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interface

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Interface | SPRING 2020

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RESEARCHERS
 HACK IOT DEVICES
 TO DISCOVER
 BETTER WAYS TO
 PROTECT USERS

Sharon Henry

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Last December, Amazon notified millions of its Ring video surveillance doorbell customers that hackers had gained access, from the company's security devices, to live camera feeds inside their homes.

One Mississippi family reported hackers had used a Ring security camera to spy on their 8-year-old daughter in her bedroom and speak to the child via the device.

The risk of having your home security camera hacked is fairly high, according to lan Harris, UC Irvine professor of computer science. He sees evidence of it all the time.

Harris heads the recently launched Cyber Test Range at CALIT2. The lab was created to simulate different types of cyberattacks on IoT-connected devices, those billions of smart appliances and devices – from home security cameras and internet routers to health care trackers and smart lightbulbs – that connect to each other and the internet.

The lab sets up and launches attacks against a variety of systems. "We launch attacks over the network. We launch physical attacks. We open the device and see if we can steal data. We see if it can be reverse-engineered," says Harris. "The goal is to find out how secure the device is in general, and how resistant it is to attacks." The Cyber Test Range is one of three research projects overseen by UCI's Cybersecurity Policy & Research Institute (CPRI) and its executive director, Bryan Cunningham. The effort to advance the institute's investigations into cybersecurity vulnerabilities is funded in part by a \$1.4 million gift from the Herman P. & Sophia Taubman Foundation.

Security vulnerabilities in IoT devices can yield a host of dangers. Hacking into a home security camera allows cybercriminals to see inside a house and know if someone is home. Most cameras also have microphones, allowing hackers to eavesdrop or record conversations. Temperature sensors and smart thermostats can help criminals determine when someone is out of town. And because these devices are connected to the internet, hackers can move laterally to hijack other connected devices in a home.

Vulnerable IoT devices are also at risk of becoming exploited as botnets. Cybercriminals can infect these devices with malicious software that enables the hacker to hijack the processing power of the small devices. Thousands of infected devices, known as botnets, can produce computing power to rival that of a supercomputer; they can be used to route traffic and launch cyberattacks designed to overwhelm servers and disrupt the internet.

The problem with security today isn't that you can't make things secure. "You can make things secure, but it's going to cost you, and nobody wants to spend the money," Harris says.

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There are people who write the code and design these systems but they're not trained in how to write secure code. Programmers learn how to get their code to work; security is optional.

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One reason is perceived value, he says. "If the cost of a device increases 20 percent because it's more secure, people probably won't see the value nearly as much as when the cost is reflected in a brand new, cool feature."

Harris also believes programmers hold some of the blame. "There are people who write the code and design these systems but they're not trained in how to write secure code. Programmers learn how to get their code to work; security is optional," he says.

The work, which Harris, Cunningham and the Cyber Test Range are doing, is multidisciplinary, encompassing law, policy and government standards alongside security. CPRI's Cunningham, an expert in cybersecurity law and policy, is a former White House lawyer who served as deputy legal adviser to former National Security Adviser Condoleezza Rice. He also served six years in the Clinton Administration as a senior CIA officer and federal prosecutor.

Cunningham works closely with UCI law professor Shauhin Talesh, who explores the role insurance companies play in helping organizations comply with privacy laws and deal with cyber theft. The U.S. doesn't have a law that regulates security and privacy across the entire economy.



"In the absence of this, insurance companies are setting the standards for online cybersecurity," Cunningham says. "They're becoming the de facto cyber regulators."

Another key player in the lab's effort is Scott Jordan, UCI professor of computer science, who leads efforts to research government regulation and standards, and works to create regulations for laws that govern connected-device security and privacy.

California is the first state in the country to have an actual IoT device security law. Senate Bill 327 requires companies that make Internet of Things (IoT) devices to incorporate minimum security features for every device. CPRI is helping to write draft regulations around the new IoT security law. "Much of how the law will be implemented will depend on these regulations," Cunningham says.

The Cyber Test Range also develops prototype systems based on standards recommendations to evaluate strength and security, as well as other properties that could be affected. "If the standard makes a prototype completely secure but it doubles the cost or slows performance, there's no way a company is going to adopt that," Cunningham says.

The lab expects to take advantage of CENIC, a high-performance, highbandwidth network that links California's research universities. The Cyber Test Range currently conducts local attacks within the CALIT2 Building, but using the network would allow for more realistic remote attacks. "To do that, we need an isolatable network because we're running real attacks; we can't let them get out into the internet," says Harris.

Another research problem: even when companies do build security into their devices, they're not necessarily communicating and coordinating with other companies building devices that will connect to their product. One example is home device hubs. Consumers may have several smart TVs from different manufacturers that aren't configured to talk to each other. This can cause user frustration and the possibility that security features will be disabled or never turned on. "The Cyber Test Range will be working to find ways to create new technologies that will allow devices to be secure even when they aren't originally designed to be compatible," Cunningham says.

