Northwestern | McCORMICK SCHOOL OF ENGINEERING

FALL 2017

INDUSTRIAL ENGINEERING AND MANAGEMENT SCIENCES

PERSONALIZING CANCER TREATMENTS

Omid Nohadani uses algorithms to improve patient outcomes from radiation treatment

Often, when a patient is diagnosed with cancer, their oncologist prescribes a regiment of radiation to help shrink or eliminate the tumor.

While this technique is used in about two thirds of all cancer cases, the outcome is often uncertain and in many cases could benefit from adjustments to help prevent adverse side effects.

Associate Professor **Omid Nohadani** and his students are using algorithms to help improve radiation treatment outcomes. They have developed a novel optimization algorithm that adjusts treatment based on how the cancer changes as a tumor shrinks or grows, and on how the tumor's position moves as a person undergoing therapy coughs or breathes.

"You want to use the best angles and radiation intensity to harm the tumor while sparing the healthy tissue," Nohadani said. "There are many variables you have to take into account to deliver the optimal dose."

To best meet this goal, Nohadani uses a strategy called robust optimization, which uses algorithms that take risk and uncertainties into account when deciding the best position. With radiation therapy, for example, there are trade-offs between how fast the radiation can shrink the tumor and the patient's overall health. A lower radiation dose might take longer to shrink the tumor, but it might also minimize damage to the surrounding tissue when uncertainties arise.

"Uncertainties cannot only be managed, but they can be actually leveraged to augment solutions," Nohadani says.

In an NSF-funded project with Northwestern's Bharat Mittal, professor of radiation oncology, Nohadani is developing a novel recommendation system that "learns" from past decisions to support treatment decisions for subsequent patients. For the system, the team is developing novel machine-learning methods that account for uncertainties and measurement errors in data associated with previous patients. This quantifies the knowledge and experience of an oncologist and exploits it in a systematic way.

Nohadani is also working with Professor **Seyed Iravani** to develop a framework to make use of such knowledge to directly optimize institutional and national guidelines for a broad range of treatments.

Omid Nohadani

"UNCERTAINTIES CANNOT ONLY BE MANAGED, BUT THEY CAN BE ACTUALLY LEVERAGED TO AUGMENT SOLUTIONS."

OMID NOHADANI

FROM THE CHAIR

Dear friends,

September 2017 marked the beginning of my time as department chair. As I reflect back on my first two months, I must first thank former chair **Jorge Nocedal** for his wonderful leadership. He is currently on a well-earned sabbatical, returning to full-time research. Although, if you know Jorge, you know his remarkable research productivity and deep thinking continued as he energetically led IEMS in his term as chair.

It's an exciting time to be working in industrial engineering. We see explosive growth in analytics, machine learning, and high-dimensional statistics. Innovative and transformative applications are emerging in new and rapidly evolving forms of e-commerce, healthcare, and energy systems, and our department is leading the way.

In this newsletter, you will get a glimpse into how **Omid Nohadani**, his students, and his collaborators are advancing robust optimization to improve and personalize radiation therapy for cancer treatment. Omid's interdisciplinary research team includes medical researchers Thomas Bortfeld (Harvard Medical School), Indra Das (NYU School of Medicine), and Bharat Mittal (Northwestern's Feinberg School of Medicine), as well as our professor **Seyed Iravani**. This newsletter also celebrates the election of **Sanjay Mehrotra** as an INFORMS Fellow, class of 2016. Sanjay has made profound and lasting contributions to optimization, and he has impactful applied work, including research in healthcare systems and policy as he leads Northwestern's Center for Engineering and Health.

This past year, we hired two new faculty members as assistant professors. **Matt Plumlee** earned his PhD at Georgia Tech, and **Zhaoran Wang** earned his PhD at Princeton. Matt works in statistics, on uncertainty quantification, model calibration, and deriving insights from physical and computational experiments. Matt spent the summer of 2015 visiting IEMS before joining the faculty at the University of Michigan, and we're pleased to welcome him back to Northwestern. Zhaoran works in machine learning, at the interface of high-dimensional statistics and large-scale optimization. He is a postdoctoral fellow this year and will formally join IEMS in fall 2018. Both Matt and Zhaoran significantly strengthen Northwestern's and IEMS's presence in machine learning and statistics, and we're thrilled to have them on board.

We will miss **Jorge Nocedal**'s leadership in his role as chair, but our department will continue to benefit from his strong intellect and scholarly instincts. Over the years, Jorge has made many seminal contributions to the area of unconstrained and constrained nonlinear optimization, which have fundamentally reshaped the field. He is the foremost individual responsible for showing how to make second-order methods efficient and effective in the truly large-scale problems that modern machine learning now addresses.

As chair, Jorge launched the Center for Optimization and Statistical Learning, a joint center between IEMS and Northwestern's Department of Electrical Engineering and Computer Science. Also under Jorge's leadership (with Sanjay Mehrotra), the Center for Engineering and Health has continued to grow and thrive. We just welcomed **Nikolaos Maglaveras** as a clinical professor in IEMS, and he will help the center continue to grow. Our undergraduate program will continue to benefit from hires on Jorge's watch, including **Gail Berger**, who teaches IEMS courses in leadership and in negotiations and conflict resolution, and most recently, **Marita Labedz Poll**, who will help enhance our undergraduates' experiences through her expertise in advising.

I hope this newsletter helps convey a sampling of the exciting developments in industrial engineering, in general, and in our department, in particular.

Dave Morton
David A. and Karen Richards Sachs Professor and Chair

2016-17 Gifts to the Department

The Department of Industrial Engineering and Management Sciences is extremely grateful for the generous donations it continues to receive from private and corporate donors. Below are donations received this year through June 30, 2017. Every dollar is used to support the academic, administrative, and research endeavors of our department. Please accept this acknowledgement with our deepest appreciation.

