Northwestern | McCORMICK SCHOOL OF ENGINEERING

FALL 2015

MECHANICAL ENGINEERING

A BIG YEAR FOR HAPTICS

Edward Colgate and Michael Peshkin host world conference, grow startup company

If June's World Haptics Conference was any indication, more researchers are getting in touch with touch. And mechanical engineering professors J. Edward Colgate and Michael Peshkin are right at the forefront of the excitement.

Colgate was the general co-chair of the largest conference in the event's history. Nearly 450 researchers and students from academia and industry crowded into Northwestern's Norris University Center for a week of workshops, presentations, and hands-on demonstrations. All projects revolved around haptics, a tactile feedback technology that allows users to interact with the digital world through touch.

One of the most popular tables during the hands-on demonstrations was that of Tanvas, a company founded by Colgate and Peshkin. Tanvas, formerly known as Tangible Haptics, is developing a surface technology that allows users to feel what they see on their touchscreens. Attendees lined up to try the device and marveled at the ability to feel bumps and textures on a flat glass screen.

Tanvas is already having a good year. The company recently received a $5 million investment from Chicago venture fund R7 Partners, trading firm Peak6, and Northwestern.

"This round of funding allows Tanvas to move from working on key engineering discoveries and building our patent portfolio," Peshkin said. "Now we are able to hire more people, move toward products, and build relationships with consumer electronics companies."

As their company gains momentum, Colgate and Peshkin, too, have had a successful year. In October, the pair was inducted into the Chicago Area Entrepreneurship Hall of Fame. In March, they were inducted into the National Academy of Inventors (NAI). Election as fellow to the NAI is a high professional distinction accorded to academic inventors who have demonstrated a prolific spirit of innovation in creating or facilitating outstanding inventions that have made a tangible impact on the quality of life, economic development, and the welfare of society.

The team also made a fascinating research discovery this winter that provides insight into how the brain makes sense of data from fingers. Published in the *Proceedings of the National Academy of Sciences*, the experiment presented two virtual bumps on a touchscreen, with the distance between them varying across trials, to subjects participating in the study. When the bump and finger spacing were identical, subjects reported feeling two bumps as one. In this case, the brain thinks it is too coincidental that there should be two bumps at the same time, so it registers the bumps as one.

TOP: *Michael Peshkin and Ed Colgate.*
BELOW: *Mondher Cherif, chief scientist of Tanvas, explains the new haptics technology to guests at this year's World Haptics Conference.*

"By leveraging the virtual bump illusion, we were able to design a meaningful experiment that shed light on the way the brain integrates information from multiple fingers," Colgate said. "Our big finding was 'collapse' — the idea that separate bumps felt in separate fingers are nonetheless experienced as one bump if their separation happens to match that of the fingers."

FROM THE CHAIR

Dear friends and colleagues,

Reuters recently ranked the world's most innovative universities, using a combination of measures based on patents and research publications ("The World's Most Innovative Universities," **www.reuters.com**, September 15, 2015). Northwestern ranked number six.

This led me to reflect on the ways mechanical engineering drives innovation at Northwestern. Certainly there is the innovative research, patent licensing, and startups by faculty in our department. This newsletter contains a sampling of the exciting new research coming out of our department, including research that shows how to keep a surface dry underwater (page 4). One of the promising new startups originating from research in our department is Tanvas, a company led by Professors **Ed Colgate** and **Michael Peshkin** (page 1).

Our faculty members are innovating in teaching, too. The portable lab ("lab-in-a-backpack") concept adopted by ME 233 Electronics Design (Peshkin) and ME 333 Introduction to Mechatronics (Professor **Nick Marchuk** and myself) is being taken to the next level by Marchuk and PhD student **David Meyer**, who ran a successful Kickstarter campaign to develop an inexpensive programmable oscilloscope and function generator that uses the student's laptop as a display, allowing electronics prototyping out of the lab (page 7).

