Fall 2019

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Engineering Innovation @LehighU

HEALTH CARE IN FOCUS

Examining the intersection of engineering and community well-being

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/ New degree in Biocomputational Engineering

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LEHIGH UNIVERSITY | P.C. Rossin College of Engineering and Applied Science

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The Health, Science & Technology Building, a state-of-the-art academic and research facility, will house the College of Health and provide new venues for interdisciplinary collaboration on the Asa Packer Campus.

MORE IN-DEPTH COVERAGE: lehigh.edu/**resolve**

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LEHIGH UNIVERSITY

A singular impact

Welcome to the Fall 2019 issue of *Resolve*—a magazine dedicated to research and educational innovation in the P.C. Rossin College of Engineering and Applied Science at Lehigh University.

At its best, engineering addresses complex societal challenges and improves the human condition. No field of endeavor impacts the human condition quite as deeply and directly as health care.

Advances in computer science, mechanical engineering, and bioengineering, coupled with breakthroughs in the biological sciences and related fields, have the power to enhance medical treatment and health care delivery on a global scale. Here in the Rossin College, and across Lehigh as a whole, a range of emerging research initiatives and educational programs are focusing on improving health care outcomes, accessibility, and affordability.

Headlining this issue of *Resolve* (page 16) is a profile of teams from across the college and university who are exploring new avenues in biomaterials, sensors, and electronics and integrating them with communications, imaging, and analytics systems. The ultimate goal of such collaborations are devices, materials, software, and hardware that "can literally change someone's world."

The ability to collect, interpret, and use enormous datasets to improve medical diagnosis, prognosis, and cybersecurity is the focus of "Mining Medical Data" on page 14. Advances in the application of deep learning techniques are unlocking valuable insights from patient data to inform critical treatment decisions.

We also check in with our innovative Healthcare Systems Engineering program (page 21), a professional master's in engineering degree rooted in the complex, often fragmented environment of health care delivery.

Elsewhere in this issue, we have the honor of introducing *Resolve* readers to Dean Whitney P. Witt, the inaugural dean of Lehigh's College of Health (page 8). This new enterprise will focus on understanding, preserving, and improving the health and well-being of populations. As the College of Health moves toward enrolling students in Fall 2020, Whitney and I share excitement around the possibilities for collaborative inquiry and discovery at the intersection of our two colleges.

The fall of 2020 will see another milestone in Lehigh's health portfolio, as our Department of Bioengineering begins accepting students into a new major—a B.S. degree in Biocomputational Engineering. Students will explore the nexus of computational and data science, biological sciences, and bioengineering through this new program. This cutting-edge offering positions Lehigh at the forefront of this emerging field; read more about it on page 22.

NO FIELD OF ENDEAVOR **IMPACTS** THE HUMAN CONDITION QUITE AS DEEPLY AND DIRECTLY AS **HEALTH CARE.**

As you dig into these stories, you may also notice an updated design to our magazine—it's a bold, fresh look that reflects the many exciting initiatives emerging all around our beautiful campus.

I hope you enjoy this issue of *Resolve*; as always, thank you for your interest in the Rossin College and please drop me a note with your thoughts and comments.

Stephen P. DeWeerth, *Professor and Dean*
P.C. Rossin College of
Engineering and Applied Science
steve.deweerth@lehigh.edu

Virtual mechanical test predicts leg fracture healing time

Fellowship takes PhD student to Switzerland for groundbreaking bone research

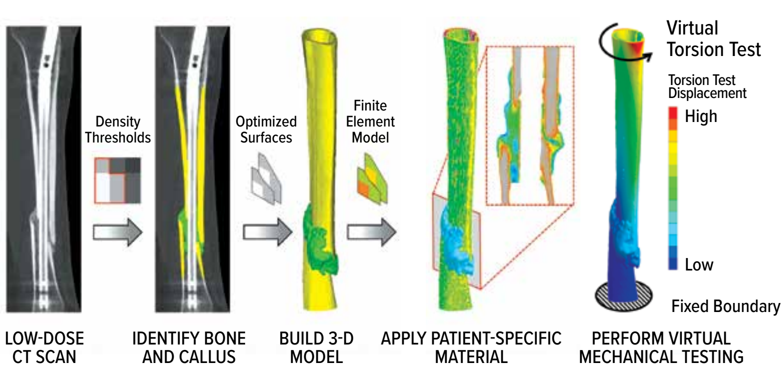
He's a self-described "computer nerd" who loves the computational side of research. And now, Peter Schwarzenberg '16 gets to put his nerd skills to work in a country renowned for research into orthopaedic trauma.

Schwarzenberg, a third-year PhD student in mechanical engineering, was one of just 10 students selected from across the country for the Institute of International Education's Graduate International Research Experiences (IIE-GIRE) program.

As a grantee, Schwarzenberg is spending six months in Switzerland at the University of Zurich's Musculoskeletal Research Unit (MSRU) developing new mechanical models for callus, the bony tissue that forms during fracture healing.

The IIE-GIRE is a new program funded by the National Science Foundation. Its goal, according to its website, is to "support U.S. engineering graduate students and their academic advisors, for graduate student research experiences abroad."

Grantees in this first cohort of the program received funding for up to six months to conduct innovative research and promote meaningful connections between their home and host institutions. Stipends are provided for travel, living expenses, health insurance, visa fees, and educational materials. Each student's advisor also receives $2000 for travel to the host institution or to support similar international endeavors in their home campus graduate programs.



Results from the virtual mechanical test correlated with how long it took each patient to heal.

A telling twist

Most people who break their tibia, or shin bone, proceed along a normal healing timeline. As the weeks go by, more and more new bone called callus forms along the fracture line.

But some people do not heal normally. This failure to heal is called a nonunion, and it can be utterly debilitating. The problem, however, is that surgeons typically rely on X-rays to determine the cause of a nonunion. But X-rays are two-dimensional and often fuzzy, and they may provide an incomplete picture if something is blocking the problem area.

Schwarzenberg and his PhD advisor, Hannah Dailey, an assistant professor of mechanical engineering and mechanics, recently published two papers describing how they've used virtual structural analysis of low-dose computerized tomography (CT) scans to predict healing in tibial fractures.

Using specialized, commercially available software on the CT scans of patients with lower leg breaks, Schwarzenberg built 3-D mechanical structural models that identified the different regions of both the bone and the new bone, or callus. He ran those models through finite element analysis software, and then he and Dailey simulated fixing the bottom of the bone and putting a load on the top of the bone in the form of a one-degree rotational twist. The technique is known as a virtual torsion test.

The test revealed how much the bone flexed when it was twisted. The stiffer a bone was early in the healing process, the quicker the patient could bear weight.

In the end, Schwarzenberg and Dailey found that the virtual mechanical test could accurately predict how long it would take a patient to heal. Currently, there are no other tools that can do that. If a patient isn't healing, it's an educated guessing game on the surgeon's part as to why that is, how long the healing process might take—if it takes place at all—and whether to wait or intervene surgically.

The pair's ultimate goal is to produce a diagnostic test that can help surgeons determine if an additional operation is necessary.

Characterizing callus

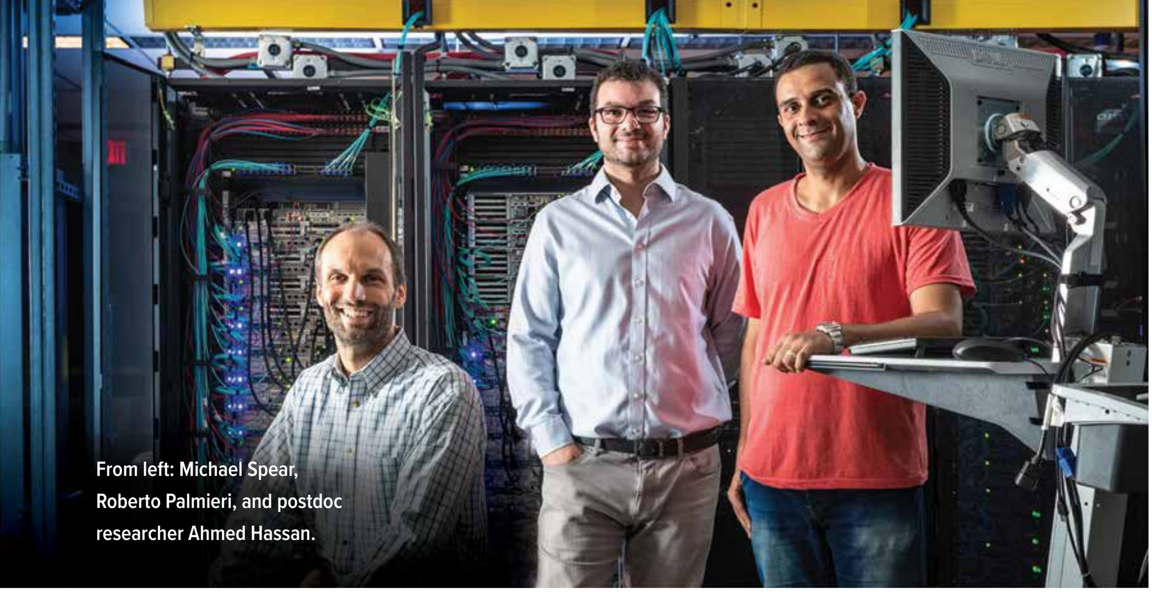
"There's one big flaw in our experimental design," says Schwarzenberg. "There's a lot of data in the literature for the mechanical properties of bone. It's easy to get cadaver bones. It's next to impossible to get cadaver bones with callus. Bone is this nice, organized, hard structure, and callus is almost like cartilage, kind of soft. It remodels into bone, but at the time points we're looking at, we don't expect the callus to have the same underlying structure as bone. We think we're making it too strong—closer to bone than it should be—because we're using a model that was developed from only bone. So every time we present somewhere, someone in the audience shoots up their hand, and says, 'Isn't callus completely different than bone?' So our goal is to characterize that callus."

And that is exactly what he's doing as a 2019 IIE-GIRE fellow at the University of Zurich.

Now at the MSRU, Schwarzenberg is combining his and Dailey's virtual technique with an optimization algorithm to refine their understanding of the mechanical properties of callus.

Schwarzenberg says he's proud of landing the fellowship. He's flattered that he's one of just 10 recipients. But he is convinced that such recognition hinges on the fact that very high level research is being conducted every day at Lehigh, and specifically, in Dailey's lab.

"We're doing world-class research here," he says. "We're working with a world-class animal research institute in Switzerland, and making a difference with what they're doing. We're very new, but we're turning heads at conferences, and we're butting heads with the big dogs."

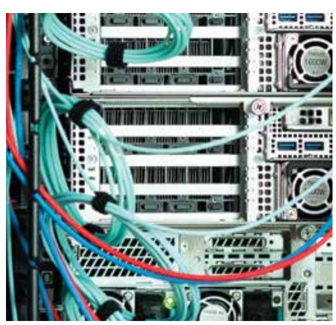


From left: Michael Spear, Roberto Palmieri, and postdoc researcher Ahmed Hassan.

A shortcut to a faster supercomputer

High-performance computing systems power the complex calculations and simulations behind our data-driven life—from better weather prediction to improved disease detection. Even the sophisticated supply chains that ensure Cyber Monday deals are delivered to your doorstep in two days depend on them.

To do all that requires very large machines that can handle vast amounts of data efficiently, says Roberto Palmieri, an assistant professor of computer science and engineering. It's a challenge, he explains, because unlike a typical laptop, which has four or eight processors housed inside one chip's processing unit, a supercomputer has hundreds of processor cores divided across several chips.



"When you execute a program on your laptop and it requires accessing data in memory, the latency time needed to retrieve the data is the same no matter which core you are executing from," he explains. "But if you have hundreds of computer cores, then finding a specific piece of data is akin to finding a particular object in a town filled with many buildings. Someone looking for an object that's not in their own house must spend time traversing a relatively extensive path to find it."