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SANJAY MEHROTRA ELECTED INFORMS FELLOW

Mehrotra is honored for his many contributions to optimization methodology

Professor **Sanjay Mehrotra** was among 12 researchers elected as INFORMS fellows in the class of 2016.

He was selected for his "contributions to continuous, discrete, and stochastic optimization methodology and their impact on operations research technology implementation and application."

Mehrotra, who directs Northwestern's Center for Engineering and Health, has made important contributions in stochastic optimization and multi-objective optimization under risk-based constraints. He has developed the theory of interior point methods for two-stage quadratic, semidefinite, conic, and convex optimization models. In part, his work shows that the number of iterations required to solve a stochastic semidefinite program does not grow relative to that for a deterministic model. More precisely, the iteration complexity is preserved, using a scenario-based decomposition algorithm.

A sampling of Mehrotra's applied work in healthcare has ranged from developing optimization models that infer the nature of gene regularity networks from DNA-array data to optimizing the staffing and scheduling of nurses under uncertain demand. Recently, he has been active in providing scientifically rigorous input to a national debate on how to best deal with geographic disparities for US patients with end-stage liver disease who require a liver transplant. With colleague Daniela Ladner of Northwestern's Feinberg School of Medicine, Mehrotra has proposed modeling uncertainty in input data to better inform liver allocation. The pair estimates that over 150 percent additional lives could be saved over an alternate plan being put forward.

Sanjay Mehrotra

MEHROTRA HAS MADE IMPORTANT CONTRIBUTIONS IN STOCHASTIC OPTIMIZATION AND MULTI-OBJECTIVE OPTIMIZATION UNDER RISK-BASED CONSTRAINTS.

Early in his career, Mehrotra investigated variants of Karmakar's interior point algorithm for solving linear programs. A few years later, he developed what is now called the "Mehrotra predictor-corrector method for interior point algorithms." Mehrotra's famous method is now integral to all commercial software that implements a primal-dual interior point algorithm. Google Scholar attributes approximately 100 citations per year to his seminal 1992 paper in *SIAM Journal on Optimization* describing his important discovery.

Lift-and-project methods provide a key means for solving mixed-integer 0-1 linear programs, and were developed in the early 1990s. In a 1999 paper in *Mathematical Programming*, with his PhD student Robert Stubbs, Mehrotra was the first to show that this theory could be extended to handle the more general case of mixed-integer 0-1 convex programs. In a series of subsequent papers, Mehrotra built on this central idea, making use of it for developing nonlinear cuts, effective branching schemes, and well-motivated heuristics.

Mehrotra has also provided critical leadership in the field, including as chair of INFORMS Optimization Society and as general chair for the 2013 INFORMS Healthcare Conference in Chicago.

NORTHWESTERN HOSTS INFORMS APPLIED PROBABILITY CONFERENCE

Ohad Perry co-organized the event

EMS assistant professor **Ohad Perry** co-organized the 2017 INFORMS Applied Probability Society (APS) Conference, which was hosted at Northwestern. For this year's conference, Perry and the rest of the organizing committee aimed to broaden participation of researchers from academic disciplines that are not traditionally emphasized in APS meetings.

Applied Probability Conference, July 2017.

To help meet this goal, professors **Barry Nelson** and **Vadim Linetsky** organized conference clusters in the simulation and financial engineering areas. Alexandre Belloni from Duke University's Fuqua School of Business organized a cluster in statistical learning.

"I would like to thanks the IEMS department for supporting the conference," Perry said. "Former chair **Jorge Nocedal** and the Kellogg School of Management provided generous financial support, and the department staff helped tremendously."

Plenary speakers included Asu Ozdaglar (MIT), Yuliy Sannikov (Stanford), R. Srikant (UIUC), Jose Blanchet (Columbia and Stanford) and Bert Zwart (CWI, the Netherlands).

Ozdaglar delivered a plenary talk about dynamical Bayesian learning in online platforms; Sannikov presented his work on dynamic incentives in a continuous-time principal agent model, which employs tools from applied probability that are not familiar to most economists; and Srikant discussed approximate graph matching on random graphs. Blanchet and Zwart served as tutorial speakers.

Perry presented his work in queueing theory, which is the mathematical modeling of systems with delays. The theory plays a fundamental role whenever resources in a system that processes "jobs" are scarce relative to demand.

"To illustrate, consider a hospital as a queueing system, with beds or physicians playing the role of servers. Hospitals around the world are struggling with inefficiencies associated with their patient-flow, and experience frequent congestion and long delays," Perry explained.

Ohad Perry

"Adding beds or increasing staffing levels can alleviate congestion, but this leads to non-trivial tradeoffs between costs associated with the additional resources and the costs associated with congestion. A queueing model for the patient-flow can be employed to quantify and optimize the number of beds or staffing levels, subject to waiting time constraints, say, and can also be used to explore optimal routing and scheduling policies. However, due to the complexity of the system, exact analysis of an effective queueing model is unlikely to be possible, so that approximations are needed."

Perry's research also focuses on modeling queueing and inventory systems, deriving asymptotic approximations for those models, and analyzing the limits. Dynamical systems control plays a significant role when functional weak laws of large numbers, known as "fluid limits," are used to approximate a system.

THIS YEAR'S CONFERENCE AIMED TO BROADEN THE PARTICIPATION OF RESEARCHERS FROM ACADEMIC DISCIPLINES NOT TRADITIONALLY EMPHASIZED AT APS MEETINGS.

