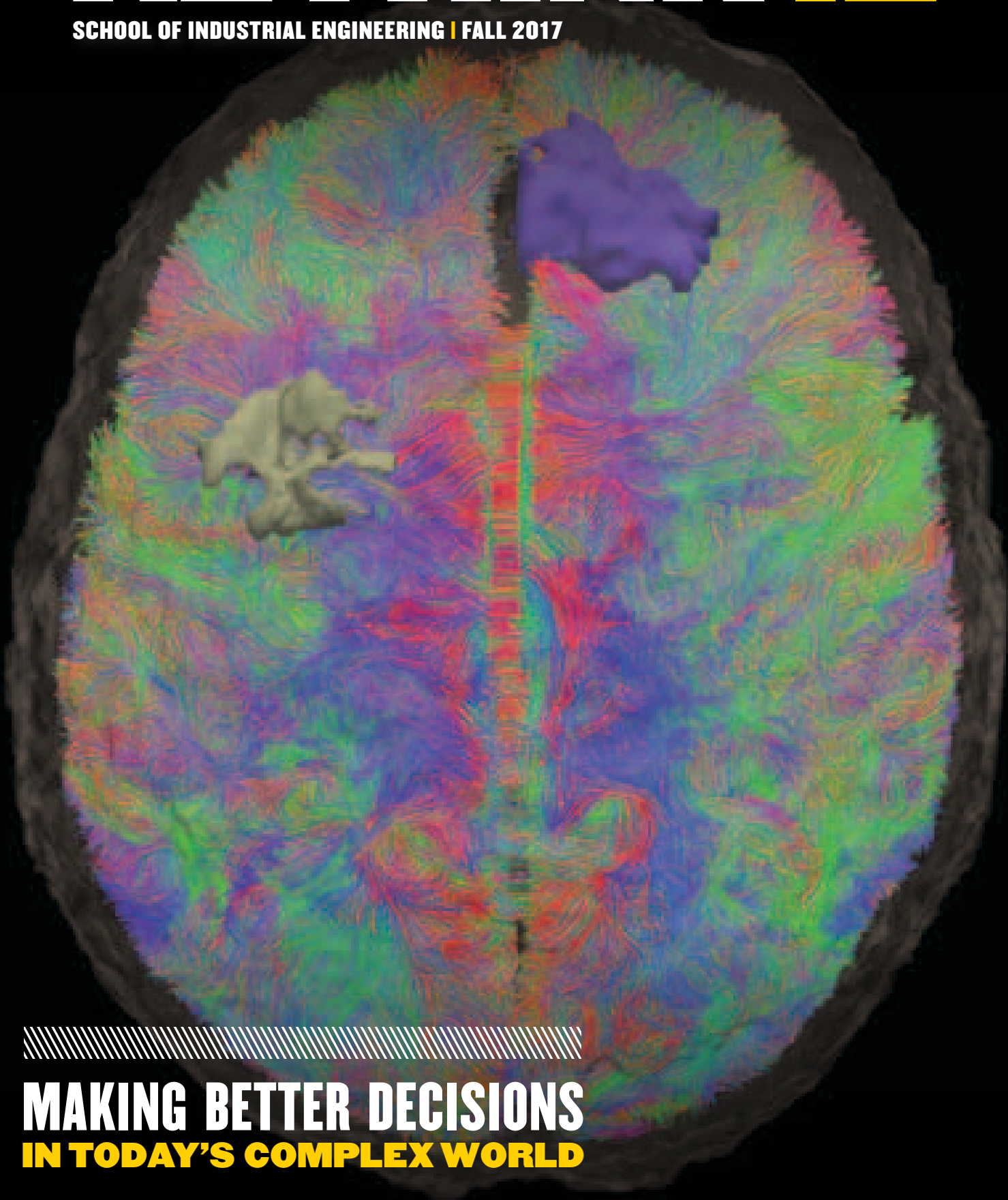
PURDUE UNIVERSITY

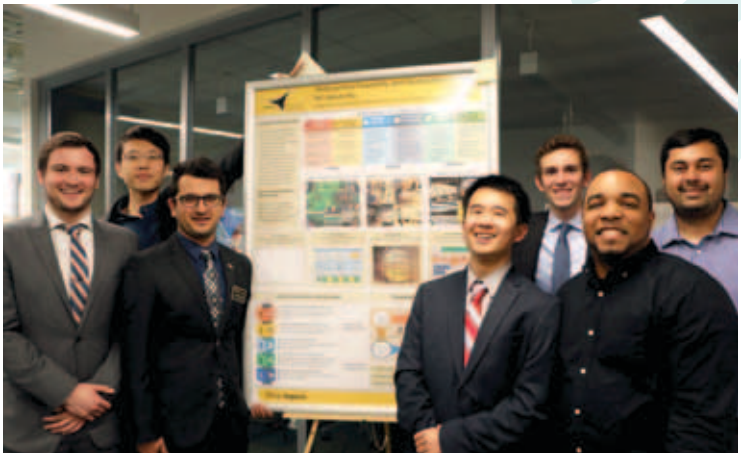
RETHINK IE

SCHOOL OF INDUSTRIAL ENGINEERING | FALL 2017



MAKING BETTER DECISIONS
IN TODAY'S COMPLEX WORLD

ON POSSIBILITIES



Students are at the heart of what we do in Purdue IE. Besides our excellent courses, we give them opportunities beyond the classroom with Senior Projects (top) and Career Fairs (middle), and we showcase them in Grissom Hall itself (bottom).

What does the future of industrial engineering look like?

Rethinking IE is about coordinating different perspectives to develop new methods to teach our students how to respond to today's and tomorrow's challenges.

This is the mindset we have at Purdue Industrial Engineering. We're "Rethinking IE" through supporting exciting faculty research on decision making (pp. 2-5), promoting new faculty collaboration (pp. 6-7), using our facilities to improve our education and research (p. 8), augmenting our Corporate Partners program and increasing our students' opportunities to learn beyond the traditional classroom (p. 9).

In all these ways and more, we continue to *Rethink IE*. I hope you will enjoy this issue, and please contact me if you'd like to get involved.

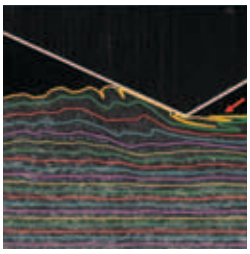
Abhijit Deshmukh
James J. Solberg Head and
Professor of Industrial Engineering
abhi@purdue.edu

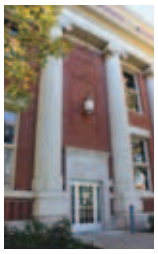
RETHINK
industrial engineering





