Coordinated Science Lab Newsletter
GRAINGER COLLEGE OF ENGINEERING

SUMMER 2019

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ILLINOIS
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Director's Message
Klara Nahrstedt

Computer science pioneer Alan Kay famously said, "The best way to predict the future is to invent it." While his quote underscores CSL's strategy in many areas – including computing, communication and control -- we recently have made significant investments in our future as it relates to robotics and autonomy. While this has always been a focus for CSL, particularly in the area of control, we have recently made significant investments in our future by hiring new faculty who specialize in these thrusts and improving our facilities to accommodate the next generation of research. A significant impetus for this investment was the 2018 launch of the Center for Autonomy, which is housed at CSL and will enable high-impact research and develop new educational programs for students and professionals. The center is partially funded through the campus-level Investment for Growth program. In the past year, we have added a number of new faculty in robotics and autonomy, including Katie Driggs-Campbell (ECE), Nancy Amato, (CS Head), and Roy Dong (CS). Two additional faculty, Kris Hauser (CS) and Saurabh Gupta (ECE) will join us this fall. Together, they bring both theoretical and experimental leadership that will help catalyze multidisciplinary research. This summer, CSL is also unveiling 1,080 square feet of additional research space in the CSL Studio. The expansion of the Intelligent Robotics Lab is intended to provide a laboratory environment that is more conducive to research on ground and mobile robots. The lab space, combined with the aerial arena, which facilitates UAV research, means that CSL researchers now have roughly 2,400 square feet of lab space in which to build next-gen systems, such as the cyberoctopus that Girish Chowdhury and his team are creating through a new MURI award (page 6). The expanded IRL offers new opportunities to practice programming of autonomous vehicles, such as students are doing in a class taught by CSL's Sayan Mitra and Driggs-Campbell this summer. These students will be using a GEM utility vehicle for their coursework. It was donated to Illinois by AutonomouStuff, a subsidiary of Swedish-based Hexagon AB. The GEM will also be used for research purposes in months to come. Of course, these new initiatives join the world-class research that has been underway for years at CSL. Several of these projects were featured during Robotics Week in early April. CSL has committed to leading research and education in robotics and autonomy. Look for additional announcements that highlight new opportunities in these areas soon.

CSL ACHIEVEMENTS

Al-Hassanieh named Sloan Research Fellow

CSL Assistant Professor Haitham Al-Hassanieh has been named as one of the 126 recipients of the 2019 Sloan Research Fellowships from the Alfred P. Sloan Foundation. The awards "honor early career scholars whose achievements mark them as among the most promising researchers in their fields."

Al-Hassanieh works on designing systems and algorithms for wireless networking and mobile sensing in order to enhance and scale connectivity in future networks and the Internet of Things.

Chen and Choudhury elevated as IEEE Fellows

CSL Professors Deming Chen and Romit Roy Choudhury have been elevated to IEEE Fellows by the IEEE Fellow Committee for their contributions to FPGA high-level synthesis and to wireless network protocols and indoor localization, respectively. Each year, the IEEE Fellow Committee recommends a select group of recipients for elevation to IEEE Fellow following a rigorous evaluation procedure. Less than 0.1% of voting members are annually selected for this member elevation.

Chen named as next editor-in-chief of ACM TRETS

CSL Professor and Donald Biggar Willett Scholar of Electrical and Computer Engineering Deming Chen has been named as the next Editor-in-Chief of ACM Transactions on Reconfigurable Technology and Systems (TRETS) by the ACM Publications Board. ACM TRETS is a peer-reviewed and archival journal that covers topics including reconfigurable technology, systems, and applications on reconfigurable computers.

CSL faculty receive Google Faculty Research Awards

Through the Google Faculty Research Awards, Google annually funds unrestricted support to a select number of researchers in the field of computer science and engineering. This year, four faculty from the Coordinated Science Lab and Information Trust Institute received this honor: Sarita Adve, Richard T. Cheng Professor of CS; Haitham Al-Hassanieh, Assistant Professor of ECE and CS; Jian Huang, Assistant Professor of ECE; and Shobha Vasudevan, Associate Professor of ECE.

