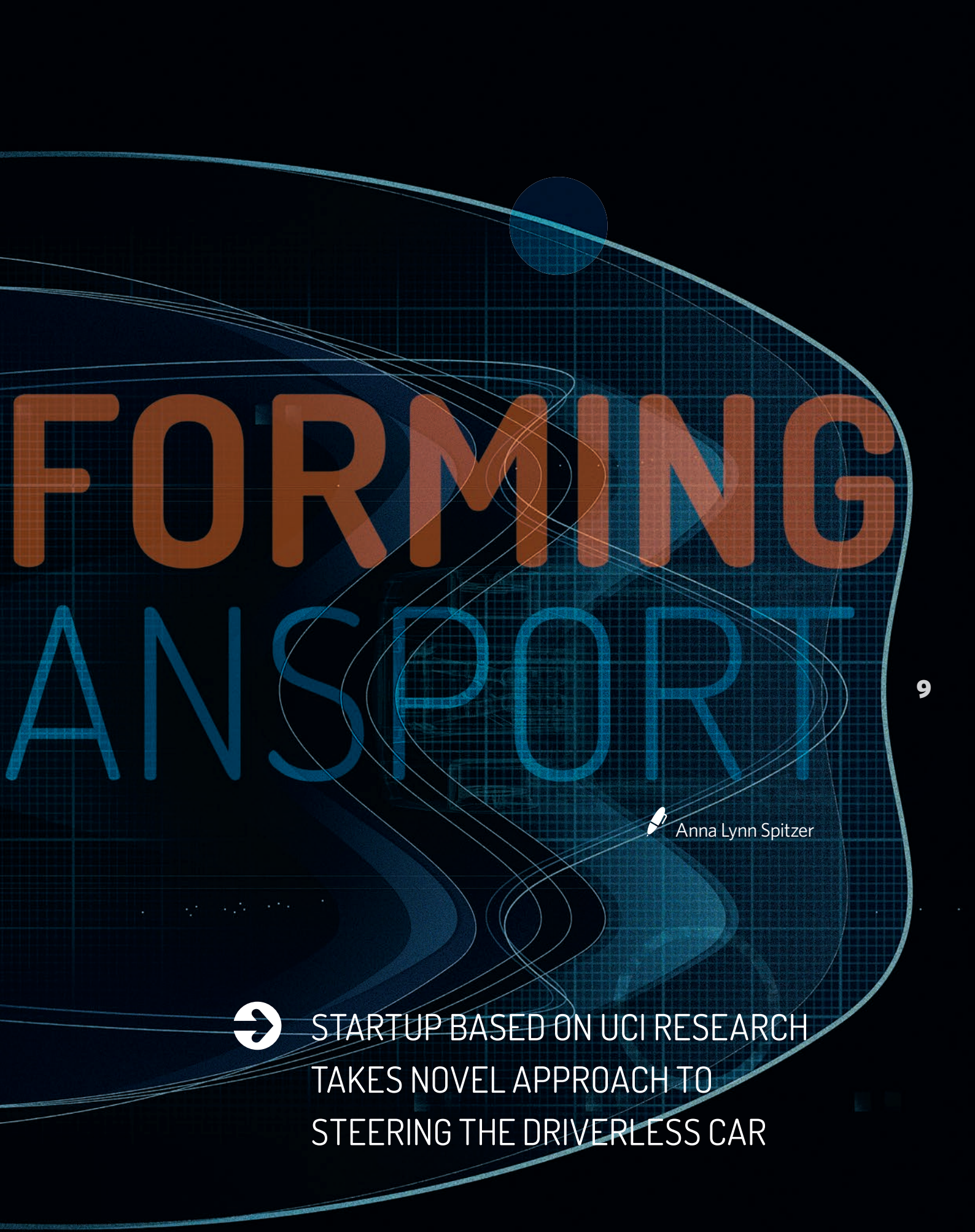


Anna Lynn Spitzer

STARTUP BASED ON UCI RESEARCH TAKES NOVEL APPROACH TO STEERING THE DRIVERLESS CAR

Intel is in. Apple, Google, Uber and chipmaker Nvidia are on board, too. Now, a company called PerceptIN, founded by an entrepreneur who earned all of his degrees, including a doctorate, from UC Irvine, is competing in Silicon Valley's hottest race: to develop and market autonomous vehicle navigation systems.

Autonomous vehicles could outnumber driver-controlled cars by 2040, and PerceptIN's founder and chairman, Shaoshan Liu, predicts that in the not-so-distant future, autonomous transportation will become a basic utility like electricity and water.

While numerous companies are competing to develop the advanced technology, several noteworthy differences set PerceptIN apart, according to Liu. The startup, incorporated in 2016 and headquartered in Santa Clara, Calif., has upended the current paradigm. Its product consumes less computing and electrical power, dissipates a much smaller amount of heat and costs a fraction of the price of its competitors'. The company's methodology, influenced in part by Liu's UCI doctoral research, is the focus of an August 2017 cover story in IEEE Computing, authored by a team that includes Liu and his UCI graduate adviser, Jean-Luc Gaudiot.

Gaudiot, professor of electrical engineering and computer science, specializes in computer architecture, parallel and distributed processing, and reconfigurable architectures. The latest advances in those fields can be seen clearly in PerceptIN's modular, high-performance, configurable and dynamic architecture.

"Researchers are actively exploring computer architectures that can reduce the cost of autonomous driving to make it affordable for the general population," says Gaudiot, who also serves as the 2017 IEEE Computer Society president. "And this system is also secure; each node has a mechanism that prevents other nodes

from impacting it. No one is going to hack into your car."

The team's software doles out computing tasks using a heterogeneous ARM mobile system on a chip that matches individual workloads to specific computing units. This results in a highly efficient system. The best part: the company can produce the hardware, sensors and software for around $2,000. By comparison, top-of-the-line LiDAR (laser imaging detection and ranging), the backbone of most current autonomous vehicles, can cost $80,000 or more – twice as much as the vehicle itself. (Smaller LiDAR systems are available for less, but they provide far less information, too.)

In addition to being expensive and unsightly – it looks like a large rotating top positioned on the roof of the car – LiDAR's acuity diminishes in certain weather conditions because it uses light spectrum wavelengths. LiDAR cannot detect color or contrast, and cannot provide optical character recognition capabilities, important in recognizing and analyzing traffic signs and other roadway symbols.

By contrast, Gaudiot and Liu say, their panoramic-stereovision-and-sensor-fusion system, besides being smaller, more efficient and less expensive, still delivers highly reliable computing performance with far fewer constraints than LiDAR systems.

A fully autonomous vehicle uses numerous sensors to perceive its environment and navigate safely, generating a huge amount of data, which the car must process on board in order to make driving decisions. This high volume of sensor data not only requires a complex computational pipeline, but processing can consume thousands of watts of electrical power.

PerceptIN's vision-based system breaks down the computing tasks, assigning them to multiple platforms and processing solutions, radically reducing the required computational pipeline. Both computing power and energy expenditure are also reduced. The proprietary software figures out the most suitable computing resource for each autonomous driving task – sensing, perception and decision-making – and assigns it to that resource.

> "We may not feel it strongly yet, but this is the dawn of the AI (artificial intelligence) era. In the next 10 years we will see explosive development in this field."

For real-time localization, path planning and obstacle avoidance, the system utilizes central processing units. It controls deep-learning tasks, such as object recognition, with graphics processing units. Field-programmable gate arrays handle object-tracking, lane-change prediction, and data compression and uploading; while digital signal processors process image data. Liu says PerceptIN's system reduces electrical processing power to a measly 15 watts.

Gaudiot, Liu and their collaborators analyzed all the tasks required to produce safe and effective autonomous driving, and determined that some of them need to be performed only sporadically. "We thought, why not start having things that are more tailored to each part of the computation?" says Gaudiot. "So we've got specialized architectures, multiple types of cores and we're doing heterogeneous computing." Because the system is modular, it is easy to add computing resources as needed.

While Gaudiot has spent his research capital investigating distributed computing architectures, his former student has long prepared for the advent of artificial intelligence. As a UCI grad student, Liu says, he read an article written by Microsoft founder Bill Gates that envisioned a future where robots were nearly ubiquitous. "That gave me a lot of inspiration and I decided that I should work on providing computing solutions for robots."

After earning his doctorate in computer engineering in 2010, Liu worked at Microsoft, LinkedIn and Baidu USA before founding PerceptIN last year. In addition to its autonomous computing product, the company provides hardware and software for a variety of robots, including intelligent toys, robots for cleaning and other in-home services, surveillance and virtual reality applications.

"We may not feel it strongly yet, but this is the dawn of the AI (artificial intelligence) era," Liu says. "In the next 10 years we will see explosive development in this field."

