SUMMER 2018

MECHANICAL ENGINEERING

UNIVERSITY OF WISCONSIN-MADISON

‘MACHINE’ LEARNING EMPOWERS CREATIVITY

Photo: Renee Meiller

CHAIR'S MESSAGE

Jaal Ghandhi

Greetings!

I am excited to share with you this snapshot of the latest news from the department. The past academic year has seen a number of milestones reached by our students and faculty. The College of Engineering has held its own spring graduation ceremony for the past five years or so, and ME students have been chosen to give the graduation address on multiple occasions. This year's address was given by Jacob Anderson, who has overcome some incredible obstacles to graduate. During his sophomore year, Jacob was injured in a diving accident in Lake Mendota that left him paralyzed from the neck down, with some limited motion in one hand. In his address, he discussed the mental and physical struggles he dealt with in order to return to campus to complete his degree last fall. It is an incredible story and a compelling speech that I invite you to view on the ME website: **www.engr.wisc.edu/me**.

In faculty news, the Society of Automotive Engineers recognized Assistant Professor Sage Kokjohn with both the Teetor Education Award and the Max Bentele Award for Engine Technology Innovation. In addition, he will be starting a new ARPA-e project that will push the boundaries of energy conversion efficiency using a coupled fuel cell and internal combustion engine; we will give more detail in a future issue. Professor Melih Eriten, who was recently promoted to associate professor, won a National Science Foundation major research instrumentation grant that has enabled him to purchase a multi-point laser vibrometer. This system provides detailed vibration data simultaneously at 40 unique locations. The vibrometer, which is the only system of its type in the United States and one of two installed worldwide, will open the doors to incredible new insights.

Thank you for your continued support and engagement, and be sure to like us on Facebook and follow us on Twitter via the handle @UW_MechEngr to stay involved with all the happenings in the department.

ON, WISCONSIN!

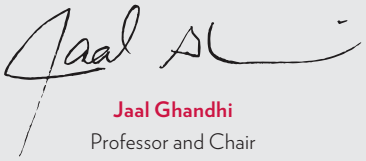

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Photo: Renee Meiller

New makerspace helps students visualize creations

For her *Design of Orthopedic Implants* course, Associate Professor Heidi Ploeg is harnessing cutting-edge learning technology in the College of Engineering's new makerspace, the Grainger Engineering Design Innovation Laboratory. Students are using the makerspace's enormous interactive touchscreen and virtual reality headset to study bone joint anatomy.

Read more: **www.engr.wisc.edu/new-makerspace-helps-students-visualize-creations/**

AFTER AN EXCEPTIONAL CAREER, ALUM SHOWS APPRECIATION WITH ESTATE GIFT

When Tom Jehn graduated debt-free from UW-Madison in 1970 with a bachelor's degree in mechanical engineering, he didn't yet know just how much his education would lead to a successful career. Today, nearly 50 years later, Jehn is a decade into a comfortable retirement alongside his wife, Heidi, and can look back at his life and see the impact his training at Madison has had. The Jehns are recognizing that impact by extending it to a new generation of Badger engineers with an estate gift to the department's annual fund. The Jehns hope the gift will help more students graduate without debt—a much more difficult prospect today than it was in 1970.

"Everything I have achieved is due to my education," says Jehn, who over the years has amassed an abundance of professional and personal achievements with the help of his engineering skills.

The first two decades of his career included various engineering and management positions at Wisconsin manufacturing companies, as well as a return to UW-Madison for a master's degree in mechanical engineering. Then in the early 1990s, Jehn was recruited by Bretting Manufacturing in Ashland, Wisconsin. A lifelong outdoors enthusiast, Jehn says he jumped at the opportunity to live on the shore of Lake Superior in rural northern Wisconsin. He worked for Bretting as director of engineering and as Geschaeftsfurer (general manager) of Bretting's German subsidiary, Serv-O-Tec, in Langenfeld, Germany, until his retirement in 2005. Jehn's affinity for the outdoors has flourished in the 13 years since.