Illinois Engineering names Sanders as Dieckamp Endowed Chair in Engineering

CSL Professor (and former director) William H. Sanders has been named the Herman M. Dieckamp Endowed Chair in Engineering. The professorship is made possible by a gift from Illinois alumnus Herman Dieckamp.

Sanders is a professor of Electrical and Computer Engineering, as well as Interim Director of the Discovery Partners Institute. He was also the founding Director of the Information Trust Institute (2004-2011).

CSL Director Klara Nahrstedt receives College of Engineering Faculty Award

CSL Director and Ralph M. and Catherine V. Fisher Professor of Computer Science (CS) Klara Nahrstedt was recently honored with the Tau Beta Pi Daniel C. Drucker Eminent Faculty Award.

Called "as close to the Nobel Prize as you can get in this college" by Executive Associate Dean Philippe H. Geubelle, this award is given to a faculty member who has received national or international acclaim for dedication to academic excellence through teaching and research, and who has made exemplary contributions to the understanding of their field.

"Klara's outstanding contributions, influence, and leadership have been pivotal in shaping the future of multimedia systems," said Nancy Amato, department head of CS. "Her ability to balance extraordinary research and outreach, coupled with an overwhelming dedication to service, sets her apart."

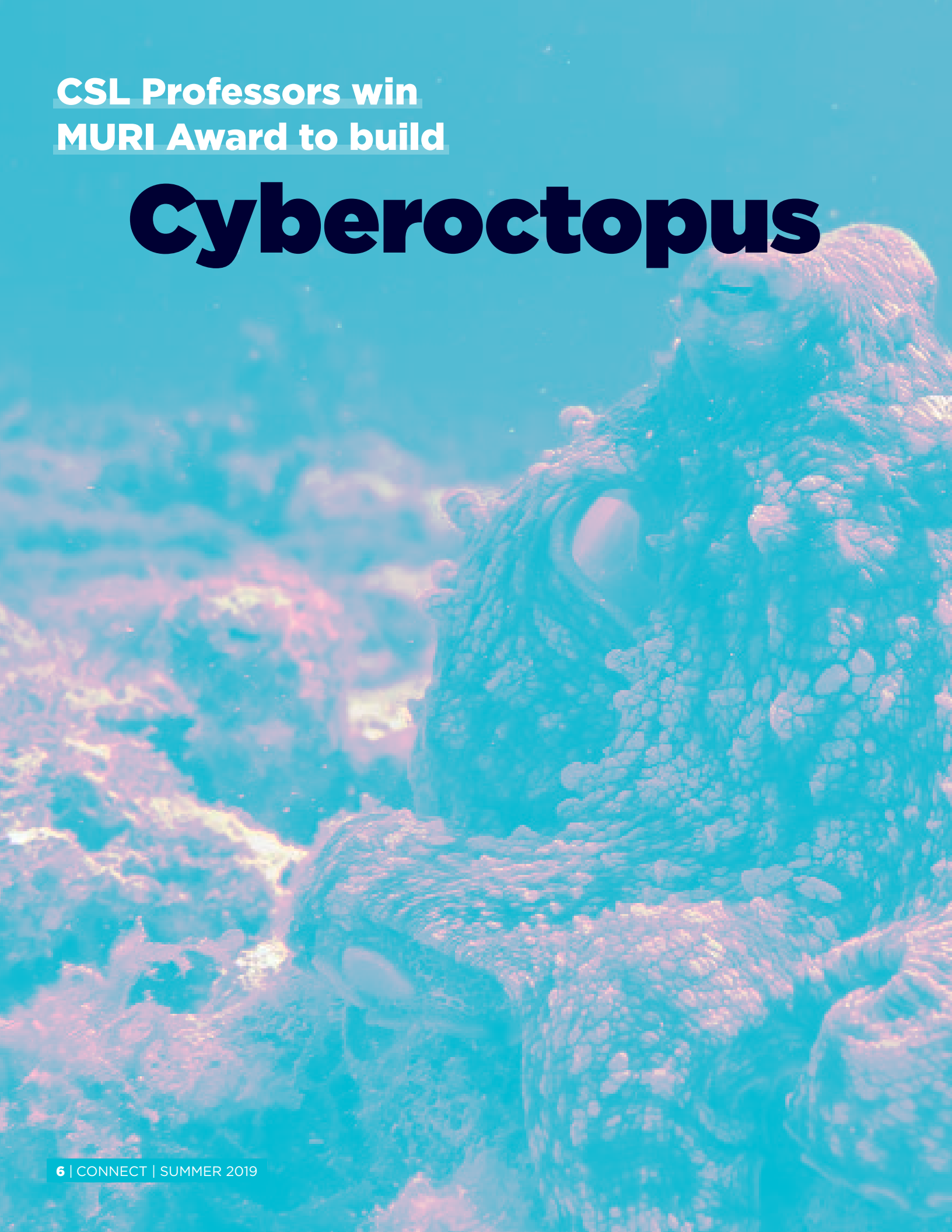
Nahrstedt receives the 2018 Robert Piloty Prize for outstanding research

