DESIGNING SOLUTIONS TO GRAND CHALLENGES

by CURTIS VICKERS ’07 M.A. • photos by JAMIE KINGHAM ’93

When Mridul Gautam, vice president for research and innovation, talks about the University of Nevada, Reno, it is easy to grow excited for the future of the campus and the community it serves.

“All across campus, our students and faculty strive to identify, define and design solutions to the grand challenges we face both globally and locally,” Gautam said. “By pooling and expanding our internal resources—from our labs and facilities to the researchers and innovators who run them—we work together toward the same simple goal that is at the heart of all intellectual pursuit: the improvement of real human lives.”

In the pages ahead, you’ll meet four outstanding Nevada faculty and take a behind-the-scenes look at the grand challenges they have devoted their careers to solving.
Since Computer Science & Engineering Assistant Professor Shamik Sengupta joined the University in 2013, he has taken an aggressive approach to addressing the grand challenge of improving cybersecurity efforts locally and globally.

After all, for Sengupta, cybersecurity is not a minor concern. It is warfare, and the stakes are high.

“‘Sniffer’ or ‘jammer’ devices threaten to compromise your digital devices and steal your personal or professional information from your smart phone or computers. Credit card security breaches in stores like Target and Home Depot threaten to deplete your finances. Infiltration of biometric devices threatens to expose your personal medical information,” Sengupta said. “These are becoming highly coordinated, sponsored attacks. And our response to the present and future threats must be equally robust.”

Enter the Sandbox

The Sandbox is a computer lab housed in the University’s Cyber Security Center that is completely quarantined from the rest of the University. Led by Sengupta, researchers utilize this safe space to explore existing cyberattack methods and devise ways to defeat them through attack/defense scenarios not unlike war games. And just like war games, the goal is to defeat today’s adversary while preparing for tomorrow’s.

“The key is not merely understanding how to defeat existing attacks,” Sengupta said. “It is to understand how existing attacks work, where weaknesses are, and to propose ways to eliminate entry points for future attacks.”

Shamik Sengupta, Ph.D.

Joined the University in 2013

Research Interests:
- Wireless networking and mobile computing
- Cybersecurity
- Inter-disciplinary research

Four National Science Foundation (NSF) Grants
Two NSF Research Experiences for Undergraduates (REU) Supplement Grants

For more, visit www.cse.unr.edu/~shamik/
The advances made in the Sandbox are important, but Sengupta recognizes that they are not enough. In order to respond fully to cyber threats, researchers like Sengupta must reach out beyond the walls of the Computer Science & Engineering Department.

“Because cyberattacks occur on a variety of fronts, it is critical that our response addresses each of these fronts,” Sengupta said. “To do this, we need interdisciplinary cooperation, from fields as diverse as judicial studies, computer science and engineering, political science, information systems and many others. And that is where the National Science Foundation Capacity Building in Cybersecurity-literacy: An inter-disciplinary approach Grant and NSF CYBEX Grant come in.”

**CYBEX: Cyber Security Information Exchange**

In order to provide better cyber defense to companies across the world, Sengupta has received NSF funding to pursue the implementation of CYBEX, the Cyber Security Information Exchange program. Designed to be a secure, anonymous way for businesses of all sizes that have experienced a security breach to share information about how their systems were compromised, the idea behind CYBEX is to gather as much data from real-world attacks on businesses as possible to mount effective defense against future breaches.

“If we can provide a safe space for businesses to share all of the information about their breaches, we will be able to reduce the financial impact of future breaches,” Sengupta said. “By working together, we can help safeguard business systems, and in so doing, we can reduce operating costs and protect the loss of customers.”

**Teaching Teachers: Research Experience for Teachers**

Integral to Sengupta’s holistic approach to countering cyberattacks is education, not only of his own undergraduate and graduate students but also of local middle and high school teachers.

“Improved cybersecurity begins with educating the next generation,” he said. “This is why it is imperative that we devise ways to incorporate cybersecurity awareness into the curriculum in middle and high school classrooms. That is precisely what the RET site is designed to do, providing us with the opportunity to make sure that what we do in the Sandbox becomes a part of the community in a meaningful way.”