Palmieri and Scalable Systems and Software (SSS) Research Group collaborator Michael Spear, an associate professor of computer science and engineering, have found a way to meet the need for speed by avoiding that journey altogether. Their novel method of building efficient data structures ensures that applications interacting with a computer's data structure no longer need to contact other computing units to access the desired data.

The resulting increase in processor speeds could significantly improve the performance of any application that organizes large amounts of data, such as security tools or massive databases.

"Literally any complex application that requires data management can use this structure," says Palmieri. "And because the software is open-source, anyone in the world can use it."

Using a computer with 200 cores distributed across four different processors, the team proved that when key metadata governing core memory is replicated across computing units, memory operations simply access memory in their local nonuniform memory access (NUMA) zone, and so perform at far greater speeds. It's a shortcut—an index that links directly to the next step and avoids the full journey.

"With this approach, we are able to provide well-known data structure designs with performance in the range of 250 million operations per second on a data structure with 100 elements," Palmieri says.

The team observed speeds more than 10 times faster than normal on a data structure with 256 elements and 160 parallel threads operating on it. Those threads performed typical operations on the data structure, such as inserting, deleting, or looking up an element. Each of these operations involve many read/write memory accesses.

Innovations like this one, Palmieri explains, are a credit to the collaborative nature of the SSS group, which he founded with Spear in 2018 following a three-year, $500,000 grant from the National Science Foundation. Since then, faculty members and numerous graduate and undergraduate students have joined. The team is also exploring energy-efficient architectures, speculative parallelization, and transactional memory.

NAITO RECEIVES CONCRETE INDUSTRY HONOR

Clay Naito, a professor of civil and environmental engineering, has been elected as a Fellow of the Precast/Prestressed Concrete Institute (PCI), in recognition of his outstanding contributions to education, research, and service.

Naito teaches prestressed concrete design and, as an associated member of the ATLSS Research Center, conducts industry-related testing projects.

"Clay has been a leader within the PCI community," says Panos Diplas, P.C. Rossin Professor and chair of civil and environmental engineering. "This is a well-deserved recognition of his many and substantive research contributions."

Those endeavors include the PCI/NSF-funded development of a seismic design methodology for precast concrete diaphragms, integration of self-consolidating concrete for use in precast concrete bridge beam production, evaluation of bond mechanics for prestressed elements, implementation of welding methods for embedded connections in precast concrete elements in harsh weather conditions, and examination of blast resistance of precast concrete cladding and development of new response limits for these systems.

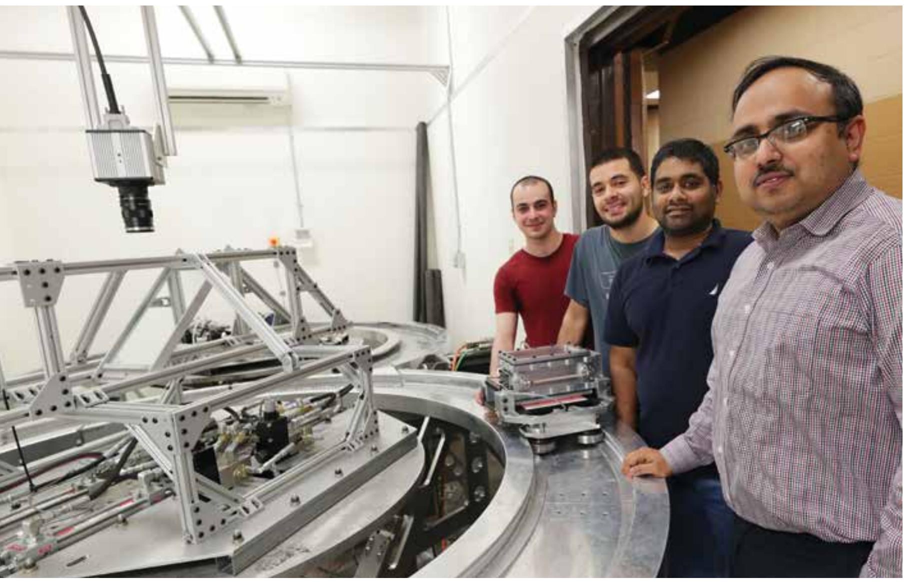
Naito has been a member of PCI's Technical Activities Council since 2010, has served as past chair of the PCI Blast Committee, and has served on many other PCI committees.

Spreading fusion's reach

The tangy condiment on your fridge door plays a new role in energy research

Mayonnaise: You either love it, hate it, or use it to study the fundamental hydrodynamics of nuclear fusion.

Arindam Banerjee, an associate professor of mechanical engineering and mechanics who studies fluid dynamics in extreme environments, has taken the third approach—generating new understanding of the "instability threshold" of elastic-plastic material in the process.



Banerjee and his students built the Rotating Wheel Rayleigh-Taylor Instability Experiment, which studies two-fluid mixing to mimic inertial confinement fusion.

Banerjee leads Lehigh's Turbulent Mixing Laboratory and, with his team, has built several one-of-a-kind, highly specialized devices to effectively investigate the dynamics of fluids and other materials under the influence of high acceleration and centrifugal force. The experiments replicate the conditions of inertial confinement, one of the most promising paths to generating energy through nuclear fusion.

So where does the kitchen staple come into play?

First, you need a basic understanding of how inertial confinement experiments work: Gas (hydrogen isotopes) is frozen inside pea-sized metal pellets. The pellets are placed in a chamber and then hit with high-powered lasers that compress the gas and heat it up to a few million Kelvin—about 400 million degrees Fahrenheit—creating the conditions for fusion.

The massive transfer of heat, which happens in nanoseconds, melts the metal. Under extreme compression, the gas inside wants to burst out, causing an unwelcome outcome: The capsule explodes before the hydrogen ions can fuse.

To study the process, Banerjee and researchers in his field mimic the molten metal by using—yep, you guessed it—mayonnaise. The material properties and dynamics of the metal at a high temperature are much like those of mayo at low temperature, he explains.

One of the lab's unique devices is the Rotating Wheel Rayleigh-Taylor Instability Experiment. It looks like a high-speed train track in a figure-eight shape and took the team five years and continuous funding from the Department of Energy (National Nuclear Security Administration) through their Stewardship Science Academic Alliance Program, along with subcontracts from Los Alamos National Laboratory and the National Science Foundation (CAREER and regular awards) to build.

Rayleigh-Taylor instability occurs between materials of different densities when the density and pressure gradients are in opposite directions creating an unstable stratification.

"In the presence of gravity—or any accelerating field—the two materials penetrate one another like 'fingers,'" he says.

For the experiment, Hellmann's Real Mayonnaise was poured into a Plexiglass container. Different wave-like perturbations were formed on the mayonnaise and the sample was then accelerated on the rotating wheel device. The growth of the material was tracked using a high-speed camera. An image-processing algorithm was then applied to compute various parameters associated with the instability. Experimental growth rates for various wavelength and amplitude combinations were then compared to existing analytical models for such flows.

Banerjee's team discovered that the onset of the instability—or instability threshold—was related to the size of the amplitude (perturbation) and wavelength (distance between crests of a wave) applied. Their results published in a recent article in the journal *Physical Review E* showed that for both two-dimensional and three-dimensional perturbations (or motions) a decrease in initial amplitude and wavelength produced a more stable interface, thereby increasing the acceleration required for instability.

"There has been an ongoing debate in the scientific community about whether instability growth is a function of the initial conditions or a more local catastrophic process," says Banerjee, who works with Lawrence Livermore National Laboratory and Los Alamos, the two major U.S. labs studying inertial confinement. "Our experiments confirm the former conclusion: that interface growth is strongly dependent on the choice of initial conditions, such as amplitude and wavelength."

This work allows researchers to visualize both the elastic-plastic and instability evolution of the material while providing a useful database for development, validation, and verification of models of such flows, says Banerjee.

He adds that the new understanding of the instability threshold of elastic-plastic material under acceleration could be of value in helping to solve challenges in geophysics, astrophysics, and industrial processes such as explosive welding, as well as high-energy density physics problems related to inertial confinement fusion.

Watch the Rotating Wheel Rayleigh-Taylor Instability Experiment in action at **go.lehigh.edu/wheel.**

New reversible superglue inspired by snail biology

Softened gel conforms to surface, then dries and locks into place

Snails secrete a mucus that acts like superglue, allowing them to adhere to rough surfaces like rocks.

Inspired by this aspect of snail biology, scientists at the University of Pennsylvania, Lehigh University, and the Korea Institute of Science and Technology have created a superglue-like material that is "intrinsically reversible." In other words, it can easily come unglued.

Adhesives are everywhere—in daily life as well as industry. But achieving both strong adhesion and reversibility is challenging. According to Anand Jagota, professor and founding chair of Lehigh's Department of Bioengineering, this is especially true of hydrogels, which are 90 percent water.

He says that adhesives usually fall into one of two classes: strong but irreversible, like superglues; or reversible and reusable but weak.

The team, which recently published its findings in *Proceedings of the National Academy of Sciences*, has managed to overcome these limitations.

"We report a hydrogel-based, reversible, superglue-like adhesive by combining the benefits of both liquid and dry adhesives in a single material," says Jagota.

When hydrated, the softened gel conformally adapts to the target surface by low-energy deformation. Upon drying, it is then locked in a manner similar to the action of the epiphragm of snails. An epiphragm is a temporary structure created by snails and mollusks. Made of dried mucus, it holds in moisture during periods of inactivity and enables snails to adhere to surfaces.

The scientists show that reversible, superstrong adhesion can be achieved from a nonstructured material when the criterion of shape adaption is met, with minimal residual strain energy stored in the system.

According to the researchers, the new material can be applied to both flat and rough target surfaces.

Vacuum furnace stokes excitement for additive manufacturing

Solar Atmospheres donates equipment to support metallurgy teaching and research

New to Whitaker Lab—a $300,000 commercial-grade vacuum heat treating and brazing furnace donated by thermal processing company Solar Atmospheres and its CEO and founder, William R. Jones.

"This is a very powerful, advanced piece of equipment that will allow us to conduct important experiments in our metallurgy teaching and research, especially around additive manufacturing, which is a hot topic these days," explains Wojciech Misiolek, professor and chair of the Department of Materials Science and Engineering.

The furnace's chamber holds up to 250 pounds, with a hot zone that can reach a maximum temperature of 2800^{0}F. Heat treating metals improves and/or tailors their properties—hardness, strength, ductility, and so on—by changing the microstructure of the materials.

Although Jones has been developing vacuum furnace and processing technology for more than 40 years—with facilities just 25 miles from Lehigh's campus—he was connected to the Rossin College only recently through local chapters of ASM International, of which he and Misiolek are both Fellows.

"Bill was thoroughly impressed during his tour of the metallurgical labs," says Tim Steber, a regional sales manager for Solar Atmospheres and past chair of ASM Philadelphia Liberty Bell Chapter. "He saw an opportunity to advance Lehigh's capabilities and launch them into another area."

In June, Laura Moyer, manager of metallography, light optical, microscopy, and X-ray diffraction labs and chair of the Lehigh Valley chapter of ASM International, oversaw installation of the furnace, including a transformer and a specially designed water-cooling system.

"Lehigh's educational system is known for being very hands-on," says Misiolek. "Having industry-grade equipment increases opportunities for our students and helps them hit the ground running when they go into industry."

"Many of our students go on to work in facilities where they use heat-treat furnaces for materials," says Laura Moyer (pictured with Wojciech Misiolek, left, and Tim Steber, center).

New faculty deepen interdisciplinary strength

Additions enrich expertise in robotics, machine learning, and other cutting-edge fields

A recent surge in hiring—11 new faculty members across four departments—will have a widespread impact on research and teaching at the Rossin College and support the interdisciplinary mission of Lehigh's Institute for Data, Intelligent Systems, and Computation (I-DISC).

