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Engineering Research 2014

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Health

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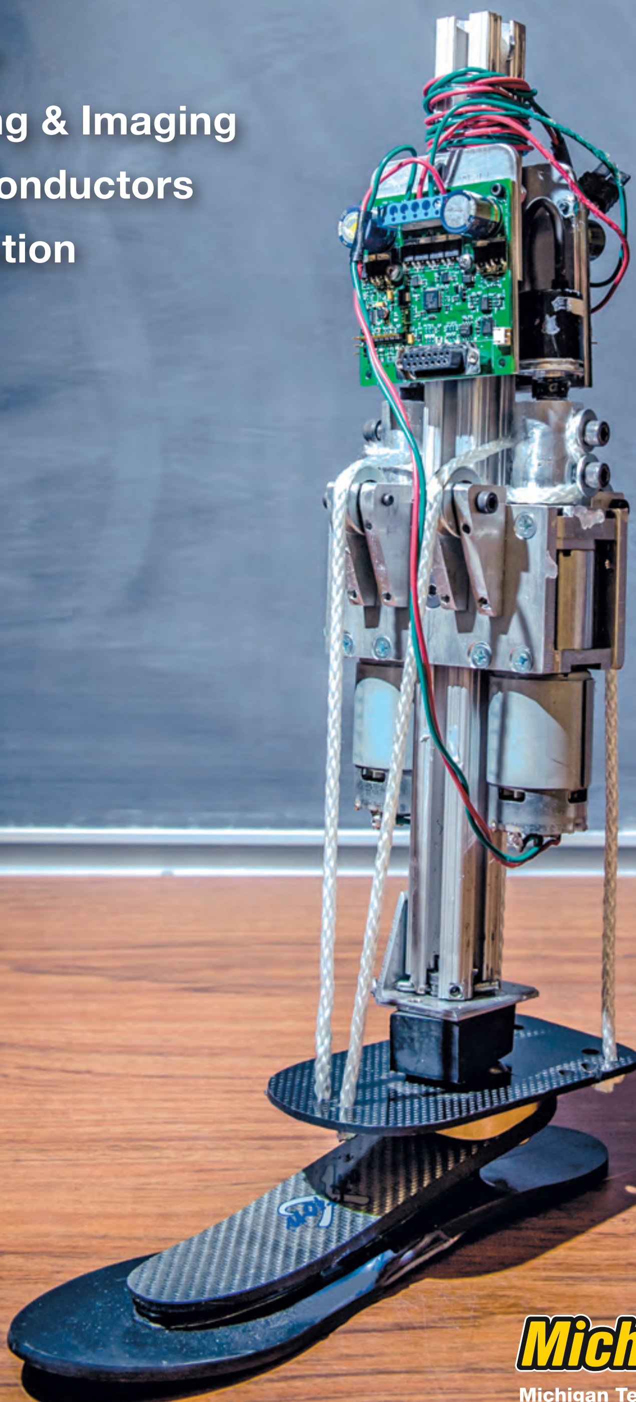

Michigan Tech

Michigan Technological University

Wayne D. Pennington

Leonard J. Bohmann

Letter from the Deans

It is our pleasure to introduce you to the latest issue of the College of Engineering research magazine from Michigan Tech. This issue in particular is a joy to see in development—it highlights the accomplishments of many of our younger academic researchers and graduates. All of the faculty and graduates in this issue are younger than 42 years of age, and the faculty are within eleven years of obtaining their PhDs. Some have received NSF Career Awards (the College had a record number of four recipients this year!)—these allow young investigators to pursue research that is somewhat riskier than usual, but with tremendous potential.

You may notice something else that is unusual in this issue. One of the hallmarks of modern research is that the greatest breakthroughs are inevitably interdisciplinary, and the investigators presented here demonstrate that trait. The research they perform has long-range applications in some field, but the approach that these researchers take may come from another field. We identify the home departments of the investigators in the captions below their photographs; if we did not do that, you would probably not have guessed which department most of them hail from. This is the way of the future—researchers use their knowledge and experience in one or more fields to solve problems that become apparent in neighboring disciplines.

The interdisciplinary approach that our faculty represent is also evident in the accomplishments of the recent graduates highlighted in this magazine. Both are using "traditional" engineering degrees to tackle problems in fields that require imagination and . . . shall we say . . . unexpected applications of that traditional knowledge to their pioneering work. It is a great honor to be associated with programs that provide the education and training that enable our graduates to spread their wings and have such beneficial impact on our society.

With best regards,

Wayne D. Pennington
Dean

Leonard J. Bohmann
Associate Dean for Academic Affairs

On the cover: A prototype of Mo Rastgaar's ankle-foot prosthesis, which adjusts to match the gait of an amputee, improving agility in turning steps and safety on undulating terrain. His research is funded with a 2014 National Science Foundation CAREER Award. See page 4.