The department's leadership in innovative teaching was once again recognized with the University's most prestigious teaching award. In May 2015, Professor **Walter Herbst** was awarded the Charles Deering McCormick Clinical Professorship in Teaching Excellence. Students praised Walter's positivity, his belief in their creativity, and the way he inspires them to do more than they thought possible. Including Professors **Todd Murphey** and **Neelesh Patankar** (2014), our department received three of the ten Charles Deering McCormick Professorships awarded University-wide in the past two years.

In addition to innovative teaching, mechanical engineering is leading the way in teaching innovation. Our faculty members play leadership roles in the Segal Design Institute, the Master of Science in Engineering Design and Innovation program, and Design for America (DFA). DFA, founded by Professor **Liz Gerber**, is now a network of 29 student-run design studios across the country. DFA held its annual Leadership Studio at Northwestern in August, and more than 90 DFAers from 28 studios spent four days applying human-centered design principles to help those touched by Down syndrome.

Two new campus-wide initiatives originated from the department in the past year: the Northwestern Initiative for Manufacturing Science and Innovation (page 6) and the Institute for Cellular Engineering Technologies (iCET). iCET, directed by Professor **Horacio Espinosa**, focuses on the creation of tools for cell manipulation and analysis and combines our historic strength in mechanics with emerging opportunities in medicine.

In September we welcomed our newest faculty member **Mike Rubenstein** (below). We also mourned the passing of **Stanton Cook**, Mechanical Engineering Advisory Board member and longtime friend and supporter of Northwestern. Stan was a graduate of our department and went on to a long and distinguished career with the Tribune Company, serving as chairman and CEO. Stan's leadership and generosity led to the establishment of the Wilson-Cook Professorship in mechanical engineering and the gift that led to the naming of the McCormick School of Engineering and Applied Science. Stan was a gentleman, a leader, and a trusted adviser, and his impact on Northwestern, Chicago, and the nation was enormous.

I am pleased to present this newsletter highlighting some of the recent innovations coming out of our department. Thank you for taking the time to look through it, and I wish you a healthy and fruitful 2015–16.

Kevin Lynch
Chair and Professor of Mechanical Engineering

Department Welcomes Rubenstein

Mike Rubenstein joined the department in September

An expert in swarm robotics, **Mike Rubenstein** joined the department this September as an assistant professor. He has a joint appointment with Northwestern's Department of Electrical Engineering and Computer Science.

"I am excited to join Northwestern and collaborate with its strong robotics team to create the next generation of robot swarms," Rubenstein said.

Swarm robotics is the design and programming of simple robots to perform complex, collective tasks—similar to ants working together to transport larger objects. As a researcher at Harvard University, Rubenstein designed and built a 1,024-robot swarm, which is the first swarm of this scale. His work on controlling shape formation with his custom-designed Kilobot robots has been featured in *Science*, BBC News, *Wall Street Journal*, *National Geographic*, and NPR. Kilobots are now commercialized and being used by many other research groups around the world, including two groups with more than 900 robots each.

This fall, Rubenstein is teaching a special topics course called "Swarms and Multi-robot Systems," which surveys the state-of-the-art in robotic swarms and challenges students to program swarm behaviors.

Rubenstein is also developing low-cost robots designed for STEM education. The inexpensive, easy-to-use robots are attractive for classrooms and have been used by more than 300 students. For these commercially available robots, Rubenstein won the affordable education robot design challenge, sponsored by the African Robotics Network.

Mike Rubenstein displays his 1,024-robot swarm.

ROBOTICS MASTER'S STUDENTS COMPLETE FIRST YEAR

The first cohort featured students from a wide variety of academic backgrounds

The first Master of Science in Robotics class has successfully completed the one-year, interdisciplinary program, led by the Department of Mechanical Engineering in cooperation with several other departments.

