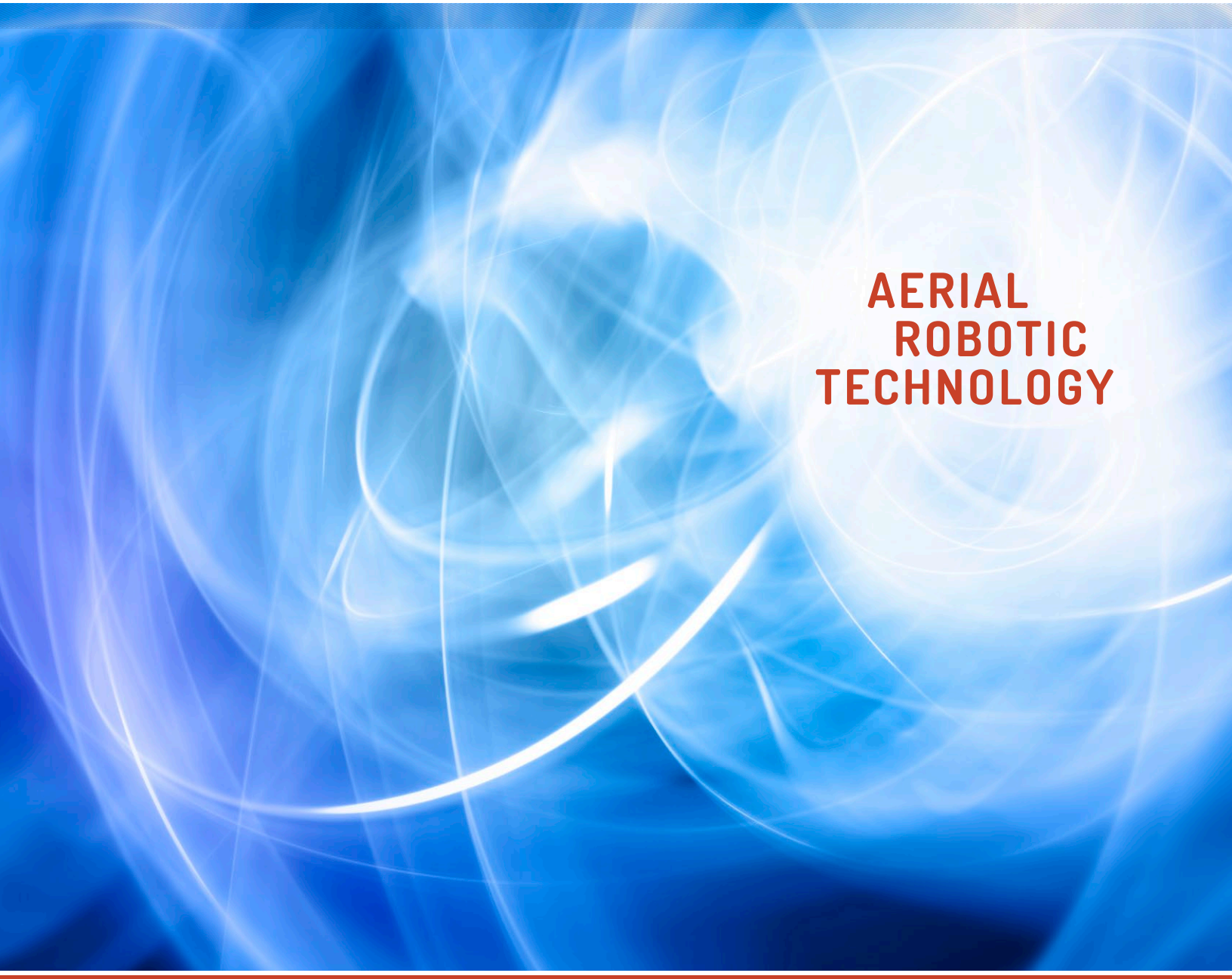
ENGINEERING AT ILLINOIS
COORDINATED SCIENCE LAB: NEWSLETTER

:CONNECT



AERIAL ROBOTIC TECHNOLOGY

SPRING 2015

CSL: COORDINATED SCIENCE LAB

:CONTENTS

:CONNECT

Spring 2015

Coordinated Science Lab
College of Engineering
University of Illinois at Urbana-Champaign

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A MESSAGE FROM OUR DIRECTOR

Whether on the ground or in the air, robots are revolutionizing the way we live, work and play.

Robotics is the fastest growing industry in the world, with as many as half of all U.S. jobs projected to use intricate machines or software by 2025, according to a report from labor firm Littler Mendelson.

The Coordinated Science Laboratory has long recognized the importance that robotics plays in everything from defense to medicine. For decades, researchers have been advancing artificial intelligence, bioengineering, communications, control theory, signal processing, telecommunications and other disciplines that are critical to making breakthroughs in the field. As demand for smarter, more autonomous robotics increases, so does our investment in the area - starting with a new Intelligent Robotics Lab that will open this spring.