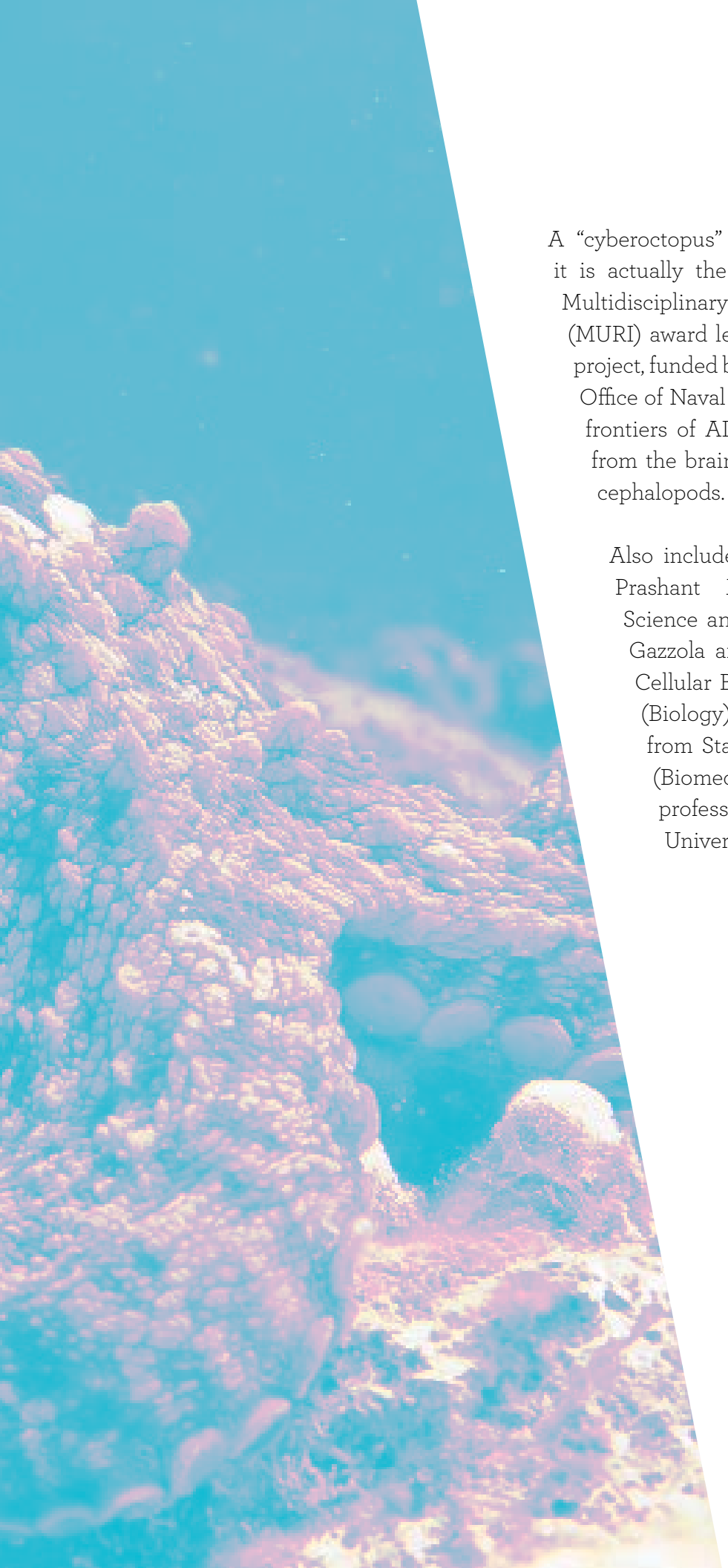
CSL Director Klara Nahrstedt received the 2018 Robert Piloty Prize for her research contributions. The Piloty Prize is conferred by the TU Darmstadt in Germany to recipients who have demonstrated "outstanding achievements and exceptional research and development work in the fields of computer science, electrical engineering, information technology and mathematics."

