Northwestern | McCORMICK SCHOOL OF ENGINEERING

FALL 2016

MECHANICAL ENGINEERING

WHISKERS SHED LIGHT ON HOW NEURONS COMMUNICATE TOUCH

Researchers use rat whiskers to understand how neurons encode touch

Because human and rodent brains process touch in similar ways, the rodent whisker system has been used to study the sense of touch since 1909.

Rodents use their whiskers — essentially long, thick hairs — as touch sensors to explore their environment. While hundreds of papers are published each year that use the whisker system to study sensorimotor processing, crucial aspects of the information transfer from whiskers to the brain have remained unresolved.

"Specialized cells convert touch information from the whiskers into electrical signals that the brain can interpret," said Professor **Mitra Hartmann**. "But exactly what information is represented electrically by these primary sensory neurons has been unclear."

Now Hartmann and her team are bringing the world closer to an answer. In a recent study, they discovered that whisker sensory neurons encode information about the forces and torques at the whisker's base. This finding could resolve fundamental questions about how touch is represented and processed by neurons in both the rat and the human brain.

Mitra Hartmann

The research, published in August in the journal *eLife*, brought together an interdisciplinary team that spanned five Northwestern departments. The study had two co-first authors: Nicholas E. Bush, a PhD student in the Interdepartmental Neuroscience Program (NUIN), and Christopher L. Schroeder, a recent PhD graduate in biomedical engineering. Co-senior author Professor Sara A. Solla guided the mathematical analysis of neural responses.

The study's goal was to resolve whether touch-sensitive neurons in the whisker system encode kinematic or kinetic information, a distinction that has historically posed a major challenge.

Continued on page 3

Department Ranked Third in US, Fourth in World

Northwestern's Department of Mechanical Engineering was ranked as the fourth best mechanical engineering department in the world by ShanghaiRanking's Global Ranking of Academic Subjects.

ShanghaiRanking has been ranking universities and engineering schools since 2003, but this is the first year it has ranked individual engineering departments.

Rankings are based on third-party data and include measures of research productivity, high quality research, average global research impact, extent of international collaboration, extent of academic-corporation collaboration, researchers with global academic influence, and academic awards.

"While no ranking can fully capture the performance of a department, it is nice to see the research productivity of our faculty and students recognized this way," said Department Chair **Kevin Lynch**.

FROM THE CHAIR

Dear Friends and colleagues,

Recognition continues to come in for the outstanding educational experience provided by our department. In May, **Liz Gerber** and **David Gatchell** were two of five Northwestern faculty members to receive the three-year Charles Deering McCormick Professorship of Teaching Excellence, Northwestern's highest teaching honor (see page 2). They join **Walter Herbst**, **Todd Murphey**, and **Neelesh Patankar** as a McCormick Professor, meaning that mechanical engineering faculty currently hold five of the 15 McCormick Professorships across the entire University. No other single department has more than two McCormick Professors. Other past mechanical engineering recipients include **Ed Colgate**, **Rich Lueptow**, **Michael Peshkin**, and myself.

Continuing the good news, **Yonggang Huang** and **Alex Birdwell** were respectively chosen as the outstanding teacher and adviser in the engineering school for 2015-16 (page 2).

The women faculty in the Department of Mechanical Engineering feature prominently in this newsletter. Approximately one quarter of our tenure-line faculty are women, and you can find news items featuring the accomplishments of **Brenna Argall** (page 6), **Cate Brinson** (page 6), **Jian Cao** (page 6), **Wei Chen** (pages 4 and 6), **Liz Gerber** (pages 2 and 6), **Mitra Hartmann** (page 1), and **Jane Wang** (page 7).

This past summer **Mitra Hartmann** and **Malcolm MacIver** were promoted to full professor. This fall, Malcolm is co-teaching an innovative new course at the intersection of art and engineering entitled "Risk," focusing on human-centered design to address societal challenges. Courses such as Malcolm's advance Northwestern Engineering's "Whole-Brain Engineering" initiative.

My deepest congratulations to **Zdeněk Bažant**, who was awarded the Austrian Cross of Honor for Science and Art from Austrian President Heinz Fischer in May. **Jan Achenbach**, past winner of the National Medal of Science and the National Medal of Technology, will receive Sigma Xi's 2016 William Procter Prize for Scientific Achievement in November.

