College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

FALL 2024 NEWSLETTER

DEPARTMENT OF

INDUSTRIAL AND SYSTEMS ENGINEERING

Greetings from Madison!

I'm excited to be writing to you as the newly appointed David H. Gustafson Chair of the Department of Industrial and Systems Engineering. In July, I took the reins from former chair Laura Albert, under whose direction we expanded our world-class faculty, explored cutting-edge research, and enriched the student experience for both undergraduates and graduates. We are grateful for her leadership as chair, and thankful that she will continue to serve our department, and the greater good, through her work as professor.

Over the past several years, our department has worked diligently to expand our curriculum and research to adapt to a changing world. We've added courses in exploding fields like industrial artificial intelligence and data-driven decision-making. We've hired accomplished and promising faculty members who will help us further establish our reputation in these areas and maintain our status as world leaders in areas such as operations research, human factors and ergonomics, advanced manufacturing, and health systems engineering. As a faculty member for more than 22 years, I can confidently say there's never been a better time to be part of this community.

The results of these efforts speak for themselves through the work, and related recognition, of our programs, students and faculty.

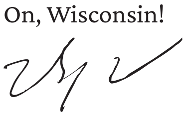
Our program has never been stronger. Currently our undergraduate program ranks 10th among all public universities, while our graduate program ranks sixth among all universities, public and private. We have a thriving community of more than 470 students this fall. Many are pursuing research, working alongside prestigious faculty on important projects involving everything from health disparities in cancer screening to 3-D printing in space. All of them are being challenged daily, and we are proud of their contributions to our success.

The work of our faculty and students over the last several months has been recognized on a national level. Our student groups have all received silver or gold level awards in their respective societies. Our faculty have been recognized for excellence across the fields of operations research, industrial AI and human factors and ergonomics. Two of our assistant professors, Qiaomin Xie and new hire Dan Li, have received prestigious National Science Foundation CAREER Awards. Congratulations are in order for all.

This fall, we welcomed two new faculty members whose research focus, like mine, lies in manufacturing and industrial AI. Andi Wang has done impactful work in data-driven manufacturing process modeling and monitoring, while Dan Li is an expert in the security of cyber-physical systems. I know I speak for our entire community when we say we are thrilled that they have joined our department.

I come into the position of chair with immense pride for what we've accomplished so far, and enthusiasm for what lies ahead. I am grateful for your continued support of our department.

On, Wisconsin!



Shiyu Zhou
David H. Gustafson Department Chair
Vilas Distinguished Achievement Professor
shiyuzhou@wisc.edu
(608) 262-9534

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On the cover: Assistant Professor Hantang Qin (center) tests his lab's 3D-printing technology for in-space applications through parabolic test flights that include 30-second windows of zero-gravity conditions. Submitted photo.

Submitted photo

Qin lab makes 3D printing breakthrough in race to in-space manufacturing

In the end, Rayne Wolf could hardly bear to look at the monitor attached to the microscope she and her labmates had set up in a hangar at Fort Lauderdale-Hollywood International Airport.

Wolf and her fellow UW-Madison graduate students had spent the past two-plus weeks in the muggy Florida heat finishing final preparations for a series of parabolic test flights to validate their 3D printing technology in a zero-gravity environment.

But the first two flights—roughly 40-minute jaunts comprised of alternating 30-second periods of zero-gravity and 2G conditions (also known as "vomit comets" for their tendency to make passengers sick)—hadn't gone as planned. The printer's stages had stubbornly refused to move, leaving the students and their advisor, Assistant Professor Hantang Qin, with one final shot. They spent the week leading up to their third flight troubleshooting any and all potential causes during 12- to 15-hour days.

"A lot rides on these experiments," says Wolf, a PhD student from Potosi, Wisconsin, and one of the team leads on the NASA-funded project.

The group's perseverance paid off: Qin's lab made history in March 2024 by successfully 3D printing RAM device units in zero gravity—the first time it's been done.