The Intelligent Robotics Lab, headed by CSL Professor Naira Hovakimyan (MechSE), will facilitate research related to UAVs and other robots. It will be housed in the new CSL Studio space located in the parking deck on the northeast corner of Clark Street and Mathews Avenue in Urbana. More than a dozen CSL researchers will be able to use the space to conduct research on everything from coordinating swarms of UAVs to creating ways to navigate in GPS-denied environments.

The new robotics lab comes on the heels of a $1.5 million grant to support the design of a robotic bat capable of supervising construction sites. The project, funded by the National Science Foundation, supports the research efforts of CSL researchers Seth Hutchinson, Soon-Jo Chung and Tim Bretl, among others. Bretl also is working on a similar project that is using robotic bats to supervise the construction of the new Sacramento Kings arena in California and a residence hall here on campus.

In addition, CSL has acquired or is in the process of acquiring two new robots to help facilitate research. Baxter, who has joined Tim Bretl's group, is a low-cost robot designed to help automate manufacturing in small- and medium-sized businesses. The lab is testing its hardware on Baxter, who could be used to assemble flexible parts, such as installing a cable harness in a car.

The Health Care Engineering Systems Center is also purchasing an open-source surgical robot called the Raven II. The system includes a two-armed surgical robot, a guiding video camera and a surgeon-interface system, and will enable HCESC researchers to test out more advanced surgical robotics techniques.

CSL is committed to investing in the people and infrastructure needed to solve the grand challenges facing advancements in robotics. We hope that you will take a few minutes to read more about our robotics efforts on page 8.

Klara Nahrstedt

WHITE SMELL RESEARCH:

Imagine a machine that could analyze all of the smells in a room and produce the perfect combination to cancel the room's odors, leaving it smelling completely neutral. CSL and ECE Assistant Professor Lav R. Varshney and his brother, IBM researcher Kush Varshney, have come a step closer to this scenario with an algorithm for creating what they call "olfactory white," or white smell: the equivalent of white noise for your nose.

"Every smell a human encounters is composed of a number of chemical compounds," Lav Varshney explained. "Each of those compounds can be matched with other compounds that cancel out its smell." By analyzing how much of each chemical compound is in the smell, the Varshneys' algorithm can compute the compounds needed to create a counter-smell that would combine with the prevailing one to form olfactory white. The scent itself is described by researchers at the Weizmann Institute of Science in Israel as "neither pleasant nor unpleasant."

Apart from canceling odors in a room, the Varshneys' algorithm could also make foods more palatable in a practice called food steganography: disguising certain smells to accentuate others.

CSL SOCIAL HOUR:

CSL began hosting Social Hours in January 2014, as an informal way to connect students, postdoctoral researchers, faculty and others throughout CSL. Each Friday throughout the semester, groups have been gathering over refreshments to hear from fellow students and researchers about their research and its broader impact, as well as mingle and network. The short talks vary each week, and topics come from each of the eight research groups across CSL.

MINDCRAFTEDU:

Jana Sebestik of the Office for Mathematics, Science, and Technology Education (MSTE) has been working with the MSTE student staff to develop a Minecraft world that asks players to work together to create a system that generates and supplies electricity to their world. Minecraft, a computer game that allows users to create and build structures out of cubes in a 3D world by breaking and placing blocks, has captivated millions of people worldwide since it was released in 2009 and now allows for user-generated modifications and new worlds that are available for users to download.

The MSTE group, working with TCIPG, created a world with several interactive lessons that teaches users about different types of electricity generation. Their Minecraft game includes a miniature power grid with renewable and non renewable energy sources such as a wind farm, a solar PV array, coal and nuclear power plants, as well as substations and other buildings. The world is divided into four main sections: power generation, lessons that teach basics about electricity generation, a building area and the passive house. The TCIPG Minecraft world focuses more on building and learning about electricity and less on survival than typical Minecraft worlds. The world is available for download via tcipg.mste.illinois.edu/minecraft.

CSL STUDENT CONFERENCE:

The 10th annual CSL Student Conference was held Feb. 26 - 27, 2015 and featured talks in the areas of robotics and control, privacy and security, machine learning, big data and smart cities. The conference, which is organized by CSL's graduate students, is a way for Illinois and outside students to present their work to faculty, invited speakers and fellow students. The two-day event included presentations, poster sessions, talks by invited speakers from Stanford, University of Chicago, Microsoft and Carnegie Mellon University, a panel discussion and reception.