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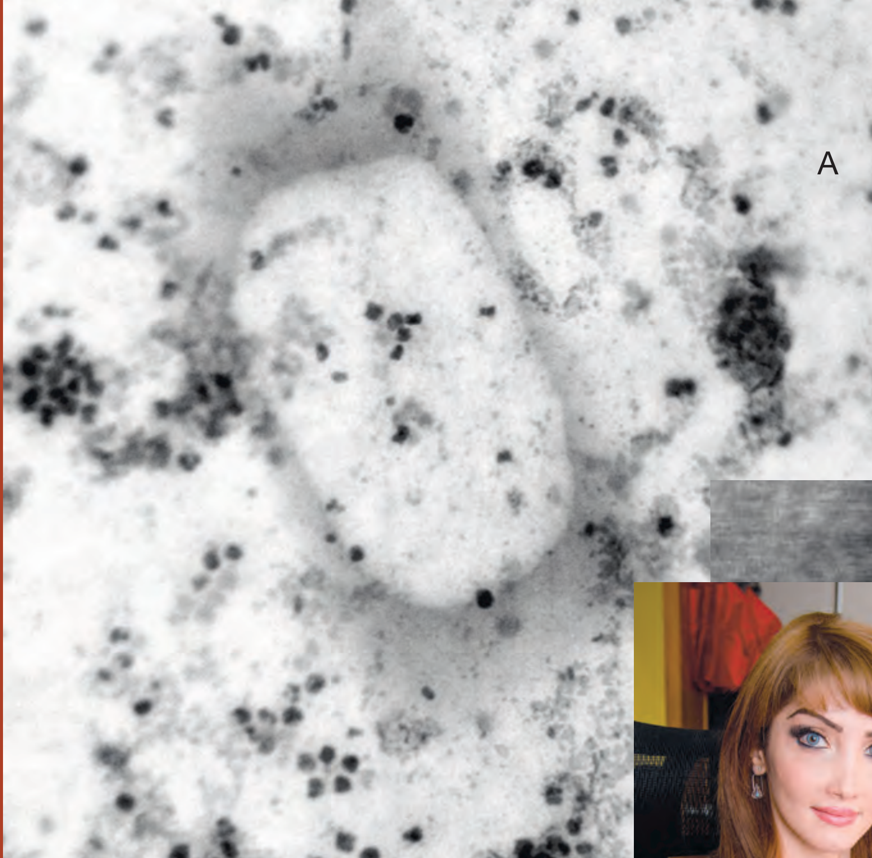
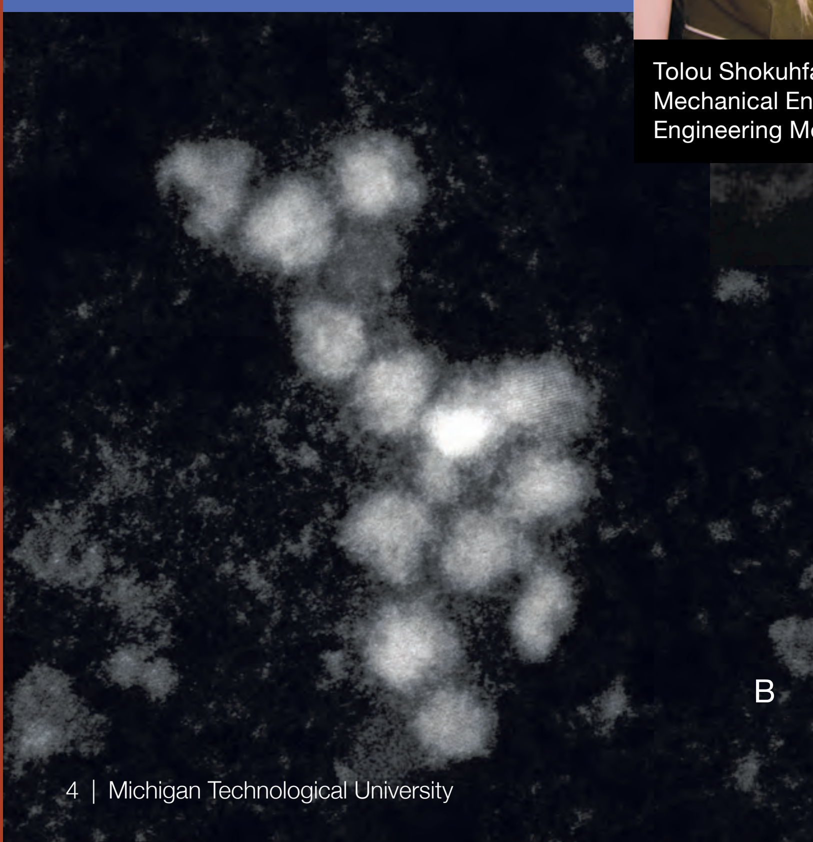


Ferritin is protected by two monolayers of graphene in a liquid environment, allowing its biochemical activity to be studied within a single molecule using electron microscopy.

Tolou Shokuhfar
Mechanical Engineering–
Engineering Mechanics



A: 3D structure of the graphene liquid cell
B: A group of ferritin molecules, with molecules storing more iron appearing brighter.
C: Individual Fe atoms inside a single ferritin molecule

Ferritin—the ninja protein

Gaining a new perspective on serious illness

Many chronic diseases are adversely affected by moderate to significant levels of iron overload. Excess iron can accelerate the aging process by catalyzing the production of free radicals that cause harmful oxidative stress leading to cell and tissue damage. Importantly, an environment of inadequate antioxidant defenses can accelerate aging and devastating chronic diseases. Iron overload has been implicated in multiple metabolic disorders, the worsening of many disease conditions, and premature death and disability.

Tolou Shokuhfar will be investigating the inner workings of ferritin with a $400,000 Faculty Early Career Development (CAREER) Award from the National Science Foundation.

"Fortunately there exists in the body a tiny globular protein that saves us from such iron ion toxicities," Shokuhfar explains. "This 'ninja' protein is called ferritin and does its job by converting the toxic ferrous irons to the safe ferric iron within its core and then releases it when the body needs iron." Any dysfunction of this ferritin protein can result in iron toxicity, serious illness, chronic diseases, and especially neurological diseases.

"Viewing how this protein transforms the bad guy (toxic ferrous iron ions) to the good guy (safe ferric iron) is of great importance in the study of neurodegeneration and other chronic diseases. For more than 100 years this unique protein has been the subject of intense research in biology and chemistry fields due to its importance in many chronic diseases, but no one has yet been able to observe its working mechanism at the atomic level."

Shokuhfar will observe ferritin molecules in real time using a revolutionary technique she developed with colleagues at the University of Illinois–Chicago. By encapsulating ferritin in a microscopic graphene bubble, they were able to observe the fully hydrated molecule using an electron microscope. Usually samples must be freeze-dried and sliced, because electron microscope samples are imaged in a vacuum, but this new technique allows scientists to capture images of biomolecules in their natural state.

So far, Shokuhfar and her team have been able to capture a variety of images from the healthy ferritin protein revealing its core and its atomic structure. In addition, they use a special type of spectroscopy to identify various atomic and electronic structures within the ferritin. Those images show healthy ferritin releasing iron and pinpoint its specific form.

Their next step includes comparing the atomic-scale morphological and structural differences between healthy and diseased ferritins in their native conditions, in order to provide new insights into illness at the molecular level. "Such discoveries can have a huge impact on human health by allowing us to identify disease signatures in ferritin and many other dysfunctional proteins and help design new therapeutic approaches," says Shokuhfar.

Her goal: to unveil the fundamental characteristics of the dysfunctional ferritins responsible for many degenerative and neurological diseases, such as Alzheimer's and Parkinson's.

Sure-footed

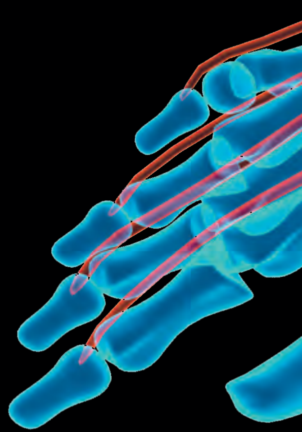
Improving mobility and agility in amputees

Mobility is a key factor to well being, both emotionally and physically. Over a million US citizens are limb amputees, primarily lower-leg amputees.