"We have faculty coming in who are doing groundbreaking work in robotics, data science and machine learning, cybersecurity, and social media, among other fields," says computer science and engineering professor Héctor Muñoz-Avila, who also serves as co-director of I-DISC. "These are very current directions followed by people everywhere with natural connections to our institute's research."

It's an especially exciting time for Department of Computer Science and Engineering with three new professors of practice, three assistant professors, and a new department chair, Jeff Trinkle, an expert in advanced robotics, coming on board.

"Jeff was in charge of the National Robotics Initiative at the National Science Foundation so anyone who does robotics research will know him," says Muñoz-Avila. "Having a researcher like Jeff on our team really puts Lehigh in a strong position."

Trinkle says he looks forward to leading the department and strengthening Lehigh's robotics research activities, while "fostering interdisciplinary collaboration across campus."

NEW FACULTY

Computer Science and Engineering

DOMINIC DiFRANZO
Assistant Professor

PREVIOUS ROLE: Postdoctoral associate, Social Media Lab, Communication and Information Science, Cornell University

FOCUS: Human-computer interaction; practical design interventions that encourage social media users to stand up to cyberbullies, fact-check fake news stories, and engage in prosocial actions; new experimental tools/methods that create ecologically valid social media simulations for large-scale experiments

PhD: Computer Science, Rensselaer Polytechnic Institute

LIFANG HE
Assistant Professor

PREVIOUS ROLE: Postdoctoral research fellow; Biostatistics, Epidemiology, and Informatics; University of Pennsylvania

FOCUS: Machine learning, data mining, tensor analysis, and biomedical informatics; developing advanced computational and statistical methods to analyze multidimensional, graph-structured data, and multi-source data, with applications to medical and social sciences

PhD: Computer Science, South China University of Technology

COREY MONTELLA '19
Professor of Practice

PREVIOUS ROLE: PhD student, Computer Engineering, Lehigh University

FOCUS: Programming language design and implementation, computational thinking in education, dynamic systems and control, human-computer interaction, autonomous intelligent systems and robotics, and reinforcement learning

PhD: Computer Engineering, Lehigh University

HOURIA OUDGHIRI
Professor of Practice

PREVIOUS ROLE: Visiting assistant professor, Computer Science, SUNY Polytechnic Institute

FOCUS: Game development, software engineering, programming, and VLSI design automation tools

PhD: Computer Engineering, McGill University

WILLIAM PHILLIPS
Professor of Practice

PREVIOUS ROLE: Lecturer, Computer Science, Fairleigh Dickinson University

FOCUS: Software engineering and development, cybersecurity, and robotics; teaching critical thinking through simulated and real-life software projects

PhD: Computer Science, New Jersey Institute of Technology

DAVID SALDAÑA
Assistant Professor

PREVIOUS ROLE: Postdoctoral researcher, Robotics, University of Pennsylvania

FOCUS: Developing geometric algorithms and control strategies for multi-robot systems with applications in environmental monitoring, disaster response, aerial manipulation, and construction

PhD: Artificial Intelligence and Robotics, Universidade Federal de Minas Gerais (Brazil)

JEFF TRINKLE
P.C. Rossin Professor and Chair

PREVIOUS ROLE: Professor, Computer Science and Electrical, Computer, and Systems Engineering; director, CS Robotics Lab; Rensselaer Polytechnic Institute

FOCUS: Investigating problems that arise when robots try to grasp and manipulate things in unstructured environments; applications in smart homes of the future, with robots helping elderly and infirm people live independently longer; in manufacturing tasks such as assembly, maintenance, and repair; and in environmental cleanup tasks

PhD: Systems Engineering, University of Pennsylvania

Electrical and Computer Engineering

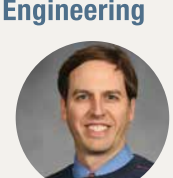
WUJIE WEN
Assistant Professor

PREVIOUS ROLE: Assistant professor, Electrical and Computer Engineering, Florida International University

FOCUS: Deep learning hardware acceleration and neuromorphic computing; VLSI design/architecture of emerging memory and storage systems; electronic design automation; security of machine learning and its application in embedded, IoT, and edge computing systems

PhD: Computer Engineering, University of Pittsburgh

Industrial and Systems Engineering



DANIEL P. ROBINSON
Associate Professor

PREVIOUS ROLE: Assistant professor, Applied Mathematics and Statistics, Johns Hopkins University

FOCUS: Mathematical optimization and data science; operations research; designing, analyzing, and implementing algorithms for solving continuous optimization problems in fields such as computer vision and health care

PhD: Mathematics, University of California, San Diego

XIU YANG
Assistant Professor

PREVIOUS ROLE: Scientist; Advanced Computing, Mathematics, and Data Division; Pacific Northwest National Laboratory

FOCUS: Uncertainty quantification and stochastic simulation; physics-informed machine learning and data-driven scientific discovery; multiscale modeling and model order reduction; scientific and engineering computing

PhD: Applied Mathematics, Brown University

Mechanical Engineering and Mechanics

CRISTIAN-IOAN VASILE
Assistant Professor

PREVIOUS ROLE: Postdoctoral associate; Laboratory for Information and Decision Systems (LIDS), and Distributed Robotics Laboratory, Computer Science and Artificial Intelligence Laboratory (CSAIL); Massachusetts Institute of Technology

FOCUS: Enabling autonomy in robotic systems; automated synthesis and decision making, explainability, scalability, and learning, with emphasis on deployment on physical robots, leveraging methods from motion planning, formal methods, automata-theory, machine learning, and control engineering

PhDs: Control Engineering, Politehnica University of Bucharest; Systems Engineering, Boston University

LECTURE SERIES DIVES INTO SOCIAL IMPACT OF WATER SCIENCE

"The global, humanity-wide importance of access to clean water is self-evident," says clean-water champion and renowned researcher, educator, author, and inventor Arup SenGupta. "It is not up to water scientists alone to address the issue. The world needs all of us—engineers of every stripe, businesspeople, educators, journalists, artists, and designers, among others—to learn about the challenges and engage in the search for sustainable global solutions."

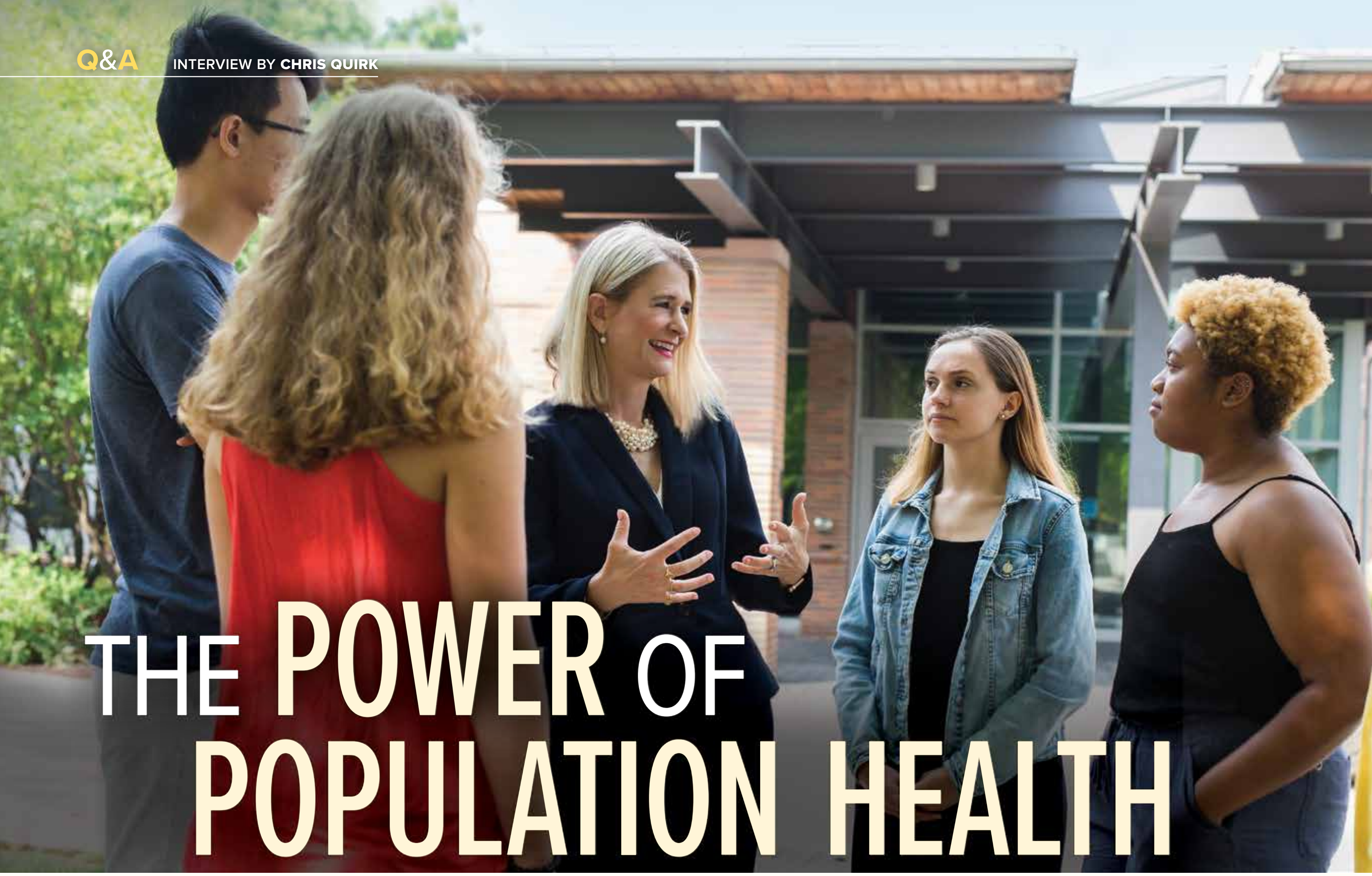
To engage the Lehigh community more deeply in this issue, SenGupta, the P.C. Rossin Professor of Civil and Environmental and Chemical and Biomolecular Engineering, has recently led an interdisciplinary faculty team in founding a new public lecture series to bring top researchers, innovators, and policy makers in water science to campus.

On October 29, 2019, Joan Rose, the Homer Nowlin Chair in Water Research at Michigan State University, will deliver the inaugural Distinguished Water Lecture, "Linking Animal and Human Sources of Water Pollution to the Landscape." Rose is a member of the National Academy of Engineering and received the internationally prestigious Stockholm Water Prize in 2016 for her research on microbial risk to human health and her work in creating policy tools and guidelines.

"THE WORLD NEEDS **ALL OF US** TO LEARN ABOUT THE CHALLENGES AND **ENGAGE** IN THE SEARCH FOR SUSTAINABLE **GLOBAL SOLUTIONS**."—Arup SenGupta

While one aim of the series is to broaden the dialogue about unmet needs around water issues, SenGupta notes that it also serves to honor the many Lehigh students who have studied, researched, supported, implemented, and extended his efforts over his 30-plus years on the Rossin College faculty.

Their combined efforts have made safe water accessible to millions while creating new opportunities to reuse impaired water sources. In doing so, SenGupta's research has expanded the field of ion exchange science and technology in solving environmental problems, and has led to the development of new classes of hybrid ion exchangers that have been incorporated into water and wastewater treatment processes.



THE POWER OF POPULATION HEALTH

College of Health Dean Whitney P. Witt on preserving and improving the well-being of our communities

In January 2019, Whitney P. Witt was appointed as the inaugural dean of Lehigh's new College of Health. She is an experienced leader in the field of population health, with a distinguished career spanning government, private, nonprofit, and academic spheres. Prior to arriving at Lehigh, Dean Witt directed the Center for Maternal and Child Health Research at IBM Watson Health. She holds a doctorate and a master's degree in public health from the Johns Hopkins Bloomberg School of Public Health and completed a postdoctoral fellowship at the Harvard University School of Medicine.