ALUMNUS TO TEACH NEW MEM COURSE

MEM 490 introduces students to product management

This fall, alumnus **Birju Shah** joins the Master of Engineering Management program and will offer a new course, MEM 490: Product Management.

Armed with a dual degree in industrial engineering and economics from Northwestern and an MBA from MIT, Shah is currently the lead product manager of intelligence at Uber. He draws upon 15 years of building, launching, and scaling software, hardware, and big data solutions to solve large consumer problems.

What motivated you to start teaching?
Technology is at an inflection point where we are exponentially innovating new products every day that will dramatically impact everyone's daily life. From thinking about living on Mars, 3D-printing food, and how we measure the health on our body, sharing information and experiences is one of the greatest inventions and unique to the human mind outside the genetic code.

What is your definition of product management? And what is the difference between that and project management?
Good project management skill is fundamental and a component of product management. The simple answer is: as a product manager you are responsible for the ideation, vision, execution of a sellable or usable product for whatever use-case you are solving. Good product managers identify a problem and build a product to solve that problem. Great product managers figure out a way to do this at scale, create roadmaps to continuously enhance their product, measure the success and failures, and ultimately figure out how to cannibalize and build the next generation of their product.

Product managers (PMs) can have a big impact on a technology company's performance. PMs define a product's functional requirements and then lead a team responsible for its development, launch, and ongoing improvement. MEM 490: Product Management aims to build understanding of the PM role and develop skills required to perform the role.

How does your background fit with teaching the topic of product management?
I have built my own products in my own start-up, for big companies, and even re-built products for medium sized companies to get them out of trouble and sold to private equity. My products are used by more than one billion people and in nearly 200 countries, and range from large every day usage like traffic time in maps applications to lesser used niche but difficult to adopt markets like doctors and farmers diagnostics. (Check out the products at birju.me).

What Is different about your course and teaching style?
This course is all about action learning. This means using your mind and hands to think strategically and get down and dirty in execution. We will use case-based approaches in each class, walking through real-life products and problems to emphasize how you should build your product and market it to enable your success.

What do you expect students to take away from the course?
MEM490: Product Management is designed as a 101 course for students who lack prior product management experience but want to work in that role after graduation at a big tech company or in a startup. I want aspiring founders to gain a better understanding of the product development process.

The class goals are simple: (1) learn how to launch a product, and (2) learn how to obtain a top-notch product management job in tech. Students will gain the skills to do product management at a tech company or startup or for their own companies.

To learn more about the course and review the course syllabus, visit www.mccormick.northwestern.edu/engineering-management/curriculum/descriptions/490a.html.

Birju Shah

> "THE CLASS GOALS ARE SIMPLE: (1) LEARN HOW TO LAUNCH A PRODUCT, AND (2) LEARN HOW TO OBTAIN A TOP-NOTCH PRODUCT MANAGEMENT JOB IN TECH."
>
> BIRJU SHAH

IEMS 2017 GRADUATION

The McCormick School of Engineering graduated 237 master's and 97 PhD students over three ceremonies in June in the Technological Institute. Undergraduates participated in the Northwestern ceremony at Ryan Field, where Billie Jean King provided the address for the 159th Annual Commencement. After the main commencement ceremonies, IEMS also celebrated its undergraduates and PhDs in dedicated events.

PhD GRADUATES

In 2016-17, IEMS graduated 10 PhD candidates: **Kingsley Di**, **Ben Feng**, **Nitish Shirish Keskar**, **Yujing Lin**, **Yutian Nie**, **Likuan Qin**, **Aaron Schecter**, **Kezban Yagci Sokat**, **Eunhye Song**, and **Yaxiong Zeng**.

SENIOR CEREMONY

On Friday, June 16, IEMS held a department ceremony for 89 graduating seniors and their families and friends. The event highlighted special student awards and achievements and provided time for students to connect with faculty members and families and share their body of work through student-led presentations and design project posters.

ENGINEERS OPTIMIZE MARATHON VOLUNTEERS

Data analytics team works to ensure medical supply can meet race-day demand

As runners tackled the Bank of America Chicago Marathon last month, they had an unseen support system to help keep them — and the race — running smoothly.

Professor **Karen Smilowitz**, her student team, and the Feinberg School of Medicine's George Chiampas used data analytics to help marathon organizers ensure that medical tents were well-staffed throughout the 26.2-mile course.

Four years ago, Smilowitz and her students began developing a custom-designed data visualization system that provides a computer simulation of the race as it unfolds. Using data from the past nine Bank of America Chicago Marathons, the system can forecast where large concentrations of participants will be along the course and help race officials plan accordingly. Staff members stay connected to the system via mobile dashboards to ensure that the race is seamless and safe.

"Every year, our product is just better," said Smilowitz, an expert in the study and application of data analytics for mass-scale events. "In the past, we mostly focused on developing and prototyping the system. This year, the students really cleaned it up and fine-tuned it. They have done a phenomenal job."

To update the system to help optimize medical personnel, Smilowitz and her team first examined historical data and calculated the demand at each tent location over time. More recently, to determine whether medical tents are well-staffed, they turned to another data source: "stress levels." One volunteer per medical station gauged the general stress level of the tent's atmosphere on a scale of 1 to 5 and reported it to a radio team. (One being the most relaxed, and five being the most overwhelmed.)

Stationed in forward command: (back) Karen Smilowitz, George Chiampas, Mehmet Basdere, Kate Larsen, Christian Rozolis; (front) Gabriel Caniglia and Charlie Collar

Karen Smilowitz

Every time the level of stress changed, the volunteer updated the report. Smilowitz's students then accessed the report data and input it into the dashboard system. By monitoring this input, Chiampas, the marathon's medical director, determined areas with staff shortages and made informed decisions about redeploying teams to keep up with demand.