For automobiles, this means progressing successfully through the four stages of autonomous driving – from level zero, which denotes complete control by the driver, to level four, where the car does everything, including parking, without human participation.

PerceptIN currently is testing a demo vehicle at its R&D facility in Shenzhen, China – Liu calls it the "Asian Silicon Valley" – and results are encouraging. The company will test the system later this year in the U.S., and has scheduled a global product launch this fall.

Liu, who says his company's complete autonomous vehicle system costs less than $10,000 for hardware, software and chassis, envisions a future where driver-controlled cars are obsolete, and autonomous vehicles are shared and scheduled by a community-wide central system. "Imagine how this would help the environment and alleviate the global-warming problem," he says. "Thanks to autonomous driving technologies, our future vehicles, roads and even the world at large will be safer, run more efficiently, and suffer far less from combustion-related pollution."

There are still hurdles, however. "We have closely collaborated with the UCI engineering school, mainly with Professor Gaudiot's group, to develop cutting-edge technologies on AI and autonomous driving, and we have a series of good results coming out," says Liu. "But this will not be an easy journey. There will be a lot of barriers ahead for us to get around."

Gaudiot, however, thinks advances in computer engineering can successfully challenge those obstacles. "Computing capabilities in the form of denser chips, multiprocessors, heterogeneous computing and power-aware techniques will allow us to meet the intensive requirements for embedded autonomous systems," he says. "And this system makes it affordable. This is our goal: to make something practical, usable and affordable."

PerceptIN currently is testing this demonstration vehicle at its R&D facility in Shenzhen, China. The autonomous vehicle navigation system, powered by an NVIDIA Jetson TX system on a chip, employs four HD cameras for panoramic and stereo vision, an inertial measurement unit for visual odometry (estimating changes in position over time), a localization module and interfaces for control and wheel odometry. A global product launch is scheduled for later this year.

Photo courtesy of PerceptIN

For more details on PerceptIN's system, watch this video: https://youtu.be/qVX2mSvKHR8

RIDING HIGH

EIGHT UCI UNDERGRADS STOKED TO THE MAX ABOUT THEIR INTERNET-OF-THINGS PROJECT EXPERIENCES DURING SURF, A 10-WEEK SUMMER UNDERGRADUATE RESEARCH FELLOWSHIP PROGRAM

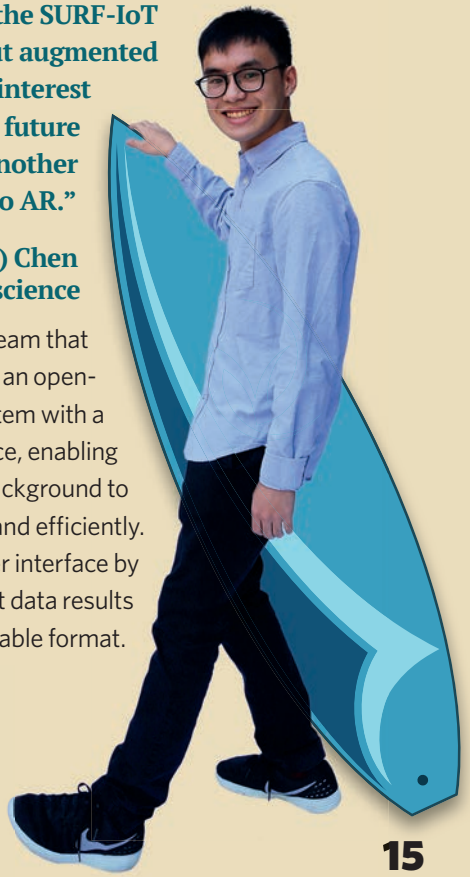
Shelly Nazarenus Debbie Morales

EPIC

"After listening to the SURF-IoT seminar presentation about augmented reality, I started to gain interest in that field. I think in the future I will take a class or do another research project related to AR."

—Wei Han (Henry) Chen
computer science

Chen was part of a research team that further developed Texera, an open-source data-management system with a simple graphical user interface, enabling people with no programming background to do deep data analytics easily and efficiently. He improved Texera's user interface by developing a method to present data results in an Excel table format.



KILLER DUDE

"My summer research experience was absolutely engaging with my mentor, and it kept me on my toes in terms of finishing my workload. Also, listening to the research presentations by my fellow peers gave me insight into how multifaceted the software industry is, the emerging technologies you should look out for, and a plethora of future career options I can possibly dive into."

—Ahmed Gorashi
criminology, law and society

Gorashi worked on PET (Personal Embodied Trainer), an interactive user-centered application that guides people through at-home physical exercises by tracking progress during use and providing constant feedback for improving form. PET differs from traditional workout apps by employing motion sensor data to provide real-time, accurate feedback with visual and verbal guidance.

TOTALLY TUBULAR

"This summer I dove deep into the world of IoT by experimenting with new technology and learning from UCI's most innovative professors. I engaged in detailed seminars that discussed the power of augmented reality and Twitter data mining. And most importantly, I joined a network of highly motivated students all with the passion to create or discover something new."

—Emma Anderson, informatics

Iris is a social media platform that promotes healthy living among the Orange County senior community. The Iris website offers games, health services, news and local events that help users stay active. Anderson integrated the platform with Amazon's Alexa, paving the way for connecting Iris to health-monitoring devices and other wearables.

RAD

"My summer research was a fun and impactful experience, which helped me build technical skills for the future. Doing SURF-IoT showed me that graduate school is something I want to do so I can make a difference in the computer science field."

—John Janecek, computer science

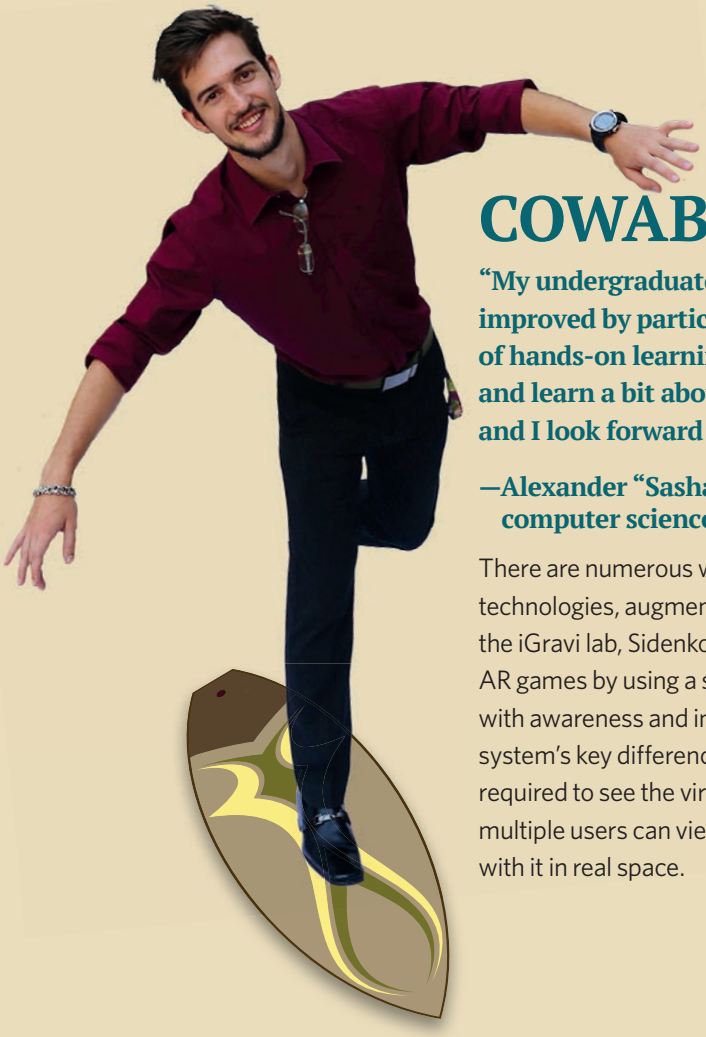
Janecek's project involved developing voice-driven technology to assist stroke survivors in performing tasks that would otherwise be restricted by physical impairments. He built an application using Amazon's Echo device to allow stroke survivors to connect with each other, send messages via Twitter and socialize with family and friends.

BODACIOUS

"Research is always surprising, and there are lots of times we believe we can't solve a problem or the goal is unrealistic. But we still manage to make it by looking deeper, thinking about it and simply doing it despite our doubts."

—Rouyi Nie, computer science

Health monitoring, essential for accurate medical diagnosis, commonly occurs in a hospital setting. Using IoT technologies, Nie helped build a stable, customized in-home health-monitoring system with a three-tier architecture that employs a smart gateway between sensors and the cloud. This so-called fog computing is rarely applied to the health care domain.



COWABUNGA

"My undergraduate experience has definitely been improved by participating in SURF-IoT. I got to do a lot of hands-on learning, work with many different people and learn a bit about myself. It was a very fun summer, and I look forward to continuing to work in the lab."