Q: How did you become involved in public health and decide to pursue it as a career?

A: I received a degree in law and women's studies from Hampshire College and was headed to law school. First, I went to New York City and worked as a legal advocate for the Gay Men's Health Crisis, one of the oldest AIDS organizations in the country. Most of the work that we did was around landlord-tenant issues, because at that time, so many people were getting very sick and could no longer work, and they were in danger of being evicted from their homes. We were trying to prevent them from becoming homeless. And it was in that moment I realized I wanted to understand health policy, and how we could better support some of our most vulnerable populations. So I switched gears and started looking for public health programs, and I found a wonderful one in health policy and management at Johns Hopkins.

I'm telling you all of this because many people in the field often end up there by chance. And in the College of Health, we'll have the opportunity to introduce students to this field very early in their career, as undergraduates. So that's very exciting.

Q: What persuaded you to take the reins of the new College of Health?

A: We have an opportunity at Lehigh to train undergraduate, graduate, and professional students in the kinds of innovations that are being developed—mostly in the private sector right now—but are being applied in real-time in health and health care. We can also have students begin to think innovatively and creatively about how to solve problems using these innovations, whether it's artificial intelligence or virtual reality. My time at IBM very much informed my vision, and I think the power of this technology is going to make health care more efficient and effective, and it will empower and free health care providers on the front lines to bring the "care" back into health care.

Q: The College of Health's focus is population health. What is population health, and how is it distinguished from public health?

A: Traditionally, public health has been focused on providing services to improve

Dean Whitney P. Witt (left) is leading the development of the College of Health, which will launch in Fall 2020. Its future headquarters, the Health, Science & Technology Building, or HST (renderings, right), will provide modern, flexible research and teaching space for faculty working across the university.

the health of communities. Vaccination and health promotion programs are examples. Population health is part of the larger field of public health, and is the science of understanding multiple determinants, from cell to society. That means everything—from your DNA to health policies—that might affect access to care, and how those determinants interact to produce the outcomes we observe on a population level. For instance, with a particular outcome there may be biological factors involved. You might also look at sociodemographic information and clinical information. You put that all into a statistical model that would show the most important risk factors, which could inform how a public health practitioner might address that particular health condition or outcome. Population health is a data science that provides critical insights that stand to make an impact on millions of lives.

Q: Are there health challenges particularly suited to a population health approach?

A: Definitely. In the U.S., we've seen a decrease in life expectancy for the first time in several decades. This is partially due to the alarming number of opioid-related deaths among young people. We've also seen a dramatic increase in neonatal abstinence syndrome as a result of pregnant mothers with opiate use disorder. So domestically, that's one of the biggest challenges we have.

Around the world, we're seeing growing rates of obesity and physical inactivity that are contributing to an increasing incidence of cardiovascular disease and diabetes. There are also emerging health issues, like Zika, antimicrobial resistance, and the impact of air pollution and climate change.

Q: What are the initial goals for the college and what do you see as its mission?

A: The mission of the College of Health is to leverage population health science to understand, preserve, and improve the health and well-being of populations and communities through excellence and innovation in three areas: education, research, and service. The college also aims to prepare the next generation of students—who will be highly skilled, diverse scientists and leaders in the field of population health—

through novel coursework, distance learning, and experiential learning.

We'll be the first university in the nation to offer an undergraduate bachelor's of science degree in population health with a focus on health innovation and technology. We intend to disrupt the educational model through incorporating experiential learning opportunities. We will give students the foundational courses in population health, but much of what we want them to have under their belts is the application of those concepts in the real world. That will be a very important part of our educational process.

Q: Is there anything that an academic institution—rather than a corporate or advocacy entity—can bring to the table to improve population health outcomes?

A: Yes, absolutely. Academic institutions overall bring scientific rigor and expertise. We also bring some critically important, substantive knowledge about how innovations created in the private sector can be effectively implemented into health and health care. A lot of the private entities that are creating these tools—and they're amazing tools—don't always understand the context in which they're being implemented. And that's where we can help.

We also have the methodological expertise in terms of data analysis. Health and health care data are different than other types of data, and sometimes particular approaches are needed to analyze those data. Finally, we bring a deep understanding of how to interpret health data, and translate that into action and into policy reform.

Q: How do you foresee working with the Rossin College at the junction of health and engineering?

A: The history of public health is actually rooted in engineering. John Snow was a physician in London in the 1850s who identified the source of a cholera outbreak. It was a public water pump, and he broke the handle off the pump and was able to stop the outbreak. Snow is really the grandfather of the public health field, and I see this story as an example of the profound intersection between the fields of public health, population health, and engineering.

What's wonderful about Lehigh is that health research and educational programs are occurring in every college. So there's a rich foundation from which to build. Also, there's a spirit of entrepreneurship here that I would like to see instilled in the College of Health.

Construction of the Health, Science & Technology Building is expected to be completed by 2021. Take a virtual walk-through of this strategically important academic and research facility at **lehigh.edu/resolve.**

PUSHING THE PEDAL TO THE METAL

From left, standing, Ankit Roy; Helen M. Chan, Christopher Marvel, Ganesh Balasubramanian; seated, Martin P. Harmer, Jeffrey M. Rickman, Joshua Smeltzer

BY AMY WHITE

Data analytics and experimental microscopy power the discovery of extremely hard high-entropy alloys—a novel approach that could accelerate the search for new materials

A NEW METHOD of discovering materials using data analytics and electron microscopy has found a new class of extremely hard alloys—materials that could potentially withstand severe impact from projectiles and provide better protection to soldiers in combat.

Lehigh researchers describe the method and findings in a recent article published in *Nature Communications*.

"We used materials informatics, the application of the methods of data science to materials problems, to predict a class of materials that have superior mechanical properties," says primary author Jeffrey M. Rickman, a professor of materials science and engineering and physics and a Class of '61 Professor.

Researchers also used experimental tools, such as electron microscopy, to gain insight into the physical mechanisms that led to the observed behavior in the class of materials known as high-entropy alloys (HEAs). High-entropy alloys contain many different elements that, when combined, may result in systems having beneficial and sometimes unexpected thermal and mechanical properties. For that reason, they are currently the subject of intense research.

"We thought that the techniques that we have developed would be useful in identifying promising HEAs," Rickman explains. "However, we found alloys that had hardness values that exceeded our initial expectations. Their hardness values are about a factor of two better than other, more typical high-entropy alloys and other relatively hard binary alloys."

All seven authors are from the Rossin College: Rickman; fellow materials science and engineering faculty members Helen M. Chan and Martin P. Harmer; materials science and engineering graduate student Joshua Smeltzer and postdoctoral research associate Christopher Marvel; mechanical engineering and mechanics graduate student Ankit Roy; and Ganesh Balasubramanian, an assistant professor of mechanical engineering and mechanics.

The research was funded by the Office of Naval Research with support from Lehigh's Nano/Human Interface Presidential Engineering Research Initiative (see "The Human Element," page 12).

Synthesis of HEAs in Balasubramanian's lab utilizes a compact electric arc melter with an arc temperature of more than 3500°C.

Dawn of a paradigm shift

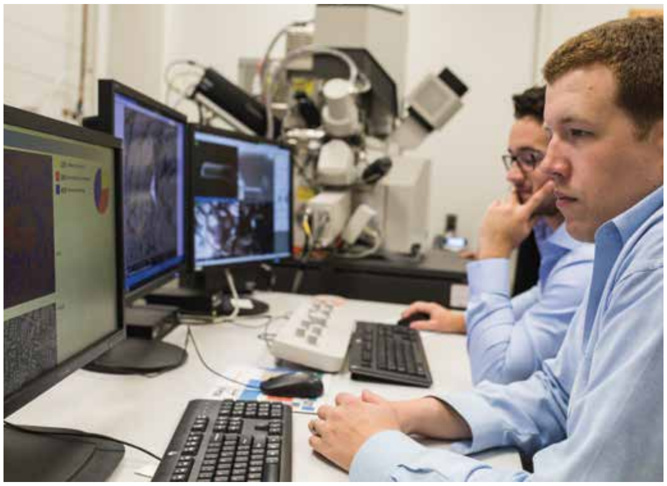
The field of high-entropy, or multi-principal element, alloys has recently seen exponential growth. These systems represent a paradigm shift in alloy development, as some exhibit new structures and superior mechanical properties, as well as enhanced oxidation resistance and magnetic properties, relative to conventional alloys. However, identifying promising HEAs has presented a daunting challenge, given the vast palette of possible elements and combinations that could exist.

THE FIELD OF **HIGH-ENTROPY**, OR **MULTI-PRINCIPAL** ELEMENT, ALLOYS HAS RECENTLY SEEN **EXPONENTIAL GROWTH**.

Researchers have sought a way to identify the element combinations and compositions that lead to high-strength, high-hardness alloys and other desirable qualities, which are a relatively small subset of the large number of potential HSAs that could be created.

In recent years, materials informatics has emerged as a powerful tool for materials discovery and design. The relatively new field is already having a significant impact on the interpretation of data for a variety of materials systems, including those used in thermoelectrics, ferroelectrics, battery anodes and cathodes, hydrogen storage materials, and polymer dielectrics.

"WE BELIEVE THAT OUR APPROACH HAS THE POTENTIAL TO **CHANGE THE WAY** RESEARCHERS **DISCOVER** SUCH SYSTEMS GOING FORWARD."—Jeffrey M. Rickman



Researchers acquire compositional maps of the metallic alloys using a scanning electron microscope.

"Creation of large datasets in materials science, in particular, is transforming the way research is done in the field by providing opportunities to identify complex relationships and to extract information that will enable new discoveries and catalyze materials design," Rickman says. The tools of data science, including multivariate statistics, machine learning, dimensional reduction, and data visualization, have already led to the identification of structure-property-processing relationships, screening of promising alloys, and correlation of microstructure with processing parameters.

Lehigh's research contributes to the field of materials informatics by demonstrating that this suite of tools is extremely useful for identifying promising materials from among myriad possibilities. "These tools can be used in a variety of contexts to narrow large experimental parameter spaces to accelerate the search for new materials," Rickman says.

New method combines complementary tools

Lehigh researchers combined two complementary tools to employ a supervised learning strategy for the efficient screening of high-entropy alloys and to identify promising HEAs: (1) a canonical-correlation analysis and (2) a genetic algorithm with a canonical-correlation analysis-inspired fitness function.

They implemented this procedure using a database for which mechanical property information exists and highlighting new alloys with high hardnesses. The methodology

THE HUMAN ELEMENT

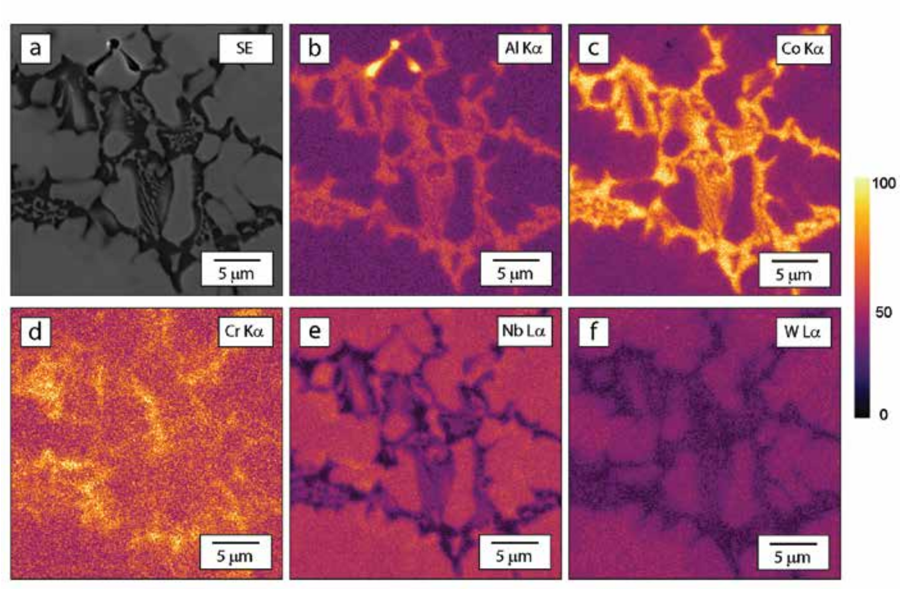
LEHIGH'S MULTIDISCIPLINARY Nano/Human Interface Presidential Engineering Research Initiative proposes to develop a human-machine interface to improve the ability of scientists to visualize and interpret the vast amounts of data generated by scientific research.