Our young faculty continue to excel, too, with **Brenna Argall** receiving the NSF CAREER award and **Sinan Keten** (page 5) receiving the Young Investigator Award from ONR and the Office of the Naval Director of Research Early Career Award. Sinan was also promoted to associate professor with tenure.

We are excited to welcome **Ken Park** to the department starting January 1 (page 3). Also joining the department with a courtesy appointment is **John Rogers**, who will lead the new Center for Bio-Integrated Electronics. John is the recipient of a MacArthur fellowship and a member of the National Academy of Engineering, National Academy of Science, and National Academy of Inventors. He joins Northwestern from the University of Illinois at Urbana-Champaign.

I am pleased to present our fall 2016 newsletter. Please accept my best wishes for a healthy and fruitful 2016-17.

Kevin Lynch
Department Chair

Excellence in Teaching

In May 2016, Associate Professor **Elizabeth Gerber** received the Charles Deering McCormick Associate Professor of Teaching Excellence award, and Clinical Associate Professor **David Gatchell** received the Charles Deering McCormick Distinguished Clinical Professor award. Gerber was praised by her students for her teaching in human-centered design, inspiring them to take an active role in changing the world for the better. Gatchell was cited for driving his students to identify their passions and realize their potential.

Elizabeth Gerber

David Gatchell

The three-year McCormick Professorships are the highest teaching honor conferred by Northwestern.

Alex Birdwell and Yonggang Huang

Currently, five out of 15 McCormick Professors across the entire University are from mechanical engineering.

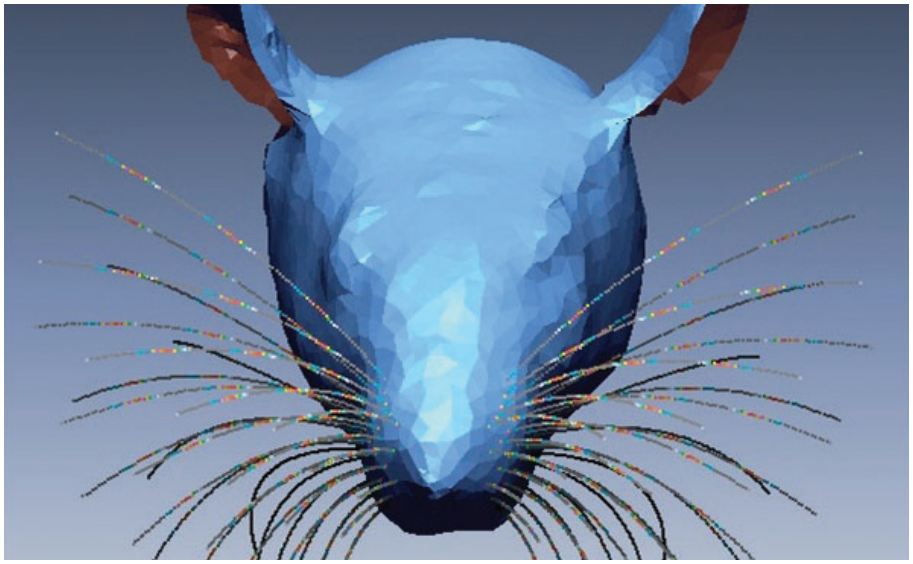
Recognition for mechanical engineering faculty teaching excellence continued in September, when Professor **Yonggang Huang** received the Cole-Higgins Award for Excellence in Teaching, and Assistant Professor of Instruction **Alex Birdwell** received the Cole-Higgins Award for Excellence in Advising.

Recent Events

J.N. Reddy, the Oscar S. Wyatt Endowed Chair of Mechanical Engineering at Texas A&M University, delivered the Simpson Lecture on April 13. Reddy talked about his research in mechanical engineering in a lecture titled "On Non-local and Non-classical Continuum Mechanics Theories in Solid Mechanics."

Mary C. Boyce, dean of engineering at Columbia University, delivered the fourth annual Jan D. Achenbach Lecture on April 19. Titled "Solid-State Mechanics of Soft Composites: The Interplay Between Geometrical Structuring and Large Deformation to Achieve Novel Behavior," Boyce's talk addressed her work in the field, which led to innovative hybrid designs with novel properties.