—Alexander "Sasha" Sidenko
computer science and engineering

There are numerous ways to play video games. One of the newer technologies, augmented reality, brings the game to the user. In the iGravi lab, Sidenko was part of a team making projected AR games by using a system of projectors and cameras with awareness and interaction capabilities. This system's key difference is that no screen is required to see the virtual world, and multiple users can view and interact with it in real space.

GNARLY

"There was sort of a "Eureka!" moment during my research. One of the sensor units I was building wasn't working initially, even though I was certain I had made it correctly. After much examination, the solution was surprisingly simple. It was a fix I needed on my computer, not the actual sensor itself!"

—Brandon Metcalf
electrical engineering

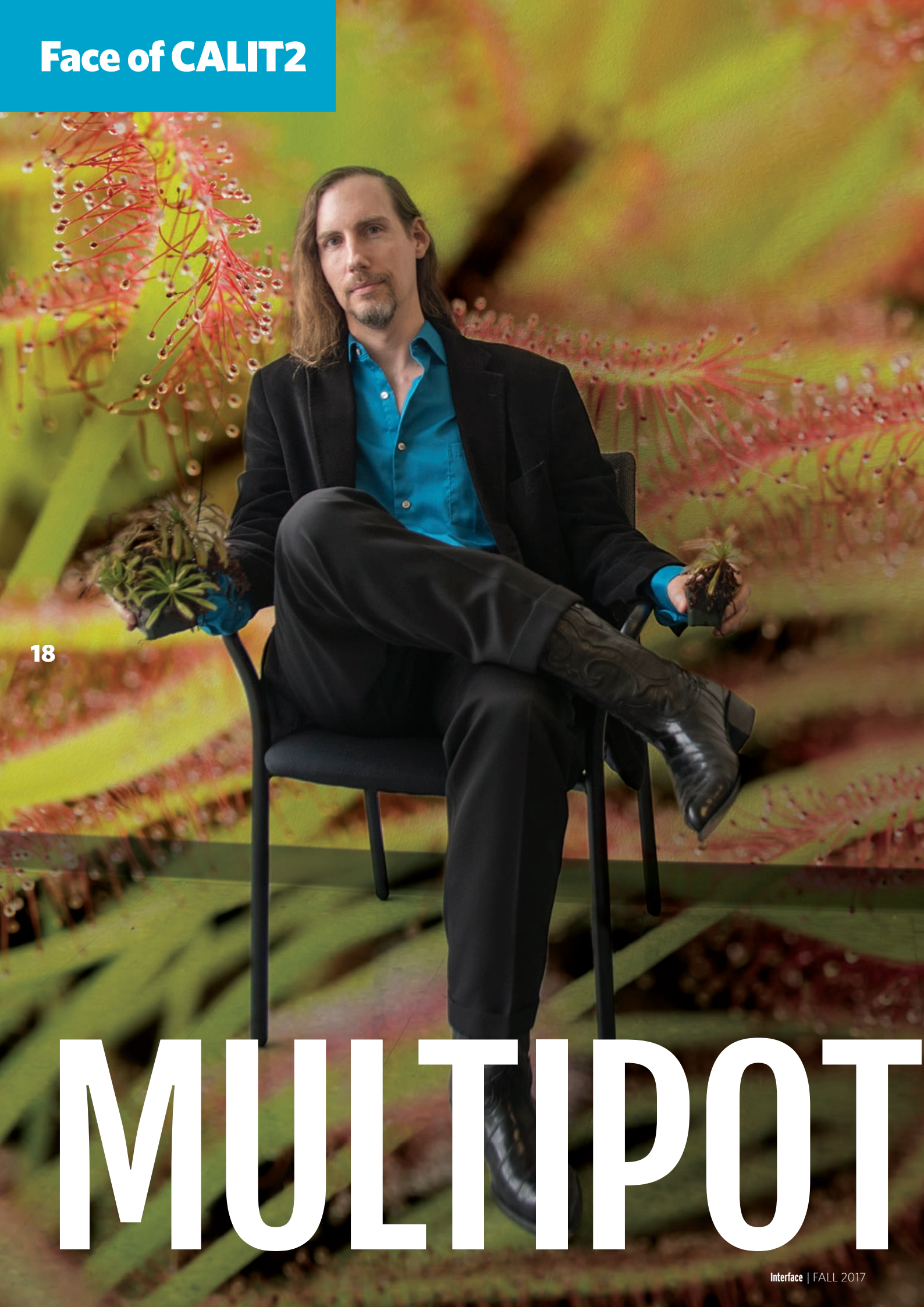
Instruments like GPS have made tracking objects in outdoor large-scale environments highly effective, but tracking objects indoors for search and rescue and firefighting purposes still requires improvement. The project Metcalf worked on created new algorithms for indoor positioning systems, which are more accurate for moving sensors.

AMPED

"I started this summer's program as a stranger to the field of machine learning, and to now understand and even implement certain aspects of it feels nothing short of amazing to me."

—Ajan Subramanian, computer engineering

Current pain-assessment techniques rely on subjective measures to determine a patient's pain level. This SURF-IoT project proposed a unique platform that uses both cloud and IoT technologies to create an automatic pain-assessment tool for remote patient-monitoring systems. The system maps pain levels to physiological parameters like heart rate, breath rate and galvanic skin response.