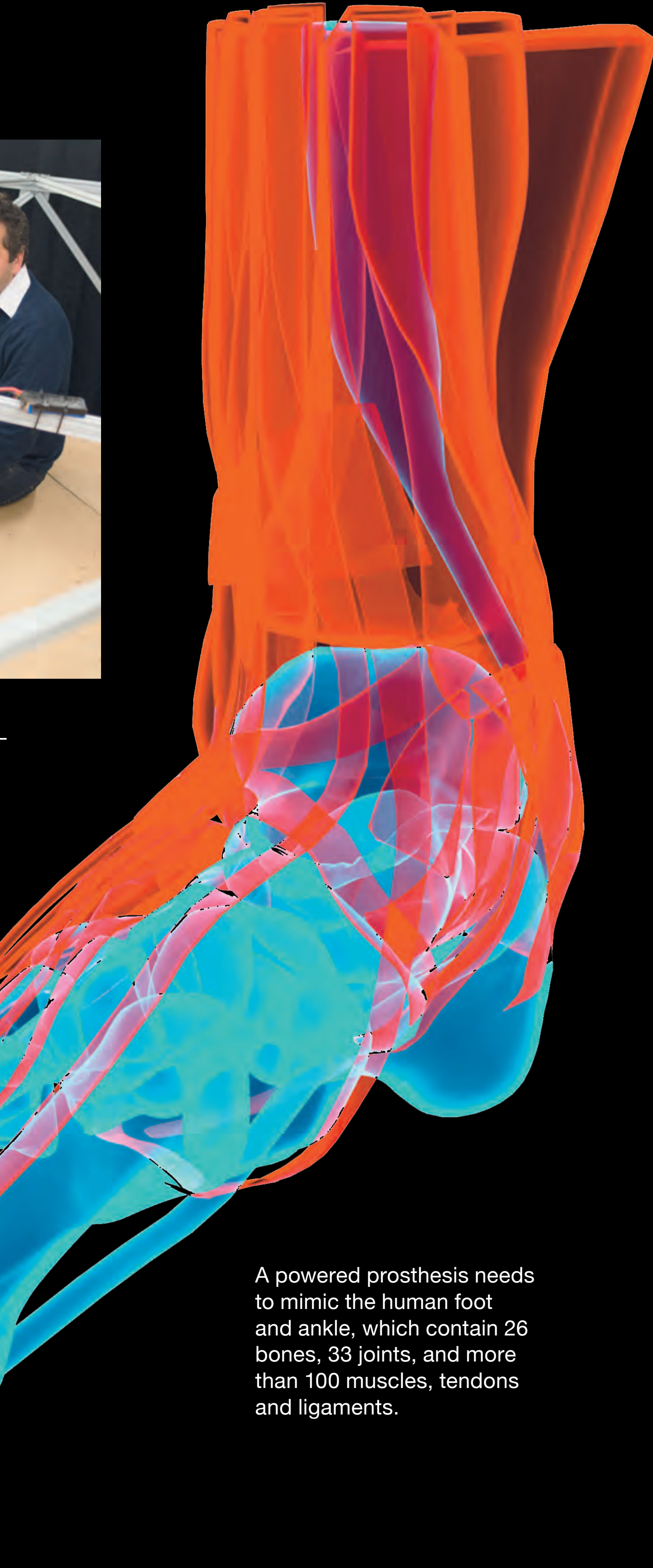
Powered prostheses have the ability to reduce metabolic cost and increase the preferred speed of gait for below-knee amputees during straight walking by providing sufficient power during push-off. Additionally, they reduce the asymmetrical gait pattern and secondary complications. The current powered prostheses are designed for walking on a straight path; however, studies have shown that turning steps account for 8 to 50 percent of steps in different activities of daily living, and, on average, account for 25 percent of daily steps.

Mo Rastgaar is developing a lightweight, cable-driven, powered ankle-foot prosthesis capable of steering and even traversing slopes. He has received a National Science Foundation grant of nearly $500,000 to make his new artificial-limb design a reality. With this five-year Faculty Early Career Development (CAREER) Award, Rastgaar will create an artificial lower leg with the unique ability to restore amputees' mobility and agility.

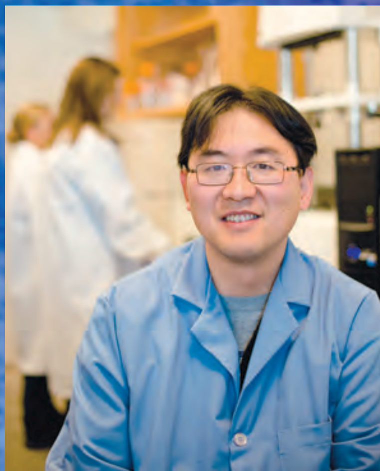
To do this, Rastgaar will develop an ankle joint with two controllable degrees of freedom. His research is based on exploring the turning mechanisms in humans, and understanding the contribution of the ankle and steering mechanisms in human gait. Rastgaar's team of graduate and undergraduate students at the Human-Interactive Robotics Lab (HIRoLab) have developed a prototype of a powered, steerable ankle-foot prosthesis as well as the infrastructure for evaluating this novel prosthetic robot, which features different sensors to detect how an amputee is walking and incorporate real-time force and trajectory feedback control. As the person walks, signals are sent to a microprocessor that adjusts the prosthesis to match the gait of the individual. The additional degrees of freedom provided in this innovative ankle-foot prosthesis will not only improve the gait of amputees as they stride across undulating terrain, but also reduce the likelihood of falling.



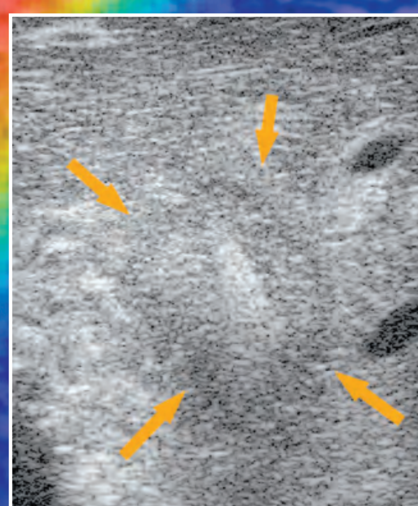
Mo Rastgaar
Mechanical Engineering–
Engineering Mechanics



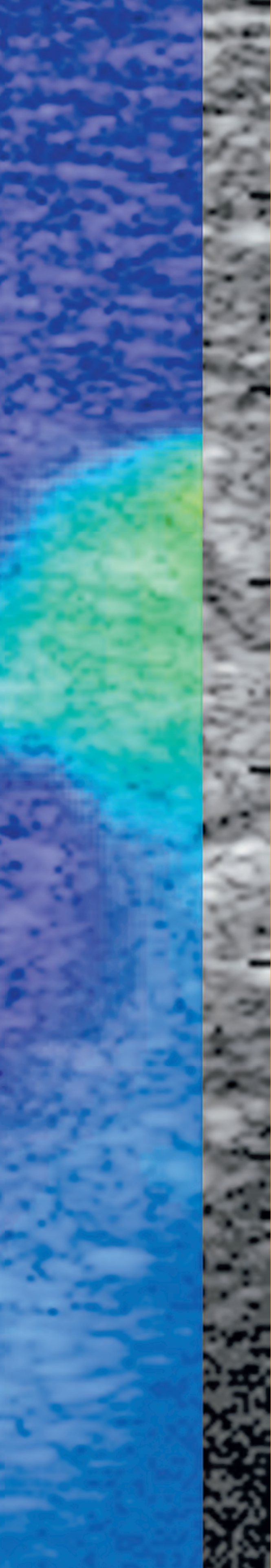
A powered prosthesis needs to mimic the human foot and ankle, which contain 26 bones, 33 joints, and more than 100 muscles, tendons and ligaments.



Jingfeng Jiang
Biomedical Engineering



B-mode ultrasound (B&W) shows ablated zones; elastic modulus imaging (color) shows a significantly enhanced visualization of the ablated zone.



Accuracy and precision

Destroying tumors with image-guided therapy

An alternative to risky surgery, thermal ablation is used to treat tumors in the liver, kidneys, and lungs. Thermal ablation uses very high temperatures to destroy a small area of cells. The high heat kills cancer cells by coagulating their proteins and destroying nearby blood vessels—in effect "cooking" them.