NASA is interested in developing in-space manufacturing capabilities for electronic components such as semiconductors, actuators and sensors. That would offer a viable option for making repairs during longer-duration space missions, without needing to transport replacement parts.

Since traditional 3D printing relies upon gravity to extrude material from a printer nozzle, in-space printing requires a different approach. Qin's lab has developed an alternative called electrohydrodynamic (EHD) printing, which applies electrical force to drive the flow of liquid materials through an extremely thin nozzle that's 30 micrometers in diameter.

"Under this small scale, the surface tension will prevent the liquid from flowing out from this nozzle," says Qin, whose group is leading the collaboration with researchers from Iowa State University, Arizona State University, Intel and other industry partners. "And then we apply this electrical force to break out of this surface tension force."

Qin says EHD printing technology has advantages beyond its ability to function in zero-gravity environments. With traditional 3D printing, nozzle size essentially determines droplet size.

"But using our printing system, we can make the droplet way smaller than the size of nozzle," he says. "Given a 2-micrometer nozzle, we can make a nanoscale pattern. That's the huge advantage of this."

After pinning down an issue with their printer's stage calibration sensors caused by the vibrations of the plane's engine and rewriting some of their system's code to compensate, the team capitalized on its final test flight. Under the manual control of Wolf and Jacob Kocemba (BSBME '23), the lab's EHD printer successfully produced more than a dozen units with zinc oxide, a semiconducting ink, and a half dozen more with polydimethylsiloxane, an insulating polymer ink.

Still, while the researchers could see their printer was working as they floated around the plane's cabin, they couldn't confirm their results on the micro- and nanoscales until that fateful postflight huddle around the microscope.

"We got a good feeling when we were in the air and the stages were working," says Khawlah Alharbi, a first-year PhD student who was in the air for two of the test flights.

If the researchers continue to meet their project milestones, they hope to launch their technology for testing aboard the International Space Station.

"If we can send this up to the ISS," says Liangkui Jiang, a fifth-year PhD student who's worked on the project since conception, "it would be a happy ending."

FOCUS ON NEW FACULTY

Dan Li safeguards manufacturing systems from cyberattacks

Soon after starting a master's program in operations research at Georgia Tech, Dan Li remained restless. She wanted more—more challenging courses, more avenues to make a wider-reaching impact. And so she swapped the master's for the long haul of pursuing a PhD.

Clearly, Li gravitates toward demanding work.

Li, who joined ISyE as an assistant professor in fall 2024, develops algorithms to prevent and detect cyberattacks in industrial and control systems, specifically those used in manufacturing plants.

According to the IBM Security X-Force Threat Intelligence Index 2023, manufacturing was the most attacked operational-technology-related industry in 2022.

"Those are not initiated by an amateur hacker sitting in front of the computer at their home, but actually a group of experts of engineering and computer science and networks, all together to design a very sophisticated attack to target some critical infrastructure," says Li. "But there are a lot of things we can do."

By leveraging data from the array of sensors and control systems employed in so-called "cyber-physical" manufacturing systems, Li develops more accurate and time-sensitive attack detection algorithms.

"That's a huge difference from the traditional IT cyberattack detection algorithms, because they mostly work on the network traffic data," says Li, whose research group also conducts risk assessment to identify weak points across cyber networks and the physical processes they control. "This is a very nice extra layer of protection. It's not a substitute for those types of technologies, but really another layer by taking how the system works physically into consideration."

Prior to arriving in Madison, Li spent three years on the faculty of Clemson University, where she earned a National Science Foundation CAREER Award to support her work safeguarding critical manufacturing systems.

While at Clemson, Li also collaborated with colleagues specializing in human factors engineering, incorporating the perspectives and considerations of the workers who interact with complex cyber-physical systems. She's teaming with former Clemson colleague Jackie Cha, a human factors and ergonomics researcher, on another NSF-funded project to thwart attacks to the cyberinfrastructure supporting robot-assisted surgeries.

Li sees potential for similar collaborations across the ISyE department and beyond.