By improving security and regulation standards, he foresees opportunities to greatly enhance consumer apps. For example, many vehicles are already equipped with an onboard safety feature that can sense when there has been an accident and call for medical help. But what if you've had an automobile accident and the interface on your Apple watch could transmit your vital statistics to the paramedics before they arrive? It's unlikely that Apple and Chevrolet are talking to each other about how to make this happen, Cunningham says. "It's impossible for an automobile manufacturer to predict every type of app being built that can connect to their car." The solution would be uniform standards for all medical and health technology, not unlike specific standards now required for Bluetooth devices.

"There are 10,000 things we could be working on," he adds. "It's a blessing and the curse for cybersecurity. In some ways the biggest challenge we have is figuring out what to prioritize and focus on, but it's a good problem to have as long as we're being funded." *«*

Tech 101 🥒

, Sharon Henry

IOT BOTNET BASICS

Traditional botnets are networks of computers that have been infected by malware that controls machines remotely and orders them to steal private data and join in distributed denial of service (DDoS) attacks. Similarly, IoT botnets are a collection of smart devices hijacked by cybercriminals to perform nefarious acts. Here's how it works:



ATTACK

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An army of bots can be ordered to bombard servers with traffic and requests - known as a DDoS attack.

DAMAGE

When servers can't keep up with the demands, the websites they host are disrupted and go offline. Typical targets are popular websites, and corporate and government sites.







How to avoid being part of an IoT botnet

Here are some basic rules to help prevent your IoT devices from becoming infected.

Give your router a new name

Don't use the name issued by the router manufacturer — it can help hackers identify the make or model. Don't use a name that identifies you or your address.

Use a strong encryption method for Wi-Fi

In your router settings, use an encryption method, like WPA2, when setting up Wi-Fi network access.

Set up a guest network

Keep your Wi-Fi account private. Have visitors log into a separate network that isn't connected to your IoT devices.

Change default usernames and passwords

Cybercriminals can easily learn the default passwords issued by manufacturers to their IoT products.

Create strong passwords

Use unique, complex passwords made up of letters, numbers and symbols.

Check the devices' settings

IoT devices often come with default privacy and security settings. You may want to change them.

Disable unneeded features

IoT devices come with lots of services such as remote access. If you don't need it, disable it.

Keep software up to date

Software updates can often include a patch for a security flaw.

processing unit (CPU) and memory

to a point where it is

unable to respond to

requests from real

users.

Propio Camino



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🖉 Anna Lynn Spitzer

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Interface | SPRING 2020



A NEW APP OVERCOMES NEGATIVE BELIEFS ABOUT MEDICATIONS WITH A "SEE-FOR-YOURSELF" APPROACH

Modern medical science has produced therapies to treat chronic illnesses like hypertension, high cholesterol, diabetes and heart disease that can kill hundreds of thousands each year.

But a medicine can only be effective if a patient actually takes it. What about those who won't take prescribed medication due to suspicions about overprescribing or exaggerated potential benefits?

A CALIT2 researcher is collaborating with a UC Irvine medical researcher to develop an app that seeks to intervene in one specific population in which concerns about the safety and benefits of medications are especially high. Funded by the National Institutes of Health through its National Heart, Lung and Blood Institute, the \$2.9 million endeavor is called Mi Propio Camino (My Own Way): Addressing Negative Beliefs about Medication to Improve Adherence among Hispanic Adults with Hypertension.

Sergio Gago-Masague, director of CALIT2's Engaging Technology and Application Design (ETAD) lab, is working with John Billimek, who leads the HELIOS lab health equity research program in the Department of Family Medicine and the Health Policy Research Institute. The team is developing and testing an IoT-driven intervention that encourages patients in the Latino community who have diabetes and high blood pressure – a large, high-risk population – to take their medication and make healthy lifestyle choices.

"Culturally bound, negative beliefs about medications and a preference to replace medications with natural remedies are common in medically underserved Latino communities," the pair stated in their grant proposal.

Billimek and Gago-Masague, who have collaborated before, were discussing medication adherence among this population, and based on the suggestions of an advisory group of Spanish-speaking patients at UCI's Family Health Center Santa Ana, they decided to develop an app to address the issue. They began work on a proofof-concept prototype through MDP, the Multidisciplinary Design Program, a partnership between CALIT2 and UCI's Undergraduate Research Opportunities Program. "Thanks to a great collaboration, and funding and students provided through the MDP, we were able to achieve the federal funding

will be easier for new users to learn the features," says CALIT2 lead developer Quinn Levine.

A "reflection" section encourages users to fill out daily surveys. These surveys track when patients take their medication and document how they feel physically, including energy level, symptoms like headache or dizziness, and current blood pressure. "We want participants to see over time just how effective their medication, exercise or other healthy lifestyle choices are," Levine explains.