:NEWS BRIEFS

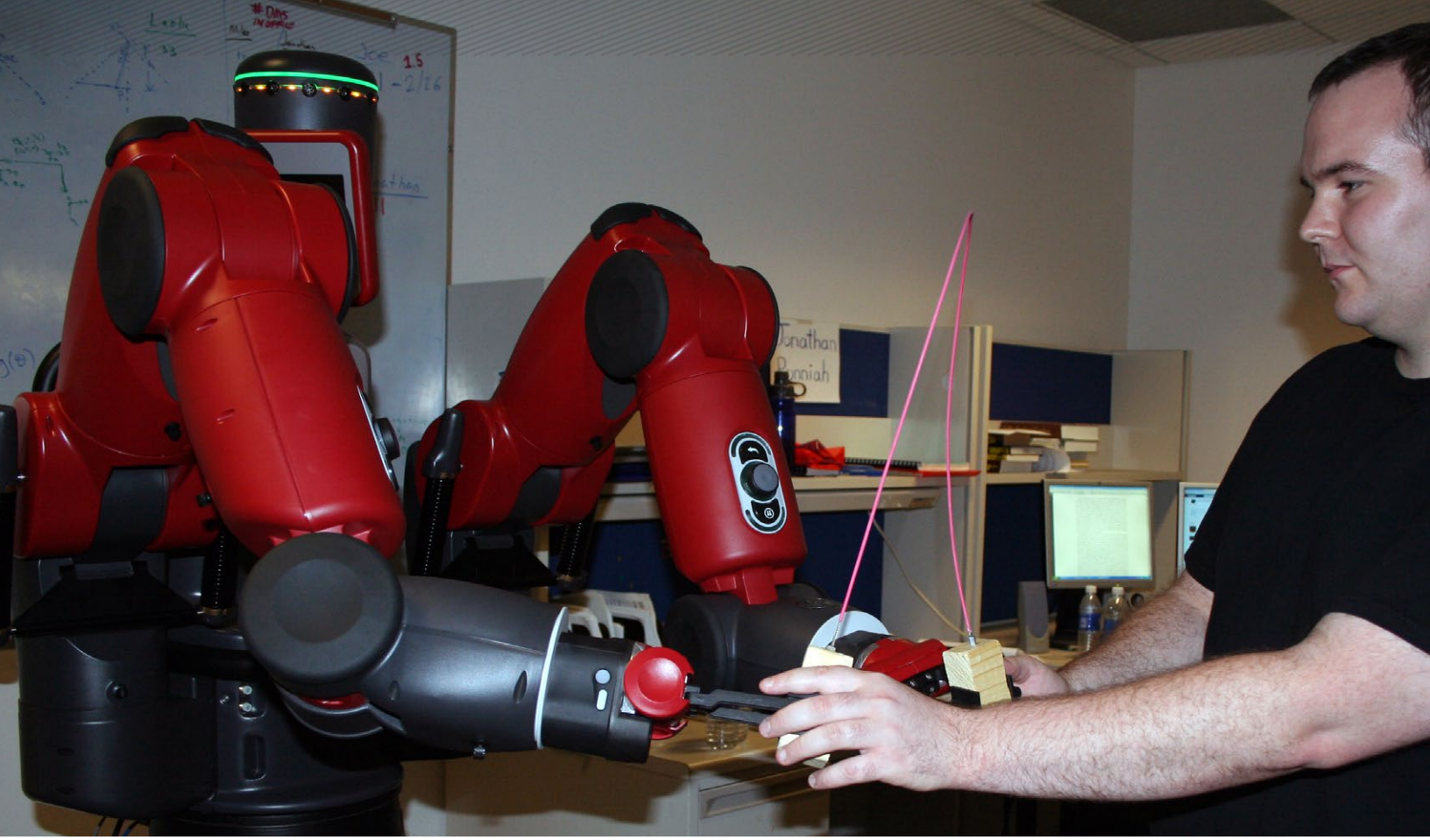
MARCO CACCAMO

University of Illinois Computer Science Professor Marco Caccamo recently joined CSL in the reliable and high performance computing area. His research interests include real-time systems, cyber-physical systems, real-time scheduling and resource management in next generation embedded infrastructures. Caccamo graduated from University of Pisa in July 1997 with a degree in computer engineering. He received his Ph.D. in computer engineering from Scuola Superiore Sant'Anna in January 2002. He has authored/coauthored more than 80 refereed publications in real-time and embedded networked computing systems. Additionally, he is a guest editor of the Journal of Real-Time Systems, was program chair of RTAS and later served as general chair of RTAS and Cyber Physical Systems Week (CPSWeek) 2011. He is one of the PIs at the Real Time System Laboratory at Illinois, was awarded an NSF CAREER Award in 2003 and is a senior member of IEEE.

ADSC GRANTS:

ADSC recently received two new grants, with one from Singapore's National Research Foundation and one from the Ministry of Defense. The projects are both collaborations with fellow Singapore research, academic and industry institutions, which is a goal of ADSC researchers.

ADSC will be working in collaboration with the Institute for Infocomm Research (I2R) on a project that focuses on safeguarding urban transportation systems against cybersecurity attacks. Additionally, the Ministry of Defense is funding a project on Ka-band signal attenuation estimates from cloud analysis using ground-based cameras. The project is led by Yee Hui Lee at Nanyang Technological University, Stefan Winkler of ADSC and Yusong Meng of A*STAR's National Metrology Center.



:NEW AERIAL ROBOTIC TECHNOLOGY TAKES FLIGHT

In the future, robots will likely do everything from helping fight fires to boosting crop productivity. According to a 2014 report by employment law firm Littler Mendelson, robotics is the fastest growing industry in the world. And it's easy to see why: The field is transforming everything from aviation to medicine to surveillance.