"The marathon is always a big challenge," Chiampas said. "But Chicago has set the bar globally with regards to large event planning, and Karen's work is a part of that."

As medical director, Chiampas has witnessed first-hand how difficult it can be to effectively distribute 1,200 medical personnel. Volunteers often do not make it to their pre-assigned tent, sometimes getting confused about locations or drifting instead to tents where their friends are working.

"With any event that relies on volunteers, there is a natural attrition rate," Chiampas said. "Now we can be more confident in knowing if they make it to the right place."

DO EARTHQUAKES HAVE A 'TELL'?

Data scientists and seismologists use "deep tremor" activity to forecast strong earthquakes

Researchers have long had good reason to believe that earthquakes are inherently unpredictable. But a new finding from Northwestern University might be a seismic shift for that old way of thinking.

An interdisciplinary team recently discovered that "slow earthquakes," which release energy over a period of hours to months, could potentially lead to nearby "regular earthquakes." The finding could help seismologists better forecast some strong earthquakes set to occur within a certain window of time, enabling warnings and other preparations that may save lives.

"While the build-up of stress in the Earth's crust is largely predictable, stress release via regular earthquakes is more chaotic in nature, which makes it challenging to predict when they might occur," said **Kevin Chao**, a data science scholar in the Center for Optimization and Statistical Learning. "But in recent years, more and more research has found that large earthquakes in subduction zones are often preceded by foreshocks and slow earthquakes."

Supported by the National Science Foundation, the research was published in the *Journal of Geophysical Research: Solid Earth*. Chao, who is also a member of the Northwestern Institute on Complex Systems (NICO), served as the paper's first author. Suzan van der Lee, a professor of earth and planetary sciences in Northwestern's Weinberg College of Arts and Sciences, also contributed to the work.

Chao and his colleagues began their work several years ago by turning to a region within Taiwan, home to approximately 100 seismic stations that have continuously recorded ground motion for years. It was there the team noticed a phenomenon called deep tremor, a type of slow earthquake that typically recurs in days- or weeks-long cycles.

"Deep tremor is very sensitive to small stress changes," Chao said. "So, we decided to use them as stress meters to monitor local variations in stress build-up and release before and after large earthquakes."

To detect and monitor this deep tremor activity, Chao's team developed a sophisticated set of algorithms and applied it to data from 10 seismic stations in Taiwan. They discovered that deep tremor started to change its behavior about two months before the occurrence of a 6.4-magnitude earthquake in March 2010 in southern Taiwan. The tremor's duration, for example, increased by two-fold before this event and continued to increase afterwards.

Although deep tremor was first reported in 2002, scientists have not found many cases in which behavior changed before large earthquakes. "After the 6.4-magnitude earthquake occurred, we noticed a potential to study deep tremor near the event," Chao said. "We identified the increase in tremor duration three weeks before the earthquake, but we initially could not draw conclusions because tremor rates increase all the time and for different reasons.

But three years after the 6.4-magnitude, Chao and his colleagues noticed that their observations of tremor activity coincided with a nearby GPS recording, which indicated a flip in the direction of ground motion near tremor sources.

By combining data from earth observatories, such as GPS and seismic stations, with statistics and a series of algorithms, the team showed that changes in deep tremor patterns could signal an impending earthquake nearby. To further test the finding, Chao examined four additional earthquakes and discovered that similar precursory patterns did exist. He and Van der Lee hope that this work will inspire more data-driven research in the seismology field.

Kevin Chao

"Much more data analysis of these tiny but fascinating tremor signals is necessary," he said, "before mid- to short-term earthquake forecasting become reliable."

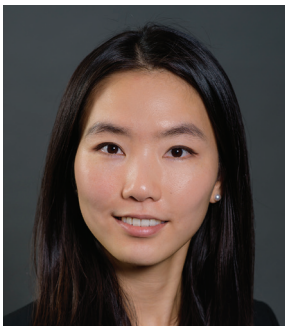
> "IN RECENT YEARS, MORE AND MORE RESEARCH HAS FOUND THAT LARGE EARTHQUAKES IN SUBDUCTION ZONES ARE OFTEN PRECEDED BY FORESHOCKS AND SLOW EARTHQUAKES."
>
> KEVIN CHAO

OUTSTANDING GRADUATING PHDS

Graduates share their research, memories, and where they are now.

Faculty members selected three outstanding PhD graduates this year to celebrate their academic excellence, dedicated service, and work ethic. We posed questions to graduates Eunhye Song, Likuan Qin, and Nitish Shirish Keskar, and then asked the students' advisers to answer questions about them.

Eunhye Song



Describe your research.
My broad research area is simulation analysis. One thread of my research is to quantify input model risk in simulation. Input model risk refers to the risk of making a suboptimal choice due to the statistical error in simulation input models estimated from data. My goal is to provide a simulation-optimization algorithm that can identify the optimal solution under the true input distribution, not under the estimated input model. The other thread of my research is to develop a globally convergent adaptive random search algorithm for a large-scale discrete simulation- optimization problem.

What attracted you to Northwestern IEMS?
During my junior year at KAIST, I was first exposed to simulation modeling by a friend in the undergraduate research program. Her team was building an ARENA model to find a more efficient layout for the school cafeteria. I thought it was really cool to use something you learn in the class to make a relevant change in real life. So I joined a simulation research lab in my master's study and worked on several industry/government projects. While building simulation models for different application areas was fun, I noticed that the clients received little guidance about how to solve their problems using these models. I wanted to study more than just simulation modeling and decided to pursue a PhD.

What is the biggest positive takeaway from your experience?
I learned how to communicate my academic work to others; that was the most valuable skill I have learned from my PhD. Other students in the department were interested in knowing what I'm working on and eager to share their work as well. And I just loved that intellectual stimulation and enthusiasm.