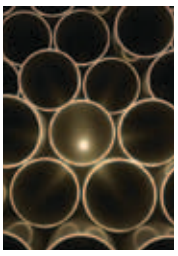




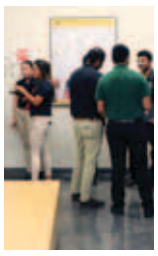





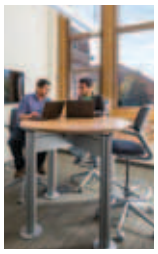












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COVER: *The human connectome: a network model of the most prominent white matter tracts (edges) connecting gray matter regions (nodes) within the human brain. See story p. 2. (Graphic/Joaquín Goñi)*

MAKING BETTER DECISIONS IN TODAY'S COMPLEX WORLD

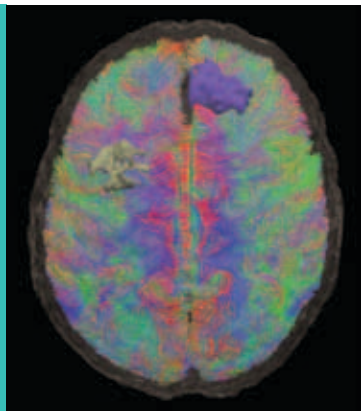
■ BY DE ETTE STARR

Decision making requires data, but the amount we're generating can be overwhelming.

Former Google CEO Eric Schmidt stated that every two days "we create as much info as we did from the dawn of civilization up until 2003" (and that was in 2010). How much more data are we creating daily now? The problem in making decisions today is how to sort through massive amounts of information to find what is relevant to our decisions.

To handle all of this "big data," we need better decision making paradigms. How can we make better decisions while utilizing the massive amounts of data available? Industrial engineering is uniquely positioned to look at the entire information cycle to help people make better decisions.

Purdue University School of Industrial Engineering (IE) faculty members are researching ways to make sense of data. Our faculty is going beyond big data research to try to understand human decision making and to develop new methods to comprehend and improve complex systems.