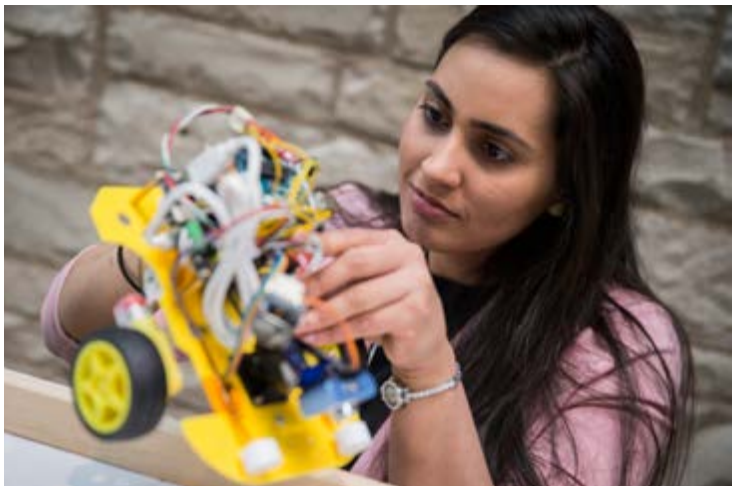
The program, intended to prepare students with a variety of technical backgrounds for careers in robotics, allows students to participate in courses and research spanning mechanical engineering, biomedical engineering, electrical engineering, and computer science.

"We have a wide variety of academic backgrounds in the program, ranging from economics and psychology to physics and computer science," said **Todd Murphey**, associate professor and director of the program. "The cohort model allowed these students to take advantage of their various expertise, enriching both their individual experiences and the program as a whole."

After arriving on campus last September, the 14-student cohort kicked off the program with a robot-programming boot camp. Then they took a variety of robotics courses covering topics such as machine learning, dynamic simulation, robotic manipulation, and embedded systems. In the winter term, each student completed an independent, self-proposed project, many of which can be seen here: **robotics.northwestern.edu**.

Students also participated in research projects, directed by faculty members from across the University and beyond, including the Neuroscience and Robotics Laboratory and the Rehabilitation Institute of Chicago. Projects included research in multi-robot systems, robotic manipulation, haptics, swarm robotics, bio-inspired sensing and control, and prosthetics engineering.

During summer 2015, students either completed the program requirements with a full-time research project or completed external internships at companies such as Disney, Auris Robotics, and Applied Dexterity. Several of the more entrepreneurial students received funding through Northwestern's Summer Accelerator to develop startup companies in the Northwestern Garage (**thegarage.northwestern.edu**)



TOP: *MSR students gain practical experience working with commercial robot systems, such as Rethink Robotics' Baxter robot.* **MIDDLE:** *Students design and build autonomous vehicles in ME 433 Advanced Mechatronics.* **BOTTOM:** *All students engage in individual faculty-directed research projects in labs across the University and at the Rehabilitation Institute of Chicago.*

RESEARCH HIGHLIGHTS

Staying Dry Underwater

Engineers identify how to keep surfaces dry when submerged

What is the ideal "roughness" needed in the texture of a surface to keep it dry for a long period of time when submerged in water? A Northwestern mechanical engineering team has found that the valleys in the surface roughness typically need to be less than one micron in width. That's really small—less than one millionth of a meter—but these nanoscopic valleys have macroscopic impact.

Patankar

Understanding how the surfaces deflect water so well means the valuable feature could be reproduced in other materials on a mass scale, potentially saving billions of dollars in a variety of industries, from antifouling surfaces for shipping to pipe coatings resulting in lower drag. That's science and engineering at work for the benefit of the economy. The research was published in the August 18 issue of *Scientific Reports*.

"The trick is to use rough surfaces of the right chemistry and size to promote vapor formation, which we can use to our advantage," said **Neelesh A. Patankar**, the professor of mechanical engineering who led the research. "When the valleys are less than one micron wide, pockets of water vapor or gas accumulate in them by underwater evaporation or effervescence, just like a drop of water evaporates without having to boil it. These gas pockets deflect water, keeping the surface dry."