"After spending 35 years at a desk inside, my goal in retirement is to be outside as much as I can," Jehn says.

After a successful career, alumnus Tom Jehn is spending much of his retirement outdoors. Among his outdoor pursuits, Jehn trains bird dogs, as seen here with his English Setter, Max. *Submitted photo.*

In the warmer months, he makes frequent excursions from his home in Elkhart Lake, Wisconsin, to hunt, fish, camp and simply spend time outside in Wisconsin's state and national forests. In the winter, he and Heidi reside in Florida to be near their son, Carl, also a UW-Madison graduate (BS '98, DVM '02), and Carl's family and spend more time recreating outdoors in the mild climate. Dovetailing with his outdoors interests, Jehn has taken up a hobby training bird dogs. He first took to the hobby when his son was young and asked for a pet dog.

"I thought I'd get a dog that could hunt too," Jehn says. "So, we got a German Shorthair, and that dog turned out to be one of the best dogs I've ever had. I won a whole bunch of dog field trials with it."

Jehn has since been involved in similar competitions as he's continued to train a new dog every two to three years. He's also put his engineering skills to use in redesigning and rebuilding a large cargo van into a "rolling hunting shack" that includes dog kennels and a living space. The Jehns have taken on similar redesign and rebuilding projects at their homes in Elkhart Lake and Florida as well. "Being able to apply engineering skills to real-life applications at work and at home has made me appreciate my education," Jehn says.

That appreciation for a quality education which didn't break the bank is the Jehns' primary motivator for establishing the estate gift.

"We are a family where education is very important," says Heidi, who graduated from UW-La Crosse. "This gift is important to my husband and to me. It gives us some peace of mind knowing that we're helping out with somebody else receiving an education."

The UW experience was great for him, Tom adds, noting that he would like to see more investment in public education. "I want to help others achieve that experience without having to go into debt," he says. "If I can help achieve that goal for others, as well as support the professors in the department, I'll be happy."

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IN REVITALIZED ROBOTICS COURSE, LEARNING IS FAR FROM AUTOMATED

The classroom was abuzz with activity as small groups of students huddled around their robots. The robots, which resembled small, motorized chariots, jolted to life and began driving various routes across the floor of the spacious, newly remodeled classroom in the Wendt building.

The goal: to "teach" the robots to follow a specific path as they move.

For many of the teams in Assistant Professor Peter Adamczyk's *Introduction to Robotics* course in fall 2017, the first attempt didn't go as planned. Some robots veered and spun back and forth rapidly. Others whirled until they collided with furniture.

As he circled around the room, Adamczyk fielded questions from students as they worked to troubleshoot issues with their robots. These in-class interactions between the instructor and students spark many fruitful discussions and "a-ha" moments, Adamczyk says.

This kind of active, hands-on learning is precisely what Adamczyk had in mind when, soon after joining the faculty, he began a significant undertaking in 2016 to completely reinvent the *Introduction to Robotics* course.

Noting that robotics is fundamentally about "doing," Adamczyk structured the course to focus largely on practical aspects of robotics and hands-on activities. He teaches the class for seniors and graduate students in a blended learning format: Students watch video lectures, complete and submit homework, and take quizzes, all online; while in class, they work in teams and use modern, low-cost hardware and open-source software to build and interact with robotic systems during almost every class period.

By also teaching some practical skills for mechanical assembly and working with electronics, he aims to empower students to become makers. In class, the students assemble their own robots from components including motors, wheels, ultrasonic sensors, free wires and circuit boards. "The course gives students a unique opportunity to build whole systems and physically interact with them, and they really find that valuable," he says.

Students in the *Introduction to Robotics* course build mobile robots (pictured above) for hands-on activities during class. Assistant Professor Peter Adamczyk completely reinvented the course in 2016.