The human connectome: a network model of the most prominent white matter tracts (edges) connecting gray matter regions (nodes) within the human brain. Tracts are represented by streamlines, and their color denotes their orientation. Two brain regions are shown, one on each brain hemisphere. They represent neural populations connected to other regions through the streamlines, which act as a wiring system. (Graphic/Joaquín Goñi)

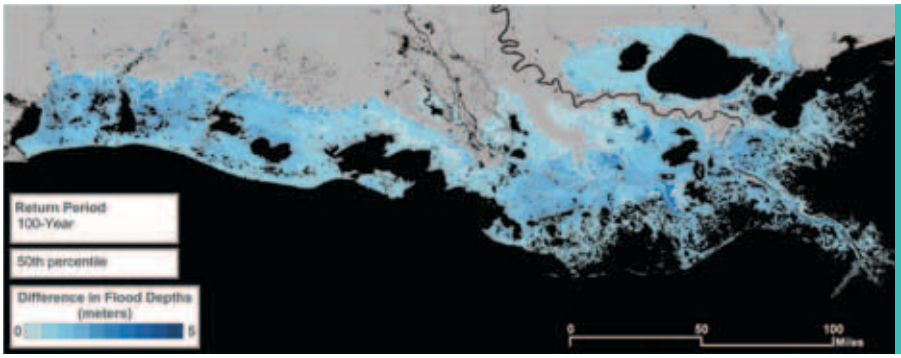
HOW DO WE MAKE DECISIONS?

Understanding how we make decisions when confronted with large volumes of data requires better insights into how our brains process information. Along this line, Assistant Professor **Joaquín Goñi** collaborates with faculty in both Industrial and Biomedical Engineering to study neuroimaging and brain connectomics.

"Our group is focused at the crossroads of brain connectomics and complex systems," Goñi explains. "We are addressing the challenge of understanding the human brain structure and function through the lens of complexity. Our research plans cover understanding the relationship between structural connectivity, functional connectivity, cognition and diseases within the human brain.

"We are modeling the structure and function of the brain as networks, for both healthy and clinical populations, and assessing the intrinsic relationships between structural and functional connectivity," says Goñi. "To do so, we use approaches based on complex systems, such as network science and information theory. We collaborate with groups located in the U.S. and in Europe. It is very exciting to learn more about the human brain, and to do so from a complex systems point of view."

Goñi applies his research to better understanding brain changes as they occur in aging, in neurodegenertive diseases, in neurological disorders, and during pharmacological treatments. By studying how the brain processes and integrates information, researchers can better understand the involvement and functioning of different neural circuits in decision making.



This shows one possible projection of the change in 100-year flood depths in coastal Louisiana over the next fifty years. The scenario shown assumes relatively high sea level rise, land subsidence, and future storm intensity. (Graphic/David Johnson)

COPING WITH UNCERTAINTY

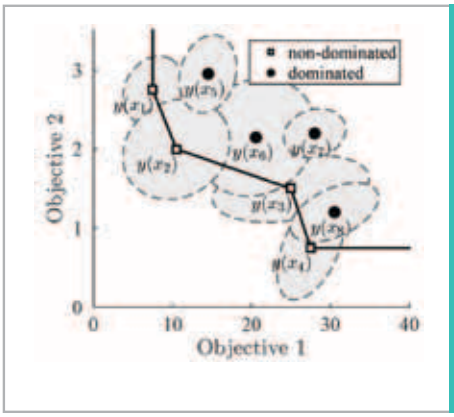
Decision making also involves assessing risk in the face of uncertain futures. Assistant Professor **David Johnson** connects decision theory and decision analysis to show how we handle uncertainties in decision making. "A lot of IE is related to decision making under uncertainty," he says. "My work is extending that to say 'If you don't even know what a probability distribution looks like, or you have conflicting models that tell you different things — how do you reconcile that? How do you still make good decisions when you have that lack of information at more of a foundational level?'"

Johnson collaborates with the State of Louisiana on flood risk modeling, including developing a 50-year coastal master plan. "I'm part of a team that's in charge of all of the flood risk modeling, so I've developed the flood risk model that's used to evaluate what the impact of different levee configurations would be, or what the impacts on risk are of elevating homes, floodproofing commercial property, and having voluntary acquisition of properties that are too high-risk to mitigate otherwise," Johnson explains. "They have to update the plan every five years. My research started in support of their 2012 plan, and now we are working to update it for 2017."

He also studies biofuels and renewable energy, and helps the State of California manage drought and build climate change uncertainties into its long-range planning. "I want to make sure that I'm working on methods that are very much motivated by real problems and can be immediately put to use," says Johnson.

The need to make decisions under uncertainty arises in many fields, including finance, energy, transportation, facility location, supply chain management, telecommunication, and healthcare management. Assistant Professor **Susan Hunter** develops theory, methods, and algorithms for decision making under uncertainty in complex systems that are modeled using computer-based simulations.