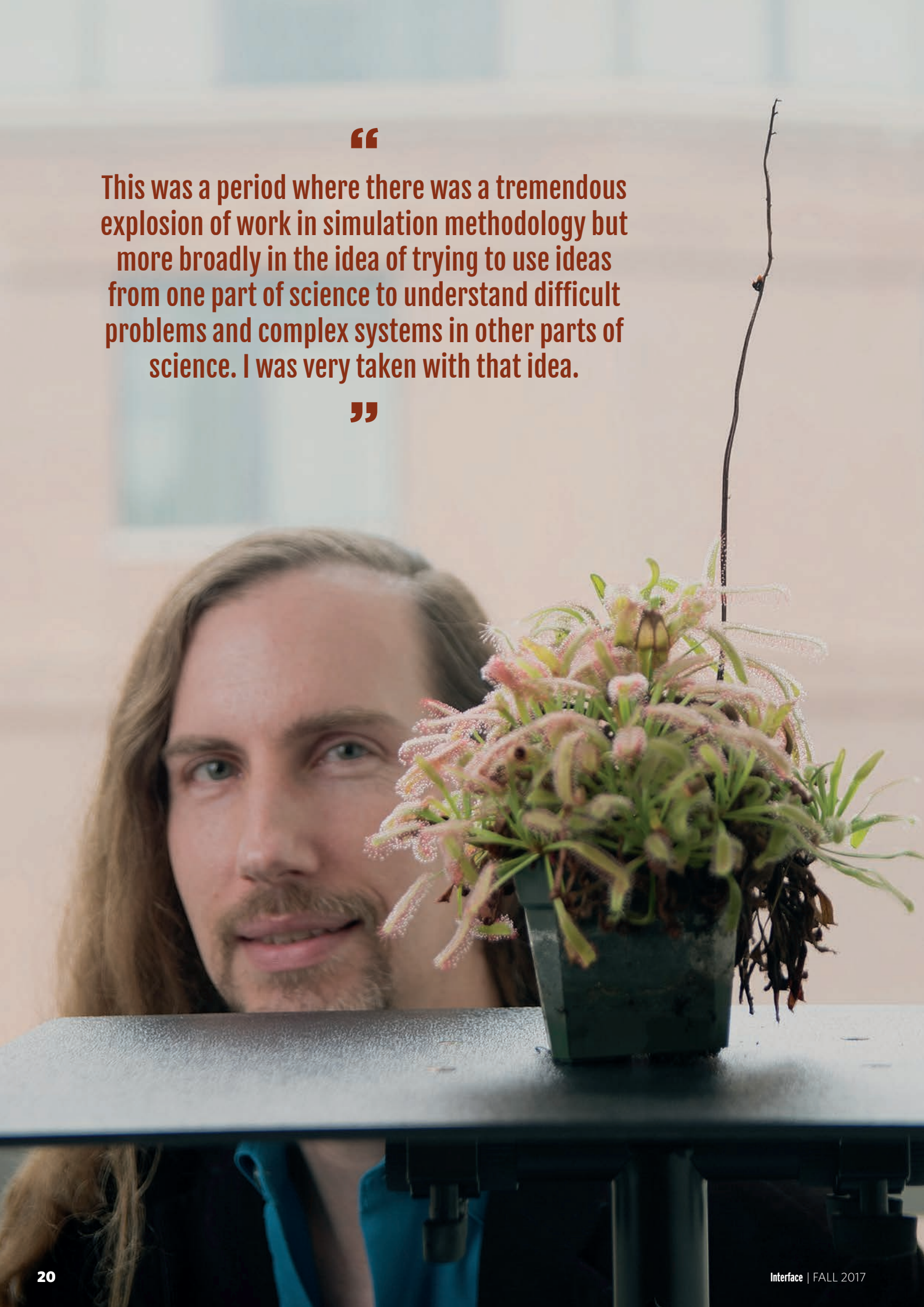


MULTIPOT

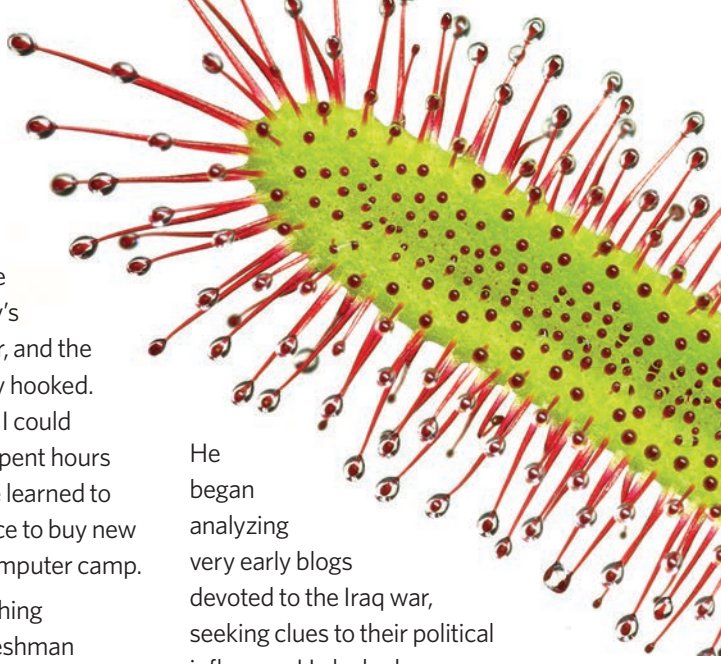
Anna Lynn Spitzer Mike Kitada

AN ENDLESS QUEST FOR KNOWLEDGE FUELS SOCIAL SCIENTIST

ENTIALITE



> “This was a period where there was a tremendous explosion of work in simulation methodology but more broadly in the idea of trying to use ideas from one part of science to understand difficult problems and complex systems in other parts of science. I was very taken with that idea.”



MOST PEOPLE STRUGGLE MIGHTILY TO SEE ANY SIMILARITIES IN BIOLOGY AND SOCIOLOGY, OR UNDERSTAND PARALLELS BETWEEN ECONOMICS AND ELECTRICAL ENGINEERING. CARTER BUTTS IS NOT MOST PEOPLE.

The UC Irvine sociology professor models complex systems in divergent arenas, seeking comparisons that can help solve difficult problems.

If that seems esoteric, it's anything but to Butts. His unparalleled enthusiasm, coupled with an outright joy at charging headfirst into uncharted territory, has opened doors to a dizzying array of seemingly unrelated projects.

The articulate, personable professor has analyzed communication networks in a presidential election, noting important episodic patterns. He has examined proteins as they form new structures, leading to insight about Alzheimer's disease and diabetes. He has graphed online social networks and the transmission of sexual diseases, and he has analyzed the role Twitter plays in emergency management.

His most recent coup: sequencing and studying the genome of a carnivorous plant called *Drosera capensis*, the cape sundew, with his wife, Rachel Martin, a UCI chemistry professor. Their findings could yield improvements in biomedical tools and the fight against infection.

"If you understand how one system works, you can leverage that to understand another," Butts says. "There are unifying principles you can exploit."

Growing up in North Carolina in a blended family – his parents and stepparents included a psychiatrist, an engineer, a forensic pathologist and an accountant – Butts always knew he would be a scientist. "What kind of scientist was much more up for grabs," he says.

He was captivated by computers, first a Sinclair ZX80 and later a Timex Sinclair 1000 with 1KB of RAM, which Butts wryly describes as "hot stuff at the time." Then came the family's first IBM personal computer, and the young scientist was formally hooked. "That was the first machine I could really do something with; I spent hours and hours on that thing." He learned to program, saved his allowance to buy new hardware, and reveled in computer camp.

Butts thrives on demolishing academic silos. Even as a freshman at Duke University, he refused to be constrained by traditional boundaries. Instead of majoring in computer science as he originally had intended, he designed his own interdisciplinary major.

"This was a period where there was a tremendous explosion of work in simulation methodology but more broadly in the idea of trying to use ideas from one part of science to understand difficult problems and complex systems in other parts of science," Butts says. "I was very taken with that idea."

He graduated in 1996 and headed to graduate school in mathematical sociology at Carnegie Mellon University, which he describes as "a real hotbed of intellectual activity around networks."

Sporting waist-length hair, a goatee and a sharp wit, Butts is no shrinking violet. "I like a certain amount of flash," he says. "Go big or go home."

He channeled that philosophy as a grad student, writing and developing a software package that integrated network analysis into other types of statistical analyses. The idea, considered heretical when he started, became the root of a broadly used open-source software system called statnet, which analyzes, simulates and visualizes network data.

"There was a division between statistical methodology and network methodology. The mantra was that you couldn't use standard statistical tools and techniques on networks, but I was interested in pulling those two things together," he says.

Butts joined the UCI faculty in 2002. He began analyzing very early blogs devoted to the Iraq war, seeking clues to their political influence. He lacked resources, but convinced undergraduates to save pages from websites by hand because "it seemed like this was an important social moment." That effort informed his next big challenge, analyzing network structure in the 2004 presidential election. This was the first time that the nascent blogosphere had become an important media resource, and Butts says he still publishes on the results of that study. "This was really the first time we were able to see networks flexing and changing throughout the day and the week."

One of his largest-scale endeavors was participation in a $12.5 million NSF project called ResCUE. The five-year project brought together computer scientists, engineers, social scientists and disaster science experts to transform first responders' ability to gather and disseminate information after large-scale emergencies.

Butts also led the first study of interpersonal communication networks in an unfolding disaster. Utilizing radio communications transcripts from the 2001 World Trade Center disaster, his group coded time-stamped communications from 17 different responders into a dynamic network. To analyze this data, Butts had to develop a new family of statistical models that could handle the complications of observational data on complex interactions driven by many factors at once. This new approach, called the relational event framework, has since been widely used by researchers worldwide to conduct their own studies.

Top left: Butts, first row far left, is joined by former and present UCI compatriots at the 2014 International Sunbelt Social Network Conference. Next to Butts is sociology professor Katherine Faust; David Krackhardt, who earned a Ph.D. from UCI and was a Butts mentor at CMU; and Lin Freeman, sociology professor emeritus. Standing, from left: Jeff Johnson and Steve Borgatti, who both earned doctorates at UCI; Borgatti's wife Roberta Chase; and Martin Everett, a former UCI postdoctoral researcher. "Irvine has been one of the preeminent hubs for social network research since the late 1970s, with many of 'the greats' in the field having either worked or trained here," Butts says. "Coming to UCI was a chance to contribute to this legacy."

Top right: As a young sociology professor, Butts led the ResCUE project's social sciences component. Here, he and his team pose with cameras developed to allow first responders to send images and audio from a disaster site to an emergency operations center.

Bottom: Butts and his multidisciplinary team, pictured in 2012, study network-related issues that transcend any one field

"It's incredible; it has been really rewarding," Butts says of that success. "It was a technical achievement but at the end of the day, we did it because we needed to solve a problem."

He believes his software tools are among his greatest accomplishments. "They have probably made the most difference out there in the world, because they have enabled others to do thousands of studies of all sorts of things. That's pretty cool."

Butts began analyzing social media networks, specifically Twitter, after teaming up with a researcher named Jeannette Sutton. Sutton, who met Butts while working on the ResCUE project as a University of Colorado postdoctoral researcher, pulled Butts aside a few years later at a meeting and said, '"Look, there's this thing called Twitter, and emergency managers are going gaga over it," he remembers.

Butts was skeptical. "I had heard of Twitter but it seemed like a very pointless technology, which was not very interesting and didn't seem to be going anywhere." But Sutton convinced him to write an NSF grant with her, a proposal to use Twitter to study the online rumor mill. "I was terrified that Twitter was going to fold before the grant was over and we wouldn't have any data," Butts laughs. The study yielded a groundbreaking way to measure informal communication in real time during a disaster.

The two have continued to work together for more than a decade. "He is the 'man behind the curtain,' who does the necessary computation," Sutton says. "His depth of knowledge is incredible, and I can say with certainty that his colleagues from the social network analysis community have described him as a 'young genius.' He leaves no stone unturned when considering various approaches to problems that we are investigating."