What are you doing now?
This fall, I joined the Department of Industrial and Manufacturing Engineering at Penn State as the Hal and Inge Marcus Early Career Assistant Professor. I'm excited to start my career because I have always wanted to work in academia ever since I entered graduate school. I'm not advising a PhD student yet, but I'm looking forward to it.

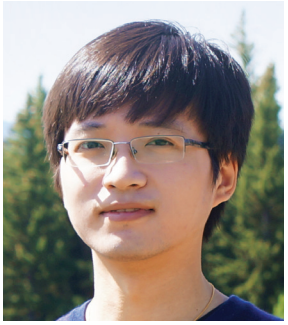
Adviser: Barry Nelson

What makes Eunhye exceptional?
Eunhye has all of the skills you can teach, but also the most important that one you cannot: insight. Many of her research contributions are leaps, not increments. Her bachelor's and master's from KAIST gave her a foundation in modeling, computing, and applications that you seldom get in a student whose goal is to work on methodology; she is the rare graduate who is outstanding at both. For the work I do, that is the *perfect* combination.

Is there a good story that comes to mind?
Eunhye gave a most impressive phone interview. We spoke late one night, US time. When I got off the phone, I made it my mission to convince her to come here. I should also give her credit for the following: I made her defend her dissertation at a conference in Banff in front of some of the most famous researchers in simulation (who were not on her committee). I am not sure I would have done that to anyone else but knew she could handle it. (And she is still speaking to me.)

How has Eunhye changed since you first met?
It is standard to say how much of a pleasure it was to work with a student, and that is certainly true with Eunhye. She is kind, invariably upbeat, and funny. But what will stay with me are the thoughtful discussions we had about what it means to optimize a simulated system in the presence of model risk, what is useful, what is possible, and how to interpret it. That is asking a lot of a student, but after her first year Eunhye was not really a student; she is truly fearless, and it was a great collaboration.

Likuan Qin



Describe your research.
My research interests include mathematical finance, stochastic modeling, empirical finance, and machine learning.

What is the biggest positive takeaway from your experience?
The biggest takeaway from my PhD experience is I had the chance to learn so many interesting research fields, topics, and techniques, thanks to the interdisciplinary nature of IEMS. Different fields adopt different approaches to tackle a problem, and you never know which is the best one for your next problem.

What are you doing now?
I am currently a quantitative analyst at D.E. Shaw, a quant hedge fund. Although I am in industry now, my work is still research-oriented. I am excited that I can leverage my knowledge base built in the past years, and I am ready for the next challenge.

Adviser: Vadim Linetksy

What makes Likuan exceptional?
Likuan is exceptionally versatile in his abilities. Most PhD students have a particular strength and focus on developing that strength. Likuan is equally at home working with the deepest and most challenging mathematics, computational algorithms, and empirical data. He is also an exceptionally fast learner and generally does everything very fast. I never really understood how he managed to do things so fast. Some people do things fast, but they make a lot of mistakes. Likuan does things right from the first try.

Is there a good story that comes to mind?
To illustrate how fast Likuan progressed: He started doing research within a month of joining the program. By the end of fall quarter of his first year, he had a first draft of a paper. He did his dissertation prospectus in the fall quarter of his second year, when he already had a close-to-finished major paper, and first drafts of two other papers, a remarkable feat. I am not sure he slept much during those early years.

How has Likuan changed since you first met?
Likuan arrived on campus as the first prize winner in the National Mathematical Olympiad in China two years in a row. I was not surprised to discover firsthand his remarkable mathematical abilities. What has been remarkable is observing how Likuan used every opportunity offered by IEMS to develop and expand his interests and research skill set.

Nitish Shirish Keskar

Describe your research.
My research involved designing second-order optimization algorithms for nonsmooth and stochastic problems. The former class of problems could either be structured, such as in the case of regularized machine learning models, or unstructured, requiring general-purpose methods. Many problems in machine learning can be posed as stochastic optimization problems, which often are large-scale, given the growing size of the models and the available data. In both classes of problems, I primarily dealt with the design and implementation of second-order methods, which use curvature information to speed up the optimization process.

What attracted you to Northwestern?
As a senior student back in India, I interned at a supercomputing facility in India (SERC, Bangalore) where I worked on large-scale quadratic optimization problems. I thoroughly enjoyed my time there and eventually wrote my bachelor's thesis on the same topic. Enrolling in graduate school seemed to be the next logical step.

What is the biggest positive takeaway from your experience?
Patience! Coming up with and testing ideas often took a frustrating amount of time and this frustration was aggravated further when the ideas failed to deliver as expected. The PhD experience taught me to stay calm and patient, and keep digging until the 'Aha!' moment.

What are you doing now?
I'm currently a senior research scientist at Salesforce Research in Palo Alto, where I work on deep learning and, specifically, on natural language processing.

Advisers: Andreas Wächter and Jorge Nocedal

What makes Nitish exceptional?
Nitish was an extremely curious and driven student. Beside working with his advisers, he started projects on his own and published a paper solely with a fellow student. And, by diving into online courses and blogs, he became a true expert in deep learning. He has also become somewhat famous in the (huge!) deep learning community for his paper on sharp minima, which made quite a splash and influenced other researchers to look at the same research question.

Is there a good story that comes to mind?
Nitish is a very funny and happy person. His office mates already miss his pranks. He would flip the screens on their computers or make them suddenly play music. One time he created a fake twitter post that pretended that a famous researcher had just published a paper on exactly the topic that his office mate was working on. After a huge scare, his friend, with the rest of the office, exploded in laughter.