The National Science Foundation has funded a Faculty Early Career Development Program (CAREER) award for her research on "Multi-Objective Optimization via Simulation: Theory, Methods, and Parallel Computation." This research focuses on developing implementable algorithms that identify optimal decisions with respect to multiple stochastic performance measures.



The figure shows the performances of eight potential system configurations on two objectives. The gray clouds represent uncertainty in the performance of the systems on the objective functions. Larger clouds imply greater uncertainty. (Graphic/Susan Hunter)

"Though widespread, these problems are under-studied, and current solution methods may be slow, imprecise, or inaccurate," she explains. "Developing methods to solve such problems with provable guarantees on speed, precision, and accuracy will enable decision makers to make better, timely decisions across a variety of disciplines." Understanding *how* we make decisions can help us make *better* decisions.

UNDERSTANDING COMPLEXITY

As the problems we face become more and more interconnected, they naturally become more complex. One way to address much of this complexity is to use network theory. Assistant Professor **Christopher Quinn** studies complex networks as diverse as gene regulatory systems, the human brain, the Internet, and global financial infrastructure. "My research group is developing rigorous methods to characterize the

structure and flow in real-world networks," he says. "But for many large, complex networks, little is understood about the structure or how problems in one part of the network can spread to other areas. My group will create new computational and statistical approaches to analyze such large systems.

"My research aims to analyze complex systems, creating simple pictures that depict the interactions that make up today's complex world," continues Quinn. "This in turn facilitates decision making by giving the decision maker a better understanding of the world. The overall goal is to develop tools that scientists can use to better understand how all the networks in our bodies and society work, leading to better medicines and economic policies."

Assistant Professor **Mario Ventresca's** group also analyzes complex systems. "Fundamentally, my group is concerned with understanding evolution and adaptation in real and artificial systems with the goal of motivating novel solutions for engineering, optimizing and controlling them," he says. "To this end, one project I am working on is automatically inferring models of complex systems in order to elucidate fundamental principles of system formation and/or dynamics, for example to better understand social or neurodegenerative processes."

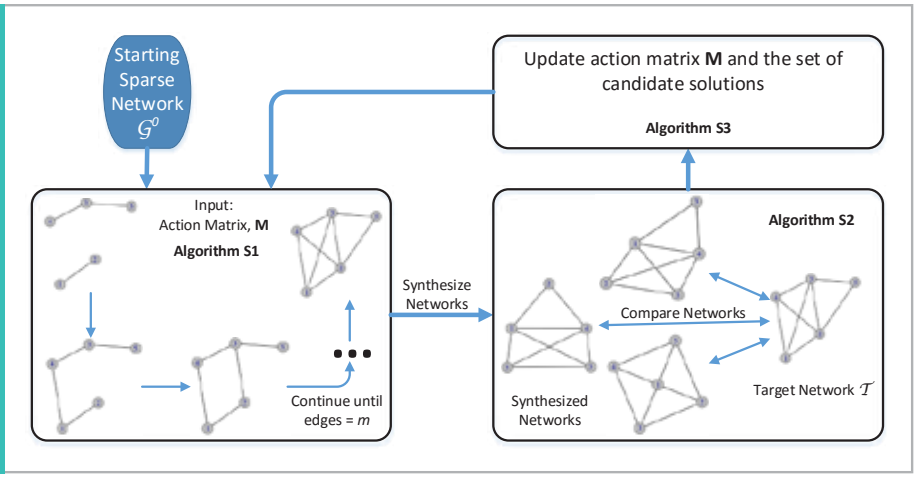
Ventresca's research emphasizes studying things that evolve or adapt over time. "Sometimes it means studying them to better understand their adaptability and how to control them — that is, how to design things that inherently adapt in a way that you would like," he explains. "Other times, you may want to devise effective algorithms to influence a system, for instance how to distribute vaccines or other means to best mitigate disease transmission. Another option is to look at complex systems, particularly in nature, and use them as motivation to develop new algorithms or solutions to problems that are sufficiently difficult that existing strategies don't work very well, if at all. So, I either take real-world systems as a motivation to develop new algorithms or to devise new approaches to better understand real-world complex systems."