Early on, however, not everyone in his intellectual circle had the same admiration. Butts remembers attending a session on blogs and email networks at a prominent network conference when he was a junior faculty member. Several of the more seasoned faculty in attendance were less than impressed that the subject was even under discussion. "They weren't aware that I had a paper in the session, and they were grousing. 'Blogs? Email networks? This is junk; what are these kids doing?' They couldn't see why this was important or why anyone would even care about any of it."

He adds, in typically droll fashion, "And I'm just thinking, well, the longer you think that way, the more time I have to publish."

In addition to his appointment in sociology, Butts flexes his interdisciplinary muscles on a daily basis with courtesy appointments in statistics, electrical engineering and computer science, and mathematical behavioral sciences.

CALIT2 became his home away from home during his early days with ResCUE, and it's still the site of most of his meetings, as well as his Networks, Computation, and Social Dynamics Laboratory, part of the Center for Networks and Relational Analysis.

"We at CALIT2 are about trying to bring ideas together across many different intellectual domains," he says. "That's why the connection has always jelled and why I wound up making a home here. It would be very hard for me to do what I do if we didn't have this infrastructure in place."

UCI engineering professor Athina Markopoulou, a longtime Butts collaborator, calls him "a unique asset for UCI and especially for CALIT2. She cites the depth and breadth of his expertise. "He is a polymath who does not shy away from attacking problems in different fields," Markopoulou says. "And he combines a strong, energetic and outspoken personality with thoughtfulness, kindness and humor."

As one would expect, his lab group includes graduate students from multiple disciplines. "When we sit around the table, the research – whether it's Twitter, or proteins or sexual contact networks or a bombing – whatever it is, is being evaluated by a group that's got sociologists and statisticians and computer scientists and engineers and physical scientists. They're all coming to these problems with different points of view but they're all talking to each other and building common ground," Butts says proudly.

Zack Almquist, an assistant professor of sociology and statistics at the University of Minnesota, was one of his students. "Carter is a fantastic mentor who is always looking to grow and develop his students – and as importantly, to train them as future leaders in the field," Almquist says. "He has a deep passion for understanding the social (and physical) world and a great ability to make anything engaging – from chemical bonds to human connections. I think his dedication to truth and his careful, exacting nature make you realize how important the small details are and how they build up to the larger research goals."

Not one to leave his work at the office, Butts exemplifies intellectual curiosity. When asked what he likes to do in his spare time, he answers, "Science. My hobby is science. I just do other science from what I'm supposed to be working on."

He and his wife started their *Drosera capensis* genome project during their winter break a couple of years ago. "We were going to have a genome vacation," Butts says. "Okay, it took a little longer than that, but we did it. That was a really exciting personal accomplishment. But it was also this great adventure because I had never done anything like it."

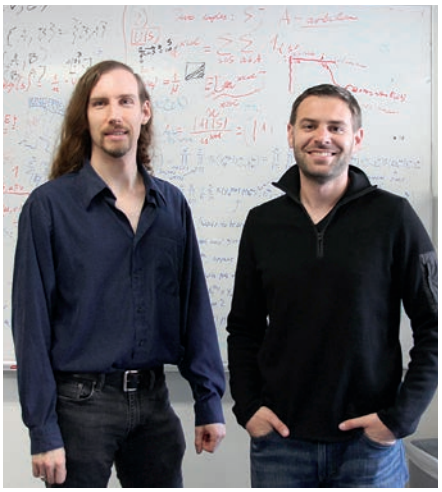
The two continued their adventure, traveling to South Africa last summer on a carnivorous plant expedition. They cultivate nearly 500 carnivorous plants at their Irvine home but wanted to see the flora in its native environment. Braving wind, rain and a steep mountainside, they hunted a rare plant called *Drosera regia*, which grows only in two places worldwide. "It was very exciting ...," Butts says. "You don't get to see something that rare and endangered every day."

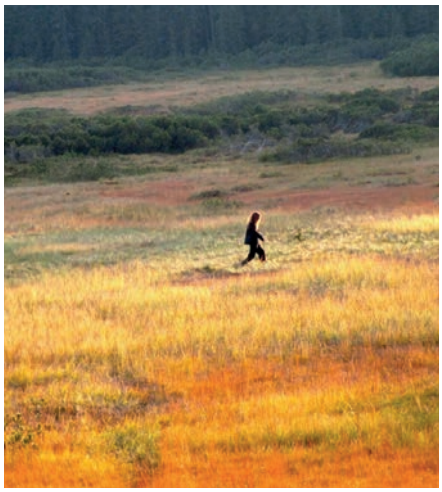
Seemingly surprised that some might consider uncommon his ´round-the-clock pursuit of academic interests, Butts clarifies. "You know, I always try to learn things. You always have to be looking to learn and expand your knowledge because you never know what you're going to need to know next."

Left: Butts mentored doctoral candidate Zack Almquist, who is now on the faculty at the University of Minnesota.

Middle: Butts was the keynote speaker at a conference in Slovenia, when the conference organizer invited him to view sundews in a peat bog. He and his wife, Martin (pictured at right), ran around the bog until dark, missing the official dinner.

Right: Butts, Martin and one of their 500 carnivorous plants. "Carter is excited to learn everything about anything," Martin says. "He can find something to get excited about in almost any topic."





MIND CONTROL

IMPLANTABLE TECHNOLOGY OFFERS RESTORATIVE PROMISE FOR THOSE WITH PARALYSIS

Brian Bell
Debbie Morales

THE NATIONAL SCIENCE FOUNDATION HAS AWARDED $8 MILLION TO A CONSORTIUM LED BY UC IRVINE TO DEVELOP A BRAIN-COMPUTER INTERFACE THAT CAN RESTORE WALKING ABILITY AND SENSATION IN INDIVIDUALS WITH SPINAL CORD INJURY. This initiative represents the largest NSF award received by faculty researchers in the UCI engineering and medical schools.

"The goal of this multidisciplinary project is to create an implantable system that by circumventing the damaged portion of the spinal cord can enable patients with these injuries to regain feeling in their legs and walk again," said principal investigator Payam Heydari, UCI professor of electrical engineering and computer science.

"Spinal cord injuries are devastating and have a profoundly negative impact on independence and quality of life of those affected," he added. "These resulting disabilities cost the U.S. roughly $50 billion per year in primary and secondary health care expenditures, so we hope that our work can solve a major national public health problem."

The five-year grant, sponsored by the NSF's Cyber-Physical Systems Frontier program, will be divided among UCI, California Institute of Technology and the University of Southern California. Heydari's co-principal investigators on the project are Zoran Nenadic, UCI professor of biomedical engineering; An Do, UCI assistant clinical professor of neurology; Richard Andersen, the James G. Boswell Professor of neuroscience at Caltech; and Charles Liu, professor of neurological surgery at Keck School of Medicine of USC.

Nenadic said that the UCI research team has been working in recent years to miniaturize brain-computer-interface systems, shrinking them from the size of a desktop computer to pacemaker scale. Nenadic and Do collaborated previously on a proof-of-concept study to implement a brain-computer interface that enabled a paraplegic man to walk a short distance. The goal of this new NSF-funded project is to perfect the technology and decrease its size.

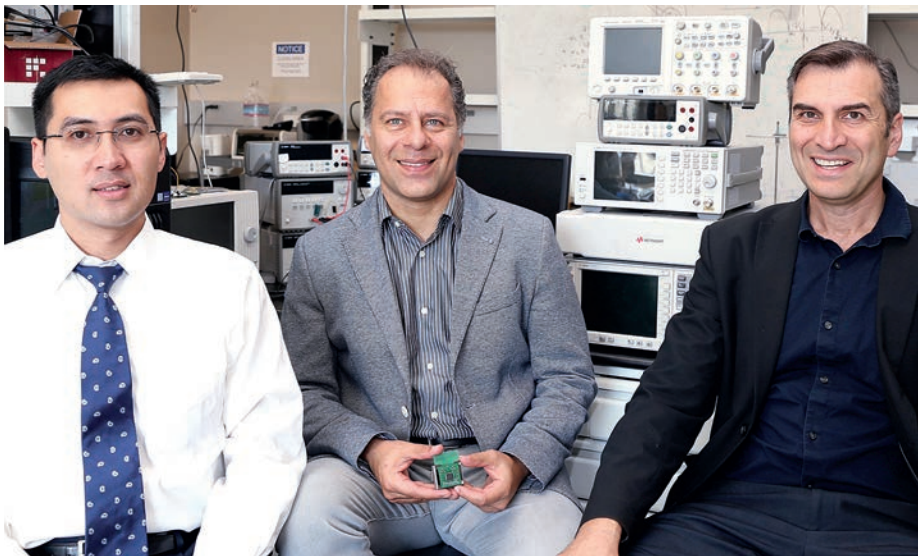
"Professor Heydari's lab, which specializes in low-power, nanoscale electronics, designed and implemented several critical integrated circuits that make scaling to this small size possible," Nenadic added.