The researchers also reported that nature uses the same strategy of surface roughness in certain aquatic insects, such as water bugs and water striders. Small hairs on the surfaces of their body have the less-than-one-micron spacing, allowing gas to be retained between the hairs.

Learning from Biology to Accelerate Discovery

New paper explores the strategies nature employs to achieve different mechanical functions

A spider's web is one of the most intricate constructions in nature, but its precious silk has more than one use. Silk threads can be used as drag-lines, guidelines, anchors, pheromonal trails, nest lining, or even food. And each use requires a slightly different type of silk, optimized for its function.

Keten

"Each type of silk has similar proteins, but they are synthesized differently," said **Sinan Keten**, assistant professor of mechanical and civil engineering. "Then the spider knows how fast to reel the silk to get different properties. Nature is smart. It can tailor a structure to get different mechanical properties."

Spider silk is one biological material that Keten discusses in his new paper "The role of mechanics in biological and bio-inspired systems," published in the July 6 issue of *Nature Communications*. Surveying everything from sea cucumbers and Venus flytraps to human muscles and trees, the review paper broadly explores the strategies that biology employs to create different functions and the mechanics at play within those functions.

Discovering how and why biological systems attain desirable static and dynamic mechanical functionalities often reveals principles that inform new synthetic designs based on biological systems.

Blu-Ray Discs Can Be Used to Improve Solar Cells

Data storage pattern transferred to solar cell increases light absorption

Who knew Blu-ray discs were so useful? A Northwestern Engineering team has discovered that the pattern of information written on a Blu-ray disc works very well for improving light absorption across the solar spectrum. And better yet, the researchers know why.

Sun

Blu-ray discs contain a higher density of data than DVDs or CDs, and the associated quasi-random pattern, perfected by engineers over decades for data storage that offers unique capabilities to control the absorption of solar light. When transferred to the surface of solar cells using nano-imprinting process, the quasi-random pattern provides the right texture to improve the cells' light absorption and performance.

Working with **Cheng Sun**, an associate professor of mechanical engineering, materials science and engineering professor **Jiaxing Huang** and his team tested a wide range of movies and television shows stored on Blu-ray discs, including action movies, dramas, documentaries, cartoons and black-and-white content, and found the video content did not matter. All worked equally well for enhancing light absorption in solar cells. The findings were published in *Nature Communications*.

The overall broadband absorption enhancement of a Blu-ray patterned solar cell was measured to be 21.8 percent, the researchers reported.

"In addition to improving polymer solar cells, our simulation suggests the Blu-ray patterns could be broadly applied for light trapping in other kinds of solar cells," Sun said.

Saving Money and the Environment with 3-D Printing

A new case study finds the method could reduce an airplane's weight by 4 to 7 percent

A Northwestern engineering team has confirmed a new way to help the airline industry save dollars while also saving the environment. By manufacturing aircrafts' metal parts with 3-D printing, airlines could save a significant amount of fuel, materials, and other resources.