MANAGING BIG DATA

One of the biggest challenges in helping today's policy makers make informed decisions is to capture the critical information contained in the massive amounts of available data. Assistant Professor **Roshanak Nateghi** uses advanced modeling and analysis techniques to develop future predictions about critical infrastructure such as energy, water, transportation, healthcare, security, financial services, and information and communications technology. Her research projects include developing predictive models for electric power and water consumption levels at various spatio-temporal scales in the U.S., to identify the main drivers of demand for water and power resources. The results of her research help governmental and other entities create policies to promote sustainable consumption patterns.

Roshanak Nateghi (2nd from left) discusses sustainable and resilient urban systems with members of her Laboratory for Advancing Sustainable Critical Infrastructure (LASCI) research group.

Nateghi has also created reliability models for critical infrastructure systems impacted by extreme events such as natural disasters and climate change, both in the short term and long term. She and her group are developing frameworks to model the impact of climate extremes on the resilience of infrastructure under deep uncertainty.

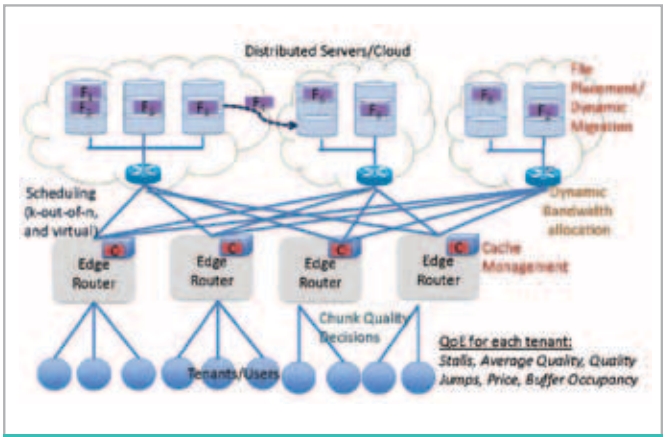


A flowchart depiction of the optimization framework used to determine a compact matrix representation from a given complex network. (Graphic/Mario Ventresca)

The uptake of digital data driven by increasing use of smartphones, tablets, and apps necessitates new tools for data analysis, data storage, data delivery, and big data computing. Developing these tools are the goals of Assistant Professor **Vaneet Aggarwal's** research group. The group currently focuses on three broad research categories:

- ***Big Data Computing:*** Parallel big data computing frameworks (e.g., Hadoop MapReduce, Apache Spark) need scheduling algorithms with provable guarantees for determining the assignment of different tasks of each job to the servers, and ordering the processing of these tasks in the presence of precedence and networking constraints.
- ***Data Analytics:*** Low tensor rank structures must be efficiently exploited to analyze large high-dimensional data sets with missing data to discover novel data mining algorithms with provable guarantees.
- ***Streaming over Cloud:*** Video-on-Demand providers are increasingly moving their streaming services, data storage, and encoding software to cloud service providers. Coming up with a next generation end-to-end service for video streaming over cloud with capabilities of optimized content placement and service, computing, cache management, adaptive bit-rate quality decisions, and tile-based scheduling for virtual reality is a challenging problem.

"The key challenges in video streaming over cloud include effective placement of contents in the cloud, efficient multi-round cloud computing with transcoding and analytics, optimized cache management algorithms, and intelligent bit-rate selection for the video chunks," explains Aggarwal. "Our group has developed an efficient algorithm for solving the video streaming problem from a single server optimally in polynomial time, even over multiple paths. We have also proposed novel probabilistic scheduling algorithms and functional caching approaches for downloading files from cloud servers and delivering them to clients and quantified performance attributes. We have also come up with approximately optimal multi-round MapReduce-based scheduling algorithms with precedence constraints demonstrating significant improvement in computing."



This depicts the architecture of video streaming over cloud, and some of the key design objectives. (Graphic/Vaneet Aggrawal)

INVOLVING IE STUDENTS

"Much of our faculty's groundbreaking research is being used in educating IE students, at both undergraduate and graduate levels," says **Abhijit Deshmukh**, the James J. Solberg Head and Professor of Industrial Engineering. "In addition to research, we're adding educational opportunities." Purdue IE offers cutting-edge courses for students, such as "Information Engineering Optimization for Big Data," "Mathematics of Data Science," and "Systems, Decisions, and Change and the IE Profession" — and more are coming.

Professor Bob Kenley discusses systems theory with students.

The goal is to teach IE students how to harness multimodal raw data to advance decision making in industries. To this end, Professor **Nagabhushana Prabhu** is developing a new information engineering track for Purdue IE, drawing upon relevant aspects of computer science, electrical engineering, mathematics, statistics, industrial engineering and business.