"Because the students have spent some problem-solving effort on these things before finally raising their hand and asking for help, they realize the importance of these solutions and gain a deeper understanding than if I just told them a problem and then gave them the answer," Adamczyk says.

Adamczyk selected a low-cost development platform so students could afford to keep using these tools after completing the course. "My vision for the course was to focus less on theory and do some things that students can really take and run with on their own," he says.

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The course culminates in a final project. Working in teams, students choose their own advanced robotics projects that build on their prior work. These projects have included: a poster-drawing robot; robots that play tic-tac-toe and Connect Four; robots that navigate while avoiding obstacles; a teach-and-repeat robot arm; and a robot that played a guitar. "For many, the final project is the point where they really come to own their knowledge," Adamczyk says.

To introduce students to the key concepts and tools underpinning robotic systems, Adamczyk designed the course to focus on two major areas: mobile robots and kinematic

Students work in teams to "teach" their mobile robots to follow a specific path during the *Introduction to Robotics* course in fall 2017.

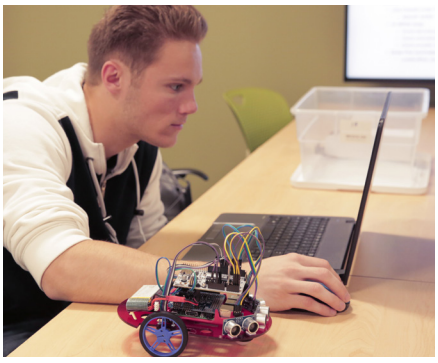
control of robot arms. "The field of robotics is broad and changing fast, but almost everything has some mobile aspect and some manipulator aspect, so I wanted to hit on those areas," he says.

However, Adamczyk says there isn't a standard textbook or curriculum that covers these areas at a level that's appropriate for this course. So, with support from an education innovation grant from UW-Madison, Adamczyk created all the course material from scratch.

He says all that work was worth it given the enthusiastic and positive response from students. The second time the course was offered, the enrollment nearly doubled.

"Students have called it their favorite class ever," Adamczyk says. "Robotics is everywhere these days, and students really want to learn this stuff."

Watch video: www.engr.wisc.edu/revitalized-robotics-course-learning-far-automated/



FOCUS ON NEW FACULTY:

STEPHAN RUDYKH, DEVELOPING DESIGN RULES FOR FINE-TUNED MATERIALS

The microstructure of a material may be small, but it can have a big impact on the material's overall performance.

Take, for example, the strength of the steel members of a bridge or the vibration-damping properties of a golf club's graphite shaft.

Nearly all of a material's physical properties depend on its microstructure—a structure larger than the atomic scale but small enough that a microscope is needed to discern it.

And the good news is that it's possible to tweak that microstructure.

In his research, Stephan Rudykh investigates how controlling and arranging the microstructures of materials in different ways can dramatically change a material's overall properties and functionality.

"By understanding how we can arrange microstructures in certain ways, I aim to provide design rules for creating and tailoring materials as we want them to be," says Rudykh, who joined the UW-Madison mechanical engineering faculty in January 2018 as an assistant professor.

As he develops these new design rules, Rudykh also taps into the age-old design wisdom found in nature. For example, inspired by the scale-tissue protective systems in fish, Rudykh has designed a flexible, lightweight body armor that could potentially protect its wearer from a bullet or a knife without restricting mobility.

The key, he says, was controlling the microstructure, which allowed him to tune the material's properties to be highly flexible while also being protective.

Rudykh uses a mix of theory, modeling and experiments involving advanced 3D printing techniques. "Using 3D printing to create these microstructured materials at different length scales allows us to realize many theoretical modeling predictions in a direct way, and in most cases we learn something new from experiments that wasn't accounted for in modeling," he says. "Experiments keep the modeling realistic."