Radio-frequency waves, microwaves, ultrasound waves, and other forms of energy can be used to heat the area. Heat can be applied by insertion of a small applicator (such as a needle or a microwave antenna) into a tumor or by focusing acoustic/laser energy on a tumor in a touchless fashion.

Early results are promising, but thermal ablation has its challenges. Failure to ablate the entire tumor, which is particularly difficult at the edges, can result in regrowth of the residual tumor. In radio-frequency ablation (RFA), using too much heat can destroy healthy surrounding tissues. For instance, renal tissues could be accidently damaged during a liver ablation procedure conducted without effective image monitoring.

Jingfeng Jiang is developing ultrasound-based image guidance algorithms for thermal ablation to ensure a complete denaturation while sparing surrounding tissue. Jiang's Biocomplexity and Mechanics Lab at Michigan Tech is partnering with an interdisciplinary team at the University of Wisconsin–Madison to investigate real-time ultrasonic monitoring of thermal ablation therapy. Jiang's novel computer algorithms will monitor the changes in tissue stiffness associated with thermal ablation, and these algorithms will be used for (Phase I) clinical trials in human patients at the University of Wisconsin Hospitals and Comprehensive Cancer Center.

Jiang uses ultrasound-based elastic modulus imaging (EMI) to better view thermal ablation zones. "Elastic modulus is a physics term for hardness. The elastic modulus image represents spatial (hardness) distributions of the tissue. EMI is created based on ultrasound-based measurements such as displacements. After all, the stiffer spring deforms less. Ablated tissue is stiffer," he explains.

"Our goal is to help surgeons gain better control during the procedure. It can be difficult to accurately measure the temperature inside a tumor. Nearby tissues can be negatively affected. By monitoring temperature and tissue stiffness during treatment and adjusting heat levels accordingly, thermal ablation can be more precise and offer patients better results. The initial answer is yes. Surgeons like what they see so far."

Distress call

Continuous monitoring of aging infrastructure

The American Society of Civil Engineers (ASCE) estimates that, in the US alone, $3.6 trillion dollars are needed by 2020 to repair and update infrastructure in order to ensure public safety and economic growth.

As infrastructure assets age, design assumptions made during the original planning stages become increasingly obsolete and outdated. These structures are often subjected to more usage, larger loads, and more environmental stresses than originally expected.

Given the vast inventory of such aging infrastructure assets in the US and other developed countries, informed decisions must be made before spending limited budgets to upgrade and replace such assets. Owners and stakeholders need information that will aid in condition-based maintenance decision-making in order to safeguard public safety but still work within limited replacement budgets.

Andrew Swartz is developing automated and embedded sensing and data interrogation of the condition of civil structures to supplement limited inspection budgets. His goal: to provide real-time alerts when distress conditions occur.

"Continuous monitoring of structures for damage is known as structural health monitoring (SHM)," Swartz explains. "SHM systems can warn owners and users when significant changes in structural performance are detected. These changes are often associated with dangerous damage conditions."

Deployment of SHM systems as long-term, low-cost, automated wireless sensor nodes is a major goal of Swartz's research group. Focused on both bridge and wind turbine structures, their research involves wireless data collection, autonomous extraction of damage-sensitive features from the data, modeling of structural behavior to correlate damage and behavior, and statistical decision making for alerts and risk assessment.

Early detection of damage in structures due to excessive loads or fatigue, as well as deterioration due to aging and environmental attack, are major challenges for bridge, building, wind turbine, and other structures, but automated monitoring and response to dangerous conditions is possible using structural control technologies," says Swartz. "Fusion of SHM and advances in semi-active control strategies make possible adaptive sensing and control networks that can work to actively redistribute loads in order to minimize stresses induced into damaged components during extreme loading events such as earthquakes," he adds.

"Such a sensor network must first be able to collect data and autonomously identify the existence, type, location, and severity of damage. A semi-active control network is composed of sensors and actuators, mechanical devices that tune the dynamic vibrational properties of a structure in real time in order to minimize unwanted or damaging vibrations. These systems are typically designed to minimize danger to a healthy structure and rely on fixed control algorithms that have been optimized assuming an undamaged state," he explains. "With the addition of damage information, a combined SHM/control network will be able to adapt itself to the presence of damage by reprogramming its own control algorithm such that vibrational modes that induce stresses into identified damaged components may be minimized. In this way, SHM information can be leveraged immediately to protect structures and their occupants."

PHOTO CREDIT: THOMAS ONDREY, THE PLAIN DEALER/LANDOV

Andrew Swartz
Civil & Environmental
Engineering

ODOT workers bolt a structural steel brace beneath the I-90 Bridge in Cleveland, Ohio.

Thomas Oommen
Geological & Mining Engineering and Sciences

Landslide damage on California Highway 1, where a 40-foot section collapsed into the Pacific Ocean

Preventive care

Proactive monitoring along the transportation corridor

Maintaining a world-class transportation infrastructure—highway, railway, and pipeline—is critical for the health of the US economy. Geotechnical assets are literally the foundation. These geotechnical assets include embankments, cut slopes, tunnels, foundations, retaining walls, and more.

Current management practices for geotechnical assets along the transportation corridor often involve restoring the asset after any failure rather than identifying and remediating hazardous conditions before they occur. Since such assets are vast, and the cost and labor for manual monitoring are prohibitive, transportation agencies are not engaged in proactive monitoring.

Thomas Oommen believes that remote sensing from satellite, aerial, or mobile platforms using Radio Detection and Ranging (RADAR), Light Detection and Ranging (LIDAR), or optical sensors could provide an economically-sustainable proactive solution. "Such sensors are not only capable of imaging the asset, but they also can be used to quantify precise measurements of movements in mm to cm scale over time," Oommen explains. "The challenge involves relating these movement measurements to the condition of the asset in a meaningful way, and identifying which platform and sensor are most useful for different geotechnical assets in varying transportation environments—highway, railway, and pipeline."

Oommen and his research team are attempting to address these challenges by imaging various geotechnical assets in a variety of transportation environments. They are employing different sensors and platforms and relating their conditions to a remotely-sensed image. The team is also conducting lab-scale studies to understand the limitations of the various sensors.

"Aging infrastructure, changing weather patterns with more precipitation, and increased volumes of heavier and faster traffic have all placed a great burden on geotechnical assets along the transportation corridor," adds Oommen. "Proactive monitoring is extremely important for strategic long-term investments and hazard prevention."

Sensing danger

Detecting explosive hazards

Since 2008, explosive hazard attacks in Afghanistan have wounded or killed nearly 10,000 US soldiers. Worldwide, explosive hazards, on average, cause 310 deaths and 833 injuries per month. Timothy Havens intends to reduce these numbers by developing methods to find these hazards by combining information from multiple types of sensors, including ground-penetrating radars and cameras.

Havens investigates signal processing and machine learning, focusing on computational intelligence (sometimes called artificial intelligence) algorithms that can perform tasks autonomously. His research team develops algorithms that automatically detect and locate explosive hazards using two different systems: a vehicle-mounted multi-band ground-penetrating radar system and a handheld multi-modal sensor system. “Each of these systems employs multiple sensors, including different frequencies of ground-penetrating radar, magnetometers and visible-spectrum cameras. We are creating methods that integrate the sensor information in order to automatically find the explosive hazards. Our imaging and detection methods provide a 150% improvement in a standard area-under-ROC (receiver operating characteristic) analysis,” he adds.