Materials science and engineering professor Martin P. Harmer leads the effort, which got a kick start in 2017 with a $3 million institutional investment. Other senior faculty collaborators include materials science and physics professor Jeffrey M. Rickman, bioengineering professor and chair Anand Jagota, computer science and engineering professor Daniel P. Lopresti, and psychology professor Catherine M. Arrington.

"Several research universities are making major investments in big data," says Rickman. "Our initiative brings in a relatively new aspect: the human element."

The initiative, which is a partnership between Lehigh, Ohio State University, and the Army Research Laboratory, emphasizes the human, says Arrington, because the successful development of new tools for data visualization and manipulation must necessarily include a consideration of the cognitive strengths and limitations of the scientist.

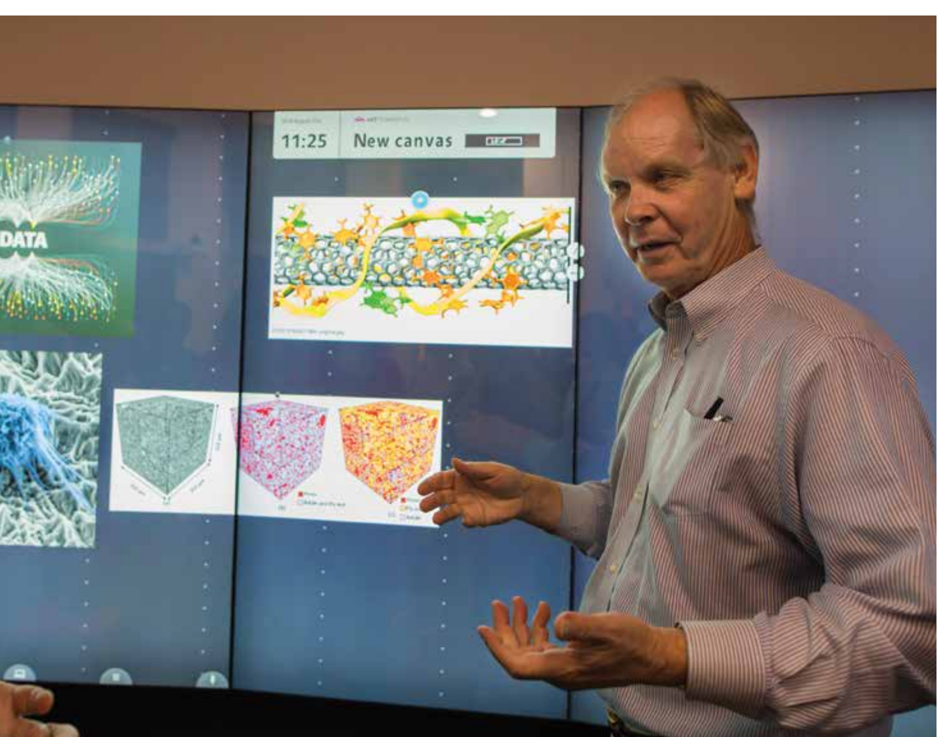
"We are at a new frontier in materials research," says Rickman, "which calls for new approaches and partners to chart the way forward."



Compositional maps of a multiple principal element alloy obtained via energy dispersive spectroscopy.

was validated by comparing predicted hardnesses with alloys fabricated in a lab using arc-melting, identifying alloys with very high measured hardnesses.

"The methods employed here involved a novel combination of existing methods adapted to the high-entropy alloy problem," Rickman says. "In addition, these methods may be generalized to discover, for example, alloys having other desirable properties. We believe that our approach, which relies on data science and experimental characterization, has the potential to change the way researchers discover such systems going forward."



I-DISC LAUNCHES DATA SCIENCE SERIES

THE WORKSHOP was over. Rows of brown-bag lunches were lined up and ready for the taking. A bus was waiting outside Iacocca Hall.

But still, workshop participants lingered, talking in small groups. It was exactly the scene the conference on applications of machine learning and data science to molecular and materials science and engineering was meant to generate.

"The event brought together a diverse range of fields, which gave people the opportunity to engage with those they wouldn't ordinarily encounter," says Srinivas Rangarajan, an assistant professor of chemical and biomolecular engineering (ChBE). "And that was the goal—to bring together top experts from a range of disciplines to share the latest techniques as well as the challenges in machine learning."

Rangarajan organized the three-day workshop in May—the first in a series funded by a National Science Foundation TRIPODS+X grant awarded to the Institute for Data, Intelligent Systems, and Computation (I-DISC)—along with ChBE professor Jeetain Mittal; Joshua Agar, an assistant professor of materials science and engineering; and Payel Das of IBM Thomas J. Watson Research Center.

"I-DISC is promoting new knowledge by creating new networks of professionals in these complex domains," says ChBE chair and R.L. McCann Professor Mayuresh V. Kothare.

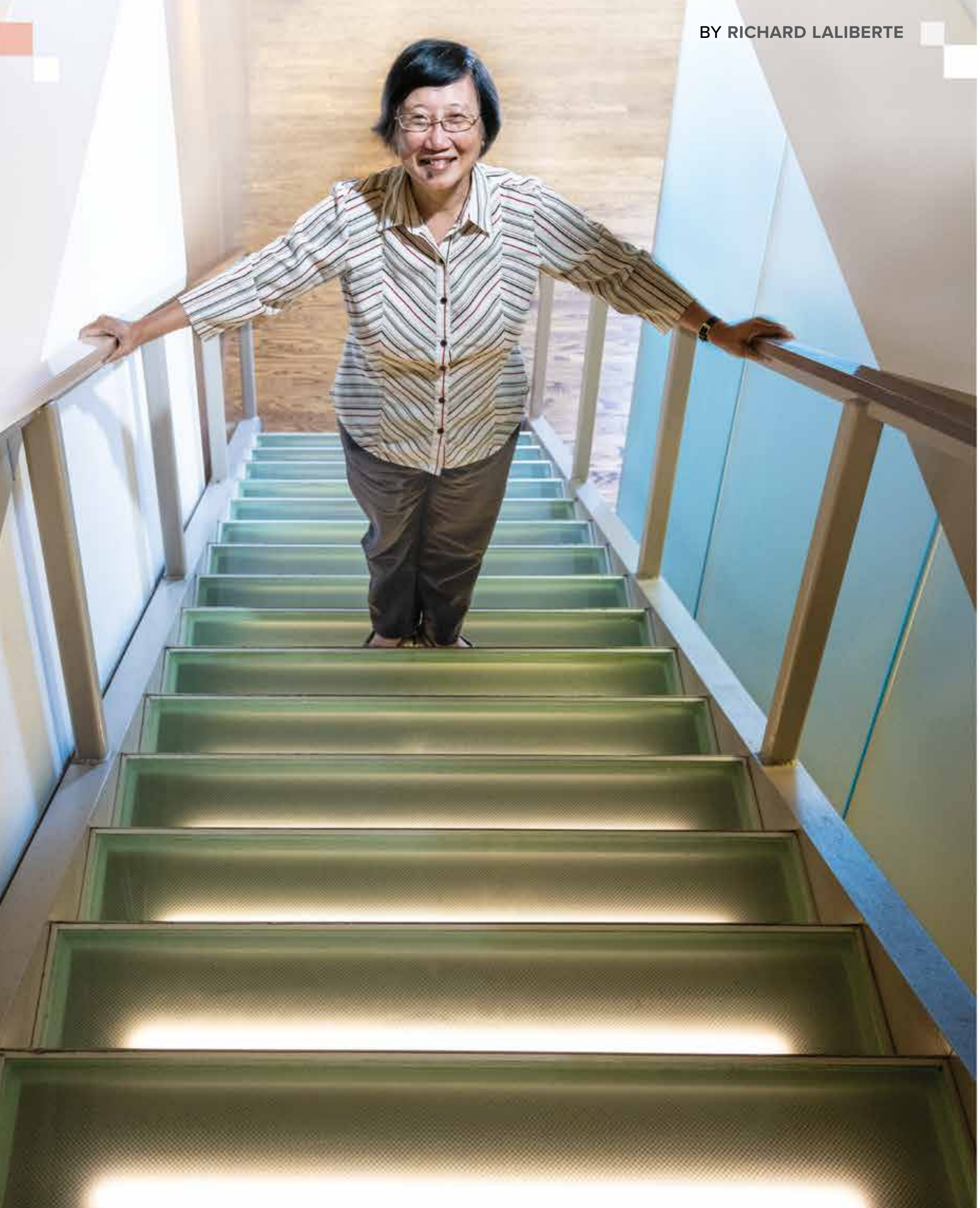
In October 2019, the second workshop in the series will focus on emerging directions at the intersection of robotics, deep and reinforcement learning, control systems, and operational research.

"There is a clear need for developing algorithms that are able to learn automatically and have the robot adapt to the environment," says I-DISC co-director Héctor Muñoz-Avila, a professor of computer science and engineering. "Anyone who is interested in robotics will get something out of this."

MINING MEDICAL DATA

Computer science and engineering professor Mooi Choo Chuah employs deep learning and data mining to improve systems for diagnosis, prognosis, and cybersecurity

BY RICHARD LALIBERTE



"HOW LONG WILL I LIVE?" This may be the most pressing question in health care, especially if you've been diagnosed with a devastating disease like amyotrophic lateral sclerosis (ALS).

Symptoms and clinical history alone may not reveal a prognosis. But data gathered from thousands of other patients may help. That, in part, is the concept behind research by Mooi Choo Chuah, a professor of computer science and engineering, that explores the use of clinical data mining to uncover patterns and better predict disease.

In the case of ALS, Chuah developed tools that improved forecasts of how rapidly the disease will progress and how long a patient will live. Information that can be used, in part, to guide treatment decisions.

But first, a person must determine what his or her health condition actually is—and that's a puzzle reliant on patterns in symptoms and other factors. Chuah has refined ways of applying deep learning methods—a form of machine learning in which computers using artificial neural networks akin to the human brain become progressively more insightful in analyzing large amounts of data—to come up with diagnoses or treatment recommendations.

Better diagnostics could improve the accuracy of websites that interpret symptoms. They could also be applied to clinical settings. "Prediction models could help extend good diagnostics into rural areas that don't have a lot of expert physicians," Chuah says. "And they could help cut health care costs associated with overdiagnosis."

Cleaning is key

Chuah began studying ALS after coming across a dataset that had been used in a crowdsourced competition designed to improve predictions of the disease's progression. She wrote to the challenge organizer and received permission to use the data.

After reviewing the set, Chuah and her then-PhD student Qinghan Xue (now at Samsung Research) found that improving the quality of the data was key to improving its predictions.

"Often, crowdsourced data is noisy," she says. There may be typos, missing fields or values, non-numeric values, and inconsistent testing from one hospital to another. According to Chuah, the data needs to be cleaned, or raw information from clinical sources needs to be improved. In a 2017 paper, she and Xue proposed how to do both.