How has Nitish changed since you first met?
Well, now he knows how to play the guitar, ukulele, bass, and even Baglama — some really important survival skills!

FROM THE ASSISTANT CHAIR

Dear friends,

As we prepare for a new academic year and a new cohort of undergraduate students, I am especially excited to introduce you to **Marita Labedz Poll**. Marita joins us as our new IEMS professional adviser. Although her primary responsibilities include advising students on undergraduate curriculum matters, Marita comes to us with an extensive background in counseling and student affairs, and we look forward to using her expertise to strengthen the undergraduate experience.

As we welcome Marita to our staff, we also say goodbye to **Zachary Guritz**, my right-hand-man for the past three years. Zack prepared materials to support advising and was always available to answer student questions. He was also responsible for many behind-the-scenes process improvements and served as an officer—including president—for our student chapter of the Institute of Industrial Systems Engineers. After receiving his degree last spring, Zack went on to lend his considerable skills to United Airlines. Congratulations, Zack!

We also benefitted greatly last academic year from the work of **Rachel Heyman**, who conducted a thorough assessment of undergraduate advising in the department. With her background in law and her participation in the MS in Higher Education program, Rachel was uniquely suited to provide an external perspective on the advising experience in IEMS. In brief, she discovered that advising standards are quite high in the department—no surprise to those of us who know just how dedicated our faculty are. Of course, as industrial engineers, we always seek improvement. Rachel proposed a model that would allow us to provide more consistent advice on nuanced details of degree requirements while maintaining close faculty ties and mentorship experiences for our undergraduates. Her proposal led to the creation of the professional adviser position.

We are very excited for the continued success of our students and alumni. Although there are too many accomplishments to list here, we would like to highlight that two members of our Class of 2017 are currently pursuing PhD studies in top-ten industrial engineering departments, and current student **Nisha Bhuva** published an article about her internship experience with Under Armour. Finally, a team of undergraduate researchers, working with faculty and PhD students, consulted with officials at Evanston School District 65 to examine their transportation systems. This work will continue through funding from the National Science Foundation, encompassing theoretical exploration, undergraduate research involvement, and curriculum development through cooperation with D65 teachers to bring related ideas to the K-8 classroom.

We look forward to all that 2017-18 will bring for our students!

Jill Wilson
Assistant Department Chair
for Undergraduate Studies

NORTHWESTERN TEAM TIES FOR TOP PRIZE AT BUSINESS COMPETITION

The PriSim Business War Games helps students build strategy, business, and leadership skills

In the fifth annual PriSim Business War Games Competition, student teams competed in a head-to-head battle for market share and profit. Teams from Northwestern and Dartmouth tied for the top prize.

During the web-based simulation competition, students ran a domestic automobile company, making decisions as a team. The five-week competition is part of the Master of Engineering Management Programs Consortium (MEMPC) and raises awareness for the Master of Engineering Management (MEM) degree. It also provides networking opportunities among employers, students, faculty, and alumni.

In addition to Northwestern and Dartmouth, Cornell, Duke, Johns Hopkins, MIT, Tufts, and the University of Southern California also participated.

"The competition underscores the unique value of an MEM education," said **Stephen Tilley**, associate director of Northwestern's MEM program. "It provides experiential learning outside the typical classroom environment and reinforces a student's need to use a combination of professional engineering practice with core business and management education to make effective business decisions."

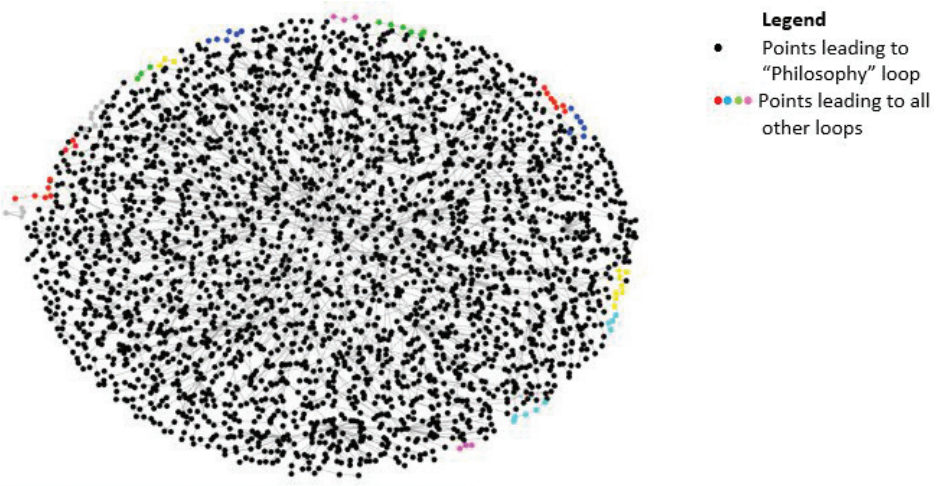
The competition challenged students to analyze the business environment and then articulate the mission of their company. Each firm began the simulation with three vehicles, then decided how to improve their performance and whether they wanted to design and produce new vehicles to enter new market segments.

Northwestern's winning team

WIKI LOOPS: VISUALIZING PATTERNS IN WIKIPEDIA LINKS

MSiA student discovers that Wikipedia pages tend to lead back to "philosophy"

By Jamie Green '16, from the MSiA blog



A data visualization shows how most Wikipedia pages lead back to the philosophy page.

What's the difference between NASCAR and philosophy? According to web cartoonist Randall Munroe, only five Wikipedia pages.

Munroe, a former NASA astronaut who produces the popular online comic *xkcd*, is best known for his humorous takes on subjects ranging from math and science to love and poetry. His primary outlet, www.xkcd.com, pulls in an estimated 2.8 million views per day.