"I was really fascinated, first of all, by the diverse research areas that ISyE faculty work on," says Li, who studied automotive engineering as an undergraduate at Tsinghua University, where she discovered her knack for data science. "As I said when I was interviewing, I feel like everyone is a rock star in their field. It's a very strong program. And also there are other strong engineering and science programs at UW-Madison, and I can see future collaboration opportunities with those faculty as well. It's an amazing place."

Supply chain modeling course puts students in charge

The hours are flying by while Helen Bartels, Isha Bhamani, Katherine Chuei and Catee Herrick look at their laptops, waiting for class to begin. Demand for their company's products has peaked and they're preparing to offload everything before their market dries up.

The four industrial engineering students are applying what they've learned in the first month of ISyE 604: *Supply Chain Modeling: Logistics* to a round-the-clock, time-lapsed simulation.

"It's a really nice way to see, long term, what would happen," says Bhamani, a senior. "If you have low periods of demand, you have to be able to work with the capacity that you have and how you're sending out your products to be able to condense and use your money the most efficiently."

Assistant Professor Yonatan Mintz, who created the course, started incorporating the simulation in 2023 in place of additional exams and a class project. Created by Responsive Learning Technologies, the game puts student teams in charge of the supply chain of a fictitious chemical manufacturer, all operating under identical conditions, with two years of simulation flying by during each weeklong assignment.

While the students compete to maximize their company's profit during two rounds at different points of the semester, the bulk of their grades comes from the written analysis they generate in the wake of the simulation.

"Exams and the class project are good, but they're a little bit contrived," says Mintz, whose background includes a year working in industry as a supply chain analyst. "The whole goal with a class like this is for students to learn using different models, and then by the end of the class be able to actually apply them in industry. But if your whole experience is homework problems where everything is very cleanly laid out, then that's not how the real world works. It's not like you go to your job and people are like, 'Our costs are this, demand is this, put it into the formula.'"

Assistant Professor Yonatan Mintz talks with students during a class session of ISyE 604. Photos: Tom Ziemer.

Near the end of the semester, the students tested what they'd learned in class about inventory management, transportation and supply chain network design on a more complex version of the game. They weighed the risks and rewards of expanding into new markets and assessed the varied demand profiles of industrial buyers versus consumers.

It's the sort of dilemmas real companies face every day.

"My hope is that when students walk out of the course, they feel like they can actually use the models that we cover in order to help make decisions in the real world, that they can identify situations where the models make sense and situations when the models don't make sense," says Mintz. "When you go to an actual business and you have to help them manage their supply chain, don't just plug stuff into the formula. Really sit down and think, 'What's true here? How does that map onto what I learned?' And critically think about how to apply things."

FOCUS ON NEW FACULTY

Andi Wang crunches numbers to improve advanced manufacturing

As a silicon wafer winds its way through a semiconductor manufacturing plant—from deposition and lithography to etching and dicing—each stop at another machine loaded with sensors also generates information.

And all those numbers, with advanced analysis, could be harnessed to further optimize the production process.

"There are many gigabytes of data for each single product," says Andi Wang, a researcher whose work applies data science to advanced manufacturing processes. "How do you use that? Industry does not want to discard this data, but they do not know how to use it. This is where our research comes into play."

Wang joined ISyE in fall 2024 as an assistant professor, bringing experience employing a variety of machine learning and other analytical methods to real-world complex manufacturing systems.

He arrived in Madison after spending three years on the faculty of Arizona State University's School of Manufacturing Systems and Networks, which provided him with insights into emerging manufacturing technologies.

"What I'd like to do is bring that knowledge that I've gained and also this experience in the manufacturing field back to industrial engineering," says Wang, who holds PhDs from Hong Kong University of Science and Technology and from Georgia Tech.

Specifically, Wang is interested in analyzing data to guide design decisions and to improve efficiency and performance in additive manufacturing systems and the semiconductor manufacturing industry. He's previously analyzed data from steel-rolling plants to uncover process and quality improvement strategies.