"My collaboration with TU Darmstadt has been one of the most productive of my career, and I am deeply honored to receive this award," Nahrstedt said.

CSL Professors win MURI Award to build

Cyberoctopus





A “cyberoctopus” may sound like a superhero, but it is actually the focus of the recently announced Multidisciplinary University Research Initiative (MURI) award led by CSL’s Girish Chowdhary. The project, funded by the Department of Defense (DoD) Office of Naval Research, is looking to advance the frontiers of AI, control, and robotics, by learning from the brain and body of octopuses and other cephalopods.

Also included on the team is CSL professor Prashant Mehta, along with Mechanical Science and Engineering’s (MechSE’s) Mattia Gazzola and Rhanor Gillette (Molecular and Cellular Biology) from Illinois, William Gilly (Biology) and Ivan Soltesz (Neurosurgery) from Stanford University, and John Rogers (Biomedical Engineering), a former Illinois professor who is now at Northwestern University.

The $7.5 million Multidisciplinary University Research Initiative (MURI) award is for building a cyberoctopus, a piece of software modeled after the marine animal that will help the team understand and leverage its ability to conduct distributed inference and decision-making, its embodied control and intelligence, and its ability to learn new behavior quickly.

"We believe that bringing autonomy to the next level will require us to learn from animals," said Chowdhary, assistant professor of agricultural and biological engineering and the lead principal Investigator of the project. "The octopus is a species with just the right mix of complexity. We believe we can learn a lot from seeing how the octopus learns, evolves, and adapts."

Inside the octopus brain

First, the group will study the neurodynamics of an octopus. In humans and many other animals, a centralized brain makes the majority of the decisions. In an octopus, most of the "brain" is distributed, not centralized, along the eight arms, meaning each appendage can act independently but also in a coordinated fashion. Being able to control a distributed system like this is a great challenge for modern AI.

"If you look at the neural networks in the brain of an octopus, each neuron is a dynamic system and not a static nonlinearity like some of the artificial neural networks," said Mehta, also a professor in MechSE. "It will be exciting to understand the role played by neurodynamics in inference, control and learning functions of the octopus brain."

Robotics

Second, the team will apply principles of embodiment of control and intelligence to the cyberoctupus, leaning on the biology expertise of world-renowned octopus experts William Kier (Biology, University of North Carolina at Chapel Hill), Gillette, and Gilly.

Gillette has a long track record of studying octopuses and other cephalopods and has observed them exhibiting a high level of intelligence. Octopuses can open jars from the inside, solve puzzles, and use other animals' shells as their own. This level of intellect could be beneficial to machines.

"Learning how the octopus intelligence emerges from the seamless interplay

between its neural and mechanical, distributed infrastructure is one of the keys to this research," said Gazzola, also a member of the National Center for Supercomputing Applications.

Gazzola will be working closely with Soltesz to build realistic simulations of an octopus. The simulations will integrate realistic models of soft mechanics with detailed models of the neural architecture uncovered by the biologists in the team.