A major focus of his research is on understanding the mechanics of soft materials, including human biological tissues. Rudykh says there is much we don't know about the role of mechanics in the behavior of the soft matter in our bodies, and he hopes his research will shed more light on how our bodies work, which could ultimately aid clinicians in treating various medical conditions.

After receiving his PhD from Ben-Gurion University in Israel, Rudykh was a postdoctoral scholar in the mechanical engineering department at MIT. He then returned to Israel, where he was an assistant professor of aerospace engineering at the Technion-Israel Institute of Technology from 2014 through 2017 before moving to Madison.

Rudykh says a big motivation for coming to UW-Madison was the opportunity to work closely with outstanding faculty in the mechanical engineering department, and across the college.

"I'm very excited to be at UW-Madison because there is a strong and growing expertise in these areas, and I'm looking forward to collaborating with my colleagues on these exciting research directions," he says.

Read more: www.engr.wisc.edu/focus-new-faculty-stephan-rudykh-developing-design-rules-fine-tuned-materials/

NEWS FROM OUR STUDENT ORGANIZATIONS


Ascent Mk II

Wisconsin Robotics

Wisconsin Robotics has been hard at work building Ascent Mk II, its next-generation Mars rover for the University Rover Challenge (URC). URC is an international competition based in Hanksville, Utah, that challenges teams to build the world's best student-designed Mars rover. The students' robotic systems must be able to traverse extreme and aggressive terrain, perform maintenance on critical field equipment, and conduct meaningful field science.

From an initial field of 95 teams, Wisconsin Robotics was one of the remaining 36 teams from 10 countries selected to compete at the 2018 URC. The competition is broken into four tasks over the course of three days, and all of the tasks are performed out of direct line of sight of the rover operators and, in some cases, up to 1 kilometer away. In 2018, the teams' Mars rovers faced the same tasks as in previous years (sample cache task, extreme retrieval and delivery task, equipment servicing task, and the autonomous traversal task), but were challenged with more difficult versions of several. Wisconsin Robotics placed 16th overall at the 2018 URC.

ASHRAE

The goal of the ASHRAE organization on campus is to get students interested in the HVAC&R industry by exposing them to exciting career opportunities and to the impact they can have on energy efficiency. In the past year, the organization went on a tour of the Charter Street power plant, held monthly meetings with speakers from industry, and co-hosted a viewing of the ASHRAE webcast with the Madison chapter. The organization encourages student participation in Madison ASHRAE chapter events such as its monthly meetings, Young engineers in ASHRAE (YEA) events, and the 2018 winter conference and AHR Expo in Chicago.

Human Powered Vehicle team

In April 2018, the Human Powered Vehicle team earned ninth place overall at the ASME East Human Powered Vehicle Competition at Penn State University. The team's vehicle, called the Badger Bus, featured a half carbon fiber fairing for improved aerodynamics. The 60-pound vehicle also featured a chromoly steel frame, an internally geared rear hub, and an adjustable, dependable drive train.

While the innovation team's system did not make it onto the final vehicle, its efforts earned the Badger Bus fifth place in innovation. This year's innovative idea was focused on changing riders easily and quickly. The team designed an automatically adjustable seat that could be programmed to adjust to any rider with a personalized RFID. Additionally, the team developed a system that could open the hatch for a vehicle designed with a full fairing.

SAE

The UW-Madison chapter of the Society of Automotive Engineers had another exciting and productive year. Students on the Wisconsin Hybrid team began work on a range extender on their fully electric Ford Escape.

After winning second place overall at the Baja SAE Kansas competition in 2017, the UW-Madison Baja SAE team returned to the competition in May 2018. Unfortunately, due to severe weather, the UW-Madison team didn't get a chance to compete in all of the events, and consequently didn't receive an overall placement in the 2018 competition. However, out of more than 100 teams, the UW-Madison team took sixth place in the acceleration event and ninth place in suspension and traction event. The team also succeeded in building its first car that weighed less than 300 pounds, and the lighter weight was a key advantage in the competition.