While Illinois researchers have been at the forefront of the field for decades, CSL is upping its investment in robotics—particularly in regards to unmanned aerial vehicles (UAVs). This spring, the Intelligent Robotics Lab is opening in the new CSL Studio space under the direction of Professor Naira Hovakimyan. The lab will provide space to more than a dozen researchers for developing smart UAVs and other robots with the aim of creating a new generation of robots that can seamlessly interact with humans.

"It's clear that robotics will play a key role in reducing the costs of and compensating for the limitations associated with a human workforce," said Naira Hovakimyan, a professor in mechanical science and engineering.

When a fire breaks out, for example, drones could be deployed to capture information about the scope of the fire or the location of survivors, sending real-time information to firefighters before arriving on the scene. UAVs could also be used to image cornfields, sending back visual clues about moisture conditions or chemical requirements to agronomists. Hovakimyan has research projects in the works that would enable both scenarios.

To use drone technology in a growing number of applications, researchers will have to overcome numerous technical problems. Among them: Devising a way to navigate drones in GPS-limited environments, processing a deluge of data in real time, creating more energy-efficient drones with longer-lasting battery power and many other challenges.

With its 13-foot ceiling, the Intelligent Robotics Lab will provide an optimal space for researchers to conduct their work. It will be outfitted with a motion-capture system that will provide feedback crucial in location estimation in the absence of GPS, which is severely limited indoors.

Hovakimyan aims to bring together more than a dozen faculty members from Aerospace Engineering, Computer Science, Electrical and Computer Engineering, Industrial Systems and Enterprise Engineering, and Mechanical Science and Engineering to collaborate in the space.

"Our hope is that this lab will provide an interdisciplinary work space where we can work together to create the next generation of drone technology," she said.

ROBOTICS@CSL

Robots are hardly an unusual sight at CSL. Here are a few that you might see within our walls:

BAXTER ROBOT

Baxter, a robot housed in CSL, is a low-cost robot designed to help automate manufacturing in small- and medium-sized businesses. CSL's Tim Bretl (Aero) and his graduate students are testing their hardware on Baxter, who could be used to assemble flexible parts, such as installing a cable harness in a car. In addition to the practical side of the research, the researchers are working to add aspects to their theory, such as taking into account external forces, like gravity, and obstacles.

RAVEN II SURGICAL ROBOT

The Health Care Engineering Systems Center (HCESC) will welcome the Raven II, an open source surgical robot, this spring. The robot will provide a platform for the research and development of new health engineering technology. It was purchased through a research equipment grant given by the Office of the Vice Chancellor for Research, with the support of faculty from the Departments of Computer Science, Mechanical Science and Engineering, Bioengineering, Industrial and Enterprise Systems Engineering, Electrical and Computer Engineering and the Coordinated Science Laboratory.

ROBOTIC WIFI

Mobile computing has traditionally implied mobile clients connected to a static infrastructure. Roy Choudhury's research is breaking away from this point of view and envisions the possibility of injecting mobility into network infrastructure.

In the near future, his team envisions WiFi base stations on wheels—called robotic WiFi—that move to optimize desired performance metrics. Movements can be in the scale of few inches on the floor, or perhaps on larger scale on top of false ceilings in a building.

In larger settings, the robotic base stations can even be controlled from the cloud to organize them into desired topologies that best optimize network performance.

In the future, perhaps cell towers could also be mobile—quad copters could fly out and hover strategically near users to offer high fidelity wireless connections.

Roy Choudhury and his students are developing algorithms on top of a platform of Roomba robots and various quad copters to make wireless networks better, both indoors and outdoors.

"OUR HOPE IS THAT THIS LAB WILL PROVIDE AN INTERDISCIPLINARY WORK SPACE WHERE WE CAN WORK TOGETHER TO CREATE THE NEXT GENERATION OF DRONE TECHNOLOGY"

NAIRA HOVAKIMYAN

AERIAL ROBOTS FOR CONSTRUCTION SITES

As the new Sacramento Kings arena goes up in California, aerial robotic technology developed by Illinois researchers will be on site to supervise. CSL's Tim Bretl (Aero) is part of a team that deployed quad rotors, which can autonomously navigate the job site indoors and outdoors, conduct visual inspection with onboard cameras and more, to monitor the construction site. These robots can measure construction progress and provide detailed and continuous performance data on workers and equipment.

In addition to his research on the Kings project, Bretl is teaming up with fellow CSL researchers Seth Hutchinson (PI, ECE) and Soon-Jo Chung (Aero) to build a robotic bat—with more advanced capabilities—for a similar purpose. The research is being funded through a $1.5 million grant through NSF's National Robotics Initiative.