“Recently, the Army has begun testing a forward-looking system that combines L-band and X-band radar arrays. Our team is also focused on developing imaging and detection methods for this sensor-fused system,” he explains.

In another project, Havens is collaborating with other researchers from Michigan Tech and the Michigan Tech Research Institute (MTRI) to create a sensor-fused platform for inspecting transportation infrastructure, such as roadways and bridges, from an unmanned aerial vehicle (UAV). His research team has developed a UAV sensor pod that combines information from Light Detection and Ranging (LIDAR), camera, and inertial sensors to measure three-dimensional information about road and bridge surfaces. “This project will revolutionize how transportation inspection is performed, both speeding up the process and also significantly improving the safety of transportation workers,” he says.

Timothy Havens
Electrical & Computer Engineering

US Navy technician inspects a disrupted improvised explosive device (IED)

Nina Mahmoudian
Mechanical Engineering–
Engineering Mechanics

Flood waters near the coastal town of Sendai, Japan, after the earthquake and tsunami that devastated the region

Mobile sensors

Autonomous exploration in a dynamic environment

The tsunami that struck Japan on March 11, 2011. Missing Malaysia Airlines flight MH37. Both show the critical need for robots capable of working together as a mobile sensor network in a highly dynamic, potentially hazardous environment.

Nina Mahmoudian wants to increase the effectiveness of the response by robots to environmental and human disasters. Her goal is to develop tools and algorithms that lower deployment and operating costs, increase efficiency and boost endurance for missions with a high level of complexity, including coastal surveillance, subsea structural inspection, hazards detection, and rescue and relief.

“What is really needed for search missions that require vast underwater inspection and detection, such as locating boats and aircrafts at sea, is an underwater robot that can explore an area with a sense of what it is looking for,” says Mahmoudian. Even better–a fleet of underwater robots. “In contrast to the use of a single vehicle, multi-robot systems could vastly increase mission area, decrease operation time, and offer a diverse suite of sensors, system resiliency, and goal redundancy,” she adds.

Mahmoudian and her research team at the Michigan Tech Nonlinear and Autonomous System Laboratory are building four such robots: low-cost autonomous underwater vehicles (AUVs), each weighing about twenty-five pounds. Named ROUGHIE (for Research Oriented Underwater Glider for Hands-On Investigative Engineering) Mahmoudian’s AUVs sport better, more powerful brains equipped with multi-agent motion control algorithms and tools for more efficient underwater discovery. They are also modular, allowing users to swap out different components depending on what tasks the AUVs undertake.

Powered only by batteries, ROUGHIEs “fly” slowly through the water simply by adjusting their buoyancy and weight. “They are designed for use near the water’s edge, which offers a special challenge,” adds Mahmoudian. “ROUGHIEs will come up on the coast, which means they have to operate where there’s lots of traffic and noise.”

ROUGHIEs are also less expensive than commercial gliders. “At a fraction of the cost of one commercial vehicle, it is possible for us to test glider swarm algorithms and compare them to established single glider models,” she says. “Testing control methods for hazardous underwater zones such as ports, shipping channels, and reefs can be done without much financial risk.”

Mahmoudian’s work combines fundamental and applied research. “One of our goals is to facilitate a seamless transition between academic modeling/simulation problem-solving approaches and real-world applications.”

Copper interconnect, meet carbon nanotube

Creating faster circuits

As technology scales beyond 16-nanometer technology node, the performance of copper interconnects in circuits is approaching its fundamental physical limit.

Timing and reliability issues that perplex copper interconnects limit circuit miniaturization.

Wires made from copper have very small cross-sectional areas. This results in increased wire resistance and excessive interconnect delay. In fact, interconnect delay has become the limiting factor for chip timing.

Due to the fundamental physical limits of copper wires, novel on-chip interconnect materials—carbon nanotubes and graphene nanoribbons—are more desirable due to their many salient features including superior electrical conductivity, increased electromigration, high thermal conductivity, and mechanical strength.

Shiyan Hu seeks to bring together the benefits of both copper interconnects and carbon nanotubes and/or graphene nanoribbons.

With a $430,000 Faculty Early Career Development (CAREER) Award from the National Science Foundation, Hu will develop an innovative codesign methodology for next-generation integrated circuits (IC)s.

The wires in a typical computer chip are very narrow indeed: with a width of about 22 nanometers, each bundle of a thousand is no bigger than a human hair.

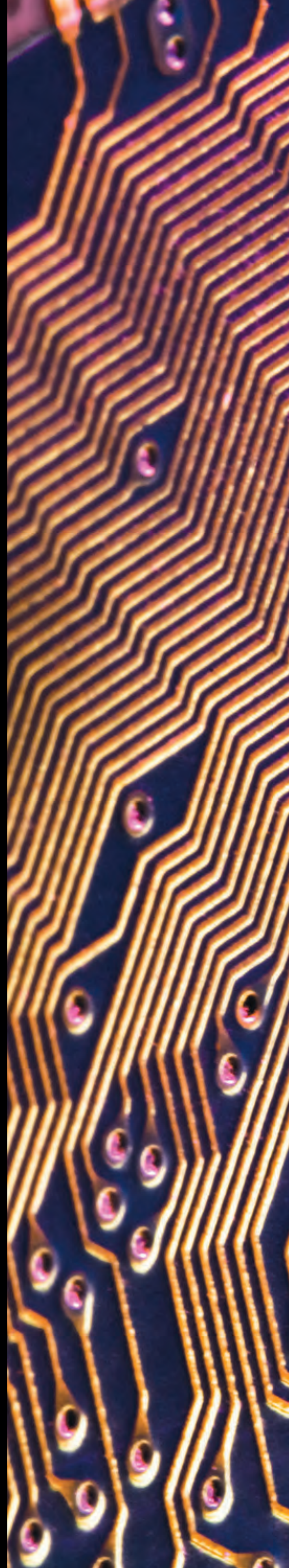
"Those wires have been getting thinner and thinner, because people want their chips to do more and more things, and for that you need more and more transistors, billions on a single chip," Hu explains. "But then the chip gets slower and slower . . . unless you do some magic."