"The proposed concentration is intended to teach students both the scientific principles of information engineering as well as the relevant state-of-the-art tools used for information management," Prabhu says. "The ability to mine, analyze, and harvest the available information, and in a timely manner, is of critical importance to a modern industrial engineer."

LEADING THE WAY

Purdue IE faculty members and alumni are reaching beyond the School of Industrial Engineering to apply their research, resulting in better policies and practical applications in many areas. Purdue IE is pushing the boundaries of existing decision making research with fresh scholarly perspectives, transmitting that research into educating students, and creating the collaborative space needed to inspire creative minds.

The superb "reinvented" Grissom Hall facilities (p. 8) offer places where both faculty and students can do "big thinking" about big data, decision making and many other industrial engineering topics.

Deshmukh sums up the importance of industrial engineering in today's world:

"We're the only discipline that looks at the whole information cycle. Who better than IEs to help people make better decisions in this complex world?"

INTRODUCE YOUR SELF(IE)

Purdue IE's phenomenal new faculty expand frontiers and collaborate across disciplines

BIG DATA ANALYTICS

HUA CAI

Assistant Professor
Industrial Engineering
and Environmental &
Ecological Engineering

As of today, over half of the global population lives in cities and this number is expected to increase to 66% by 2050. To support this growth, sustainable urbanization is critical. We integrate industrial engineering tools, big data analytics, complex systems methods, and environmental assessments to evaluate system sustainability and to inform decision making. Our current focus is the sustainability of "new mobility" systems. In this area, we use real-world travel data to study the potential environmental benefits of emerging smart transportation systems such as ride sharing, electric vehicles, autonomous vehicles, vehicle-to-infrastructure connections, and multi-model transportation systems.

JOAQUIN GOÑI

Assistant Professor
Industrial Engineering
and Biomedical Engineering

We are modeling the structure and function of the brain as networks, for both healthy and clinical populations, and assessing the intrinsic relationships between structural and functional connectivity. To do so, we use approaches based on complex systems, such as network science and information theory. It is very exciting to learn more about the human brain, and to do so from a complex systems point of view. Understanding the links of structure, function, and ultimately cognitive capabilities is a field that is getting a lot of interest, and it has great potential for developing a better understanding of the brain changes as they occur in aging, in neurodegenerative diseases, in neurological disorders, and during pharmacological treatments.

ROSHANAK NATEGHI

Assistant Professor
Industrial Engineering
and Environmental &
Ecological Engineering

Critical infrastructure systems (CIS) underlie the economic prosperity of every society. Natural catastrophes pose great risks to CIS. Examples such as Typhoon Haiyan in the Philippines, the Tōhoku earthquake and tsunami in Japan, and Hurricanes Katrina and Sandy in the U.S. highlight the extent to which both high-income and low-income countries are vulnerable. Climate change will likely increase the frequency and/or the intensity of extreme events. Our research focuses on modeling the systemic impacts of natural disasters and climate change on interdependent critical infrastructure. We've developed predictive risk and reliability models for the U.S. coastal power systems impacted by hurricanes, and also models to predict tsunami-induced death and damage rates in Japan. We're working on developing an integrated framework for projecting long-term energy demand under climate change.

DECISION MAKING

PAUL GRIFFIN

St. Vincent Health Chair of
Healthcare Engineering;
Director, Regenstrief Center
for Healthcare Engineering;
Professor of Industrial
Engineering

We are analyzing the impact of public health interventions on access, costs, and outcomes in order to inform healthcare policy. Example conditions include asthma, oral health, HIV, and HCV, with an emphasis on low-income and rural populations. We are also developing approaches that support clinical data integration and inference in order to generate evidence-based personalized care from observational data.

INFORMATION ENGINEERING

GESUALDO SCUTARI

Associate Professor
Industrial Engineering

With pervasive sensors continuously collecting massive amounts of information as well as advances in computing, communication, and storage technologies, this is an era of data deluge. Modeling, processing and ultimately making sense of these massive-scale data sets is expected to bring ground-breaking advances in science and engineering, along with improved quality of life. Aimed at exploiting the potential of big data analytics, a major research direction in our group is developing theory and online scalable algorithms for information processing over graphs. Among others, a core application of our research is biomedical imaging: we apply advances in mathematics, parallel computing, and engineering to the development of advanced imaging capabilities enabling "real-time" observation of biological structures and processes for better understanding and treatment of diseases.