Octopus behavior

How octopuses and squid learn new behavior is the third focus area. Gilly's research has shown that during the first several weeks of their lives, juvenile squid must learn how to hunt small, planktonic crustaceans to survive. If this skill isn't developed in this time period, they cannot survive on their own.

"This acquisition of behavior that is not preprogrammed, but has to be learned, is fundamental to how animals learn to be intelligent," said Chowdhary, who also holds appointments with the departments of electrical and computer engineering, computer science, and aerospace engineering. "That's good because that hints at far more efficient ways of doing reinforcement learning and adaptive control."

To try to understand the inner workings of an octopus, Rogers is helping build sensor patches that can be embedded inside a real octopus to record neural activity. Rogers has previously installed these patches in mice and other animals, but this is the first time anyone has ever tried to put such patches inside an octopus.

"We did this because we think there needs to be a new stream of thought in AI. We seem to have gotten a lot out of the current deep learning thinking, there's a lot of merit to that, but how do we go beyond its limitations?" Chowdhary explained. "Research gets done when people get out of the box."

IRL expansion completed

CSL Studio renovations have been completed to provide researchers with an additional 1,080 square feet within the Intelligent Robotics Laboratory (IRL). The area, specialized for ground robotics, is in addition to the 1,320-square-feet of aerial robotics space.

One of the main beneficiaries of the space will be the Center for Autonomy, an innovative university program meant to bring together researchers from across campus to further autonomous research. Since its inception last fall, the center has hired four robotics faculty who have already begun teaching classes on developing safe, autonomous algorithms.

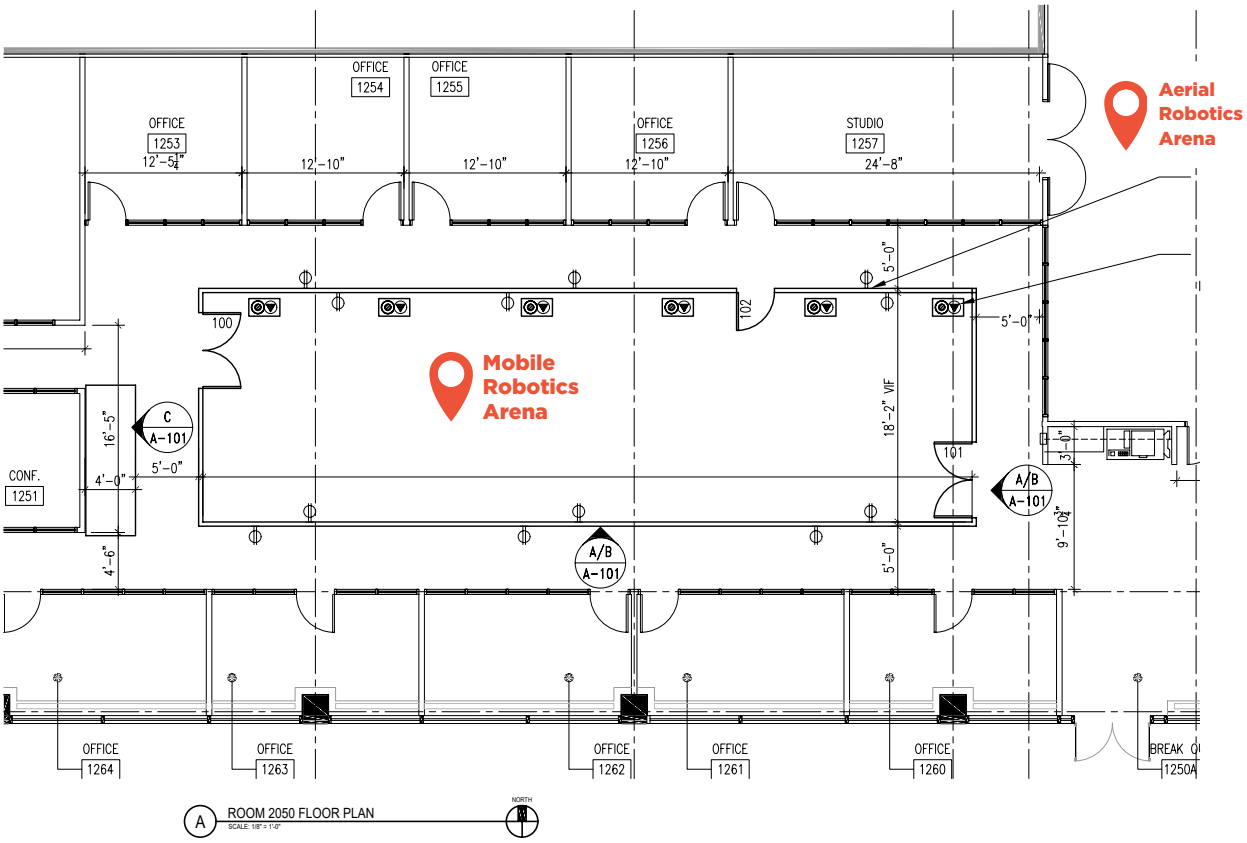
"This facility is phenomenal," Geir Dullerud, CSL professor and center director, said of the recent expansion. "This space will have a transformative effect on engineering robotics."