CUBICLE SPACE

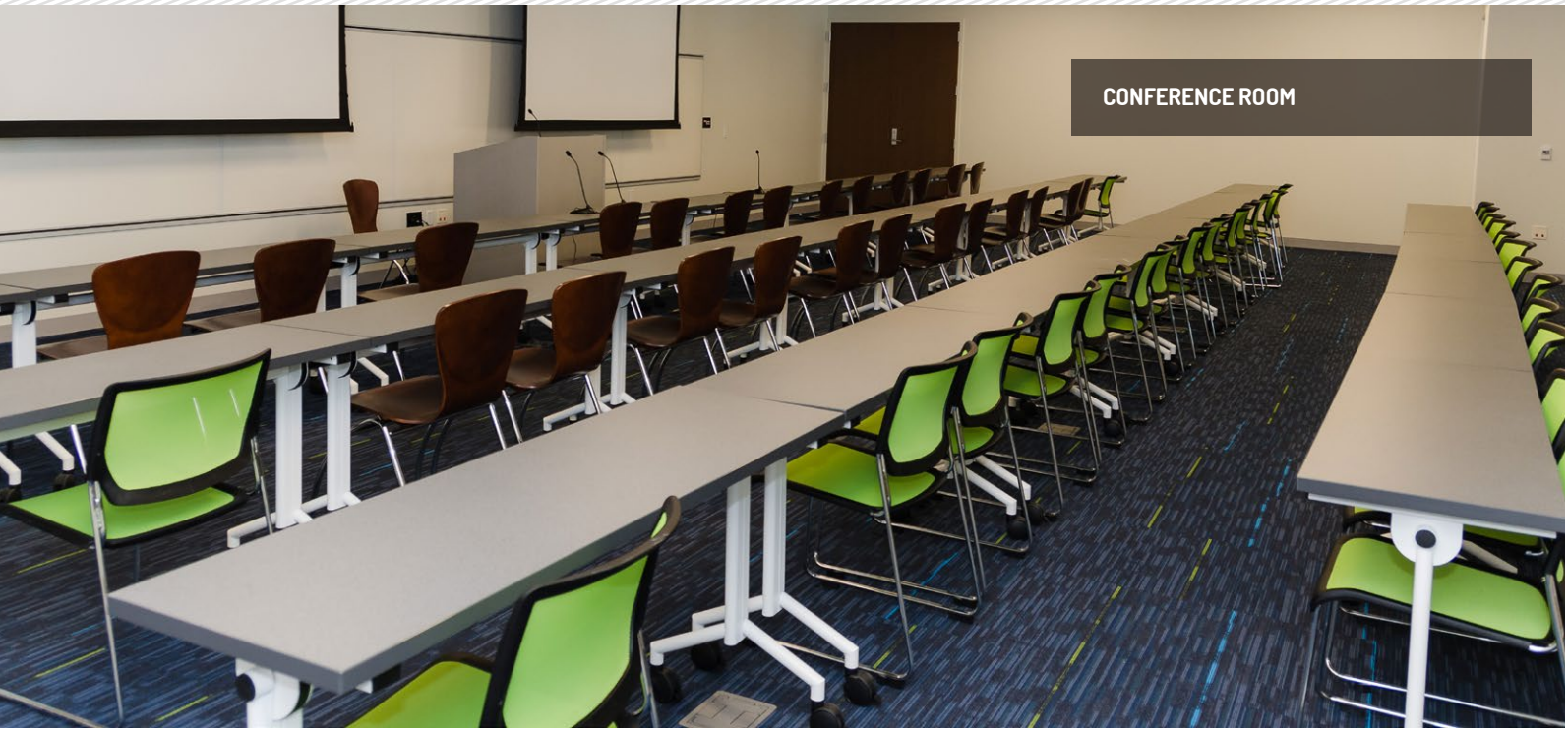
KITCHENETTE LOUNGE

A NEW SPACE FOR MULTIDISCIPLINARY COLLABORATION

During the past six years, CSL has launched two institutes, six centers and countless new initiatives ranging from computational genomics to nuclear-cyber security. As the Lab's programs have grown, so has its need for more space.