A calendar section allows for daily, weekly and monthly views of

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vel Level 4 of 5	Take a moment to reflect on how you are doing 1. How is your energy level today?	Take medications 4. What did you notice as a result? Enter text	YOU COMPLETED THE SURVEY!
ssure 118 80	1 2 3 4 5 Click one of the figures above. 2. In the last 24 hours, did you feel any of the following Headache	5. Blood Pressure	Thank you for your participation. Your answers have been successfully recorded.
	Dizzy/Lightheaded	Submit	Return to Home

necessary to support the project," says Gago-Masague, a UCI information and computer sciences assistant professor of teaching, who believes the framework can provide a foundation for developing novel interventions for other at-risk populations.

He oversees the app's technical development, while Billimek leads the clinical effort. The cross-platform prototype, which works with Android and iOS mobile devices, offers three features. "We are trying to keep it simple so it users' reflections and outcomes, and documents those weeks in which they participated every day.

Finally, the app includes a feature that prompts participants to grow an online garden by completing all of their daily reflections. Each week a new plant appears, and users spend the week growing that flower, fruit or tree. Every time they complete a daily reflection, the garden grows a bit more. "The garden is our main source of encouragement for using the application," Levine says.

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Bic S¹ m "It is a subtle form of gamification that encourages the user to return to the application daily."

Adds Gago-Masague: "The main point is for users to see how they've changed over time through various health techniques. A nice metaphor for that personal growth is a garden."

Patient trials are on hold because of the coronavirus pandemic, but the plan is to run a clinical trial with 250 patients over four years. In the meantime, community and patient stakeholders have tested early versions of the app and provided ongoing guidance to its design and implementation. "The patients like having a very well-organized system for tracking their symptoms," says Gago-Masague, adding that users indicated it was particularly helpful because tracking symptoms and medication on a daily basis had been a challenge.

"When patients are prescribed drugs, they don't have a lot of choices; they have to trust the doctor and adhere to the treatment," Billimek says. "This app allows patients to see for themselves the efficacy of the medication. It actually encourages good communication and transparency between the doctors and patients. That is probably the most important aspect of this project." *«*



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This app allows patients to see for themselves the efficacy of the medication. It actually encourages good communication and transparency between the doctors and patients. That is probably the most important aspect of this project.

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CALIT2 HOUSES POWERFUL NEW STORAGE COMPLEX



If data is the new currency, as many technology experts believe, then CALIT2 just made a large deposit. The High Performance

Wireless Research and Education Network (HPWREN) has installed a new virtual machine server and computer data storage complex on the fourth floor of the CALIT2 Building as part of HPWREN's expansion from San Diego, Imperial and Riverside counties into Orange County. The complex will become a repository for all of the county's HPWREN sensor and image data – and a rich resource for UC Irvine researchers.

The data servers are integrated with the NSF-funded Pacific Research Platform, which enables distributed computing on HPWREN data with over 6,000 central processing unitcores and 600 graphic processing units.

HPWREN is a high-bandwidth, wireless, internet-connected sensor and communication network that supports applications in research, education and public safety. The network includes hundreds of cameras, including fixed 360-degree-view and closeup point/tilt/zoom models, as well as weather sensors and seismometers. It covers hundreds of miles of rugged terrain, from hard-to-reach areas across the remote Southern California backcountry almost to the Arizona border.

"It is the largest-scale and most finegrained high-speed wireless network for environmental sensing in the world," explains Larry Smarr, founding director of CALIT2 and the Harry E. Gruber professor in computer science and engineering at UC San Diego's Jacobs School of Engineering.

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It is the largest-scale and most fine-grained high-speed wireless network for environmental sensing in the world.

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Originally funded in 2000 by the National Science Foundation, HPWREN is now supported by its user community and is managed by the Scripps Institution of Oceanography's Institute of Geophysics and Planetary Physics, in partnership with CALIT2's Qualcomm Institute and the San Diego Supercomputer Center – all located on the UCSD campus.

Over the past couple years, HPWREN added installations in the Santa Ana Mountains, along the eastern edge of Orange County, and in Laguna Hills. It has become a valuable resource for the firefighting community as cameras provide live feeds of smoke and fire progress, and weather sensors provide wind direction and air humidity levels. It became a crucial ally for firefighters during the Holy Jim Canyon fire two years ago, as they relied on publicly available HPWREN images to decode the fire's origin, stay apprised of its progress and plan their containment strategy.

Tirtha Banerjee, UCI assistant professor of civil engineering, investigates ecosystem disturbance processes through characterization, modeling and data analysis. His group plans to access the HPWREN image data for characterizing the landscape and use the associated sensor data for calibrating fire models. He is principal investigator of a UC interdisciplinary, multicampus team seeking to help mitigate wildfires in California by developing better tools for understanding the use of prescribed burns to reduce wildland fuel.

"The common element in ecosystem disturbance science, wildfires and prescribed fires, is characterization of fuels, and we anticipate the HPWREN data will be useful for this work," says Banerjee. "These characterizations are important for understanding fire behavior, but cannot be captured well from satellites and can be expensive with manual data collection."