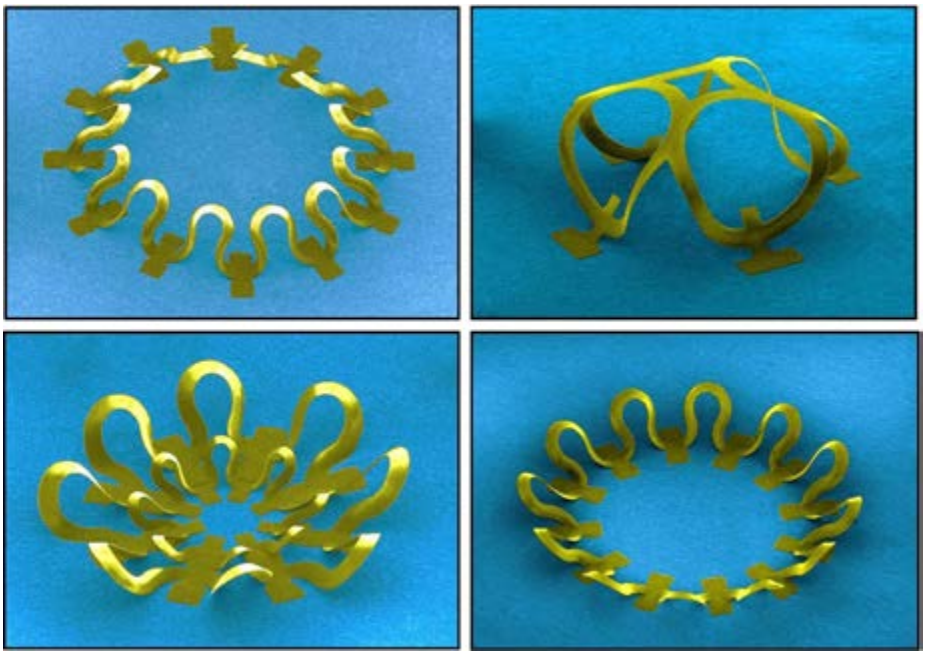
Masanet

Led by **Eric Masanet**, associate professor of mechanical engineering, the team used aircraft industry data to complete a case study of the life-cycle environmental effects of using 3-D printing for select metal aircraft parts, a technique that is already being adopted by the industry. Funded by the US Department of Energy's Advanced Manufacturing Office, the case study is described in a paper published in the May issue of the *Journal of Cleaner Production*.

Conventional manufacturing methods tend to be inefficient and wasteful. To produce a 1-kilogram bracket for an airplane, for example, it requires 10 kilograms of raw material input into the manufacturing process. And, from an engineering design perspective, that final bracket may still contain much more metal than is required for the job. 3-D printing, on the other hand, requires far less raw material input and can further produce parts that minimize weight through better design.

"There are enough parts that could be replaced by 3-D printed versions to reduce the aircraft's weight by 4 to 7 percent," Masanet said.

'POP-UP' FABRICATION TECHNIQUE DEVELOPED



Microscopic pop-up books: structures go from two dimensions to three with a simple "pop!"

New technique trumps 3-D printing

Mechanical engineering researchers at Northwestern and the University of Illinois at Urbana-Champaign have developed a simple new fabrication technique to create beautiful and complex 3-D micro- and nanostructures with many advantages over 3-D printing.

The technique mimics the action of a children's pop-up book—starting as a flat two-dimensional structure and popping up into a more complex 3-D structure. Using a variety of advanced materials, including silicon, the researchers produced more than 40 different geometric designs, including shapes resembling a peacock, flower, starburst, table, basket, tent, and starfish.

Huang

"In just one shot you get your structure," said Northwestern's **Yonggang Huang**, professor of mechanical engineering. "We first fabricate a two-dimensional structure on a stretched elastic material. Then we release the tension, and up pops a 3-D structure. The 2-D structure must have some place to go, so it pops up."

The advantages of the new pop-up method are numerous. The technique is fast and inexpensive, and it can: be used to build many different structures at one time; utilize many different materials, including silicon; incorporate different materials into one hybrid structure; be used to build structures on both micro- and nano-levels (down to a thickness of 100 nanometers); and produce a wide range of different geometries. With 3-D printing, on the other hand, it is difficult to integrate more than one material in a structure; it is almost impossible to print semiconductors or single crystalline metals; and speed is slow.

In a related paper, Huang made strategic cuts in a 2-D material to create more than 50 different, pop-up 3-D structures. Called "Kirigami," the new assembly method is based on an ancient Japanese paper art.

FACULTY NEWS

L. Catherine Brinson has joined Northwestern Engineering's senior leadership team. Effective Sept. 1, she was named associate dean and will focus on the school's professional master's programs.

Wei Chen received ASME's 2015 Design Automation Award from the American Society of Mechanical Engineers. The award recognizes Chen's contributions to the field of design automation, which have advanced both theoretical development and practical applications in many areas, including simulation-based design under uncertainty.