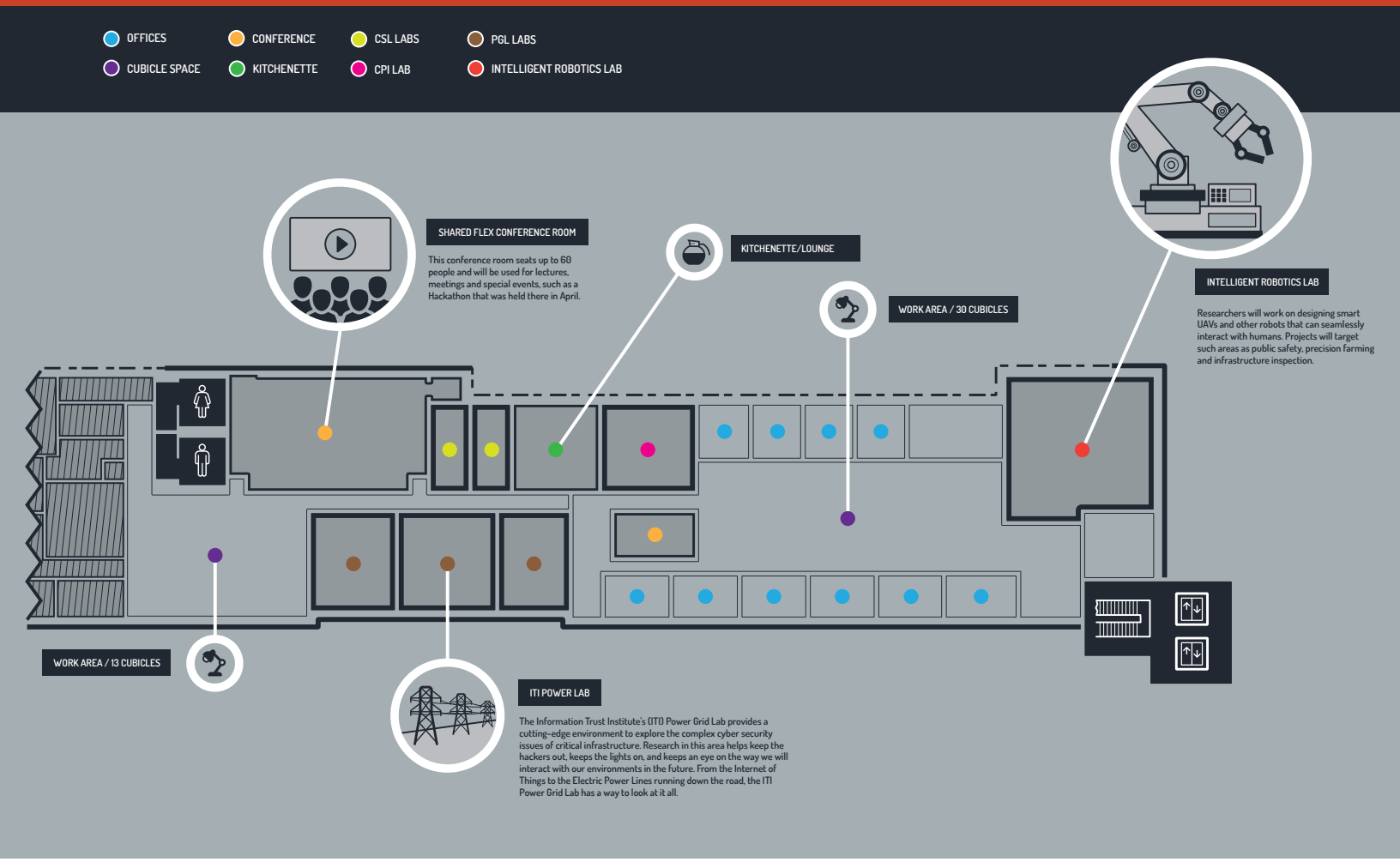
This spring, the Lab opened the CSL Studio, located on the first floor of the North Parking Deck. The 15,418-square-foot Studio includes office space for 20 people, cubicles for more than 40 students and programmers, four labs and two conference rooms.

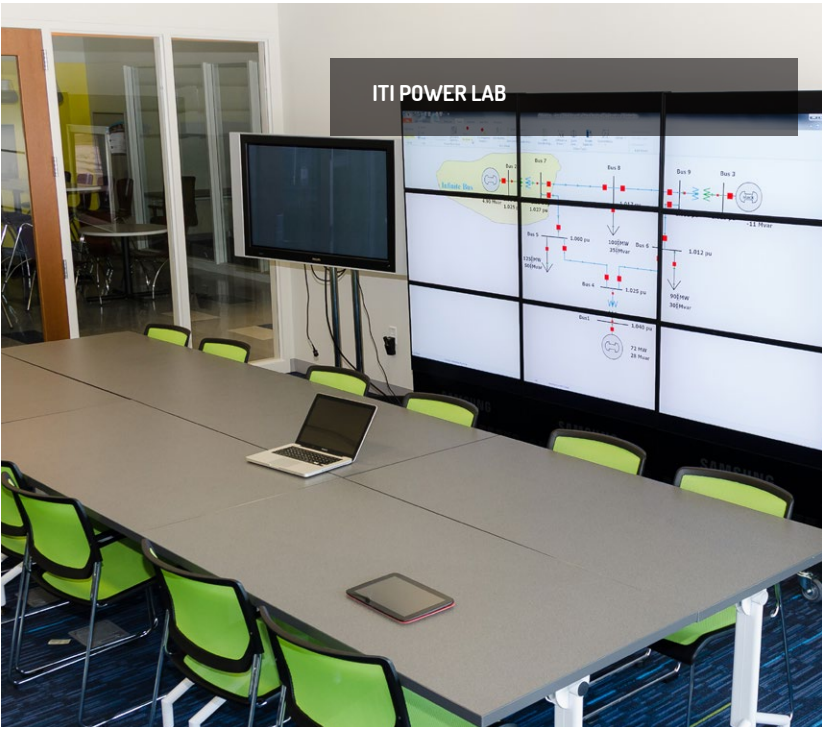
The space will accommodate staff and students in CSL's Center for People and Infrastructures and its Intelligent Robotics Lab, in addition to the Information Trust Institute's Power Grid Lab. CSL currently claims two-thirds of the entire first floor; the remaining one-third belongs to the College of Engineering and has yet to be officially allocated.