First, they removed inconsistent or noisy data, and imputed missing data. After that, they conducted experiments using a variety of data mining research tools. They were able to improve the efficiency and accuracy of previous prediction models that had been derived from the same data. "We got better results only because we had more time than teams in a competition did," Chuah says. Cleaning the data had indeed been key.

> "PHYSICIANS DON'T WANT TO USE **DEEP LEARNING** IF THEY DON'T UNDERSTAND HOW THE MODEL COMES TO A **CONCLUSION**."
>
> —Mooi Choo Chuah

As for improving data at its source, Chuah proposed an incentive model for hospitals to share their information. "If you can pool data together, you get a bigger dataset with more diverse scenarios, and the prediction model you develop will be better." Yet hospitals are often reluctant to release patient data, partly to protect privacy and partly to guard what amounts to intellectual property.

Chuah developed a model that rewards hospitals for sharing high-quality data, with greater rewards going to institutions that contribute more patients (and thus incur greater costs), report more accurately, and offer more data from especially useful cases. The study demonstrated that applying such an incentive model could facilitate better predictions.

Confusion to clarity

In theory, electronic medical records and crowdsourced health information from websites can both be used to diagnose symptoms or offer personalized advice. In practice, making accurate assessments presents challenges, according to a 2019 study by Chuah and Xue.

For one, the way people talk about their health can throw off algorithms looking for keywords. And that can cause medical websites to offer information that isn't helpful.

For example, if a patient wants information about depression, but also mentions suffering from severe hypoglycemia, the health forum website might offer advice on diabetes, but not on depression.

Chuah has found a number of data mining approaches that can improve results. "When the user types their information, we look for patterns and remove noisy sentences or transition words that are not relevant," Chuah says.

She designed a deep-learning-based medical diagnostic system that utilizes reliable medical information to generate diagnoses. She uses tools such as convolutional neural network (CNN) models and recurrent neural network (RNN) models that capture the underlying structure in sequential data. "It's like gathering expertise from multiple physicians," Chuah says. "As you reach an increasing level of opinion, you can do a better job of diagnosing a condition or personalizing care."

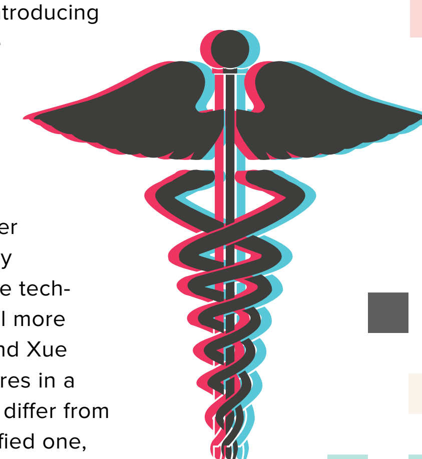
She also gave greater weight to risk factors. "I know, for example, that Asian females typically have more calcium spots on mammograms that can generate scary false reports that lead to biopsy," Chuah says. Knitting such information into a diagnostic model adds power to its predictions—and could potentially reduce health care costs.

Yet patients and doctors can be skeptical about diagnostics derived from artificial intelligence methods. "Physicians don't want to use deep learning if they don't understand how the model comes to a conclusion," Chuah says. She made explanations a part of her system's design so users can see which keywords led to specific predictions. "If you provide an explanation, it's more likely a physician will trust the results," she says.

Protecting health data

Putting trust in AI also raises concerns about cybersecurity. Chuah has investigated potential cyberattacks on these deep learning models and what might be done to detect them. Neural networks used in health care most often follow RNN models, yet the bulk of research on neural-network hacking focuses on CNN. "Few have done studies on how to attack RNN, so we decided to look at that," Chuah says.

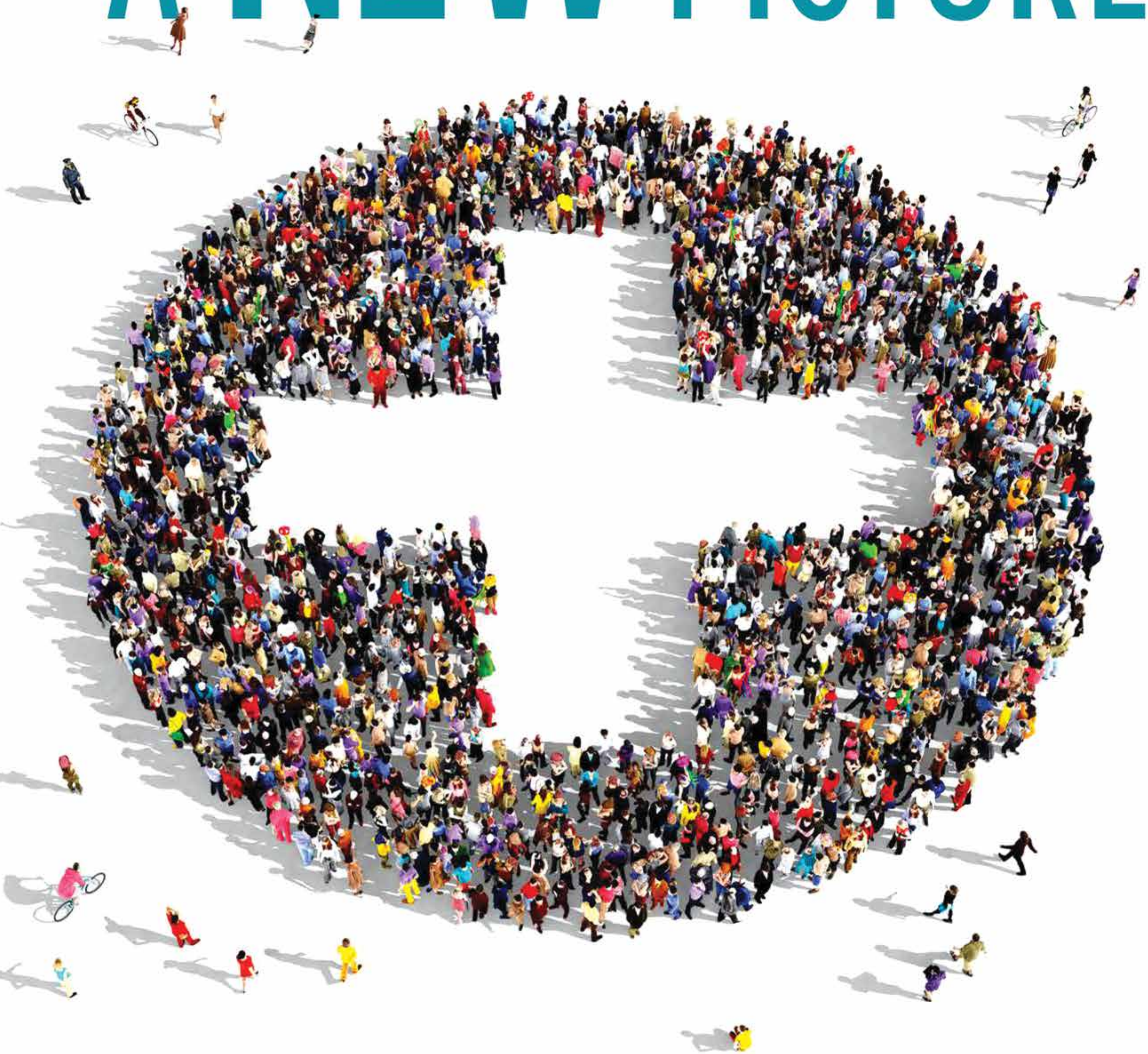
Using both synthetic and real-world datasets, Chuah and Xue introduced a new attack on an RNN machine learning system. They added random noise that affected how the system weighted data, causing the system to misclassify a group of inputs into a wrong output class. "Typically in a successful attack, you look for loopholes that cause a small perturbation of true values," Chuah says. Without necessarily introducing malicious data, they led the system to make wrong predictions and reduced its accuracy.



"The importance of demonstrating this is for researchers to take a deeper look at whatever model they come up with, and introduce techniques that make the model more robust," Chuah says. She and Xue have also shown how features in a genuine RNN-based model differ from those in a maliciously modified one, and have designed a low-cost detection scheme that could identify an attack such as the one they executed.

It's exciting work with a far reach. "That's what makes research interesting," says Chuah. "You add to the progress in developing more robust deep learning models. Whether you use them for health care or autonomous cars, it's essentially the same thing. The wisdom applies everywhere."

A NEW PICTURE



OF HEALTH

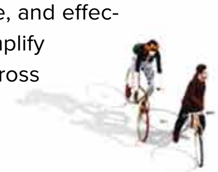
BY CHRISTINE FENNESSY

Lehigh engineers see a promising prognosis for innovation and impact in health care through interdisciplinary research and collaboration with the College of Health

IMPACT. IT'S NOT JUST A BUZZWORD. It's a value proposition of sorts. A promise to create meaningful change, to make a difference. For Lehigh faculty, and for students especially, that promise means that Lehigh will provide them with a foundation to make lasting—and potentially far-reaching—contributions.

"Students have fundamentally changed from when I was a student walking these halls," says Hannah Dailey '02, '06G, '09 PhD, now an assistant professor in the Department of Mechanical Engineering and Mechanics. "Engineers today are motivated by the idea of applying their engineering skills to doing good for others, for society, for the world as a whole. And one very significant way they can do that is through health and health care."

And now, with the announcement of Lehigh's new College of Health, there will be even more opportunity for impact through research that is devoted to making health care more accessible, affordable, and effective—collaboration that will serve to amplify research currently being conducted across the Rossin College.



A common denominator

The College of Health will begin enrolling students in Fall 2020, and will focus on population health and health data analytics. According to its inaugural dean, Whitney P. Witt, such focus will enable Lehigh to understand, preserve, and improve the health and well-being of populations and communities through excellence and innovation in education, research, and service. (See "The Power of Population Health," page 8.)

In the lab, Dailey and her students and collaborators research computational and experimental biomechanics of fracture fixation and bone healing, fracture nonunion, and the mechanics of tissues and biomaterials. Their work toward alleviating orthopedic trauma has them partnering closely with surgeons from St. Luke's University Health Network. She sees a clear intersection between her work and the mission of the new college.