In addition to wildfire research, there are potential collaborations for researchers interested in designing their own studies using HPWREN capabilities. The network offers multiple opportunities for scientists interested in environmental sensing, data science,



computational photography, machine learning and information sharing.

"It's a completely applicationagnostic platform on which you can place sensors," says Smarr. "You configure it as you need for your specific research goals. This has included everything from listening for wolf howls, to 3D sonic arrays for bats, to observing ground and plant moisture, to most recently, wildfires."

HPWREN's servers are interconnected by the Pacific Research Platform, a seamless research infrastructure that allows scientists to securely share large amounts of scientific data through high-capacity optical networks provided by **Corporation for Education Network** Initiatives in California (CENIC). Together the HPWREN and PRP create a wireless/ optical fiber cyberinfrastructure that links UCSD, San Diego State University and UCI HPWREN servers at 100 gigabytes per second, providing data redundancy, disaster recovery and constant availability.

"There are a number of multiple and parallel developments within HPWREN, such as emerging new technologies, expansion of the backbone infrastructure and additional camera technologies that are all coming together at this time in a perfect storm of opportunity," said Greg Hidley, a CENIC research engineer, HPWREN technical developer and a PRP collaborator, at a recent CALIT2@UCI workshop held to inform UCI engineering and computer science researchers about HPWREN's capabilities.

Not only will UCI researchers be able to use this connection, with eyes across the county, but they will easily be able to access massive amounts of data from the entire network using the new server and storage complex in the CALIT2 Building. The PRP uses a Ceph open-source software object-, block- and file-level storage platform that adds over 500 terabytes of available distributed storage. In addition, there is



a new industrial machine-vision camera system, along with a next-generation image-fetching system; and a Nextcloud file-sharing and collaboration platform. All together these new resources will support the creation of a repository for Orange County HPWREN sensor data and camera images. With this abundance of data, researchers can apply computational photography and machine-learning techniques to investigations that help predict the future by looking at the past.

CALIT2 Irvine Director G.P. Li encourages UCI faculty to take advantage of the network and the large quantity of accessible data now available.

"We have multiple researchers at UCI investigating different aspects of wildfires in California, and this is an important resource for them," says Li. "It could be useful for climate change research as well; imagine if we pointed the cameras at the ocean and observed changes on the coastline, sea level and tides."

"G.P. had this vision all along," says Smarr. "He saw that data growth was an exponentially increasing means of conducting research and education, so he asked me and the HPWREN leadership to expand HPWREN data generation to Orange County and to use the PRP to establish its storage complex at UCI." Happily standing in front of the newly installed HPWREN server and storage complex on the fourth floor of the CALIT2 Building are, from left: Adam Brust, HPWREN information technology support; G.P. Li, CALIT2 Irvine division director; Greg Hidley, HPWREN technical developer; and Ramesh Rao, CALIT2 San Diego division director.

Face of CALIT2

realer

Anna Lynn Spitzer



RESEARCHER INTERTWINES ART WITH TECHNOLOGY TO CREATE ENHANCED EDUCATIONAL OPPORTUNITIES

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Unbeknownst to the millions of restless children nationwide – and their parents – who have been forced by the coronavirus to adapt to a new and unprecedented at-home schooling routine, there is a passionate UC Irvine researcher who has their backs.

Kylie Peppler, an expert in connected learning and digital technology, has long extolled the virtues of learning through technology; in today's trying times, she continues seeking ways to enrich the learning experience.

"With COVID-19, parents are moving into homeschooling for the foreseeable future, which can feel like a tremendous weight," Peppler says. "Connected learning brings us back to the value that we can place on using digital technologies to connect with others in games, teleconferencing and other online applications, as well as validating the kinds of things that your child is interested in."

An associate professor of informatics and education, a key member of UCI's Connected Learning Lab and an active CALIT2 affiliate, Peppler specializes in technologies that exist at the intersection of arts, maker culture and interest-driven learning, a career path that seamlessly melds her training as an artist with her devotion to technology and education.

From as far back as she can remember, Peppler, who grew up in Fort Wayne, Indiana, loved art. Her mother, she says, tried to interest her in a host of activities from ballet to sports, but Peppler steadfastly refused. "Whenever my mom would come up with a new idea, I would say, 'No, mom. I am going to be an artist."

By the time she was an undergraduate at Indiana University, she was creating large installations that reflected her desire to shape the experiences of those around her. "I didn't want to be the kind of artist that has exhibits in a museum space," she explains. "I wanted to shape a design or an everyday experience, particularly in a school environment."

Peppler was an early research enthusiast as well. Through a high school program that partnered students with local university faculty, she engaged in a number of research projects, the first of which uncovered pervasive gender bias in local classrooms. She was hooked immediately. "I liked the idea of revealing something that hadn't been seen."