NANOMANUFACTURING

WENZHUO WU

Assistant Professor
Industrial Engineering

Seamless, adaptive interactions between electronics and their environment (e.g., the human body) are crucial for advancing emerging technologies in wearable devices, robotics, and human-machine interfacing. By carrying out highly transdisciplinary research combining principles of semiconductor physics, chemistry, materials science, electrical engineering, and nanofabrication, our goal is to conceptualize, develop, and implement new technologies through the design and nanomanufacturing of advanced functional materials with controlled composition and architecture on multiple length scales. We will then apply these new processes and materials to the development of intelligent adaptive electronics, optoelectronics, and efficient energy devices for applications in implanted devices, wearable technology, environmental monitoring, and renewable energy, among others.

HEALTHCARE

BRANDON PITTS

Assistant Professor
Industrial Engineering

The rapid development of advanced and autonomous technology has changed activities, task demands, and expectations in a wide range of work and transportation environments, such as manufacturing and driving. At the same time, recent years have witnessed significant growth in the number of adults aged 65 years and older who are expected to interact with these systems throughout later stages of life. Yet various perceptual and cognitive challenges often lead to ineffective interactions for this population. Our research group focuses on understanding age-related differences in technology trust, acceptance, and use, and quantifying age-group specific complex interactions. We use this knowledge to improve interface design and, in turn, support human-machine system transparency, awareness, and performance.

DENNY YU

Assistant Professor
Industrial Engineering

Healthcare is provided in a dynamic environment with complex human interactions. Excessive team and individual workloads impact both patient and care provider safety, but quantifying workloads in these environments remains elusive. Advances in sensors and wearable technologies provide novel methodologies for generating continuous and granular measurements at the individual level. Our research group focuses on smart wearables that may reduce physical workload, and that can capture human dynamics and inform interventions to enable the highest levels of healthcare delivery.

WEARABLE TECHNOLOGIES

GRISSOM HALL REINVENTED

Students study and collaborate in the Peter Wang Student Excellence Center.

Purdue Industrial Engineering has long had its home in classic Grissom Hall. Because training tomorrow's industrial engineers to meet 21st century challenges required modernization of the 1906 building, Purdue IE carried out a year-long "reinvention" of Grissom in 2015. Two years after the dedication ceremony, the original plans for Grissom Hall have far exceeded Purdue IE's hopes. The "new" Grissom fosters faculty and student collaboration, research and education. Purdue College of Engineering Dean **Mung Chiang** describes the building as having "sharable, visible, flexible space."

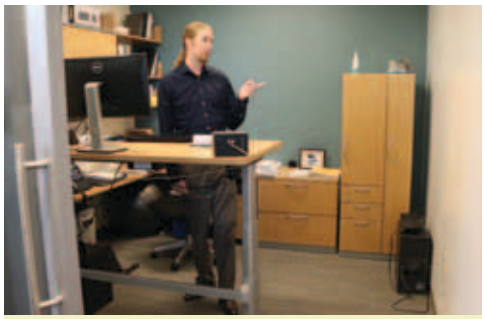
STUDENTS are enthusiastic about the "new" Grissom. "In my old space there were no windows. This is new and clean, and feels modern and professional," says PhD student **Michelle Jahn**. Recent PhD graduate **Baback Vaziri** agrees: "It feels open, collaborative and gives a better opportunity to network with other people in IE."

Jordan Hill, a PhD student who lives off-campus, likes the flexibility of working at a "touchdown station." "This is a place that I come to work when I'm on campus," she says. "So when I'm here for class or to be more productive, I need a spot to work where I don't have any distractions, and I can really buckle down and get all my work done."

"Touchdown spaces" on Grissom's 2nd and 3rd floors give graduate students space to work and collaborate.

FACULTY say the redesign helps them manage their labs and collaboration better. Professor **Barrett Caldwell** heads the GROUPER Lab at Purdue and spent the past year in Washington, DC, for a one-year appointment as a Jefferson Science Fellow. Grissom's redesign allowed him the flexibility to manage both appointments. "One of the best elements of new Grissom's collaboration capabilities, and what we need for the future of global teams, is the ability to manage hybrid in-person/distance team meetings," he says. "My lab was able to have collaborative team meetings in a way that would have been impossible before."

"I really appreciate having a standing desk here and also having the whiteboard paint on the wall, so I can draw or write equations," says Assistant Professor **David Johnson**. "Whenever other faculty members come to visit from other departments for meetings, they always comment on how nice it is."



Johnson's standing desk and whiteboard wall give him freedom to work.

Students meet teaching assistants or work in groups in the collaborative Tompkins Learning Center.

Associate Professor and Associate Head of Industrial Engineering **Steve Landry** adds that the redesigned building is improving student education.