In 2011, Munroe set his comedic sights on Wikipedia, highlighting how reliant we've all become on the crowd-sourced encyclopedia for our knowledge about even the most basic things. "Wikipedia trivia: if you take any article, click on the first link in the article text not in parentheses or italics, and then repeat, you will eventually end up at 'philosophy,'" he said.

When I first read this, of course I was intrigued. I immediately opened Wikipedia in a new browser window and began to test. I opened a page that certainly couldn't have any connection to philosophy—"NASCAR"—and began to follow his instructions.

If I wanted to prove Munroe wrong, I did not get off to a good start. The first non-italicized, non-parenthetical link on the NASCAR page is "business." Business leads to "entity," entity leads to "existence," existence leads to "ontology," and sure enough, ontology connects to philosophy.

What Munroe discovered (along with millions of his readers shortly afterwards) is a phenomenon known as "wiki loops." A wiki loop occurs when, by following the rule of "click the first link in a Wikipedia article not in parentheses or italics, and repeat," you find yourself coming back to the same sequence of entries over and over, ad infinitum. In the case of philosophy, it's actually part of a much larger loop: *Philosophy* > *Pre-Socratic Philosophy* > *Ancient Greek Philosophy* > *Hellenistic Period* > *Ancient Greece* > *Civilization* > *Complex Society* > *Anthropology* > *Human* > *Homo* > *Genus* > *Taxonomy (biology)* > *Science* > *Knowledge* > *Awareness* > *Consciousness* > *Quality (philosophy)* > *Philosophy*

As we can see, Munroe's choice of "philosophy" was at least somewhat arbitrary—if every page leads to philosophy, it also leads to "pre-Socratic philosophy," or to "human," or to "knowledge," etc.

I wanted to know more. First, what other loops can we find? Second, how likely are we to get into the philosophy loop compared with other wiki loops?

For answering these questions, we turn to an incredibly helpful (and incredibly fun) resource: WikiLoopr. Plug in any starting Wikipedia page, and it will do the hard work for you. (Special thanks to Northwestern alumnus Sean Gransee '14 for making the page available.)

I wrote a Python script that automated going to WikiLoopr with a random Wikipedia page (luckily, Wikipedia had my back with a page randomizer). Using the "selenium" package to load javascript objects, "beautifulsoup4" to parse and read the HTML, and the standard "re" package for regular expressions, I collected the results from 1,000 rounds of wiki looping. In order to visualize the results in R, I turned them into a network (using libraries "igraph," "GGally," and "ggplot2"), and the results weren't terribly surprising.

Munroe was essentially right. Of the 1,000 starting nodes, 981 ended in the philosophy loop, suggesting that on average you have a 98 percent chance of ending on that loop if you're picking random starting points. Of the 2,996 Wikipedia pages visited by my script (including intermediate steps), 2,928—or 97.7 percent—of the pages ended up leading to the philosophy loop.

To read the complete blog entry and more, visit sites.northwestern.edu/msia

BARRY NELSON SELECTED KEYNOTE SPEAKER FOR WSC 50TH ANNIVERSARY

Barry Nelson

Barry Nelson, Walter P. Murphy Professor, was invited to deliver the keynote speech for the 50th anniversary of the Winter Simulation Conference. This conference is a premier international forum for sharing research and a central hub for simulation practitioners and researchers.

Titled "WSC Turns 50: Simulation Everywhere!," this year's conference will focus on the rapidity of current technologies, immensity of data, and quickly shifting needs of their interpretation by users who are geographically distant. Nelson's talk will embrace this theme with a focus on future needs and solutions.

The Winter Simulation Conference will take place in December at the Red Rock Resorts in Las Vegas, Nevada.

PhD Candidate Awarded Grand Prize in Student Challenge

PhD candidate **Gokce Kahvecioglu** was the co-recipient of the $10,000 grand prize in the Dow Sustainability Innovation Student Challenge. The award is given to one Northwestern graduate student for innovative thinking, research excellence, potential to solve significant problems, and the use of interdisciplinary approaches.

Gokce Kahvecioglu

Gokce's proposal, "Concentrated Solar Power Technology," focused on renewable energy.

"The primary focus of my research is to quantify the uncertain nature of Concentrated Solar Power (CSP) systems and develop optimization models that operate the plant to hedge against those uncertainties," Gokce said. "A CSP plant with thermal energy storage plant has the ability to supply solar power on demand at night-time hours, during cloudy periods, or during hours with excess demand. The ever-increasing need for green energy is evident, and CSP systems, especially because of their energy storage capability, can shape the future of our renewable energy portfolio."

Spotlight: Outstanding Graders

IEMS selected **Ho Jun Choi**, **Yue Hu**, and **Jillian Geary** as its outstanding graders for 2016-17.

Jing Dong nominated Choi (IEMS 303-Statistics) and Hu (IEMS 315-Stochastic Models and Simulation) for their professionalism, timeliness, and thoughtful feedback on homework assignments.

"Working with them was always pleasant and smooth," Dong said.

Choi is now pursuing a master's degree in applied math at Northwestern. Hu is now a first-year PhD student at Columbia University, where she continues her work in operations research.

Omid Nohadani nominated Geary for her diligent work ethic in IEMS 202-Probability. She now works for Bain & Company in Chicago.

"Amongst all graders I had over the years, Jillian has proven to be truly remarkable," Nohadani said.

Each student was asked to describe their experience, and the biggest challenge of grading an IEMS course.

Ho Jun Choi: "It was great working for one of my favorite professors, and it was as if I were taking this course again but from the other side. Plus, I had the solutions in my hand before the problem sets were due, which does not happen under normal circumstances."