She carried her love for research through college. By the time she graduated from IU, she had completed four years of neuroscience research, along with majors in psychology, studio art and French. She then combined her interests in psychology, the arts and research into a doctoral program in education at UCLA. Alongside graduate advisers James Catterall and Yasmin Kafai, Peppler examined how arts and technology could provide new opportunities, particularly to traditionally overlooked populations.

With funding from the Ford Foundation and the U.S. Department of Education, she collaborated with nonprofit organizations, including Inner-City Arts and the Center for Creative Arts, to examine the role high-quality arts instruction had on the world views and cross-disciplinary academic achievement of inner-city children.

At the same time, she was actively embedded as a researcher in a Computer Clubhouse in South Los Angeles, where she examined how low-income children were given an outlet to express themselves – and learn to code at the same time – using an early prototype of the visual programming platform Scratch. Launched by a collaboration between UCLA researchers and the MIT Media Lab, Scratch helped children create their own interactive stories, games and animations.

"For me, it was a time of questioning where the arts were going and what the

role of technology was in art," Peppler says.

One experience in particular made a deep impression on her. A fourth grader, who couldn't read or write fluently and couldn't spell her own name, was teased by other kids and not taken seriously by program administrators and evaluators.

Peppler and a team of media artists began analyzing the girl's work as part

Peppler focuses on teaching complex systems to children though novel combinations of play, reflection, interaction and exploration.



of a case study, and what they learned shocked them. The child was creating some of the most noteworthy artistic work at that Computer Clubhouse, and in about six months, had gone from nonliterate to reading biblical passages.

"Schools were assuming that to do Scratch or computer science you had to be a proficient reader and writer, and good at math. And what we found was almost the opposite," Peppler says. "It was profound."

That experience prompted her to introduce the Scratch platform to more children with special needs. During her postdoctoral research at UCI under the guidance of School of Education Professor Mark Warschauer, she taught children in special education classes how to code with Scratch. Again, she saw results that astounded her, including one child who went from minimal language – talking only when she was mimicking others – to describing her Scratch project in detail during a class presentation.



"Kylie is, without a doubt, one of the most innovative and creative researchers on digital media and learning in the country," Warschauer says. "Her remarkable research is powered by her broad interdisciplinary background, drawing on the arts, media theory and the learning sciences."

After finishing her postdoctoral work, Peppler accepted a job at her alma mater, Indiana University, teaching, researching and serving as an integral member of the MacArthur Foundation-funded Connected Learning Resource Network. She also served as director of the Creativity Labs, lead of the MacArthur



The Peppler-Lindsay family, circa 2016.

Foundation's Make-to-Learn initiative, and as a member of the 2016 and 2017 National Educational Technology Plan Committee, sponsored by the U.S. Department of Education.

"What defines Kylie's work is that it is situated in visually and emotionally tangible forms of creativity, design and reflection," says Curtis Bonk, Indiana University professor of education and a renowned researcher in the field of online learning. "Online education is most effective when it occurs in a community of learners who contribute as well as gain from that community. And that is why Kylie's work is highly informative for this age of virtual learning and community building." Peppler stayed at Indiana for 11 years, until one day, she and her husband, Eric Lindsay, both of whom had attended graduate school in California, had a conversation about returning to the state.

"We just decided we were ready for a new chapter," Peppler says.

After applying for several positions, she ended up at UCI with a joint appointment in education and informatics, which she calls "perfect and really fun." Lindsay, a musician and film scorer, teaches in the Claire Trevor School of the Arts.

Peppler moved her Creativity Labs into the CALIT2 Building. The lab focuses on computational tools that support learning by leveraging youths' interests in digital culture, design and making. It is part of a campus organized research unit called the Connected Learning Lab, which studies learning technologies from a diverse range of disciplines, including anthropology, literature, computer science, education, English, informatics, nursing, psychology and sociology.

"My work is physical so having a space for that is so important," she says. "CALIT2 has been a great hub for demonstrations, tours and providing the students with an audience, which is a really important learning opportunity. And the way that CALIT2 really connects us to other folks and all the possibilities for collaboration are amazing."

Lest one think that Peppler's success with technology-based learning is limited to Scratch and other online programming, consider her forays into e-textiles, e-puppets and even e-fashion.

The co-author/co-editor of several illustrated textbooks on the topic, Peppler has created and/or documented a fantastical collection of electronic clothing, accessories and toys using the LilyPad Arduino circuit board. From handbags that store and display knitting pattern instructions, to embroidery that glows and sings, to costumes that respond to the wearer's movements, to a dress that senses and reacts to carbon dioxide concentrations, she sees limitless possibilities. She is a firm believer that helping children make things is a good way to teach them important concepts. "I always knew 'making' was good for learning," Peppler says. "And when you bring in new technologies, it's very cutting-edge, and it aligns with STEM initiatives, workforce initiatives, arts and more."

Mimi Ito, Connected Learning Lab director and a UCI professor in residence of informatics and education, has worked with Peppler for more than a decade. "Kylie's work uniquely weaves together multiple disciplines of learning sciences, computer science, engineering and the arts. Her work also integrates research, design and practice, all in the service of promoting equity as well as joy in learning and creating," Ito says. "I've always admired how Kylie has been able to pursue an ambitious and rigorous research agenda guided by issues that truly matter for children and educators in all walks of life."