Mobile Robotics Area

Construction of this new area ended in May. New equipment and tools will be added to the space to ensure it's precisely what our engineers need to conduct their research.

Aerial Robotics Area

Rather than switching between aerial and ground robotics, this part of IRL will now be entirely dedicated to flying robots!



CSL celebrates National Robotics Week

April 8-12 was National Robotics Week and CSL celebrated in a big way. CSL faculty and students are conducting a variety of robotics research projects, so to celebrate, a different project was featured each day on social media. Some of the highlights were an AgBot collaboration involving more than 10 departments across campus, the maiden flight of the Illinois Quadrotor, and coffee served by robots!

Other featured projects included a dog-like robot and robots that are being trained to express emotions through movement. National Robotics Week was a great opportunity to highlight just a few of the innovative ideas coming from CSL researchers.

Smart car

Thanks to a partnership between the Center for Autonomy, The Grainger College of Engineering, and Illinois-based platform manufacturer AutonomouStuff, CSL students and faculty have a smart car to experiment with. Graduate students and faculty are currently working on developing the programming to make the car fully autonomous. The ability to work with autonomous software and hardware as opposed to working with simulations gets faculty closer to their research applications and gives students a leg up in the job market. This is just one of the many projects that are expected to come out of IRL and the Center for Autonomy.

CSL professor leads research to improve VR technology, train professionals

CSL Professor Kesh Kesadavas is working on improving virtual reality in a way that would cut development time in half and allow for realistic training of future medical professionals.

"Most of the current virtual reality technology tends to be fully computer graphics and that takes a very long time," said Kesadavas, Health Care Engineering Systems Center (HCESC) director and Industrial and Enterprise Systems Engineering professor. "We have a different approach: mixed reality. We mix 360° videos and a limited amount of computer graphics. We merge them and augment the videos."

The combination of real-life videos with computer graphics serves well as an educational tool where interaction is key, such as in medical school education.

"The whole concept of medical education is active learning – students observing an operation and then eventually doing the procedure themselves," said Kesadavas. "There's a lot of time, effort, and resources required to give this experience to medical students. Using our technology, students can have a level of experience that is equivalent to being in an operating room."

Kesadavas previewed the technology at the American College of Surgeons annual summit. He showcased a curriculum his team developed for nurses and ER doctors at OSF in Peoria that he believes would be easily transferrable to medical schools.

"Medical directors of universities had really positive feedback about how this technology will make teaching more efficient," said Kesadavas. "This concept is the future of medical education."

This research was funded by the Jump ARCHES endowment and is a collaboration between OSF HealthCare and the University of Illinois at Urbana-Champaign.