Whiskers, continued



A model array of rat whiskers.

When a whisker brushes against an object, it moves in a particular direction, by a particular amount, and at a particular speed. Together, these features are known as kinematic properties. Kinetic properties, on the other hand, refer to the contact forces and torques at the whisker base. In the whisker literature, these kinetic variables are referred to as "mechanical variables."

"It has been challenging to characterize neural responses because kinematics and kinetics are so tightly coupled," Hartmann said. "This coupling is especially strong when whisker motion is small and stimulation is delivered near the whisker base — exactly the type of stimulation that has typically been used to date."

HARTMANN'S TEAM DEVELOPED A NOVEL WHISKER STIMULATION PARADIGM TO DECOUPLE KINEMATIC AND KINETIC VARIABLES.

Hartmann's team developed a novel whisker stimulation paradigm to decouple kinematic and kinetic variables. Solla then guided mathematical modeling that exploited this decoupling to characterize the neural encoding of tactile information. The team found that the electrical activity of whisker touch neurons was more accurately predicted by the kinetics rather than the kinematics of whisker-object contact. "This has been a long-standing discussion in the field," Solla said. "We hope this becomes the unified, accepted view of how touch is processed."

DEPARTMENT WELCOMES KEN PARK

Kyoo-Chul (Kenneth) Park will join Northwestern's Department of Mechanical Engineering as an assistant professor in January 2017.

Park is currently a research associate at the John A. Paulson School of Engineering and Applied Sciences and the Wyss Institute for Biologically Inspired Engineering at Harvard University, where he earned the Harvard Postdoctoral Award for Professional Development. Before joining Harvard, he received his PhD from the Massachusetts Institute of Technology, where he received the Wunsch Foundation Silent Hoist and Crane Award for Outstanding Graduate Research.

Park's research focuses on interdisciplinary studies of biologically-inspired interfacial thermofluidics and its applications in the field of surface design for new functions and a sustainable future. His research interests include fundamental studies of hydrodynamic and thermal interactions of droplets, bubbles, and particles with surfaces, with the goal of engineering multiple length scale functional surfaces. In particular, he is interested in water collection and treatment as well as relevant energy and environmental research.

Kenneth Park

AWARD-WINNING DESIGN RESEARCH

Wei Chen wins best paper award, chairs international design conference

Professor Wei Chen's work in design is honored once again by a prestigious ASME best paper award.

Her research on the design of engineered material systems has received the Design Automation Best Paper Award from the American Society of Mechanical Engineers for the third time in the past six years.

Chen's most recent award-winning work specifically examines quasi-random nanostructured material systems (NMS), which are emerging engineered material systems that can be fabricated with cost-effective, scalable, bottom-up processes. First authored by PhD student **Shuangcheng Yu**, the research was completed in collaboration with Professors **Cheng Sun** and Teri Odom.

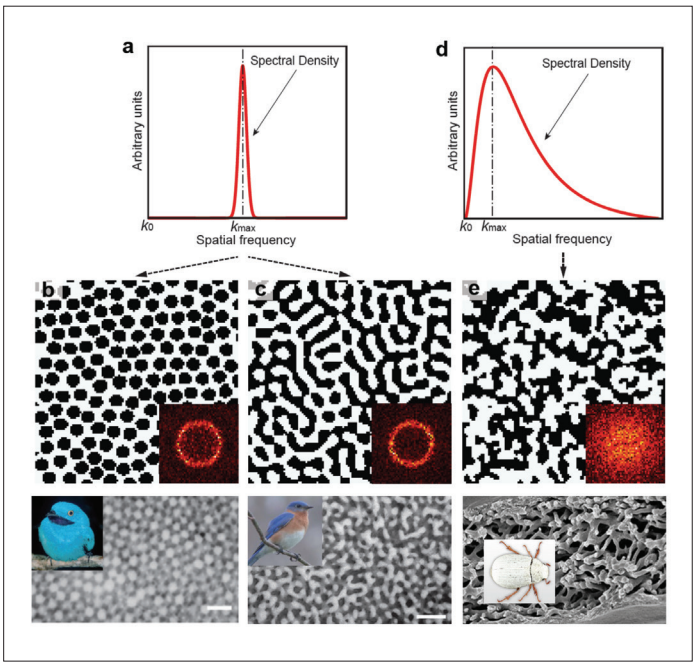
Chen and her research team proposed a novel design methodology for designing quasi-random NMS that concurrently optimizes the nanostructure and designs the corresponding nano-manufacturing conditions of a bottom-up process. The methodology employs a non-deterministic microstructure design representation rooted in the spectral density function to provide a low-dimensional and informative design representation that bridges the gap between processing-structure and structure-performance relationships. Ultimately, the process enables fast explorations of optimal fabricatable microstructures and exploits the stochastic nature of manufacturing processes.