Lately, Peppler's work includes designing museum exhibits that engage girls in engineering practices. The project, funded by NSF, focuses on narrative empathy, a concept that encourages children to design solutions to problems based on understanding the problem's impact through compassion. "Our research is starting to document that designing for empathy and narrative is consequential for how girls engage with engineering," she says. Her work has been on display in the New York Hall of Science, the Amazeum in Bentonville, Arkansas, and the Tech Museum of Innovation in San Jose, California.

Peppler often tests learning concepts and platforms on her three children – Aidan, 11, Eli, 7, and Lena, 5. "They're the hardest guinea pigs ever," she laughs. "Our whole house is a bunch of experiments right now."

She says her kids are adapting well to the quarantine routine imposed by COVID-19. "My 1st grader is having the cutest looking Zoom conferences with his teacher and peers each week, and my 5th grader is tracking his progress each week on projects and reports. I applaud





all these kids' teachers for their efforts to translate their face-to-face practices to distance learning."

She doesn't take credit for the fact that her research has formed an important foundation upon which today's online educational experiences can blossom. "Connecting and supporting our youth is our central goal," she says simply.

But her IU colleague doesn't hesitate to give kudos to Peppler. "Fortunately, the Kylie Pepplers of the world continue to remind us of the important ingredients for engagement and successful selfdirected learning in these environments," Bonk says.

Peppler's postdoc adviser Warschauer summarizes: "Kylie is a force of nature, and we are so fortunate to have her back at UCI." *CD* At a 2018 NSF-funded BioSim outreach session, Peppler worked with young students to understand biological systems – in this case, honeybees and army ants – through the use of computer-enhanced e-puppets.

Micro Connections





CALIT2-LAUNCHED SYMPOSIUM LEADS TO NATIONAL INITIATIVE

innovate | integrate | incubate | ignite

Jennifer Martiny, left, and Katrine Whiteson founded the Microbiome Initiative and Microbiome Centers Consortium to promote collaboration and help train a new generation of microbiome scientists.



When CALIT2 held its first microbiome symposium in 2013, microbiologist Karen Nelson, president of the J. Craig Venter Institute, shared with the audience her vision for the nascent field of microbiome

research. "We're just starting to understand what these microbes do," said Nelson, who led the genetic sequencing of the first human gut microbiome in 2006. She added: "I think we're in the early stages of understanding what the microbiome means to health and disease. Now that we have technologies available ... I think we're going to be making significant inroads."

Nelson, who later was elected to the National Academy of Sciences, was right. Improved sequencing techniques and lower costs have opened the floodgates to a boom in research on microbiomes, the communities of microorganisms that live in the environment and in humans.

Essential to human and environmental health, researchers now know that microbiomes govern the complex relationships between human health and disease. It is estimated that there are more than 1,000 different kinds of microorganisms living inside our bodies, containing 300 times more genes than our human cells.

Outside of the body, microbe communities regenerate soil nutrients, purify drinking water and stabilize the atmosphere. Each year, scientists better understand the degree to which microbiomes impact everything around them.

But in 2013, the field, especially in the area of human microbiomes, was relatively unexplored. Pierre Baldi, UC Irvine Distinguished Professor of



computer science and director of the campus's Institute for Genomics and Bioinformatics, along with CALIT2 Founding Director Larry Smarr, initiated the idea for a conference to bring together local experts. They called it Microbiome Connections. "The idea came up during various conversations between the two of us," Baldi says. "We thought it was important because the field was relatively new at the time and [it was] clearly a new, significant direction of research. We wanted to be among the first."

G.P. Li, CALIT2 Irvine division director, supported the idea immediately. "From a CALIT2 point of view, we always talk about digital transformation of health, energy, the environment and culture," Li says. "At first, this was a health issue. Later, we added the environmental piece. But from the beginning, we saw the alignment with CALIT2's mission to use information and communication technology for the digital transformations necessary to improve people's lives." The conference, now an annual affair held in the fall, has grown in size and expertise. Registration more than doubled over the last seven years, from 116 attendees in 2013 to 260 last year. While the original conference featured only human microbiome experts, the event now features a full roster of topics connected to both human and environmental microbiomes.

Subject matter has included microbial biogeography, biofilm formation, marine bacteria, wild herbivores and dietary toxins, antibiotic resistance, health care infections and sustainable sanitation, among dozens of other topics.

A day-long workshop was added in 2017, and now, a poster session has been added, too. The SoCal Microbiome Conference, as it is now called, has outgrown the CALIT2 auditorium, its home for the past seven years, and will move to the Beckman Center. Originally scheduled for this September, the next conference will be held in fall 2021 instead due to the worldwide coronavirus pandemic.