Jillian Geary: "Working as a grader was a very rewarding experience, being able to understand a class from the other side. It was also gratifying to see the progress of the students throughout the quarter. The biggest challenge was wrapping my head around the new and unique ways of solving problems that the students came up with."

Yue Hu: "I love stochastic processes, so I was happy that I could work with relevant materials regularly. A challenge was that I had to stay careful in grading when students applied different methods (other than the ones listed on the solution keys) to solve problems."

FACULTY NEWS

Jorge Nocedal and **Andreas Wächter** received the Charles Broyden Prize from the journal *Optimization Methods and Software*.

A paper by **Andreas Wächter** became a "Google Scholar Classic," as determined by Google Scholar. With 3,185 citations, the paper was ranked number one in Google Scholar's mathematical optimization category.

Karen Smilowitz received the 2016 Award for the Advancement of Women in Operations Research and the Management Sciences from INFORMS. Her optimization and logistics work with the Bank of America Chicago Marathon was also featured in the October 5, 2016 issue of *Newsweek*.

SPONSORED AWARDS

Bruce Ankenman received a grant from Naval Supply Systems Command Fleet Logistics Center titled "Data Farming from Simulations for Instantaneous Trade-off Analysis Using Adaptive Batch-Sequential Experiment Design."

Diego Klabjan received three new awards this year from industry sponsors: "RQS Safety Text Analytics" from AbbVie, "RNN-Based Retention Modeling and Attribution with Inverse Modeling" from Allstate, and "Automated Ontology Generation from Corpora Originating in Different Sources" from General Motors.

Barry Nelson is the primary principal investigator for "Green Simulation: A Methodology for Reusing the Output of Past Computer Simulation Experiments" from the National Science Foundation, along with Assistant Professor **Jing Dong**, who is co-PI. Associate Professor **Jeremy Staum** proposed the project.

Ohad Perry received funding from the National Science Foundation for students to travel to the 2017 INFORMS Applied Probability Society Conference.

Karen Smilowitz received a National Science Foundation grant titled "PFI: AIR-TT SAFE (Situational Awareness for Events): A Data Visualization System."

STUDENT NEWS

Our students won the 2016 Summa Cum Laude Student Chapter Award at the 2016 INFORMS Annual Meeting.

In May, **Sina Ansari**, **Mark Semelhago**, and **Andrea Trevino-Gavito** traveled to the University of Michigan as part of an exchange program between the two INFORMS student chapters. This trip was the first of a series of events planned by the students to promote collaboration between the two chapters. The University of Michigan's students will visit Northwestern this academic year.

Alexander David, **Michael Forrest**, **Jiahui Guo**, **Yue Hu**, **Stephen Hynes**, **Ann Ku**, **Aniket Lila**, **Rohan Mehta**, **Michael Pauleen**, **Arkira Tanglertsumpun**, and **Dixon Yu** received 2017 Academic Excellence Awards

Aarush Gandhi, **Anisha Ghosh**, **Christie Sui**, **Frank Zhu**, **Jeffrey Kim**, and **Robert Pillote** received the department's Thompson Senior Design Awards for "Improving Northshore Glenbrook Emergency Department Throughput." **Abhishek Chaturvedi**, **Thomas Cho**, **Yue Hu**, **Stephen Hynes**, and **Rachel Lin** also received awards for "Predicting Quality Assurance in VMAT Radiation Therapy."

Zachary Guritz received the IEMS Department Award, acknowledging his dedicated work to the undergraduate program.

Yue Hu received the Arthur P. Hurter Award for Outstanding Industrial Engineering and Management Sciences Graduating Senior.

Francisco Jara-Moroni received the Outstanding Teaching Assistant Award.

Nitish Keskar co-authored a paper with **Jorge Nocedal**, **Andreas Wächter**, and **Figen Öztoprak** that won the Charles Boyden Prize.

Rachel Lin received the IEMS Student Leadership Award.

DEPARTMENT NEWS

Our PhD program moved up the *US News & World Report* rankings from number four to number three, tied with the University of California at Berkeley.

Matthew Plumlee has joined the department from the University of Michigan, where he served as assistant professor. His research focus includes experimental and computational methods for combining observations and simulation models for descriptive, predictive, and prescriptive purposes in large-data environments.

Zhaoran Wang will join our department for the 2018-19 year after finishing an appointment as a postdoctoral fellow with Tencent. His long-term goal is to develop a new generation of statistical optimization methods, theory, and systems for large-scale data analytics and artificial intelligence. He earned his PhD from Princeton.

Assistant Professor **Jing Dong** and Associate Professor **Jeremy Staum** left the department this year to pursue their next endeavors. We will miss them and wish them the very best.

In January, **Sadia Ahmed** joined the department as graduate coordinator.

Statistics Featured in Wasserstrom Lecture

Trevor Hastie of Stanford University presented "Statistical Learning with Sparsity" as IEMS's 2016 Wasserstrom Family Distinguished Lecture. Supported by the Wasserstrom Family Endowment, Hastie's talk presented a general framework for fitting large-scale regularization paths for a variety of problems, described the approach, and demonstrated it via examples using the R package GLMNET.

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MEM Hosts Fourth Annual Industry Night

On March 16, the MEM program hosted its 4th annual Industry Night to recognize and establish community among the students, alumni, and companies who value the importance of education at the intersection of engineering and business. More than 120 guests from across 40 different companies attended.

Christine Schyvinck ('00), president and CEO of Shure Incorporated, delivered the keynote address. Schyvinck is pictured here with Julio M. Ottino, dean of Northwestern Engineering.

In June 2018, MEM will celebrate its 40th anniversary with a conference and dinner. If you are interested in participating as a panelist, volunteer, or guest, please contact Mark Werwath (m-werwath@northwestern.edu).