The Wilson-Cook Professor in Engineering Design, Chen has made groundbreaking contributions to the use of statistical techniques and computational methods for design of engineered material systems. In collaboration with Northwestern experts in mechanics, materials, and nano-manufacturing, Chen's team has developed a systematic computational design framework that provides a seamless integration of material characterization, design optimization, predictive materials modeling, processing and manufacturing, and data and informatics to enable accelerated design and development of advanced materials systems.

Chen applied her design expertise to this year's International Conference on Design Computing and Cognition, when she chaired the organizing committee. The conference brought together nearly 130 researchers in artificial intelligence, cognitive science, and computational theory of design.

Wei Chen

CHEN HAS MADE GROUNDBREAKING CONTRIBUTIONS TO THE USE OF STATISTICAL TECHNIQUES AND COMPUTATIONAL METHODS FOR DESIGN OF ENGINEERED MATERIAL SYSTEMS.



Computational methods for optimizing quasi-random nanostructures

RESEARCH HIGHLIGHTS

Masanet Uses Sabbatical to Combat Climate Change

Professor leads International Energy Agency's Energy Demand Technology Unit

Last December, representatives from 195 countries converged at the United Nation's Conference on Climate Change (COP21) in Paris. There, they reached a landmark agreement that is believed to be a historic turning point for combating climate change. Called the "Paris Agreement," it is the most significant international deal to reduce global warming since the issue first emerged.

Masanet

The agreement's arguably most ambitious goal is to limit the global temperature rise to well below 2 degrees Celsius. Associate Professor **Eric Masanet**'s modeling team is crunching numbers to help governments explore ways of getting there.

Currently spending his sabbatical with the International Energy Agency (IEA) in Paris, Masanet also participated in several COP21 side events. He leads the IEA's Energy Demand Technology Unit, which is addressing some of society's most pressing challenges by identifying clean energy technology pathways and policies that can help limit global temperature rise.

"The Paris Agreement sets very ambitious goals," said Masanet, Morris E. Fine Junior Professor in Materials and Manufacturing. "It will require major shifts in energy systems, behavior, and development pathways over the next two-to-three decades in all world regions."

Light-powered 3-D Printer Creates Terahertz Lens

The new lens could be used for biomedical research and security imaging

Associate Professor **Cheng Sun** and his team have used metamaterials and 3-D printing to develop a novel lens that works with terahertz frequencies. Supported by the National Science Foundation, the work was published online on April 22 in the journal *Advanced Optical Materials*.

The lens could make terahertz imaging, which is particularly useful for security, cheaper, higher resolution, and more available.

Sun

While x-rays can detect metal, they cannot detect plastic or chemicals. Terahertz scanners, however, can detect both materials to discover concealed weapons, biological weapons such as anthrax, and plastic explosives. And unlike x-rays, terahertz radiation is completely harmless to humans.

There are two major factors that made this new lens possible. First, it is made from a novel metamaterial that exhibits properties not readily available in nature. Second, the lens was manufactured with a 3-D printing technique called projection micro-stereo-lithography. The technique enables a scalable, rapid, and inexpensive way to produce the tiny features that are needed for the lens to operate at the terahertz frequency band. The printing technology allowed the researchers to fabricate the metamaterial to precisely fit their designs.

Preventing Protein Unfolding

Polymers can reinforce proteins under mechanical stress

Associate Professor **Sinan Keten** has theoretically demonstrated that small proteins can be reinforced with covalently bonded polymers against mechanical unfolding.

Keten

His computational model illustrates strategies for using this polymer conjugation to prevent proteins from rapidly unfolding even when stretched or pulled apart. Keten's research was featured on the cover of *ACS Nano* in February.