Microbiome research is growing by leaps and bounds on campus as well. While human and environmental microbiomes have traditionally been studied separately, UCI researchers have begun to bridge the gap. In 2017, UCI funded a new microbiome initiative with the goal of bringing together human and environmental microbiome collaborators.

The brainchild of two campus researchers – Jennifer Martiny, ecology and evolutionary biology professor, and Katrine Whiteson, assistant professor of molecular biology and biochemistry – the initiative seeks not only to encourage collaboration but also to train a new generation of interdisciplinary microbiome scientists.

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It's still early days for the consortium, but we've been in touch with people from all over the world. Getting these tips and tricks from other microbiome centers about how they're doing things is really, really helpful.

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The annual conference now falls under the purview of the Microbiome Initiative. "But we still always run everything by Pierre and Larry and get their blessing," Whiteson says.

"There's a huge amount of interest in learning how to do this kind of science," adds Whiteson, who for several years was the only human microbiome researcher on campus. When she started her campus lab in 2014, she says, she was inundated with requests for collaboration, most of which she didn't have the bandwidth to accommodate. Elizabeth Bess, assistant professor of chemistry, joined the effort a couple of years ago, and two new humanfocused microbiome researchers will be added to the biological sciences faculty by fall quarter.

The Microbiome Initiative hosts a series of training workshops as well as a weekly consulting hour that helps develop new projects, connect labs across disciplines and collect preliminary data. More than 90 individual researchers attended at least one consulting session last year seeking help with microbiome-related projects.

The initiative also sponsors a monthly update meeting, pilot project awards, fellowships for researchers and assistance with grant writing.

Growth in the field and on campus recently spawned the Microbiome Centers Consortium, also spearheaded by Martiny and Whiteson. Founded last year, the consortium serves as a network for university and national laboratory microbiome centers to promote collaboration and share intellectual and technical strengths.

"Around the time that Katrine and I started the microbiome initiative, we started realizing that there were lots of other universities that had these microbiome initiatives," Martiny says. "And we were curious: how were they doing things?"

Twenty-eight initial member institutions attended the inaugural meeting at UCI last year; since then, the number of consortium centers has exploded to more than 80 and increases almost every month. A second annual meeting was scheduled in Chicago this June but has been postponed, again because of the coronavirus.

"It's still early days for the consortium," says Whiteson, "but we've been in touch with people from all over the world. Getting these tips and tricks from other microbiome centers about how they're doing things is really, really helpful."

The annual conference with roots at CALIT2 continues to grow in size and stature. "There was a lot of very forwardthinking science from the beginning because of the way Pierre and Larry put it together," Whiteson says. "Our goal with the conference is to continue to highlight Southern California microbiome scientists. Southern California is a leader in this area, so we really attempt to showcase the great work going on in the region. Our goal with the conference is to continue to highlight Southern California microbiome scientists. Southern California is a leader in this area, so we really attempt to showcase the great work going on in the region.

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Entrepreneurial Spirit

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TECHNOLOGY MAKER



Interface | SPRING 2020

STARTUP IS SUCCESSFULLY MAKING BIG CHANGES BY INNOVATING SMALLER

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The microengineering company was founded as Integra Devices in 2015 by Mark Bachman, Paul Dhillon and James Spoto. Renamed Xidas (next-generation integrated devices and systems), the startup company produces microelectromechanical systems (MEMS) products for use in industrial, medical and internet of things applications.

Each of the company's products is unique because it uses a novel method for development, an innovative manufacturing technology that is more cost-effective than silicon fabrication. Called Amaga[™], the technique enables the miniaturization of devices and the integration of various materials (plastics, metals and ceramics) while allowing the components to be embedded in substrate or printed circuit boards. The approach is well-suited to meet the high-frequency, high-speed and high-performance demands of fifthgeneration communication/networks and IoT devices. The multi-patented method was developed by Bachman when he was an assistant professor at UCI, and G.P. Li, CALIT2Irvine division

director and professor of electrical engineering and computer science.

The startup company, a former CALIT2 TechPortal occupant, was established to commercialize this technology. Xidas has grown from one customer and four employees in its TechPortal days to 10 customers and over a dozen full-time employees today. It signed a lease in March to double its space in an industrial park in Irvine, allowing the company to complement its research and development activities with in-house low-volume manufacturing.

Then the coronavirus pandemic hit, right as Xidas was at an inflection point. Bachman and Dhillon had secured Series A venture capital funding last year, and they were readying three products for market launch: a self-charging perpetual battery, a micro-relay and a micro force sensor. All three devices are uniquely positioned with no competitors.

"We don't develop a product unless we see a need for it in the marketplace or we have a big customer that specifically wants it," says Bachman, Xidas chief technology officer, who was recognized by the Orange County Business Journal

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A lot of the reputation we enjoyed came out of our affiliation with CALIT2. And we still use some of the UCI clean rooms and microscopy equipment, but it is the intellectual relationship that benefits us the most.

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in 2019 as one of five Innovators of the Year.