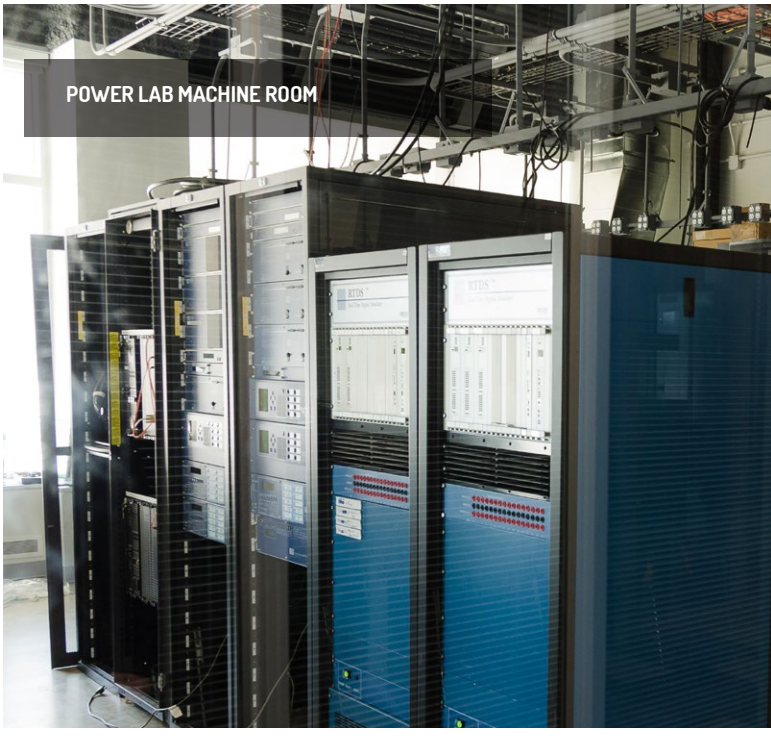


CONFERENCE ROOM

:CSL STUDIO




ITI POWER LAB


POWER LAB MACHINE ROOM

:CELEBRATING HONORS

EDEN ELECTED A FELLOW OF NATIONAL ACADEMY

CHEN NAMED WILLETT SCHOLAR

ALLEYNE WINS EXCELLENCE IN GRADUATE STUDENT MENTORING AWARD

CSL faculty members are among Illinois' top researchers and educators, confirmed by the many awards and accolades bestowed on them over the past few months. Here's a quick look at some of those honors:

CSL PROFESSOR J. GARY EDEN, who holds the Gilmore Endowed Professorship in Electrical and Computer Engineering, has been elected a fellow of the National Academy of Inventors.

Election to NAI fellow status is a high professional distinction for academic inventors who have demonstrated a prolific spirit of innovation in creating inventions that have affected quality of life, economic development, and the welfare of society.

Eden has a long, distinguished career in the area of optics, studying lasers and optical physics. He holds more than 70 patents and was elected last year to the National Academy of Engineering.

MECHSE PROFESSOR, CSL PROFESSOR AND ASSOCIATE HEAD OF UNDERGRADUATE PROGRAMS ANDREW ALLEYNE has won the Excellence in Graduate Student Mentoring Award, an honor that recognizes faculty members with graduate instructional programs that have demonstrated excellence, innovation, and impact through graduate student mentoring. He received the award based on the quality and depth of the impact of his mentoring of the department's graduate students, especially underrepresented minorities. Recipients are nominated and selected by their peers on campus. The award is presented at the Celebration of Teaching Excellence on April 30.

Alleyne earned his bachelor's degree in mechanical and aerospace engineering from Princeton in 1989, and an MS and PhD in mechanical engineering from the University of California, Berkeley, in 1992 and 1994. He has been on the faculty at MechSE since 1994, and also holds a faculty position in the Coordinated Science Lab. He served as the Associate Dean for Research at the College of Engineering from 2008 to 2012.

The College of Engineering has announced that ten faculty members have been named Donald Biggar Willett Scholars for 2015, including **CSL ASSOCIATE PROFESSOR DEMING CHEN**. Chen has been an associate professor in the Department of Electrical and Computer Engineering since 2011. He is also a research associate professor in the Coordinated Science Laboratory, an affiliate associate professor in computer science and an Advanced Digital Sciences Center faculty member.

His current research interests include system-level and high-level synthesis, nano-systems design and nano-centric CAD techniques, GPU optimization, reconfigurable computing, hardware/software co-design, hardware security, and computational biology. In the recent years, he is also actively involved with other research directions, such as computational genomics, hardware security, and computation in the Smart Grid.

In 2014, he received an IBM Faculty Award for his contributions to the areas high performance computing, synthesis, architecture and design space exploration. In addition to numerous Best Paper awards, Chen has received an NSF CAREER Award and has been included on the list of Teachers Ranked as Excellent by Students.