Sinan Keten received a 2015 Young Investigator Award from the Office of Naval Research. The Young Investigator Program is one of the oldest and most selective research advancement programs in the country.

Q. Jane Wang received the 2015 International Award from the Society of Tribologists and Lubrication Engineers. The Society's highest award, it recognizes Wang's contributions to the field of tribology.

RECENT EVENTS

C.D. Mote Jr., president of the National Academy of Engineering, delivered the third annual Jan D. Achenbach Lecture on April 30. Titled "What's coming, whether we like it or not," Mote's talk addressed the need to recognize the direction of the future in order to better plan.

Subra Suresh, president of Carnegie Mellon University and former director of the National Science Foundation, delivered the third annual Ted Belytschko Lecture on September 24. Titled "Cell mechanics in medicine," Suresh addressed recent developments in the application of mechanics, materials science, and physics of biological cells that offer new insights for diagnostics and therapeutics in the context of human cancers, hereditary blood disorders, and infectious diseases.

ALUMNA NAMED MOST POWERFUL WOMAN ENGINEER IN TECH

Gwynne Shotwell ('86) tops *Business Insider*'s list

Gwynne Shotwell

Business Insider magazine recently compiled a list of the "Top 22 Powerful Women Engineers in Tech," and **Gwynne Shotwell**, the president of Space Explorations Technology Corporation (SpaceX), was number one on the list.

Shotwell earned two degrees from McCormick—a bachelor's in mechanical engineering in 1986 and a master's in applied mathematics in 1988. After graduating, she spent more than a decade at Aerospace Corporation, where she quickly moved up the ladder. She joined SpaceX in 2002 as vice president of business development and became president in 2008.

SpaceX designs, manufactures, and launches rockets, and has a contract with NASA to carry supplies to the International Space Station. *Business Insider* said Shotwell is powerful because she "is responsible for day-to-day operations for arguably one of the most exciting companies on the planet, and off it."

NIMSI to Coordinate Manufacturing at Northwestern

On the heels of Northwestern's involvement with the revolutionary Digital Manufacturing and Design Innovation Institute (DMDII)—a $70 million federal investment—the University has launched its own initiative to coordinate research and education efforts associated with manufacturing on campus.

Cao

The Northwestern Initiative for Manufacturing Science and Innovation (NIMSI) aims to facilitate the translation of ideas to impact both mass production of products and emerging hyper-customized and personalized manufacturing. It will do so across a broad spectrum of activities, including design integration, material innovation, novel processes, computational methods, human-machine interfaces, logistics, and economic and employment analysis.

"NIMSI will link our great institutes in energy and sustainability, materials research, policy, and more, with the exceptional faculty in Northwestern Engineering, Weinberg, Feinberg, Kellogg, and elsewhere to create a manufacturing umbrella that enhances our internal structure and external presence," said NIMSI director **Jian Cao**, professor of mechanical engineering and associate vice president for research.

"Our goal is to provide a focal point where Northwestern faculty can come together and where external partners can come establish important connections," she said. "NIMSI will offer an organizational framework that will enhance our abilities to make a local, national, and global impact."

STUDENT NEWS

'Veggie Bot' Wins 2015 Design Competition

The winning team (left to right) Sean Ye, Simon Zhao, and Eric Hao.

A student-designed, autonomous robot named Veggie Bot won the ultimate game of checkers during Northwestern's 24th annual Design Competition. In a feat of dexterity and strategy, Veggie Bot outmaneuvered second-place team Snuggly Bunnies for the $1,000 award.

"Robot Checkers" took place May 23 at the Ford Motor Company Engineering Design Center. During the competition, each robot attempted to pick up two-inch cubes and place them on their team's color in the checkerboard arena. Robots could steal dropped cubes from opponents and earn extra points for stacking cubes.