Wang has also expanded his research to include nuclear reactor design optimization. He currently leads a project, backed by a $1 million grant from the U.S. Department of Energy, to develop novel data-driven modeling and optimization methodologies (driven by the special characteristics of nuclear reactor core simulations) to shorten design cycles.

He says UW-Madison's longstanding excellence in nuclear engineering was a draw, along with a growing emphasis on semiconductor research across the college.

"I'm impressed by the great research environment here," says Wang, who's seen it firsthand.

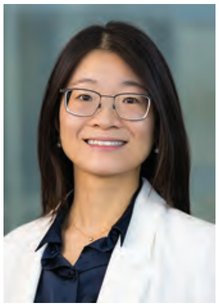
In 2015, Wang spent six months at UW-Madison as a visiting researcher while pursuing his first PhD, an experience that drove his interest in coming to the United States to continue his career. Several faculty members he met at UW-Madison, such as Professor Kaibo Liu, have remained his academic mentors.

Wang will start off teaching ISyE 210: *Introduction to Industrial Statistics*, an introductory engineering analytics course that's open to all engineering students. But he's already got plans to develop a course on artificial intelligence for industrial applications in the future.

"Lots of industrial engineering students want to know about the cutting-edge developments of AI, machine learning and data analytics approaches, and how to implement those in the industrial workflow," he says.

Wang considers himself a versatile instructor, and the same could be said about his research. The ability to apply analytical methods to a whole host of industries and systems was part of what first captured his interest as an undergraduate student at Peking University in his native Beijing.

"A very interesting aspect of industrial engineering," he says, "is that you can observe that data from different engineering systems, of different applications, sometimes share similar insights, which drive us to develop new models and methodologies. These outcomes can solve a class of problems in various applications."



Xie hopes to advance reinforcement learning with NSF CAREER Award

As requests flood a data center, the computer network must match those requests to servers in a way that balances completing each job quickly with managing overall system performance.

Assistant Professor Qiaomin Xie likes to use the analogy of directing customers at a grocery store to checkout lines—the optimal resource allocation will keep things flowing for individual consumers while also maintaining harmony for the collective group.

But to ensure complex systems function smoothly—especially when confronted with situations that require sequential decision-making—the algorithms that control them need to be properly designed. A data-driven approach, exploiting the availability of data from systems, provides a new paradigm of designing intelligent control algorithms. That's where machine learning researchers like Xie come in.

Xie will use a National Science Foundation CAREER Award to enhance a machine learning technique called reinforcement learning for use in systems like computer and communications networks. The five-year, $532,910 grant will fund Xie's work on the algorithms and theories underpinning reinforcement learning.

"Reinforcement learning is the natural tool to help us design better control algorithms for these large-scale systems," says Xie. "Reinforcement learning enables the system to learn and improve its performance autonomously through interaction with the environment, and also adapts to changes in the environment."

In contrast to other machine learning techniques, which typically learn from static datasets or independent samples, reinforcement learning follows a dynamic process that Xie says makes it well-suited to navigate problems that require sequential decision-making. Reinforcement learning also uniquely balances the tradeoff between exploratory actions to learn more about a given environment and leveraging its current knowledge to maximize rewards.

But to realize its potential in applications such as computer and communications networks, robotics and inventory control, reinforcement learning algorithms need sharpening to contend with environments that feature high levels of randomness and noise, long time horizons, and the sheer complexity of systems as compared to simplified training models.

Alums earn accolades at Engineers' Day

ISyE honored alumni Eduardo Carbajosa (BS '91) and Eric Anderson (MS '11, PhD '15) as part of the college's annual Engineers' Day festivities.

Carbajosa, the CEO of Acme Smoked Fish Corporation, received the Distinguished Achievement Award for his success in the business world.

Acme Smoked Fish, the largest producer of smoked salmon in North America (though Carbajosa prefers tuna, himself), boasts annual revenue of more than $100 million.

"I really owe my entire career to the University of Wisconsin-Madison," he says. "The university was super-welcoming. It created a perfect environment for students to thrive."

Anderson, principal engineer at Anderson Optimization by PVCase, received the Early Career Award for his work helping to guide energy companies' planning for renewable energy projects.