2015 AWARDS
COLLEGE OF ENGINEERING

Dean's Award for Excellence in Research
Brighten Godfrey, Computer Science (Parallel Computing Institute)
Alejandro Dominguez-Garcia, Electrical and Computer Engineering
Angelia Nedich, Industrial and Enterprise Systems Engineering

Collins Award for Innovative Teaching
Timothy Bretl, Aerospace Engineering

Everitt Award for Teaching Excellence
Grace Xingxin Gao, Aerospace Engineering

Tau Beta Pi Daniel C. Drucker Eminent Faculty Award
Pete Sauer, Electrical and Computer Engineering

Ross J. Martin Award
Venanzio Cichella, PhD student, Mechanical Science and Engineering (Advisor: Naira Hovakimyan)

Engineering Council Outstanding Advisors
Computer Science Marco Caccamo, Matthew Caesar, and Roy Campbell, Brighten Godfrey and John Hart (Parallel Computing Institute)
Electrical and Computational Engineering Ravi Iyer
Industrial Science and Engineering Alex Olshevsky
Materials Science and Engineering Angus Rockett
Mechanical Science and Engineering Naira Hovakimyan

:STUDENT START-UP

:LENDING A HAND TO AMPUTEES

For most amputees, the road to a more functional prosthetic device is slow and costly. However, thanks to a research group at the University of Illinois, that might be changing. It's especially good news for those most in need—residents of the developing world.

A team of researchers led by Aadeel Akhtar, an MD/PhD candidate in neuroscience, and Mary Nguyen, a master's student in aerospace engineering, developed the first 3D-printed prosthetic hand with pattern recognition capability. In addition, it can be created for a mere $270 compared to the average myoelectric prosthetic, which retails for between $30,000-$40,000.

The research team is advised by Tim Bretl, an associate professor in aerospace engineering who specializes in robotics and neuroscience. They recently launched a startup, PSYONIC, to commercialize the technology.

The new device uses a machine-learning algorithm that allows it to do more than just open and close. It is trained to replicate other positions of the hand by taking the electrical signal from muscles in the arm and sending them through an EMG board to a microprocessor with a machine-learning algorithm. Based on the signals, it sends commands to motor drivers, which churn the motor and make the hand move.

Although the EMG board being used for the current prototype is the size of a standard audio mixing board, it will eventually shrink to a size that can fit into the socket of a residual limb.

Akhtar's team has created a mathematical model of five actions—a hand at rest, open-faced, closed (tool grip), a three-finger grasp, and a fine pinch. The initial training takes about one to two minutes and involves a patient going through each one of the gestures.

"Using the machine-learning algorithm based on the signals it picks up from the muscles, it can figure out which of these grips he is actually doing," explained Akhtar. "The microcontroller with the machine-learning algorithm will then replicate the grip."

A connection last spring with David Krupa, an Illinois alumnus, accelerated the project. Krupa co-founded the Range of Motion Project (ROMP), a non-profit organization in Guatemala and Ecuador that provides prosthetic and orthotics to those without access to rehabilitative care. Krupa was back on campus to receive the International Young Humanitarian Award from the U of I, and Akhtar met with Krupa to discuss his team's research.

Akhtar and Nguyen spent two weeks in Quito, Ecuador, putting the final touches on the prototype working with patient Juan Suquillo, who has a below-elbow left arm amputation from an injury suffered 33 years ago in a war with Peru. The team demonstrated the product first by having Adam Namm, the U.S. ambassador to Ecuador, successfully control the arm.

"The goal of the trip was to get it to work with a patient," Akhtar said. "Although it took some debugging, we were successful." The hand takes about 30 hours to print, then two hours to assemble. All the electronics that are necessary to convert the neural signals into movements are located within the hand.

The team is working on the third iteration of their design with a thinner palm and stronger fingers. "In the new version, the finger will use a four-bar linkage," said team member Patrick Slade, a mechanical science and engineering major who is in charge of the mechanical design. "Rather than the tendons having to bend one joint at a time, the four-bar linkage will allow the joints to bend more smoothly and naturally. It will also be more robust and simpler to maintain."

"The next version will also have linear actuators which will allow for printing on a very small circuit board," added Michael Fatina, an electrical and computer engineering major. "Replacing the motors with linear actuators will make it stronger, more energy efficient and increase the battery life."

While Fatina and Edward and Alvin Wu (ECE) continue to improve EMG and logic circuits for making the motors work, Sam Goldfinger (ECE) and Joseph Sombeck (Bioengineering) handle the soldering work and sensory feedback., which Akhtar says will set the next prototype apart from anything else on the market.

"No commercial prosthetic device has any sort of feedback," Akhtar said. "We're going to put sensors in the fingers. Based on the amount of force that the fingertips are detecting, we are going to send a proportional amount of electrical current across your skin to stimulate your sensory nerves. By stimulating your sensory nerves in different ways with different amounts of current, we can make it feel like vibration, tingling, pain, or pressure."

Through a mechanical connection from one of the artificial fingers directly to the skin, the patient will also be able to better feel the position of their hand without looking at it. "It's really awesome to be able to help people," Nguyen aid. "I didn't imagine doing something that has this direct impact on the world while still in college."

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