Teams of undergraduates, representing a variety of engineering fields, spent five months designing, building, and programming their robots to operate autonomously. The winning team included **Eric Hao**, **Adam He**, mechanical engineering undergraduate **Sean Ye**, and **Simon Zhao**.

Team Improv Robotics received the $500 Myke Minbiole Elegant Engineering Award. The award is named for mechanical engineering alumnus and 2001 Design Competition winner Minbiole, who worked as an engineer before being killed in a hit-and-run collision in 2007. Members of Improv Robotics were **Alexander Martin** and **Jonathan Sammon**.

'Lab in a Backpack' Revitalizes Electronics Class

Northwestern-created nScope turns a laptop into an electronics workbench

A new tool is changing the way electronics is taught in the classroom at Northwestern—and its creators offered it to the public this spring through a wildly successful Kickstarter campaign.

Developed at Northwestern, the nScope is a small, portable USB-powered device that turns any laptop computer into an electronics workbench. It provides an oscilloscope, function generator, and power supply all on a small card—allowing users to build, measure, and test electronics and even acquire data onto their computers. Priced at around $100, it's ten times cheaper than the typical electronics workbench but still offers enough functionality that it is useful for both beginners and experts.

Developed by mechanical engineering graduate student **David Meyer**, lecturer **Nicholas Marchuk**, and professor **Michael Peshkin**, the nScope has quickly gained popularity and is now used in several mechanical engineering and biomedical engineering courses at Northwestern. Acknowledging the increasing demand for the nScope, Marchuk and Meyer started a campaign on the crowd-funding site Kickstarter in May. Within days they passed their $25,000 goal to qualify for funding, and the campaign has ended up generating $187,000 from more than 1,700 backers. More information can be found at **nscope.org**.

NEW COURSE MIXES ART AND ENGINEERING

McCormick and Weinberg students collaborated on social practice art

Artists and engineers typically have different ways of viewing a problem: artists want to explore it, while engineers want to solve it.

At Northwestern, faculty are working to break down this type of conventional thinking to help students look at problems in new ways. A new course offered last fall called Artists and Engineers Collaborate brought together students from both the McCormick School of Engineering and the Weinberg College of Arts and Sciences to collaborate and learn each other's cognitive styles.

Sponsored by the Barry and Mary Ann MacLean Fund for Art & Engineering, the course was co-taught by Northwestern Engineering's **Malcolm MacIver**, associate professor of mechanical engineering, and **Jeanne Dunning**, artist and professor of art theory and practice in Weinberg.