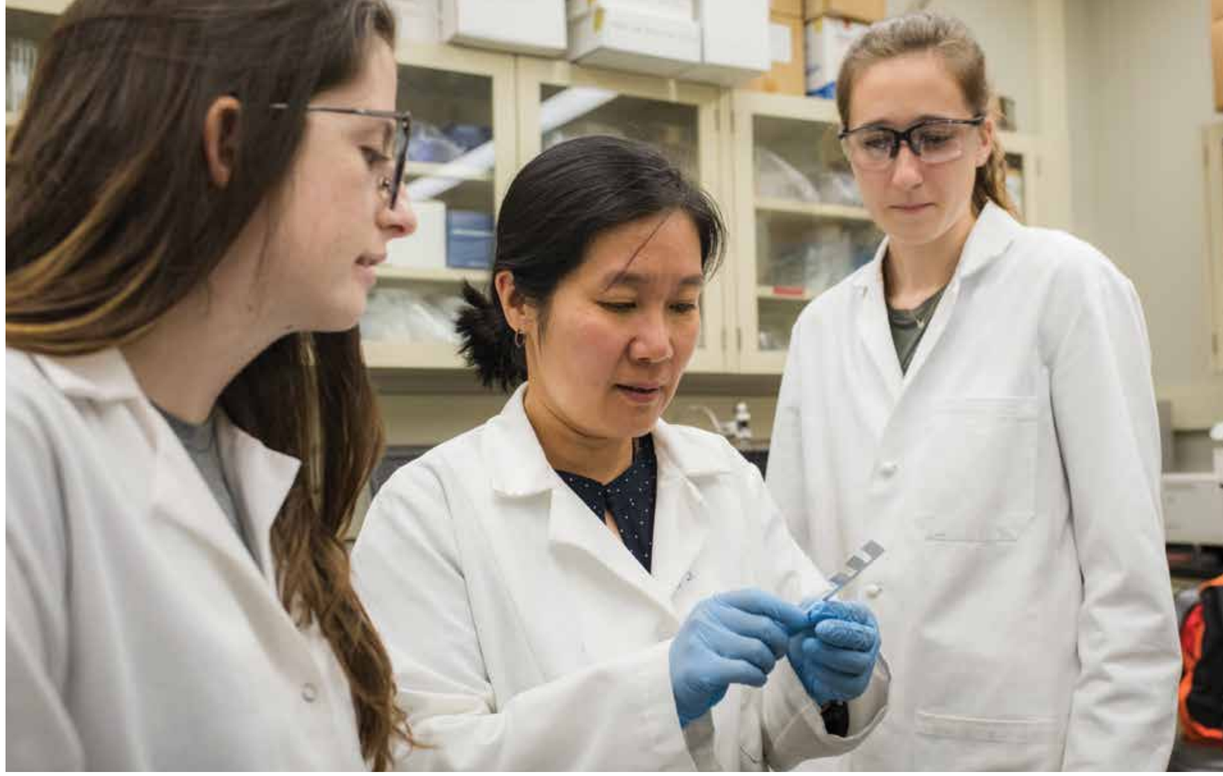
"Anything that makes it easier to partner with the medical community to help care for patients, to bring engineering tools and methodologies to bear on the problems doctors and other allied health professionals face, is a good thing," she says. "We will be stronger and more productive as a learning community."

Because the problems—and hence, the possible solutions—in health care are so complex, partnerships and collaborations are the common denominator when it comes to successful innovation, says Xuanhong Cheng, an associate professor of bioengineering and materials science and engineering.

"Take a glucose sensor, for example," says Cheng. "For something like that, you need to interface between the biological and the abiological systems. And that requires people with backgrounds in chemistry, biochemistry, chemical engineering, and bioengineering. The instrument itself requires electrical engineering and mechanical engineering. Data is being collected in analog form, and so you need people with backgrounds in computer science who can convert the analog data to digital."

Another good example, Cheng notes, is the smart watch: "It doesn't directly measure heart rate, it measures

Xuanhong Cheng mentors students developing point-of-care diagnostics for sickle cell disease and anemia for use in Sierra Leone.



an optical signal that has to be translated into heart rate. Someone with computer science knowledge has to be able to process the data and connect it.

"And if you're talking about collecting population data," she continues, "those data often need to be transmitted long distance, which requires people with experience in computer science and even mathematics. So, bottom line, the development of new technology that successfully impacts health care requires input from people with a broad array of backgrounds and expertise."

Cheng's own research is defined by such multidisciplinary collaborations and focuses on diagnostic and therapeutic devices on the microscale. One such project is a microelectrical sensor she's developing with James Hwang, a professor of electrical and computer engineering.

"I'm trained in the design and fabrication of small devices and how to incorporate biological samples, which means I don't have the background or expertise that Jim has to design sophisticated electrical sensors. But together, we're working to create a less expensive cancer diagnostic device. Basically, single-cell electrical detectors that can detect cancer cells."

Cheng is also working with Alparslan Oztekin, a professor of mechanical engineering and mechanics, and James Gilchrist, a professor of chemical and biomolecular engineering, on a microfluidic device that can detect infection. "We're looking at using the device for analyte separation, separating pathogens from bodily fluid," she says. "This particular project requires a lot of transport knowledge and experts in transport phenomena."

With Filbert Bartoli, a professor of electrical and computer engineering, she's developing optical sensors that can monitor immune function, and with Frank Zhang, an associate professor of bioengineering and mechanical engineering and mechanics, sensors that can detect and rectify mechanical stress within the body.

Cheng also mentors a student-led project that is developing point-of-care diagnostics for sickle cell disease and anemia to be used specifically in Sierra Leone. The project is part of the Global Social Impact Fellowship, a program for undergraduate and graduate students from all disciplines across the university that integrates experiential learning, research, and entrepreneurial engagement.

"There are just so many components involved in health-related problems, that I think it's natural to have these interdisciplinary connections," she says.

Such a collaborative ethos will no doubt characterize the College of Health. To dovetail with the college's focus on population health, Cheng says the Department of Bioengineering will launch a biocomputation program this fall. (See "A Major Development," page 22.)

"Studying population health means collecting data on a large scale, which requires developing hardware and training students in biocomputational skills," says Cheng. "This program will teach them health data analytics and how to analyze biophysical data. So the overlap between the new program and the new college is significant."

Breaking boundaries

For Kelly Schultz, the interdisciplinary mindset is key to the continued progress at Lehigh toward the ultimate goal of making health care more accessible, affordable, and effective.

"When it comes to the kind of research that I do, it's quite important," says Schultz, who is an associate professor of chemical and biomolecular engineering. "We've been doing work on changing the enzyme secretions of cells, and I'm not a biologist. Without help from Susan Perry [who is a professor of practice in

bioengineering] I wouldn't have known how to go about designing those experiments."

Schultz, Dailey, and Cheng are also affiliated with the Institute for Functional Materials and Devices, one of Lehigh's three Interdisciplinary Research Institutes. I-FMD assembles expertise from across the university in the synthesis, fabrication, processing, and characterization of engineered materials including semiconductors, metals, ceramics, composites, polymers, and other soft materials. I-FMD has several thrust areas, and Schultz and Dailey are part of a team looking at advancing the science of wound healing. (Cheng's team is looking at soft, active materials.)

"There are people in the group from bioengineering, chemistry, mechanical engineering, materials science," says Schultz. "We bring our interests in health and wound healing to the table, and some really interesting and creative ideas have come out of those meetings, ideas we wouldn't have considered on our own as individuals."

Schultz's interest in helping people live longer, healthier lives is largely driven by a fascination with just how well the body does on its own.

"Our bodies are already pretty efficient," she says. "People are starting to live into their hundreds now, and not just because of technological interventions. Some people just live longer and their bodies do better. So why reinvent the wheel? Why not take what already works and then try to make it somewhat better? If it's possible to live a long time with very little intervention, we can take inspiration from those people and use it to help the person who has a very bad diagnosis and a short life expectancy."

To that end, Schultz's lab is trying to ramp up the body's wound-healing ability. She's working on implantable materials called hydrogels that contain stem cells, which naturally temper inflammation.

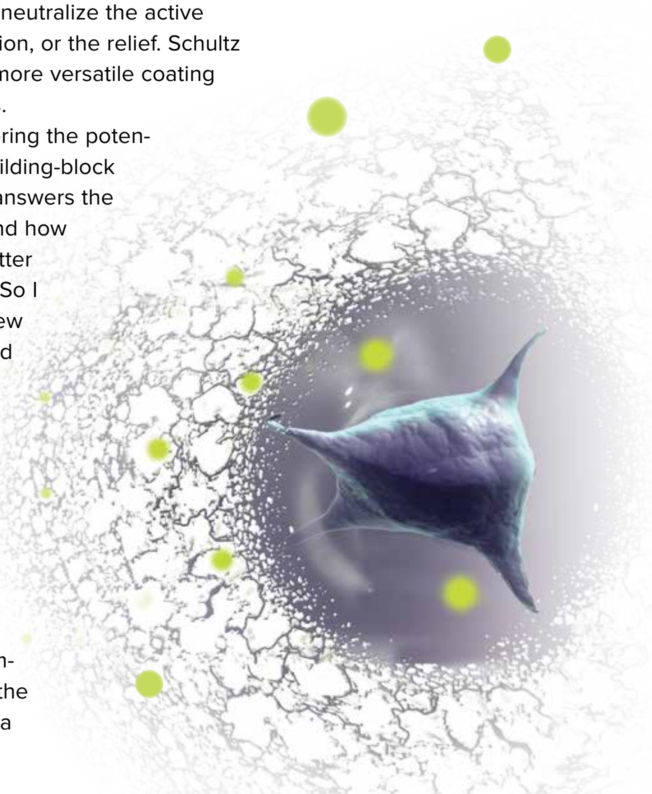
"Wounds can go chronic if there's too much inflammation, and stem cells can stop that inflammation," she says. "They do that by restarting the healing process, calling the right cells to the wound to form tissue, and changing into different cells to regenerate tissue. So what we want to know is, how can we get more of these good cells to the wound and how can we get them there faster?"

Schultz's lab is laying fundamental groundwork as they seek to reveal how cells move within the hydrogel and how that movement can be directed. The potential applications for the hydrogels could be especially profound for burn patients and people dealing with diabetes complications, both of whom experience the debilitating pain of chronic wounds.

Outside of wound healing, Schultz and her team are also looking at materials that can enhance drug delivery, specifically in the gastrointestinal tract. Nutrients and drugs are generally absorbed in the intestines, but the stomach's high acidity can often neutralize the active molecules that provide the nutrition, or the relief. Schultz is working with an inexpensive, more versatile coating that can protect those molecules.

Schultz pauses when considering the potential reach of her work. Hers is building-block research. The kind of work that answers the fundamental questions of why and how a material works, so it can be better manipulated to improve health. "So I don't see myself developing a new treatment that would be delivered directly to patients," she says. "My work will hopefully support the efforts of other researchers developing such treatments."

What she has done—and continues to do—is step outside the boundaries of her discipline and consider the types of questions and solutions that aren't typical in her scientific community of rheology, the study of the deformation and flow phenomena of materials.



Kelly Schultz researches how living cells actively reengineer their surroundings.

"In my core area, there isn't much focus on biological questions, but we could answer a lot of them. I'd like to see more people in the rheology community looking at biological problems and more people in the biomaterials community listening to what rheology has to say—a more interdisciplinary approach," she says. "There are only a few of us who collaborate across those communities, and there are just so many questions and they're so interesting. I've been trying to push to get both communities to listen to each other, broaden our areas of research, and complement each other's work."

As a student, Hannah Dailey (center, with world-renowned MIT bioengineer Robert Langer) participated in workshops to develop Lehigh's bioengineering presence; as a professor, she leads a research team in the biomechanics of bone healing.

She says the College of Health will offer yet another perspective on those interesting questions.

"The new college will provide us with much more depth around some of the social issues that we don't currently consider," says Schultz. "And that will keep us all moving in the right direction towards helping people live better lives."

Impact through innovation

It's an exciting time for an engineer at Lehigh to make her mark on health care and improve—via devices, materials, software, hardware—the well-being of society.

"The investment Lehigh is making in the College of Health reflects a long-term vision for impact through innovation," says Dailey. "There will be even more opportunity for educational experiences and meaningful contributions in health care. And that is well aligned with students' values. The added visibility of the new college will help students recognize that they can do good in the world through innovating better health care technologies and medical devices and partnering in really meaningful ways. I think that's going to be inspiring to this generation."

It's the kind of inspiration that continues to drive Dailey, whose research interests include bone fractures, bone fracture healing, and bone mechanics. Specifically,

"The investment Lehigh is making in the College of Health reflects a long-term vision for impact through innovation."

—Hannah Dailey

Hannah Dailey and her team work in partnership with surgeons from St. Luke's University Health Network.

her lab uses CT scans to model the properties of bones and how they heal after a fracture, and they do numerical modeling to predict how mechanical forces contribute to the biological response that causes those fractures to heal. Her other projects include studying the mechanics of aging bones, and combining virtual mechanical testing of CT scans with an optimization algorithm to determine the mechanical properties of callus, the spongy material that forms along a fracture line and over time hardens into new bone (see page 2).