"I really enjoy solving problems," says Anderson, who served as his company's head of technology before it was acquired by the solar energy tech company PVCase in 2023. "A lot of the problems I'm solving right now are trying to make this system that we've developed work for more users or more edge cases that we didn't think about when we developed it."

Faculty News

Professor Kaibo Liu received the Hromi Medal from the American Society for Quality for advanced, adaptive inspection and statistical process control for big data streams; and for innovative methods to quickly detect and localize anomalies by inspecting data streams in spatial domain.

Assistant Professors Tony McDonald and Yonatan Mintz earned funding through the American Family Funding Initiative to address barriers to driver feedback programs by developing a behavioral analytics algorithm to personalize feedback and optimize safety nudges.

Assistant Professor Hantang Qin has received an early-concept grant for exploratory research from the National Science Foundation to bridge the gap between on-ground experimental data and in-space manufacturing possibilities using transfer learning. Qin also received the 2024 Outstanding Young Investigator Award from the manufacturing and design division of the Institute for Industrial and Systems Engineers.

The Center for Health Enhancement Systems Studies, part of ISyE, is part of a new project funded by the National Institutes of Health to reduce missed dental appointments among vulnerable populations. The center will receive more than $3.5 million in funding over five years.

Department of Industrial and Systems Engineering
UNIVERSITY OF WISCONSIN–MADISON

1513 University Ave., Room 3107
Madison, WI 53706
engineering.wisc.edu/isye

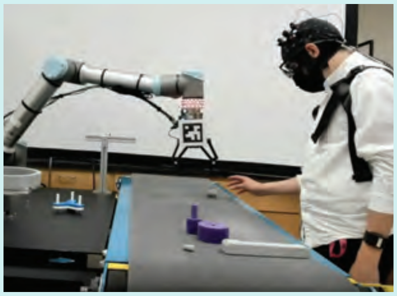
Looking into the brain through the eyes to uncover sex differences in human-robot collaboration

As human workers and robots collaborate more and more frequently, particularly in the manufacturing sector, it's important—for safety and productivity—their partnership includes a key ingredient: trust.

And to design and optimize those "cobot" systems, researchers need to be able to measure trust in a way that's more nuanced and accurate than surveys that rely on human perceptions. Professor Ranjana Mehta is exploring new methods for assessing trust in automated systems such as human-robot collaborations.

In a paper published in the journal *ACM Transactions on Human-Robot Interaction*, Mehta and her graduate students detail how they used brain imaging and eye-tracking to cross-examine human perceptions of trust, illuminate underlying trust-behavior relationships, and uncover differences across sexes in a manufacturing use case.

"It's very important that humans and their autonomous teammates play well, that they are fluent in their interactions," says Mehta. "And for that to happen, they need to communicate really well, and trust is a major driver of that communication."



A participant in the research study grabs a component delivered by a collaborative robot. Photo courtesy NeuroErgonomics Lab.

Mehta and her students asked human participants to work with a collaborative robot to assemble a gear system. However, the researchers also programmed the robot to perform unreliably in one set of trials, to assess the impact on trust. In addition to surveying participants afterward, Mehta's team recorded videos to track errors the humans made; used functional near-infrared spectroscopy to monitor brain activity; and had participants wear an eye-tracking device.

While both men and women self-reported their levels of trust the way you'd expect—trusting the robot in its reliable state, distrusting it when unreliable—it turned out their behaviors diverged. Women kept their eyes on the robot when it behaved unreliably and, in the video analysis, made fewer errors; men, meanwhile, took their eyes off the robot even when it performed unreliably and made more mistakes in assembling the pieces when they were delivered out of order.

When reviewing the brain imaging data, the researchers found men exhibited increased activation in the prefrontal cortex, which Mehta says corresponds with top-down processing (based on assumptions and expectations). The brain imaging data, combined with results from a previous study, revealed disruptions in several "trust networks" in the brain.

Differences across sexes could prove important for designing inclusive, effective human automation systems that work for all.