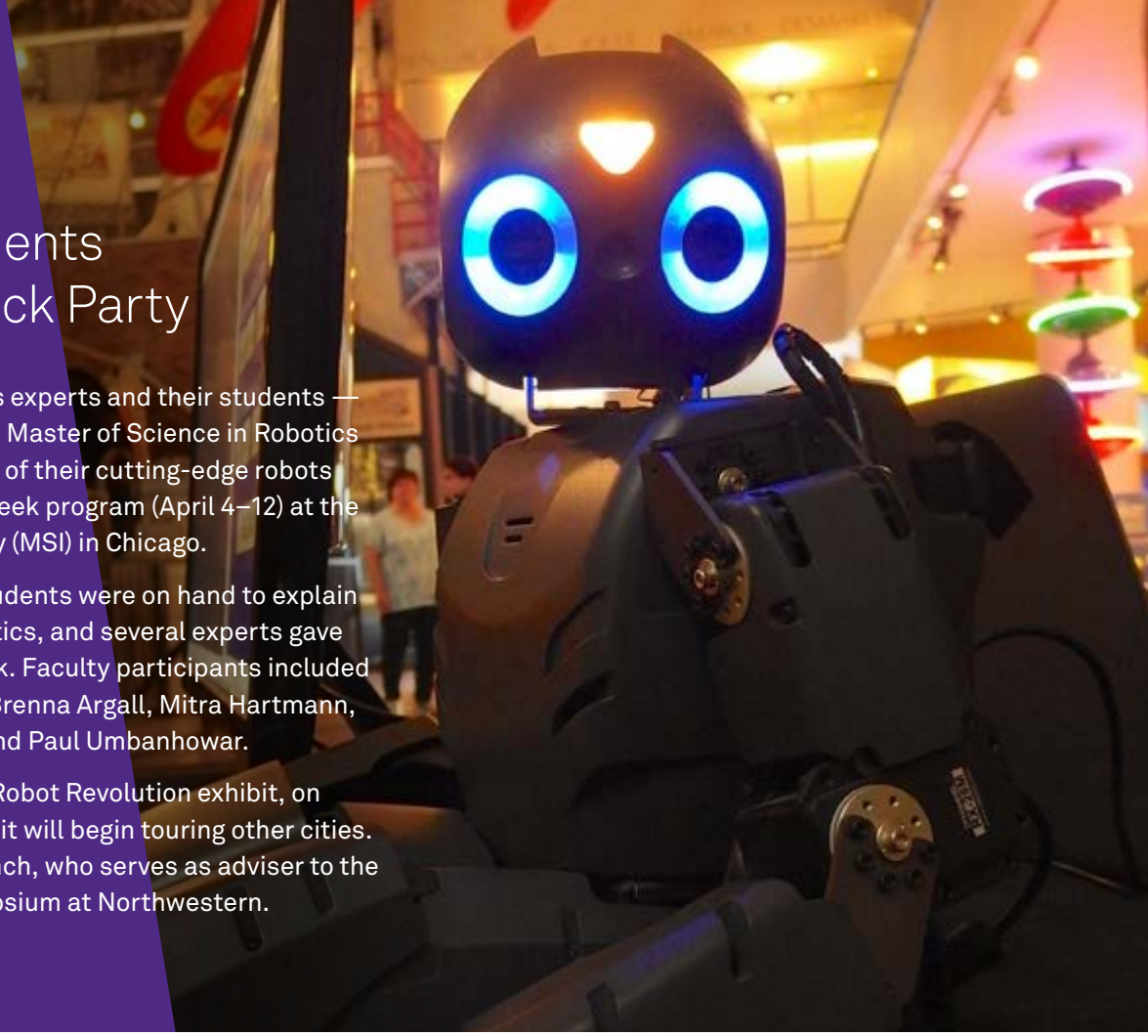
MacIver and Dunning asked the class to study social practice art, a medium that combines practicality and usefulness with aesthetics for the purpose of social engagement. "There is a vast diversity of kinds of art," MacIver said. "We wanted to choose something that was most appropriate for a collaboration with engineers. The useful component of social practice art brings to mind engineering and design."

Interdisciplinary groups converged and collaborated to design four projects: ShuttleTalk, a smartphone app that facilitates social interaction among riders on the intercampus shuttle; Spectrum, a collaborative game that helps non-autistic workers better understand their autistic colleagues; SpeakUp!, public interventions that promote awareness of street harassment; and Bable, a bench/table hybrid that encourages students to work outside.

Created in the class, the Spectrum game emphasizes shapes and pattern matching to play to the strengths of individuals with autism.

BACK PAGE

Faculty and Students Hit the Robot Block Party



Mechanical engineering robotics experts and their students — including students from the new Master of Science in Robotics program — demonstrated some of their cutting-edge robots as part of a National Robotics Week program (April 4–12) at the Museum of Science and Industry (MSI) in Chicago.

Undergraduate and graduate students were on hand to explain the "behind the scenes" of robotics, and several experts gave short presentations of their work. Faculty participants included department chair Kevin Lynch, Brenna Argall, Mitra Hartmann, Todd Murphey, Jarvis Schultz, and Paul Umbanhowar.

In May, the MSI kicked off their Robot Revolution exhibit, on display until January 2016 when it will begin touring other cities. On the exhibit's opening day, Lynch, who serves as adviser to the exhibit, hosted a robotics symposium at Northwestern.

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