The Clean Snowmobile team won third place overall in the highly competitive gasoline category at the 2018 SAE International Clean Snowmobile Challenge; it also won awards in the gasoline category for best performance, best lab emissions and best design.

The chapter also hosted the annual SAE Milwaukee chapter meeting and invited all other collegiate chapters to Madison in November 2017. This event was a great success and allowed students to show off Madison's teams and facilities. The chapter also participated in events such as Engineering EXPO, a two-day student-run event at UW-Madison to that aims to inspire the next generation to pursue STEM careers.

ASME

Over the past academic year, ASME has led and participated in several events, highlighting its professional, engineering and community engagement. ASME hosted its annual golf outing with employers from the Madison and Milwaukee areas, allowing its members to network with industry professionals before the fall career fair. Both students and employers had the opportunity to engage in small groups to develop connections for talent pipelines and professional opportunities in the summer and after graduation.

ASME also participated in the student design competition, planning and manufacturing two robots during the academic year to compete in a competition among hundreds of others at Penn State University. In addition, ASME continued community outreach by participating and winning first place for a student engineering exhibit in Engineering EXPO hosted on campus in April 2018. ASME's theme was "Star Wars" and developed several interactive exhibits—including a hovercraft, mag-lev train and even a laser "Death Star"—to bring those exciting technologies to life for young students.

Members of the 2017-18 Badgerloop team.

Badgerloop

Badgerloop has been hard at work developing its third pod for the 2018 Space X Hyperloop competition, which challenges student teams to design and build pods for an ultrafast, futuristic form of transportation.

At a well-attended unveiling event held on campus in April 2018, the public got a first glimpse of Pod III—a vehicle designed to hurtle through an airless tube at speeds exceeding 200 mph. Badgerloop has competed in two previous Space X Hyperloop competitions, taking home unprecedented back-to-back innovation awards, and the team built on those experiences to build its best pod yet.

Pod III is substantially lighter than its predecessors, thanks to a carbon-fiber composite body. Additionally, the pod boasts an electric motor propulsion system with a custom-machined mechanical wheel that can rotate at 33,000 revolutions per minute, or 10 times the stroke-rate of an automobile engine. Designing, fabricating and assembling the pod was a labor of love for the team of primarily undergraduate students, requiring long hours and late nights in the College of Engineering makerspace and TEAM Lab.

In July, Badgerloop pits its pod against other teams from around the world at the 2018 Space X Hyperloop Competition in Hawthorne, California.

Photo: Stephanie Precourt

Wisconsin Racing's team of student engineers built an electric vehicle for the first time in 2017.

Wisconsin Racing

Wisconsin Racing has had an exciting year filled with incredible developments for the combustion and electric programs. Building off a 10th place finish at Formula SAE Michigan in May 2017, the combustion team was hungry to build on the brand new platform it had created and make it even better. The powertrain team honed the potential of the new 450 cc Yamaha engine by doing extensive engine and chassis dynamometer testing to lower shift times from 600 milliseconds to less than 50 milliseconds. The powertrain team also spent a great deal of time optimizing the engine controls to provide for better mid-range power. The chassis and aerodynamics teams worked to improve the monocoque design and make it lighter and stronger than 2017's entry. With these changes, the combustion team competed with its car, called WR-218, at Formula SAE Michigan in May 2018 and won eighth place overall out of 114 teams.

The electric team had a groundbreaking year once again. Coming off a first place in design and eighth place overall at Formula SAE Electric in June 2017, the team, only in its second year, sought to go even further and become the first U.S. team to bring an all-wheel-drive electric car with custom electric motors to the competition. The team spent months perfecting the motor design, coupling it with a brand new planetary gear train, custom quad-inverter and new battery pack. While ambitious, the team hopes these design developments will be able to carry the team into the future and garner a successful result with its electric vehicle, WR-218e, at the 2018 Formula SAE Electric competition. Wisconsin Racing gives students the opportunity to apply lessons learned in the classroom to a challenging and exciting project. From metal casting to vibration testing, the combustion and electric programs use every resource that the College of Engineering has to offer to produce vehicles that able to go toe-to-toe with the best student teams from around the world.