A protein's shape is related to its function. By coiling and folding into specific three-dimensional shapes, they are able to perform their different biological tasks. Proteins are held together by weak hydrogen bonds. When they unfold, these bonds break and are often replaced by hydrogen bonds with water. "Once the water is in there, it's hard to reverse the process," Keten explained.

Keten and his team members **Elizabeth DeBenedictis** and **Elham Hamed** used a common protein structure, called an alpha helix, and a soft, nontoxic polymer called poly-ethylene-glycol to test the reinforcing strategy under mechanical forces. They found that, through hydrophobic and electrostatic interactions, the polymer can reside near the surface of the protein. This shields its backbone hydrogen bonds from being replaced by bonds with water molecules, enabling the protein to hold its specific shape much longer under constant stress.

"The protein can refold back to its original configuration more easily," he said. "When the polymer is close to the surface, you see more refolding."

FACULTY NEWS

The Big Ten Network and Crain's Chicago Business profiled **Brenna Argall** and her work to develop robotics for rehabilitation.

Cate Brinson and **Wei Chen** received a new grant to help fund NanoMine, an online platform of material genome prediction for polymer nanocomposites. The NanoMine's database infrastructure uses the Materials Data Curator, developed at the National Institute of Standards and Technology under the objective of the Materials Genome Initiative.

Jian Cao received the 2016 Frederick W. Taylor Research Medal from the SME. Cao is the first woman to receive the prestigious research award since it was established in 1957.

Zdeněk P. Bažant received the Austrian Cross of Honor for Science and Art, First Class, from the president of Austria. He received the award from President Heinz Fischer at a ceremony in Hofburg Palace in Vienna.

Elizabeth Gerber received the Elizabeth Hurlock Beckman Award, which recognizes faculty who have inspired their former students to create an organization that demonstrably confers a benefit to the community at large.

Founded by **Ed Colgate** and **Michael Peshkin**, Tanvas, a company working to commercialize tactile display technology, received an "Up-and-Comer" Award at the 14th annual Chicago Innovation Awards.

FACULTY PUBLISH NEW MECHATRONICS TEXTBOOK

Book is based on the ME 333 curriculum

Professor **Kevin Lynch** has taken mechatronics out of the lab and put it into the library.

In December, the Newnes publishing group (an imprint of Elsevier) released *Embedded Computing and Mechatronics with the PIC32 Microcontroller*, a new textbook written by Lynch, chair and professor of mechanical engineering, lecturer **Nick Marchuk**, and PhD student **Matt Elwin**.

Inspired by his love for robotics and interest in microprocessors, Lynch developed the elective course ME 333: Introduction to Mechatronics in 1999. As the course evolved over the years to include new knowledge and lab exercises, he could not find a textbook that could keep up. So Lynch and his team decided to write their own.

Based on the curriculum in ME 333, the new textbook covers fundamental topics in mechatronics, such as circuits, sensors, signal processing, motors, and feedback control. It also explores the hardware and software of the PIC32 microcontroller and its applications in mechatronics, including the development of microprocessor-controlled electromechanical systems with sensors and actuators.

The book uses three assets developed at Northwestern: the NU32 microcontroller development board, the nScope portable oscilloscope and function generator, and the Northwestern Lightboard, which was used to create 80 instructional short videos available on YouTube to augment the written material.

Links to the videos and other book materials can be found at nu32.org.

Rick Marzec Named McCormick STAR

Marzec was recognized with the second annual staff award

Rick Marzec, senior user support specialist in the Department of Mechanical Engineering, was recognized with the second annual STAR Award at a staff recognition ceremony.

The STAR Award, which stands for Staff Team Appreciation and Recognition, is an annual honor that recognizes a staff member who goes above and beyond regular job responsibilities. Marzec was nominated for his responsiveness, depth of knowledge, and positive attitude.

"The department considers him an 'invisible hero,'" the nomination stated. "Rick inspires staff and faculty to give 100 percent and to be great at every part of our jobs. He leads by example."

STAR Award winner Rick Marzec stands with Dean Julio M. Ottino.

STUDENT NEWS

PhD Team Wins BASF Science Competition

A team of Northwestern PhD students has won a nationwide science competition put on by the chemical company BASF that challenges young academic researchers to answer a major global challenge through creativity and problem solving.