CSL professor contributes to improved care for NICU babies

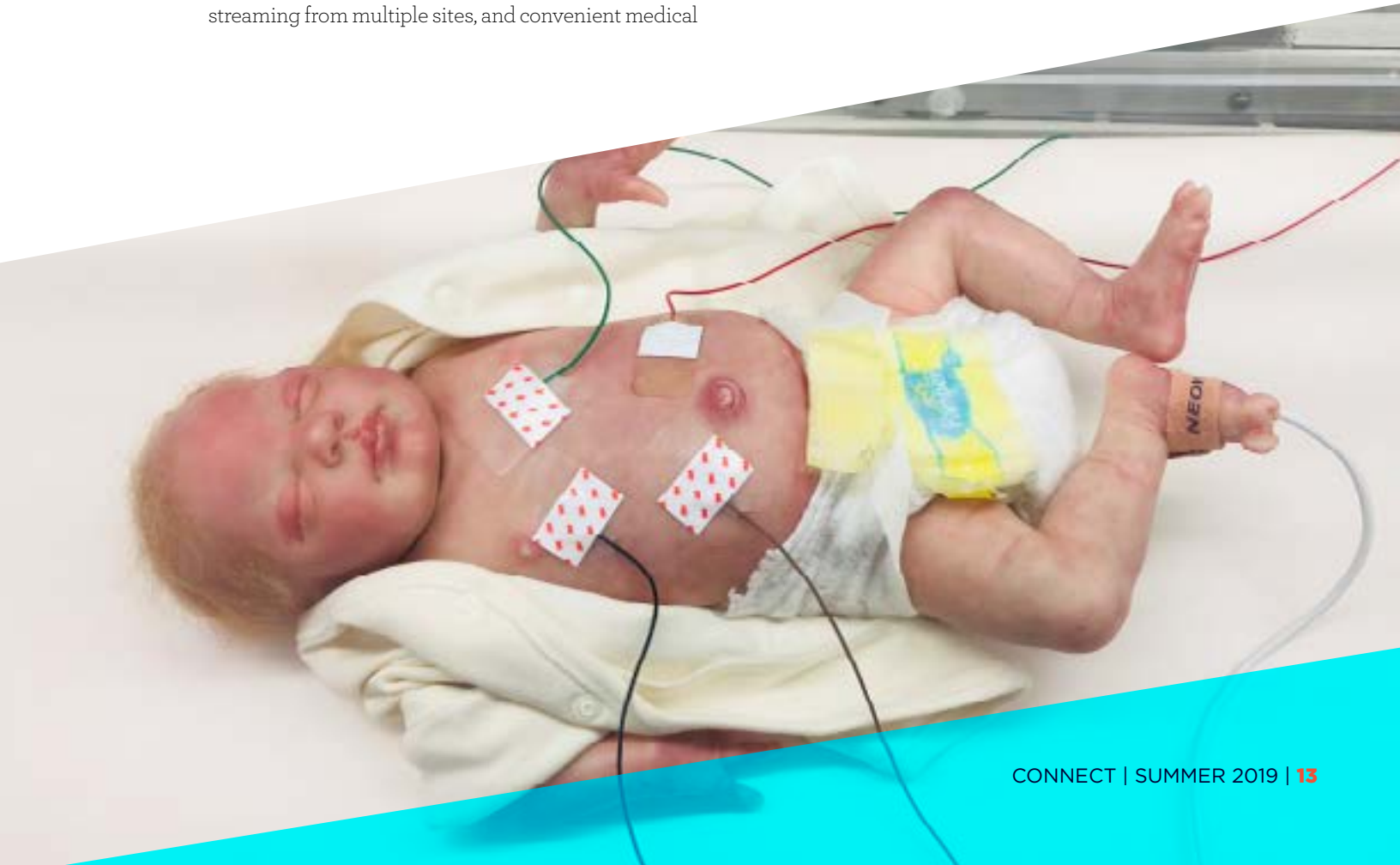
The bond between a parent and child is forged within the first weeks of life. For parents whose babies are born prematurely or with complications, these bonds are harder to establish, as the baby needs to be constantly monitored via wires. CSL Professor Naresh Shanbhag is part of a collaboration within the SONIC (Systems On Nanoscale Information fabriCs) Center, led by Northwestern University's John Rogers, that is working to replace the wires with patches that allow parents to hold their baby while it is being monitored.