FOCUS ON NEW FACULTY

REVVING UP POWER PLANT PERFORMANCE

College of Engineering
UNIVERSITY OF WISCONSIN–MADISON
www.engr.wisc.edu/me
Mechanical Engineering
1513 University Avenue, Madison, WI 53706

Mark Anderson sees big opportunities for significantly boosting the efficiency with which power plants generate electricity.

In his research, he tackles energy-related challenges from a number of angles, and advances from his projects have the potential to increase efficiency in generating power in nuclear, solar and fossil energy. These efficiency gains could ultimately lower the cost of electricity.

Anderson, who joined the faculty as an assistant professor in January 2018, currently is co-leading a major research project focused on advanced compact heat exchangers for use in nuclear systems.

Because these advanced compact heat exchangers provide more efficient heat transfer than traditional heat exchangers, they could increase the performance and lower the cost of nuclear reactor systems. However, for the new heat exchangers to be approved for future use in nuclear systems, the industry and regulators need proof they'll be able to operate safely in a nuclear setting.

With $5 million in funding from the U.S. Department of Energy, Anderson and his collaborators are studying how advanced compact heat exchangers might fail in a nuclear system. With this knowledge, their goal is to provide the safety assurances needed for the nuclear power industry to adopt them for use in advanced nuclear reactors.

In another research area, Anderson is investigating the supercritical carbon dioxide power cycle. Traditional power plants produce electricity by combusting fuel, which heats water into steam. The steam, in turn, drives a turbine that generates electricity. But the extraordinary properties of supercritical carbon dioxide—a fluid with qualities of both a liquid and a gas—make it an exciting prospect for replacing the steam turbine system with a closed-cycle gas turbine that uses supercritical carbon dioxide.

It's a change that would dramatically increase power generation efficiency. "The supercritical carbon dioxide power cycle requires a lot of heat exchanges within the cycle, and so I conduct research on that as well as on the turbomachinery and other components involved in the cycle to investigate different ways to improve the overall efficiency," Anderson says.

In addition, Anderson studies how to tune the power cycle for different energy applications, including nuclear, solar or fossil. He says the supercritical carbon dioxide cycle would also enable power plants that burn fossil fuels to reduce the carbon emissions they release into the atmosphere. That's because this cycle is well suited for capturing the carbon dioxide that's created from burning the fuel and feeding it back into the system, sequestering it or using it for chemical processes.

In a related area of research, Anderson studies a variety of fluids involved in transferring the heat from the power plant to the supercritical carbon dioxide cycle. These fluids include molten salts and sodium, which Anderson researches using test loops at the Tantalus research facility he manages. He is interested in these liquids because they could allow power plants to operate safely at higher temperatures, which is important for increasing a power plant's efficiency. Liquid salts can also be used for energy storage—another active research area for Anderson.

While Anderson is a new faculty member in the department, he's not new to the College of Engineering. After earning his PhD in mechanical engineering at UW-Madison in 1998, Anderson started working as a scientist in the Department of Engineering Physics. Over the years, he rose to the rank of engineering physics research professor.

Anderson says joining the mechanical engineering faculty was a natural next step as his interests and research have evolved over the years. "I had previously been doing mostly nuclear research, but the research has morphed more into mechanical engineering," he says. "Liquid salts are of interest to the solar industry, and the fossil industry is interested in the supercritical carbon dioxide cycle, so I started to do work in more areas."

He says he's also excited about the opportunity to teach students in his new position.

Read more: www.engr.wisc.edu/revving-power-plant-performance/