"Everything we are making, no one has made before. It's disruptive technology," continues Dhillon, company CEO. Both Dhillon and Spoto are veteran high-tech industry entrepreneurs, with multiple successful startups under their belts. Spoto, who retired from the company, still serves as an adviser, while Dhillon heads up the business side.

In addition to the three Xidas label products, the company also has developed a couple of products in partnership with industry. One is an in-body, zero-power wireless pressure sensor called the eyelash (with a footprint smaller than a human eyelash), designed for glaucoma monitoring. The other is a microfluidic inline pressure sensor, a small electromechanicalfluidic "smart" sensor for wearable drug delivery applications. Many more ideas are in the pipeline.

With Almaga as a broad technology platform for miniaturization, Xidas' ideas for microscale solutions are abundant. The founders, however, are determined to stay focused on the products they can scale and that hold value in the marketplace.

Jeff Hilbert, a local MEMS technology product development entrepreneur who serves on the Xidas advisory board, says the company has made more progress, in less time and with less (dilutive) funding, than the majority of startups he has been involved with over the past 20 years. "They have been effective in forming value-added partnerships, identifying potential markets and products, getting prototypes developed, staying flexible and lean, and raising funds," he says, adding, "They have a great team with a balance of expertise and experience. Arguably, the team is the most important factor in the early stages of a startup."

This implantable, zero-power sensor, with a footprint smaller than a human eyelash, is designed for glaucoma monitoring and other applications. The founders say they could not have reached this point without a strong interdisciplinary group that includes biomedical engineers, materials scientists, physicists, electrical engineers and mechanical engineers. Xidas also regularly hires interns from UCI, Cal State Fullerton and local community colleges as well.

After spending several years in incubator space EvoNexus, the burgeoning team and its equipment moved a year ago to its current location, 46 Waterworks Way, in Irvine. With a clean room and rapid prototyping equipment, including a computer numerical control machine, wire bonder, 3D printers and more, they're able to try out new ideas right away.

Although the company has moved on physically, its ties to CALIT2 remain strong. "It all started at CALIT2," says Bachman, referring to the technology that came out of research conducted at UCI. "A lot of the reputation we enjoyed came out of our affiliation with CALIT2. And we still use some of the UCI clean rooms and microscopy equipment, but it is the intellectual relationship that benefits us the most. I still talk to G.P., faculty, postdocs and staff researchers at CALIT2. It's the kind of invaluable interaction that stimulates and creates ideas."

> Hilbert says Xidas is at a crucial point. "Like many startups, I believe Xidas is now at the stage where they need to focus on driving a lead product into the market and starting to grow their revenue base," says Hilbert. "Often the difference between winning and losing is understanding when to be on which side of that line."

> > Being able to quickly adapt to a changing environment is one of the advantages of being a small business. "Despite the COVID-19 pandemic, we are very excited about where we are going with Xidas and the opportunities we have before us," says Bachman. "We're doubling our efforts and focusing on near-term revenue opportunities, while still building out our R&D and manufacturing capabilities. We're planning to come through this even stronger and better than before."

Xidas produces tiny electromechanical-fluidic components that can be used to control and monitor small volumes of fluid; these microfluidic sensors are used in medical devices and other life-science products.

MICRO AMAZING!

XIDAS IS READYING THREE MICRODEVICES FOR MARKET LAUNCH IN THE NEXT TWO YEARS.

MICRO-RELAY

Xidas' first device is the micro-relay for microwave frequencies. It controls radio frequency signals and aids in high-speed communications technologies such as 5G networks. Xidas is the first company worldwide to provide a miniature electromechanical relay with signal characteristics similar to its larger counterparts.

MICRO FORCE SENSOR

Xidas's miniature force-sensing components monitor loads of all different ranges. This tiny $(4 \times 4 \times 2$ mm) smart sensor has integrated digital electronics built into the package to enable dynamic filtering and calibration, offering a high-accuracy, temperaturecompensated digital output.

PERPETUAL BATTERY

Xidas makes self-charging batteries that harvest energy from the ambient environment (machine vibrations) and convert that energy to an electrical charge. These batteries can perpetually power wireless sensors, a major component of IoT applications including predictive maintenance for machinery.

AWM

A Parting Shot

When CALIT2 lab administrators received an urgent request this spring from UC Irvine's medical school, they sprang into action.

First-year medical students had launched a drive to collect masks, gloves and other personal protective equipment to be donated to COVID-19 frontline health care providers, and the institute's clean room facilities were well-positioned to help. Staff from the Integrated Nanosystems Research Facility and sister lab Bio-Organic Nanofabrication quickly rounded up 500 clean room masks, 3,000 nitrile gloves and several cases of clean room shoe covers, suits and hoods. Ryan Smith, CALIT2 facilities manager, delivered the donation to thankful recipients. "The clean room facilities were in minimal use at this time, and since our facilities have the types of PPE supplies needed, the staff wanted to contribute to the effort," said G.P Li, CALIT2 and INRF director.





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