This year's competition asked teams to develop a synthetic fluid that meets the performance requirements for high-efficiency vehicles.

Three mechanical engineering PhD students — **Blake Johnson**, **Jie Lu**, and **David Pickens** — along with chemistry PhD student Michael Desanker comprised Northwestern's winning team. Mechanical engineering Professors **Q. Jane Wang** and **Yip-Wah Chung** and chemistry professor Tobin Marks served as the group's scientific advisers.

The team's solution centered on attaching borate ester compounds to the double-bonded area of polyalphaolefin (PAO) oligomers found in a synthetic lubricant's base oil. The treated PAO oligomers were then combined with untreated PAO oligomers and additives to form a mixture that is optimized for lubricant-based uses.

EDI Class Helps Reimagine Laundry

Northwestern Engineering students recently worked with Procter & Gamble to help design Tide Spin, an app-based service that outsources laundry to professional cleaners at Tide dry-cleaning facilities.

To help design the app, students in the Engineering Design and Innovation (EDI) program observed people doing their laundry, interviewed potential users, studied interpersonal dynamics of people doing others' laundry, prototyped potential environments, and tested logistics.

The first laundry service backed by a national brand, Tide Spin sends the laundry to its own dry-cleaning facilities, which are staffed by trusted, Tide-trained professionals. The service is currently being tested in Chicago. Not only did Tide benefit from the hard work of EDI's students, but the students gained valuable insight into the complexity of designing services.

"This project was a good fit for our class because it demanded an understanding of not only product design but also service design," said Associate Professor **Elizabeth Gerber**, who co-taught the class. "To be a great designer today, one needs to understand the interdependencies of these complex systems."

Graduate Students Receive Fellowships

Elizabeth DeBenedictis (Keten) and **Stephen Lin** (Wagner) received NSF Graduate Research Fellowships. **Puikei Cheng** (Liu), **Tucker Kearney** (Chen), and **Yves Nazon** (Rouse) received honorable mention.

Elizabeth DeBenedictis (Keten) and **Katie Fitzsimons** (Murphey) received National Defense Science and Engineering Graduate Fellowships.

Ebot Etchu Ndip-Agbor, **Huaqing Ren**, and **Zixuan Zhang** — all students working with Jian Cao and Kornel Ehmann — received DOE Energy Efficiency and Renewable Energy Research Fellowships.

Department Honors Undergraduates

Every year at graduation, the Department of Mechanical Engineering honors outstanding seniors with three awards.

Matthew Collins, **Angela Yang**, and **Preston Wang** received Academic Achievement Awards for being model students in the department. While typically only one student receives this award, this year the faculty committee was so impressed by the competition that they decided to award it to three students.

Spencer Gellman won the assistant chair's annual multi-media contest.

Matthew Collins and **Jane Miller** received Undergraduate Leadership and Service Awards. Collins was honored for his leadership on the "Gibbot" project, which created a robot that locomotes by swinging much like gibbons swing through the trees.

A founding member of the robotics club, Miller was honored for serving as the club's president and leading several project teams. She also led a group that developed and delivered demonstrations to children at the Chicago Museum of Science and Industry on how motors work.

Preston Wang received the Undergraduate Research and Innovation Award for his invaluable contributions to the Northwestern Formula Racing team and for leading the mechanical design of the Gibbot project.

Northwestern | McCORMICK SCHOOL OF ENGINEERING
Mechanical Engineering

Technological Institute
2145 Sheridan Road
Evanston, Illinois 60208-3100

Space for Innovation

To be truly innovative, mechanical engineers need the tools, equipment, and space to realize their biggest ideas. The Department of Mechanical Engineering provides cutting-edge facilities across the Technological Institute, including the LEED Silver-certified Willens Wing and the Ford Motor Company Engineering Design Center.

Also LEED Silver-certified, the Ford building is home to the Rapid Prototyping Lab, Mechatronics Lab, and Prototyping and Fabrication Lab, which house fabrication machinery and prototyping equipment in a safe, collaborative environment where dreams and ideas can flourish.

Not only do these labs provide the tools for students to express their creativity, but these facilities also allow students to do so on their own time. The Mechatronics Lab and Prototyping and Fabrication Lab are open 24-hours a day, 7 days a week, so students can take advantage of bursts of creativity whenever they strike.