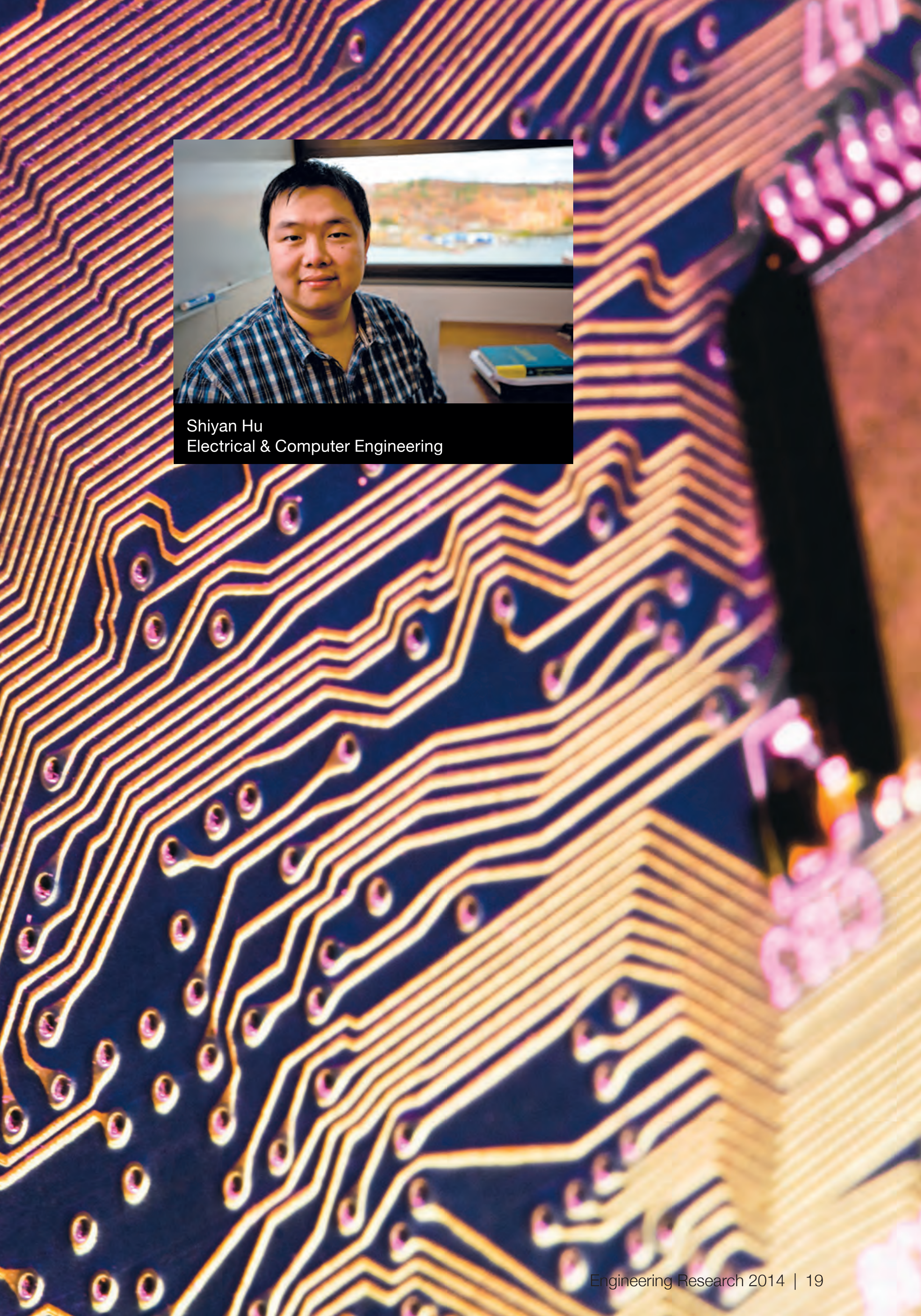
Hu will develop a variety of physical design automation techniques. A key feature will be a "variation-aware" codesign technique for the new methodology to compensate for variation and defects.

"The replacement of copper interconnects should be performed gradually in order to judiciously integrate the benefits of both technologies," adds Hu.

"My goal is to integrate pioneering nanotechnologies into practical circuit design," Hu explains. "I think we can revolutionize the prevailing circuit design paradigm."

Hu's other research interests include embedded system designs for smart homes, microfluidic biochip design, and buffer insertion, which greatly improves integrated circuits' timing performance.





Shiyan Hu
Electrical & Computer Engineering

Joshua Pearce
Materials Science & Engineering

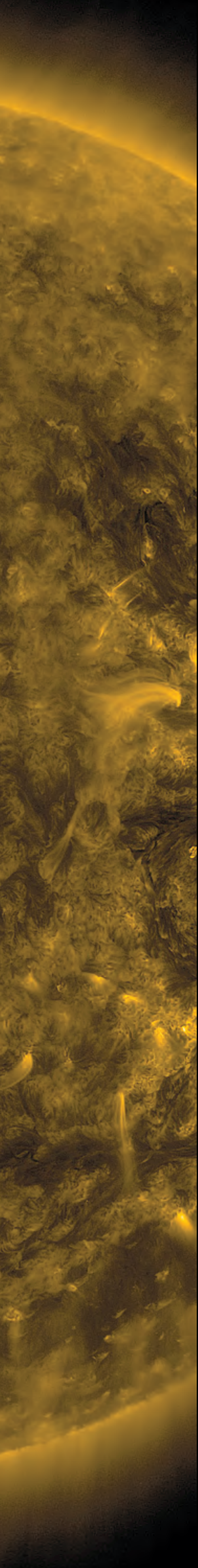


PHOTO CREDIT: NASA SOLAR DYNAMICS OBSERVATORY

Solar power

Full-spectrum dominance

Electric power has been a key factor in creating a healthy and comfortable society. Unfortunately, conventional sources are plagued with unacceptable liabilities. Solar photovoltaic (PV) technology, which converts sunlight directly into clean and green electricity, is poised to replace those sources—and this is the goal of a team of undergraduates, graduate students and post-docs working with Joshua Pearce on every aspect of PV technology, including the fundamental materials science, device physics, solar electrical system design and energy policy.

The US solar industry is growing at a record-breaking pace, while becoming more affordable and accessible than ever before. In many parts of the country, solar electricity is already cost-competitive with traditional energy sources. The average price for a utility-scale PV project dropped from about $0.21 per kilowatt-hour in 2010 to $0.11 per kilowatt-hour at the end of 2013. According to the Energy Information Administration, the average US electricity price is about $0.12 per kilowatt-hour, and can run higher than $0.20 per kilowatt-hour in Michigan's Upper Peninsula, New York, and elsewhere.

Although solar power costs have plummeted, most American families still simply do not have enough cash to purchase a PV system to meet their needs; they need a loan with reasonable terms. Securitization, or a pooling of solar assets for investors, provides a solution to this problem as shown in a study by Pearce's research group that found billions of dollars of potential solar asset-backed securities in the US. "With the current cost of solar equipment and our financing model, the home owners make money, the solar industry makes money and the firms setting up the financing make money. There is no question, the solar industry is ready for investors," says Pearce.

His group is working to reduce costs on several other fronts. Last year, the group investigated spectral effects of albedo (reflection) from surfaces around PV systems and found that by using non-tracking planar concentrators (small mirrors) they could increase PV output by more than 30 percent. "Firms avoid using such mirrors now because of fear of voiding warranties," says Pearce. "Our work is starting to provide the data needed to lessen these fears, and we are developing optical models for non-ideal surfaces to optimize PV systems for the real world."

In addition, Pearce's group found they could increase efficiency by using the PV module as a heat absorber for solar thermal applications. "The trick is to be careful about PV material choice and use the thermal system to anneal (bake) the PV to refresh it," he adds. Their results pumped up the electrical output by another 10 percent.

"Our work enables PV systems to be optimized for a specific location, which drives the cost of solar even lower," Pearce concludes. "Soon most roof tops will sport a solar power system for economic reasons alone."