This new initiative will focus on converting existing technology into a fully implantable version, which will be implemented in a manner similar to deep brain stimulators. To test the technology, the UCI team will collaborate with Caltech and USC on clinical studies in volunteers with spinal cord injury.

"Since these systems are fully implantable, they will be inconspicuous, work around the clock and access much stronger brain signals, facilitating highly accurate control of movement," said Nenadic.

Do, a neurorehabilitation expert, sees potential beyond helping individuals with spinal cord injury. "Once these systems are FDA-approved, their application can be expanded to people affected by disability due to stroke or traumatic brain injury," he said. "The study also will greatly expand our knowledge of how the human brain controls walking and processes sensation – knowledge that can help researchers better understand disease processes that affect these functions."

The Cyber-Physical Systems Frontier program is one of the largest within the NSF, providing funding for major efforts that identify and address critical problems that have the potential to be solved through the use of electronic, computing and information technologies.



Left: Last fall, a man whose legs had been paralyzed for five years walked along a 12-foot course using UCI-developed technology that lets the brain bypass the spinal cord to send messages to the legs.

Below, L-R: UCI researchers An Do, Payam Heydari and Zoran Nenadic are working with collaborators from Caltech and USC on an NSF-funded project to further develop the brain-computer interface.

WORLD-CLASS

FUELED BY UCI'S ZOT POWER, ENERGY EXPERTS EXPLORE A SUSTAINABLE FUTURE

EFFICIENCY

Sharon Henry
Debbie Morales

EEDAL 2017
Energy Efficiency in Domestic Appliances and Lighting

innovate | integrate | incubate | ignite

3 DAYS | **23** COUNTRIES | **32** SESSIONS | **109** PRESENTATIONS

ENERGY EFFICIENCY HAS BEEN CALLED "THE FIFTH FUEL," AFTER COAL, PETROLEUM, NUCLEAR POWER AND RENEWABLES.

It is one of the fastest and most cost-effective ways to reduce CO2 emissions, contribute to energy security and help create new jobs, said Paolo Bertoldi, action leader for energy efficiency at the European Commission Joint Research Centre.

In 1997, Bertoldi was part of a small group of energy-efficiency leaders meeting in Florence, Italy, to discuss developments in residential lighting and household appliances. At the time, information about technologies and policies was abundant, but it was scattered and difficult to access.

In an attempt to correct this communication quandary, the group formed EEDAL (Energy Efficiency in Domestic Appliances and Lighting). Their goal was to organize a unique forum that would attract an audience from every corner of the world and represent a variety of stakeholders – from researchers and manufacturers to policymakers and government leaders. EEDAL would welcome discussion and debate of the latest energy developments in residential appliances and lighting, as well as consumer behavior, policies and programs.

Since then, EEDAL has established itself as an influential international event with conferences in Naples, Turin, London, Berlin, Copenhagen, Coimbra and Lucerne.

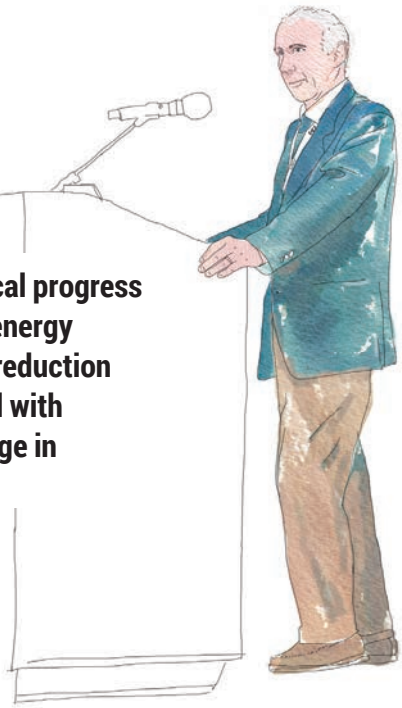
In September, the Ninth International Conference on Energy Efficiency in Domestic Appliances and Lighting, EEDAL17, was hosted at UC Irvine. The three-day event, which drew nearly 200 participants, was organized by the California Plug Load Research Center (CalPlug) and the European Commission Joint Research Centre.

"We are extremely proud to be the first location in North America to host an EEDAL International Conference," said G.P. Li, director of UCI CALIT2 and CalPlug. "Sustainability isn't just a buzzword at UCI, it's exemplified by the campus itself."

The campus is regularly recognized as a leader in green construction to reduce greenhouse gas emissions, winning numerous national awards including being ranked among Sierra magazine's top 10 most sustainable colleges for eight years in a row.

Here's a look at a few of the speakers, sessions and experiences from EEDAL17.

Paolo Bertoldi
European Commission
Joint Research Centre



"In addition to technical progress on efficiency, large energy savings and carbon reduction can only be achieved with a paradigmatic change in consumer behavior."

SESSION: POLICIES & PROGRAMS

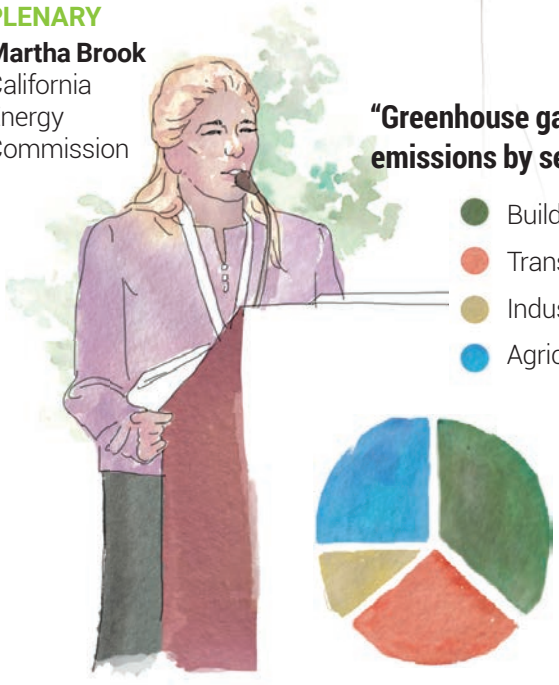
Shining a Light on Small Data Centers in the United States

Mohn Ganeshalingam
Lawrence Berkeley National Lab

"Many see a security risk in moving to the cloud, mistakenly thinking cloud facilities are more likely to be at risk."

PLENARY

Martha Brook
California Energy Commission



"Greenhouse gas emissions by sector..."

- Buildings
- Transportation
- Industry
- Agriculture

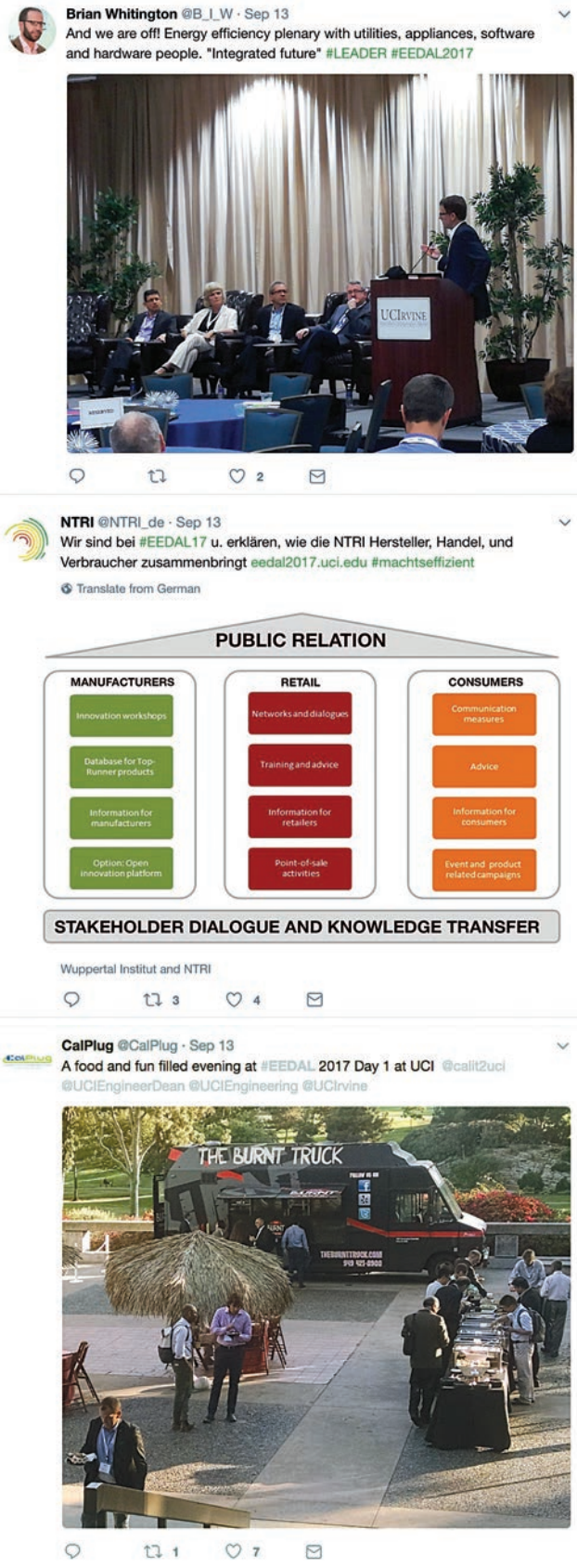
SESSION: CONSUMER BEHAVIOR

Investigation of Consumers' Behavior Toward Investments in Household Energy-efficient Appliances