"The open small conference rooms with whiteboards have proven to be immensely valuable in ad hoc student meetings," says Landry. "The classrooms are much more amenable to student-instructor interaction. The new research spaces are fantastic places for small research groups to interact."

The "new" Grissom Hall shows another way Purdue IE is meeting the decision making challenges of today's complex world: revolutionizing how our students and faculty work, collaborate and study.

We invite you to come see the "reinvented" Grissom Hall soon. In the meantime, watch the "Grissom Hall Reinvented" (https://youtu.be/oq4g5uRWxcM) virtual video tour as IE students, faculty and staff describe what they like about the new space.

AROUND IE

INDUSTRIAL ENGINEERING CORPORATE PARTNERS

Now more than 18 months after Purdue IE launched a new **Corporate Partners** program (January 2016), IE's partnership with industry has increased dramatically. This initiative builds ongoing, mutually beneficial relationships with companies who want to gain greater access to future engineers. At the same time, the program enables students to gain greater knowledge about potential employers. The partnership provides companies with a single point of contact to:

- identify IE talent to fill internships, co-ops and full-time positions
- increase accessibility to students and faculty
- bolster the company's brand name within IE
- directly distribute job openings
- sponsor a senior design project for undergrads or a research project for graduate students

Partner today with one of the highest-ranking IE schools in the country – Purdue IE! For more details, contact **Dave Kotterman**, Director of Industry Relations, at dkotter@purdue.edu or 765-496-0565. Or visit the Corporate Partners webpage: engineering.purdue.edu/IE/foryou/corporatepartners.

BEYOND THE CLASSROOM: IE STUDY ABROAD

(l) At TSF in Spain; (r) Visiting India's Taj Mahal

Purdue IE encourages undergrads to take the opportunity to gain experience beyond the classroom – with IE internships, co-ops, undergraduate research, and study abroad. "I think the Study Abroad experience helped make me a better industrial engineer because IEs are known for their systems mindset and way of thinking," said Sarah Chandler, a junior in IE. "And going abroad, stepping out of my culture and normal everyday life helped me to develop my systems mindset globally."

Because of this commitment to going beyond the classroom, Purdue IE launched **two new study abroad opportunities** this summer: a "Maymester" course in Pamplona, Spain, and an internship in India.

In May, **Systems Dynamics & Modeling for Engineers** took place in and around Pamplona, Navarra, Spain. Eight undergraduates, one graduate student, and IE faculty and staff members spent three weeks in northern Spain for the first-ever IE Pamplona Maymester. Assistant Professor **Joaquín Goñi**, who is from Pamplona, gave a unique cultural perspective to the course and outings. He was enthusiastic with the course's outcome, saying, "It was even better than I expected!"

Beyond Europe, Purdue IE offered a new Asian experience: an internship at TVS Motor Company in Bangalore and Hosur, India. Six IE students interned there this summer. **International Internship India** is a dual-discipline, 3-credit-hour joint internship program between Purdue IE and the Krannert School of Management. Projects included inbound logistics, outbound logistics, and marketing. "The students were working on real projects to improve various operations within the company under supervision of the faculty involved, and TVS senior managers," said **Patrick Brunese**, IE Director of Academic Programs.

A "JOYOUS ADVENTURE"

Patti Poppe (BSIE 1989, MSIE 1991), President and CEO of CMS & Consumers Energy, credits her Purdue IE education with helping her get to where she is today. "Purdue IE prepared me with fundamental skills upon which I still rely - basic scientific problem-solving, how to ask a lot of questions and keep learning, how to continuously improve any organization, and how to work together with other talented and capable people," she says. "My Purdue IE degrees are a true point of pride for me. Purdue IE is leading the charge in making a difference in the areas that matter the most: healthcare, manufacturing, and energy."

Poppe believes the **"new" Grissom Hall** will better prepare students for 21st-century engineering. "The collaborative spaces in Grissom Hall are the perfect training grounds to learn how to work in teams," she says. She encourages IE students to find their passion, figure out how to apply their industrial engineering talents to it, and to be curious about future possibilities. She states, "Life can be a joyous adventure if you bias your career toward what you love doing."

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Facets of Purdue Industrial Engineering

(Top left) Wearable technology, Healthcare Ergonomics Analytics Lab (Yu group); (top right) Self-powered, Paper-based Electrochemical Device (SPED), FlexiLab (Martinez group); (bottom left) Grissom in the fall; (bottom right) Purdue President Mitch Daniels with IE students.