Chip design and verification

Unleashing the power of heterogenous manycore systems

As relentless technology scaling reaches into the sub-16 nanometer regime, nanoscale integrated circuit (IC) designers are facing rapid growth of design complexity. Present-day nanoscale multicore/manycore microprocessors integrate billions of transistors into a single chip, while emerging three-dimensional ICs integrate multiple active layers in the vertical direction.

Key VLSI (very large-scale integration) subsystems, such as clock distributions, power delivery networks (PDNs), embedded memory arrays, and analog and mixed-signal systems may soon reach an unprecedented complexity of hundreds of millions of circuit components, making their modeling, analysis and verification tasks prohibitively expensive and even intractable.

With the help of a five-year, $400,000 Faculty Early Career Development (CAREER) Award from the National Science Foundation, Zhuo Feng will develop systematic approaches that can help automatically compile existing sequential or parallel multicore electronic design automation (EDA) applications onto heterogeneous manycore systems—something that would enable chip designers to achieve near-optimal computing performance. Feng's new approaches could also allow much larger circuits than ever before to be accurately analyzed.

"It is not rare to experience analog and radio-frequency (RF) circuit simulations that take a few days or weeks to finish," Feng explains. "The indispensable full-chip electrical/thermal analysis and verification for microprocessors and 3D-ICs impose even greater challenges handling 3D mesh-structured grids with many millions of system unknowns."

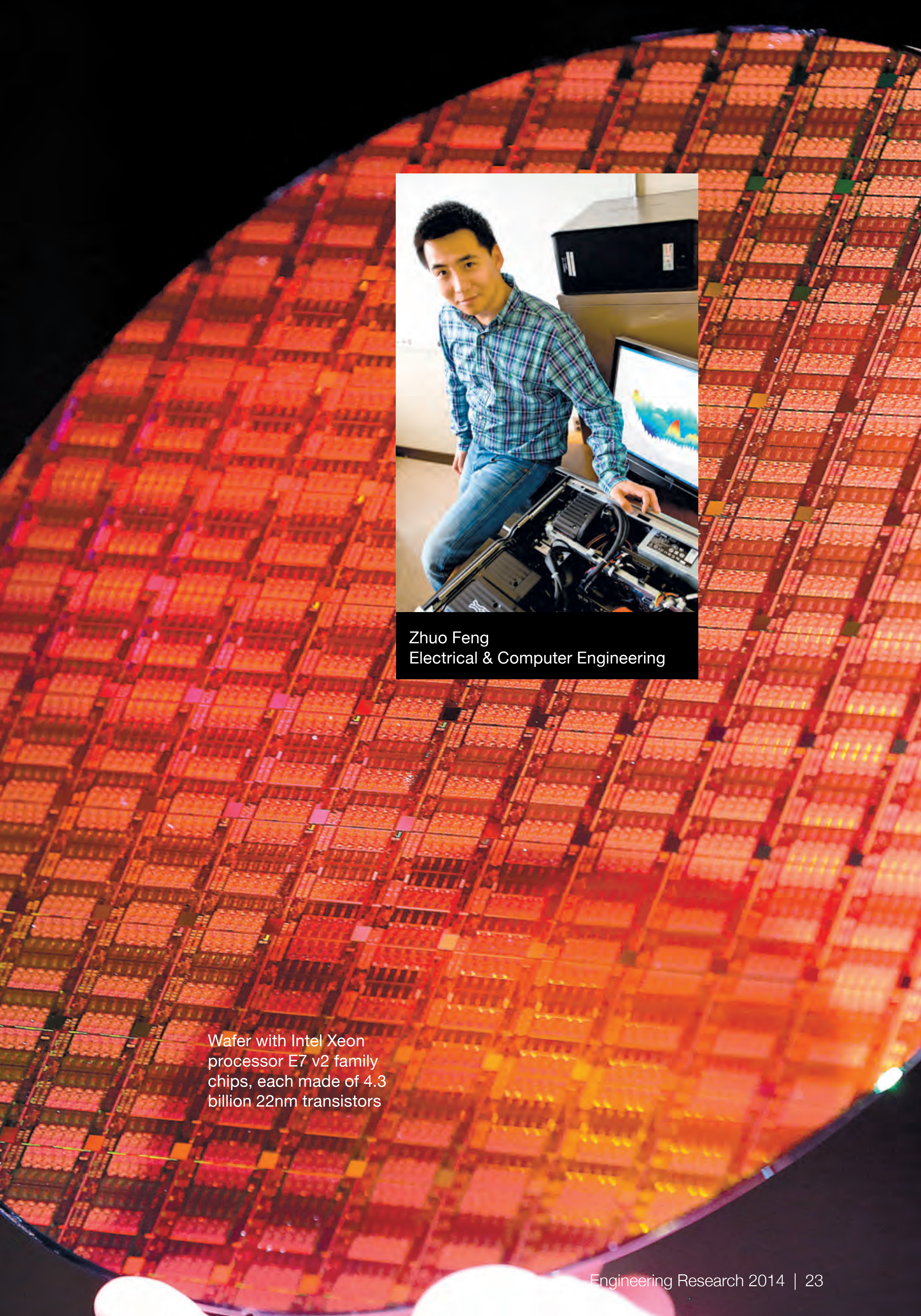
Feng is targeting and investigating a coherent set of VLSI CAD problems that are key to the design of nanoscale microprocessors, 3D-ICs, analog and mixed-signal circuits, and RF and microwave circuits.

Feng will tackle four key areas. The first involves time/frequency-domain simulation methods for nanoscale post-layout ICs. "My hope is that these new methods will prove to be indispensable for designing and verifiying a wide range of circuits," he explains. Next on Feng's list is full-chip electrical/thermal analysis and verification. "This work is critical to nanoscale microprocessor and 3D-IC designs that exhibit complex electrical/thermal coupling effects."

Feng will also investigate 3D interconnect modeling and parasitics extraction—the key to many timing and power verification issues in nanoscale microprocessors, analog and mixed-signal ICs, as well as 3D-IC designs. Last but not least, he will explore hardware-specific performance modeling/optimization for heterogeneous manycore architectures to further improve efficiency, recent runtime performance modeling, and optimization methods.

"My ultimate goal is to change how we teach and design next-generation CAD algorithms for energy-efficient heterogenous manycore systems," says Feng.

PHOTO CREDIT: INTEL CORPORATION



Zhuo Feng
Electrical & Computer Engineering

Wafer with Intel Xeon processor E7 v2 family chips, each made of 4.3 billion 22nm transistors

Megan Frost
Biomedical Engineering

Pain—and then gain

Profile of a startup

The infection started after her wisdom tooth was extracted. Then it morphed into a serious disease of the bone called osteomyelitis. To treat it, Megan Frost had to dose herself daily with drugs through a catheter inserted into a vein in her arm.

"I had forty-five days of self-administered antibiotics, and I had to change the dressing every two days," said Frost. "It was actually pretty disgusting. I thought, 'This is crazy. Why do we have to do this every two days?'"