Mattia Baldini
Technical University of Denmark

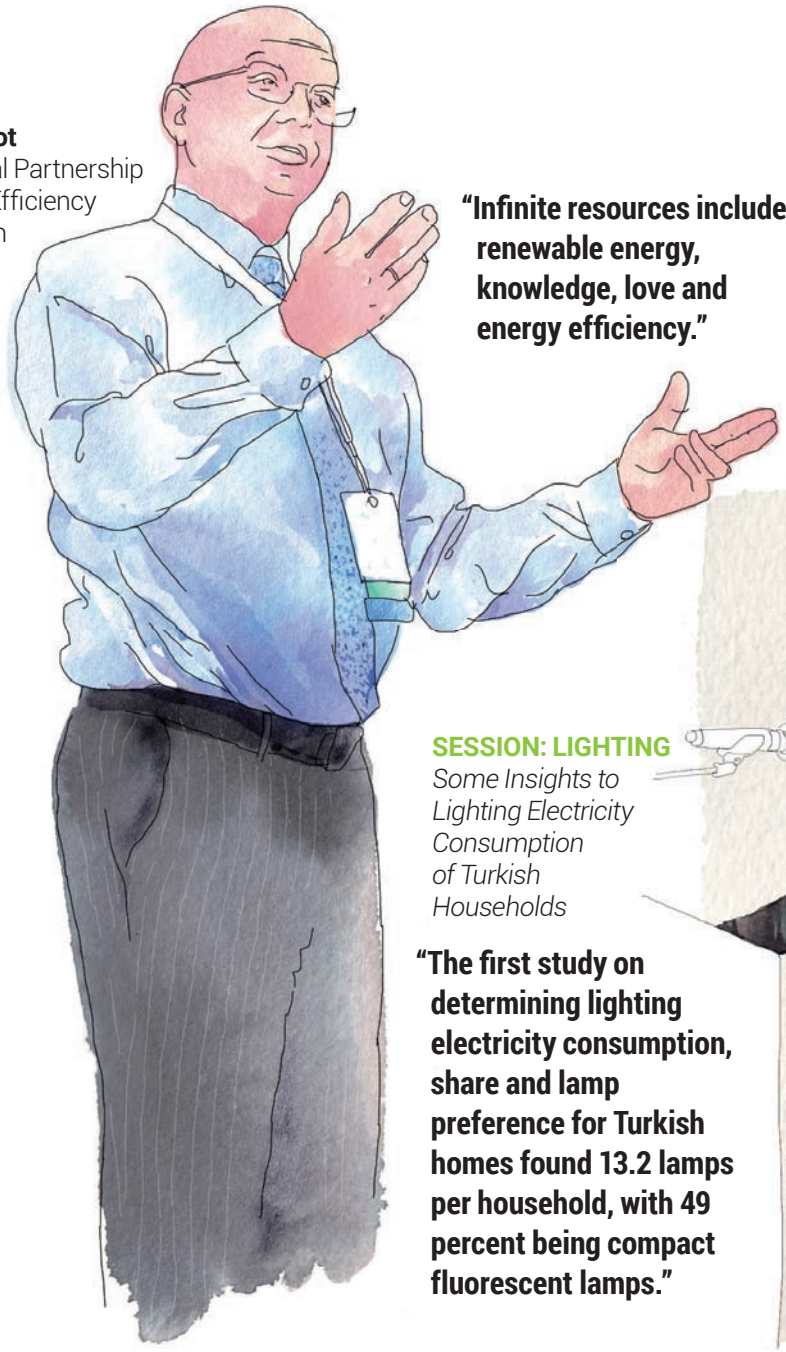
"Summing up, young, lower-income, lonely, inefficiently behaving apartment dwellers are not investing in energy-efficient appliances."

#EEDAL17



PLENARY

Benoit Lebot
International Partnership for Energy Efficiency Cooperation



"Infinite resources include renewable energy, knowledge, love and energy efficiency."

Merih Aydinalp Koksal
Environmental Engineering Department of Hacettepe University, Ankara, Turkey

SESSION: LIGHTING

Some Insights to Lighting Electricity Consumption of Turkish Households

"The first study on determining lighting electricity consumption, share and lamp preference for Turkish homes found 13.2 lamps per household, with 49 percent being compact fluorescent lamps."

KEYNOTE

Wendell Brase
is UCI's first associate chancellor for sustainability. In this role, he leads efforts to implement UC's Carbon-Neutrality Initiative at UCI as well as other campuses throughout the system.

The Irvine Smart Labs initiative has achieved 61 percent energy efficiency in UCI lab buildings.

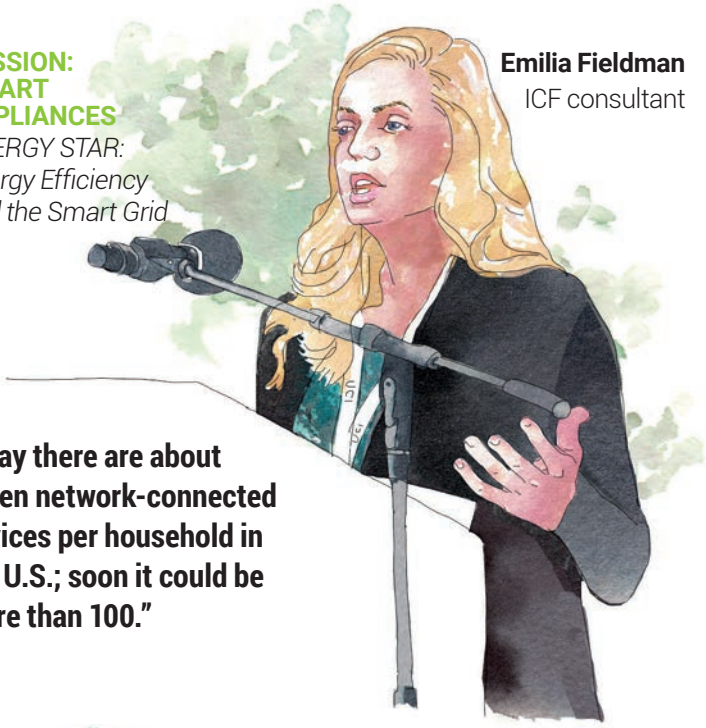
"We apply three principles to every one of these projects:

1. In every project we aim to improve energy efficiency by 50 percent.

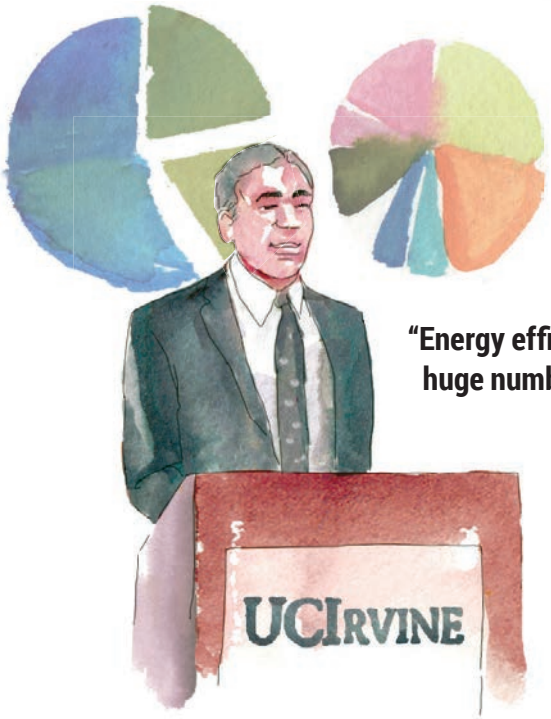
2. We question everything in terms of building design assumptions.

SESSION: SMART APPLIANCES
ENERGY STAR: Energy Efficiency and the Smart Grid

Emilia Fieldman
ICF consultant



"Today there are about seven network-connected devices per household in the U.S.; soon it could be more than 100."