"I think one of the things that's really exciting for mechanical engineers about getting into this field is that the pathway from a sketch on a whiteboard to the fruition of an idea is shorter. It's hard to translate something from a cell model into something that can go into a human. That's a really, really long pathway. My personal research strategy is to go at it from the other end of the pipeline. I partner with surgeons who already have patients and we pull that data backward into the engineering pipeline, instead of trying to push it forward from basic to clinical. So that's a different strategy," says Dailey.

"And I think that type of strategy is pretty well aligned with where the College of Health is positioning itself. We're not going to be developing new pharmaceuticals or blockbuster drugs, like basic science to clinical translation. We're going to be focused on value-based health care."

For the greater good

Impactful and valuable. Collaborative and meaningful. All words that describe the current research into improving health and health care. They also describe the promise that Lehigh is making to its future engineers. The promise that has grown even brighter as a wider range of opportunities and experiences opens up with the College of Health. The promise that they can literally change someone's world.

"My work here can have immediate impacts on people's health, well-being, and quality of life," says Dailey. "I feel deeply, passionately invested in the idea that as engineers, we can contribute in a substantive, exciting way to this communal goal of better health, and we can deliver it at a lower cost. It's why I get up in the morning. I love what I do."

AN Rx FOR SMARTER HEALTH CARE DELIVERY

"WE'RE NOT THE ONES inventing the next generation of high-resolution MRI machines or robotic surgery tools—we're the ones analyzing data to help you use that very expensive piece of equipment most efficiently."

That's how Healthcare Systems Engineering (HSE) director Ana Alexandrescu '10 '12G characterizes graduates of this professional master's (M.Eng.) program, which teaches students systems engineering tools and methodologies and how to apply them to the complex and often fragmented environment of health care delivery.

"We have a very diverse group of students: doctors and dentists and pharmacists, and students who are on those tracks," says Alexandrescu. "We've had scientists looking to pursue a path outside of a clinical career, people seeking health care leadership roles in operations, and of course, engineers who are interested in specializing in the field."

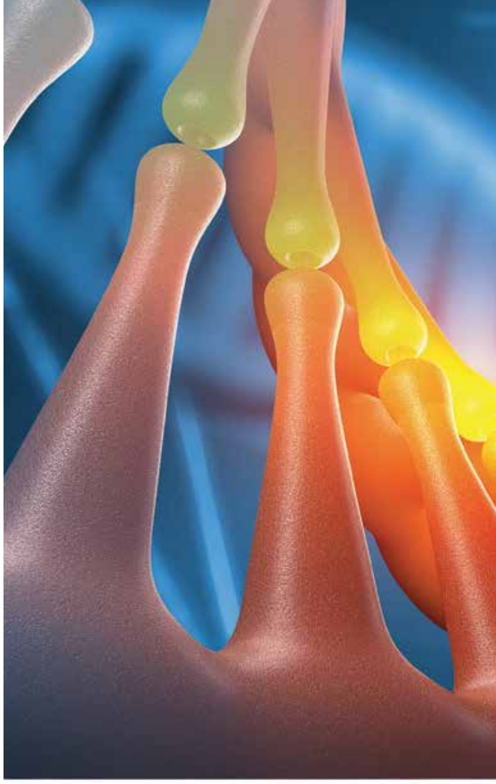
Students take a core of health care focused classes along with foundational courses led by industrial and systems engineering faculty. Capstone projects tackle real-world problems and pair students with the program's local, national, and global partners, such as B. Braun, New York Presbyterian Hospital, and the American Hospital of Dubai.

Topics span a wide range, addressing problems driven by cost pressures (devising more efficient ways to schedule operating rooms), social issues (reducing maternal mortality rates among black women), even matters of life and death (improving procedural compliance in assessing and transporting stroke patients).

The opportunities to apply optimization and systems thinking in health care are varied, explains Alexandrescu, but there is a common denominator: data.

"There's a buzz around predictive and prescriptive analytics, but healthcare systems engineers have utilized these tools for years," she explains. HSE students understand how to build models that predict and inform decisions to achieve desired outcomes.

"Unlike manufacturing or mechanical systems, health care kind of just happened. And though you can see patients flowing through the ER as similar to an assembly line, you have to understand that there are fundamental differences when you are dealing with people, no two of whom are the same," she says. "Lehigh's HSE program is giving students tools to plan, design, build, and manage systems of health care delivery and make sound, data-driven decisions as they take on positions of influence in the industry."



BY **JOHN GILPATRICK** AND **KATIE KACKENMEISTER**

A MAJOR DEVELOPMENT

Coming in Fall 2020: A new degree in Biocomputational Engineering will give undergrads an edge in the booming field of health care analytics

WORKING WITH BIG DATA doesn't require wearing a lab coat, but it still can be messy.

Take it from bioengineer Jeanna Kwon '17, a consultant at Prognos, a health care AI company based in New York City that's focused on improving the prediction of disease—and our power to prevail over it—by analyzing patient laboratory diagnostic data.

"Lab data can have lots of text, like doctors' comments and all kinds of random input," says Kwon. "Applying data science, artificial intelligence, and machine learning on that is complicated. The person coding the algorithms needs to understand what the data says and how to organize it, and that's where my role, and my background in bioengineering, comes in."

Kwon is one of a growing number of BioE graduates charting new career paths in data science and health care analytics at companies like Prognos, which analyzes de-identified patient data from diagnostic labs to provide clinical insights to its partners (insurer Cigna and biotech firm Biogen are two of them). Since 2017, Prognos has built a registry of more than 25 billion medical records for over 200 million patients.

"I specialize in oncology and help data scientists sift through lab data containing test results such as gene mutations, biopsies, and diagnosis codes—telling them, 'I need you to pick out this piece here and this piece there,'" she explains. "Together we're trying to figure out whether this patient has a certain type of cancer and what type that might be."

To give students a more direct runway to launch careers at the nexus of computational and data science, biological sciences, and bioengineering, the Rossin College is rolling out a new degree, a Bachelor of Science in Biocomputational Engineering, in the fall of 2020.

"The two areas where innovation is the strongest in the economy right now are information sciences and biotech," says Anand Jagota, professor and founding chair of the Department of Bioengineering, "and because they sit on opposite sides of the spectrum, with computation and theory on one side and experimental disciplines on the other, the confluence of these two is a huge potential growth area. How to handle health data, how to connect to diagnostic machines—that's where advances in information technology are really coming together to address health care needs, and very few places actually train people at the intersection."

Lehigh is among the first handful of top-tier U.S. research universities to offer an undergraduate major in this

subject. The program will equip students to develop new diagnostic tools and software, model the building blocks of life, identify populations at risk of diseases, shore up health care data acquisition methods and security, and design clinical research trials, among other and not-yet-conceived applications.

Faculty from across the university with expertise in BioE, computer science and engineering, biological sciences, physics, and industrial and systems engineering came together to develop a rich, interdisciplinary curriculum.

Jagota explains that computation and bioengineering typically converge in three areas: molecules/mechanics of cells, genomics data, and optimization of health care delivery. "Lehigh's program will ground students in all three areas and give them a basic bioengineering education as well," he says.

According to Lori Herz, associate chair of the Department of Bioengineering and a professor of practice, biocomputational engineering students will complete standard core classes in math, science, and engineering, followed by courses across bioengineering, computer science and engineering, and industrial and systems engineering. Options for technical electives will include bioimaging, biostatistics, and bioinformatics, which uses computers to collect and analyze information about critically important biological functions like DNA sequencing.

While Kwon and other recent bioengineering graduates have successfully landed at Prognos, Keyrus, QuintilesIMS, AthenaHealth, Axtria, and other leading companies in the health care analytics space, Herz says that with more targeted specialization in areas like bioinformatics and biophysical modeling, Lehigh can lead the way in funneling future innovators into this rapidly emerging industry.

"We already have numerous faculty engaged in health-related research, and we have more students enrolled in computer science, bioengineering, and biological sciences than ever before," she says. "There's never been a better time to do something like this."

Jagota concurs: "We're building on Lehigh's institutional strengths and our faculty who apply computational methods to problems across the sciences," he says. "What's coming are a few new courses to round out the major, as well as real-world experts in certain subject areas to help prepare students to seamlessly transition into this cutting-edge field—and excel once they get there.

"It's a little bit of a risk to step into something new," he adds, "but Lehigh can be not only one of the first to do this, we can also be one of the best."

IN 2019

DATA SCIENTIST

TOPPED THE LIST OF BEST JOBS IN AMERICA

[FOR THE **4TH YEAR** IN A ROW]

BASED ON:

EARNING POTENTIAL	NUMBER OF JOB OPENINGS	JOB SATISFACTION

Compiled by career website Glassdoor

Teaching teamwork

Optimization expert takes a collaborative approach to solving complex problems

"It's better to fail doing something hard than to do something easy very well."

That mindset, combined with a strong belief that you can only truly learn by doing, grounds the teaching philosophy of Martin Takáč, an assistant professor of industrial and systems engineering.

In May, Takáč received the inaugural Richard P. Vinci Award for Educational Excellence. The award pays tribute to the late professor of materials science and engineering who died in March of ALS.

Takáč is an expert in machine learning and designs efficient algorithms for solving large-scale optimization problems. His courses in operations research, optimization, computing, and analytics are heavily project based, he says.

"It's about teamwork. Students will sometimes tell me how hard it is to work in teams of four, and that they'd prefer teams of two. I want them to experience the fact that teamwork is sometimes difficult, but you have to learn how to manage it. You have to talk to each other, or you'll fail. When you go out into the workplace, you have to know how to extract the strongest skills from each person and collaborate as a group."

Takáč says that what ultimately happens about midway through these projects—difficult, open-ended optimization problems—is that students become more and more comfortable straying from their comfort zone. They share ideas, listen to the feedback from teammates, and realize they all bring different strengths to certain problems.

It isn't easy designing such projects, but Takáč hopes students will take from them the things he has come to value as a researcher in the field of optimization.

"I have always been driven by collaboration and the creativity of others," he says. "Trying to solve these problems by bridging fields and working together helps us all progress."

"PICK A **HARD PROBLEM** THAT YOU'LL FAIL FOR SURE BECAUSE YOU WILL **LEARN A LOT**."—Martin Takáč

Examples of that collaborative ethos are evident in Takáč's research. Recently, he teamed up with Nader Motee, an associate professor of mechanical engineering and mechanics, to study how multiple homogeneous agents (i.e., drones) collaborated to perform a classification task.

The agents each individually explored and observed a given environment, then communicated with each other to update their beliefs. The team found that coordination and cooperation between the agents could be optimized using a multi-agent reinforcement learning (MARL) framework, which allowed the agents to more correctly classify an environment. The potential implications are widespread, from health care to industrial automation to military and police support.

"If drones could talk to each other and relay just enough information, they could, for example, find a lost kid in the forest. One drone might identify footprints and tell another drone, 'Hey, go search over there,'" says Takáč. "Transmitting too much information takes too much time, so you want them communicating just enough to get the job done."

Together with Shamim Pakzad, an associate professor of civil and environmental engineering, Takáč introduced convolutional neural networks (CNN) as a solution to the problem of detecting and localizing damage or deterioration of structural systems such as bridges. The team found that CNN architecture led to greater accuracy, robustness, and computational efficiency.

It's exciting work, says Takáč. He enjoys the complexity of the problems as well as the chance to contribute different approaches to solving them.

"And you're working on these problems alongside the top researchers in the world," he says. "What's not to like?"

Ultimately, however, it's fulfilling work. He believes machine learning can make life both easier and safer. And he enjoys challenging his students to do "something cool" with it.

"Pick a hard problem that you'll fail for sure. Because you will learn a lot."

Martin Takáč's research focuses on artificial intelligence and its applications in logistics, civil engineering, machine learning, and robotics.

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A PROFOUND INTERSECTION

With Lehigh's strong foundation in health research and education, opportunities for interdisciplinary collaboration are ripe, says College of Health Dean Whitney P. Witt.

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