Frost got well, and that could have been the end of it. But then she was invited to take a ten-month crash course for women on starting a business. With undivided support from the MTEC SmartZone and Michigan Tech, she was able to learn the basics of entrepreneurship while upholding her teaching and research responsibilities. Frost began working with the SmartZone, which provided a team of experts to evaluate her new product: an antimicrobial surgical dressing that only needed to be changed once a week.

"It's a billion-dollar problem created entirely by medical intervention," she said. "We are looking to do something that can fight it, and the SmartZone absolutely got the ball rolling."

The SmartZone helped her find a partner, Jeff Millin, the former CEO of Pioneer Surgical, in Marquette, Michigan. "One thing I realized early on was that I have a very good understanding of the science and technology, but I don't know the first thing about business," Frost said. "I was looking for someone who could be a partner, and Jeff has been awesome."

They are now in the process of getting FDA approval to market the dressing. Their goal is to establish a presence in Hancock, with ten or fifteen scientists doing R&D to solve health problems.

"It's pretty exciting," Frost said. "It's been really intellectually stimulating to take a fundamental idea developed in the lab and make it into something useful. Plus, we can actually help make people's quality of life better. There's a lot of pain and suffering that goes on with those infections that's completely unnecessary."

Oil sands

Improving the process, reducing the footprint

Canada's oil sands, located in northern Alberta, are one of the largest known hydrocarbon deposits in the world, third behind those in Saudi Arabia and Venezuela. The vast majority of Canada's oil sands deposits are located at depths of 1,300 feet below the surface.

Bitumen (heavy oil), the hydrocarbon resource found in oil sands, is very viscous—think molasses or peanut butter—and therefore requires special extraction methods to get it out of the ground and into a state where it is fluid enough for transportation to refineries.

As Bitumen Treating Engineering Team Lead at ConocoPhillips, Chris Copeland is dedicated to developing and implementing cleaner, more efficient methods of extracting bitumen from oil sands.

Less than a month after earning his PhD in chemical engineering at Michigan Tech, Copeland accepted his first position with ConocoPhillips in June 2007 as a research engineer in their heavy oil R&D division in Bartlesville, Oklahoma. He was hired to evaluate technologies for water treatment and steam generation to support the company's oil sands business in Canada, which had just begun.

"ConocoPhillips utilizes a process known as steam-assisted gravity drainage (SAGD)," Copeland explains. "The purpose of my work was to develop new and innovative water treatment and steam-generation processes to improve the economic viability of oil sands, reduce environmental footprint, reduce water usage, and reduce CO_2 emissions."

SAGD is used to extract deep deposits of bitumen without removing the soil and materials above it. The process involves injecting high-temperature steam underground through a horizontal well to melt the bitumen, allowing it to flow to an adjacent horizontal well. From there, it is pumped to the surface for further processing. Unlike strip mining, with SAGD most of the land above a bitumen reservoir can be left intact. "SAGD has a much smaller footprint than traditional mining methods," notes Copeland.

Copeland moved to Calgary in 2011 to become a facilities engineer responsible for the water treatment plant at the ConocoPhillips Surmont SAGD facility. He was charged with optimizing chemical consumption, improving filtration efficiency, and reducing steam generator fouling. These initiatives were all successful, resulting in significant improvements to plant performance, and Copeland was promoted again. He now leads the team of engineers responsible for bitumen gathering and treatment at Surmont. His team also explores improvement opportunities for the new Surmont Phase 2 SAGD facility currently under construction. The expansion will raise ConocoPhillips production capacity from 27,000 to 136,000 barrels of bitumen per day.

"Multiple studies performed in coordination with our technology group in Bartlesville have allowed us to improve the operational performance of our Surmont facility," says Copeland. "This was achieved by the development of testing facilities in Bartlesville that replicated key portions of the SAGD process to allow us to replicate our biggest challenges, and develop mitigation strategies—precisely the same process I learned to follow from my faculty advisor, S. Komar Kawatra, while at Michigan Tech."

Chris Copeland, ’07
Bitumen Treating Engineering Team Lead
ConocoPhillips

ConocoPhillips Oil Sands Surmont Operations facility in Alberta, Canada

Agustin Robles-Morua climbs an eddy covariance tower used to measure water and energy exchanges in the Sonoran desert.

Sustainable water systems

From Hermosillo to Houghton and back

In Mexico, Northwestern Sonora experiences periods of both drought and abundant rain that can last from a few years to several decades. This climate variability makes it particularly challenging to operate and maintain water infrastructure. A more arid climate is predicted, however, which could worsen future droughts.

Hermosillo, the rapidly growing Sonoran state capital, is particularly vulnerable. It depends on groundwater wells and surface supply from the Sonora River Basin (SRB) to its northeast. Water from the coastal SRB aquifer that supplies Hermosillo's water is being extracted at an unsustainable rate. Insufficient water supplies cause conflict between the state's urban and agricultural sectors. Discharge of untreated wastewater into the SRB causes water pollution and waterborne diseases. Many community-level drinking and wastewater treatment systems work poorly or not at all—and some communities have no water systems in place. Many communities suffer from periodic water shortages. All of these water management challenges are further complicated by Mexico's regulatory framework.

It's a tough nut to crack for Agustin Robles-Morua, who leads the Laboratory for Sustainable Water Systems at the Instituto Tecnológico De Sonora, Mexico (ITSON). Collaborating with many individuals and groups in the US and Mexico, he works tirelessly to provide multidisciplinary approaches and practical solutions to a wide range of water sustainability problems. A hallmark of his work: processes targeted at promoting civic responsibility in the care and management of watersheds and the environment. "It is important to understand both the human dimensions and the biophysical characteristics of rivers in order to achieve sustainable water systems," he says.

Born and raised in Hermosillo, Robles-Morua earned an undergraduate degree in industrial and systems engineering at the University of Sonora. He worked for five years in Hermosillo at AMP Amermex MP, a division of Tyco Electronics, before coming to Michigan Tech to earn first an MS degree in Environmental Policy and then a PhD in Environmental Engineering under the direction of faculty advisor Alex Mayer. As a doctoral candidate, his work with residents of the rural Mexican town of Rosario to design and build support for a new wastewater system earned Robles-Morua a visit with President George Bush and the US Agency for International Development. While at Tech, Robles-Morua also earned a certificate in sustainability through Michigan Tech's Sustainable Futures Institute (SFI). "SFI provided me with the opportunity to meet and interact with faculty and graduate students from other disciplines and universities," he recalls. "These interactions greatly influenced my long term research interests in conducting studies that integrate across fields."

As a postdoctoral researcher, Robles-Morua spent two years at Arizona State University's School of Earth and Space Exploration in the Surface Hydrology Group, where he conducted water resources, sustainability, and social impact studies and co-led the creation of the US-Mexico Border Water and Environmental Sustainability Training (UMB-WEST) program for students from Arizona State University, University of Arizona, and University of Sonora.

Robles-Morua was recently promoted to associate professor in the Department of Water Sciences and Environment at ITSON. He is currently investigating—among other things—the impact of climate change on water availability to riparian ecosystems, and population growth on the transboundary Santa Cruz and San Pedro River basins. He is also assessing hydrological impacts caused by land use changes in different types of semi-arid ecosystems in the southwestern United States and northwest Mexico.

Northern lights above the Keweenaw Waterway, near the Michigan Tech campus

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