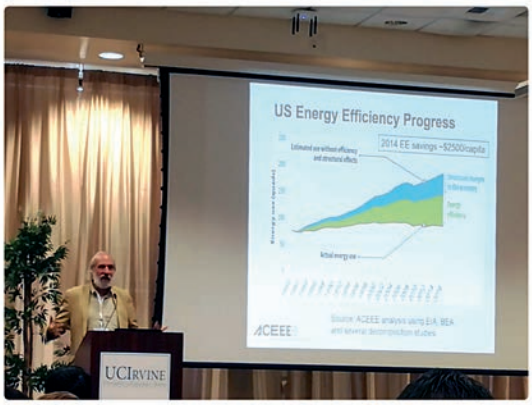
PLENARY
David Nemtzow
U.S. Department of Energy

"Energy efficiency created a huge number of jobs."

3. We find the places where we can apply sensors and software to deliver just the right amount of energy, at just the right time."

#EEDAL17

Brian Whitington @B_I_W · Sep 15
Steve Nadel, ACEEE demonstrates energy saved by programs in the US.
#EEDAL2017 #LEADER #uci



AHAM Policy @AHAM_policy · Sep 18
#AHAM's own Kevin Messner chairing a panel at #EEDAL2017

Brian Whitington @B_I_W · Sep 14
Pacific sunset

Entrepreneurial Spirit

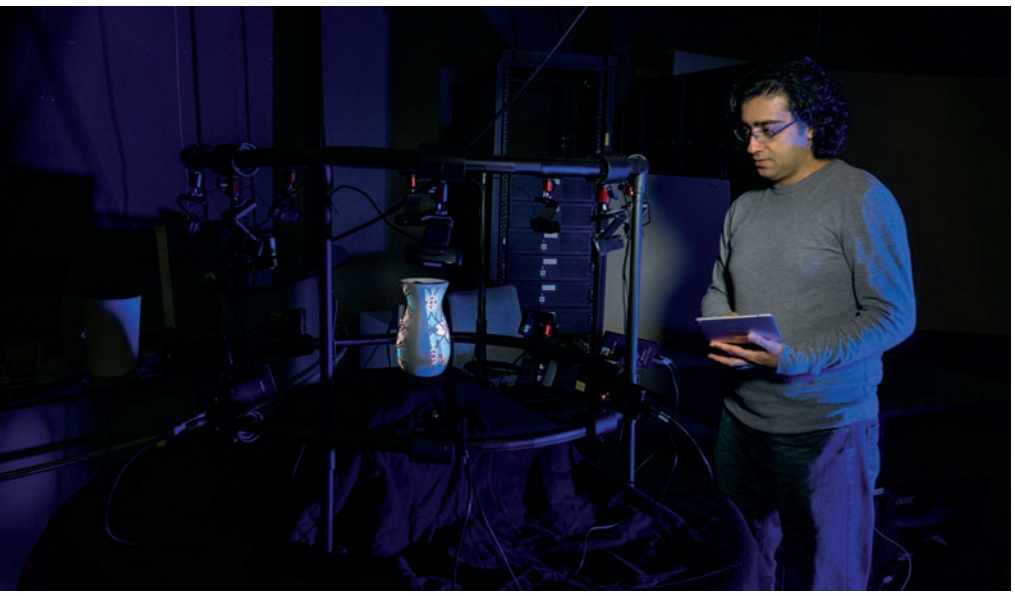
ACE FORWARD

PROFESSOR-TURNED-CEO SERVES AS TECHNOLOGY STARTUP ROLE MODEL

Lori Brandt Mike Kitada

Aditi Majumder projects confidence, determination and fearlessness, an image important to her both at work and at home, where she has two daughters, ages 4 and 12.

The professor of computer science in UC Irvine's Donald Bren School of Information and Computer Sciences excels in a field dominated by men, and she is one of only a handful of female CEOs to occupy CALIT2's startup incubator, TechPortal, with her company Summit Technology Laboratories.



Summit Technology Laboratory lead software engineer Mehdi Rahimzaden works in the CALIT2 Visualization Lab. The startup company plans to apply for more NSF funding next year.

Majumder's expertise is computer graphics, visualization and virtual reality. Over the past 10 years, she has developed novel display technology that allows anyone to create personal augmented reality experiences using multiple off-the-shelf projectors. "This visualization software allows us to harness the power of many projectors to create seamless displays on objects of any shape and size with a push of a button," she explains. In addition, unlike current projector display technologies, "viewers can interact with our system using laser pointers, tablets or just hand gestures."

This software-driven, high-resolution, scalable plug-and-play system could have applications in varied environments: education, trade shows, training simulations and entertainment.

High school students experienced the system firsthand at the recent Manufacturing Day Expo and Career Fair held in early October at Los Angeles Trade Tech College. Sponsored by Los Angeles Mayor Eric Garcetti and California Manufacturing Technology Consulting (CMTC), the event drew more than 750 local high school students. Summit Technology Laboratories demonstrated its interactive display by projecting images onto a 3-D object, in this case a white vase. Using a handheld tablet, the students decorated the vase with patterns, drawings and even selfies.

"It was our first demo and it went very well," says Majumder, "especially considering it was a bright, sunny day and we were outdoors, the worst possible scenario for projection-based displays."

"Cool. Awesome. Amazing," wrote some of the students who filled out surveys after playing with the system. Eighty-six percent said they really liked it.

The global 3-D display market is a multibillion-dollar industry, according to Shekhar Chandrashekha, the smart manufacturing practice lead at CMTC. "Technological advances in sensors, flexible hybrid electronics and algorithm design have brought this field to the limelight. Majumder's efforts represent a breakthrough; by developing technologies and leveraging the concept of 'design for extreme affordability,' she

is building solutions that can impact people around the world."

Majumder's product operates with small, laser projectors, yet produces cinematic quality images. Projectors have been around for a long time, especially in Hollywood. The entertainment industry relies on bulky, heavy, costly, high-quality projectors, ranging from $40,000 to $80,000. Majumder's system employs lightweight, portable, inexpensive projectors, around $500 each. Plus, it can be set up in a couple of hours, so it is easily deployable, unlike most current systems.

"With our software technology, we can achieve an interactive experience with any brand projector," says Majumder. "We are hoping to push this technology out to other consumer sectors."

Developed in her CALIT2 Visualization Lab, Majumder's technology has generated eight patents. Her small, four-person company is funded by a National Science Foundation Phase I Small Business Innovation Research (SBIR) grant. She plans to apply for Phase 2 funding early next year.

Majumder envisions spinning the technology off in various directions. Her first target is the trade show market. But she sees advantages for the design industry and training in smart manufacturing as well.

"Currently, workers receive hands-on training; our technology would be less expensive," she says. "We could establish small-environment simulation, fast-training stations. We could take it to other parts of the globe, where they are very price conscious."

Only 17 percent of startups in the U.S. in 2017 had a female founder, according to a recent CrunchBase study. That number has been flat for five years, the study found, even though women make up nearly half of the U.S. workforce and are majority owners of 36 percent of U.S. small businesses.

Majumder says she is proud and sad at the same time. "When you go out into the business world, especially the tech sector, and see the lack of women, it's dismal," she says as she shakes her head.

The tech entrepreneur credits her husband, ICS professor M. Gopi, for his support, as well as her former students who are now engineers in her company. CALIT2 plays a part in her success too. Her lab is always open for demonstrations when visitors tour the institute, and she appreciates the exposure. That's how she connected with CMTC.

When she read a recent school report written by her daughter that called her mother a role model, Majumder was gratified. "It's been hard, but exciting. With organization, planning, a supportive family and hard work, you can do it. But, maybe most importantly, you should always believe in yourself and your dreams."

A Parting Shot

The humble seaweed is expanding its portfolio. Scientists have discovered the aquarium staple and other macroalgae can be used in feedstock, fuels, chemicals and consumer products including toothpaste, cosmetics and paints. Now, a new breed of farmers is exploring best practices for cultivating these multifunctional water dwellers.

Armed with a $1.8 million award from the U.S. Department of Energy's Advanced Research Projects Agency-Energy, UCI oceanographic engineer Kristen Davis is leading a study on offshore kelp cultivation.

"My goal with this research is to assess new cultivation techniques and procedures to optimize productivity and to also understand the impact of the practice on coastal ecosystems," says the assistant professor of civil and environmental engineering.

According to Davis, a well-designed kelp farming operation requires a thorough knowledge of the interplay among currents, surface waves, turbulence, canopy architecture, nutrient availability and other processes. She will bring together experts from various fields to develop a strong computational framework that can serve as a foundation for establishing and deploying macroalgae farms.

Under the direction of Professor G.P. Li, CALIT2@UCI develops IoT technology-based innovations in a multidisciplinary research environment. By integrating academic research with industry experience, the institute seeks to benefit society, incubate new technology companies and ignite economic development. CALIT2 focuses on the digital transformation of health care, energy, the environment and culture.

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