The group worked closely with medical doctors to develop a wireless, battery-free sheath that can be laid on the skin. The paper-thin patch is the combination of four technologies: wireless power and data transfer, efficient onsite data analytics, time-synchronized data streaming from multiple sites, and convenient medical observation and imaging. If the patch got in the way of medical staff it wouldn't be useful.

The ability to wirelessly transfer power – instead of having a local battery on the patch -- was crucial, so as to avoid additional weight and wires for power. In addition to powering itself, the patch needed to gather medical data (temperature, heart rate, electrical heart patterns, blood oxygenation, etc.) and then process it locally to reduce the amount of information sent wirelessly to the monitors.

"We developed efficient algorithms to process data in real-time on an on-site microcontroller," said Shanbhag, the Jack S. Kilby Professor of Electrical and Computer Engineering. "The device has limited computational resources so we had to choose the most information-preserving computations."

The devices were deployed for testing at the Lurie Children's Hospital in Chicago. So far, 90 babies have successfully used the patches, and there are plans to expand to NICU units across the U.S. and in Zambia.



Illinois researchers sweeten "honeypot" to catch, blacklist hackers

"The supreme art of war is to subdue the enemy without fighting." - Sun Tzu.

This quote inspired CSL student Phuong M. Cao and a team from the National Center for Supercomputing Applications (NCSA) to conduct research to understand how systems were being attacked.

The researchers were able to attract hackers by setting up phony machines, or "honeypots," mimicking more than 65,000 servers. Using this method, the group was able to draw in millions of attack attempts and learn from them.

"Their strategy brought in a lot of bad guys, and after a quick analysis, many had their router blacklisted," said Cao's advisor Ravi Iyer, CSL and electrical and computer engineering professor and George and Ann Fisher Distinguished Professor of Engineering. "The clever thing was the students took this information and decided to use the attacks being generated to discover how our system can withstand these attacks."

The information collected about the attack techniques has already been integrated into security systems at NCSA. Justin Azoff and Alex Withers, both NCSA staff, are working closely with Cao and others to continuously audit and update the technology against ongoing attacks. This partnership shows how practical cybersecurity operations can support research and vice versa.

The University of Illinois at Urbana-Champaign's network is already benefiting from the software. In a single year, the team's software analyzed 405 million attack attempts from 73% of the autonomous systems on the internet. This has resulted in their having the largest dataset of analyzed brute-force attacks collected to date.

ALUMNI FEATURE

The Cat's Meow: Former CSL students revolutionize cat toy industry

Students that pass through CSL have the potential to change the industries they enter. For many, that means the computer science, electrical engineering, or cyber security fields. Former students Dave Cohen, Michael Friedman, and David Jun chose a different route. The industry they revolutionized? Cat toys.

Mousr, the first toy to come out of the trio's startup Petronics, is a robotic mouse. The new product officially hit the market last spring and has been a hit with cat customers ever since.

"Our feedback has been really positive," said Cohen. "People tell us all the time they've been waiting years for a product like this, but there's nothing out there."

The popular robotic mouse has two settings. The first allows the owner to control the robot's movement from a phone application, and the second runs the mouse autonomously. The final product is the result of years of testing, electrical engineering knowledge, and a broad understanding of cat behavior.

"Our experiences were unique in the sense we weren't just learning theory we were building hardware," said Cohen. "I've seen other people try this idea and fizzle out. The education and the background we received could not be replaced and were necessary to pull this off."

Cohen's PhD research involved building an algorithm that would allow a low-battery device to observe wild animals. A friend suggested applying his research to pets. The idea of using sensors in pet care combined with their own cat observations led to the original prototype -- a hobby robot with sensors, a chopstick, and some string.

While the mouse has gone through many transformations since the first prototype, the group believes there is still room for growth.

"We know there are ways we can enhance it to improve the experience for cats," Cohen said. "We feel we've only scratched the surface for (Mousr's) potential."

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