Sengupta is referring to the Research Experience for Teachers Site: Cyber Security Initiative for Nevada Teachers. The first year Site activity of the program, which is funded for three years through a $540,000 NSF grant, runs from June 20-July 29, 2016. The first of its kind in the state of Nevada, the program welcomes ten middle and high school teachers to campus for a fully funded six-week research experience. Program faculty come together to help teachers incorporate tangible, real-life lessons in four areas: robotics/unmanned autonomous systems; biometrics and hardware systems; wireless communication systems; and digital forensics.

“The idea is to lay the educational groundwork in cybersecurity knowledge and appreciation early, in high school and middle school,” Sengupta said. “That way when students advance to the University, the future network, software, and hardware developers will perform their work with cybersecurity in mind, preventing future generations of cyberattacks.”

---

When Assistant Professor of Psychology Jacqueline Snow was doing her post-doctoral work utilizing fMRI technology to analyze how the human brain represents objects, she was struck by the fact that almost all previous studies have asked subjects not to respond to real objects, but to images—2D representations—of objects.

“Scientific studies of the human brain and behavior, and, therefore, current theories about how the brain processes objects, are based on studies that have relied on stimuli in the form of pictures or computerized images of objects” Snow explained. “As a field, we have taken it for granted that a visual representation of an object is a sufficient proxy for a real graspable object. From a practical standpoint it is certainly easier to work with images in the laboratory and the fMRI scanner. The research we’re doing in my lab questions this fundamental assumption.”

The work Assistant Professor Snow has done with her team of graduate student researchers indicates that, yes, in fact we do process real-world objects differently than representations of objects. For example, Snow’s studies of human memory indicate that if we see a picture of an object like a coffee mug, we will be less likely to remember it than if the mug happened to be sitting right in front of us.

“In some respects, it should be no surprise that the brain responds to real-world objects in a different way than it responds to images. Our brains have evolved to allow us to perceive and interact with real, tangible objects—items that are graspable, meaningful, and have value in the context of our interactions with the world,” Snow said. “To have a complete understanding of human cognition, it is critical to analyze how the brain processes real-world stimuli. Relying on images may limit our understanding of the human brain, but this has rarely been recognized or acknowledged.”

**Challenging What We Think We Know**

Snow’s work has earned her a prestigious National Institutes of Health (NIH) R01 grant, a highly competitive grant designed to support cutting-edge research with strong potential for translational benefits. The NIH recognizes the innovation and potential for Snow’s work to affect our daily lives in a variety of ways, beginning with fundamental assumptions about science and the research that informs it.

“Our research has important implications for basic science that relate to the way research is conducted and the kinds of stimuli we rely on to study behavior in controlled laboratory contexts. The value of primary research to human health hinges upon the extent to which the findings transfer to real-world stimuli and contexts. If we know that the brain processes visual representations differently than real-world objects, then this suggests that we may be using the wrong types of stimuli to understand the brain,” Snow said.

Snow’s research could require a radical reevaluation of what we think we know about the human brain. If our brain responds in a fundamentally different way to a picture of an object than it does to an actual object, then we may not adequately understand which parts of the brain are involved in perceiving and acting in the world in everyday life. While this knowl-
edge drives Snow’s own work in attention, perception, memory, and decision-making, the implications extend across disciplines, critically informing practices in medicine and public health initiatives.

**Medicine, Health and Education**

Given the advances Snow is making in understanding real-world cognition, potential applications include modified strategies for rehabilitating patients who have suffered from neurological conditions that affect vision and memory—for instance, stroke survivors.

“If we hope, as some researchers do, to stimulate portions of the brain by the use of electrodes or other methods to improve memory, vision or cognition, then it is imperative that we understand which portions of the brain are actually being utilized during everyday perception. Our research could inform the development of neuro-prosthetic devices by highlighting brain areas that may be suitable, yet to date neglected, for implant placement,” Snow said.

Because what we know about human perception informs policies and programs relating to education and public health initiatives, Snow’s work may one day affect not only what we learn but how we learn it.

“The research could also change the way we approach learning and education in healthy children and adults. For example, if we want to improve a student’s ability to learn and remember, and we know that memory is better for real-world objects versus impoverished images or lists, we might find better outcomes if we present more realistic exemplars to perceive and interact with,” Snow said. “We are also studying how humans behave in decision-making contexts when confronted with real foods, compared to images of foods, which may not stimulate the same brain networks,” Snow said. “This could have important implications for understanding why health-related problems such as obesity persist, and why current public health initiatives have had little to no success in modifying real-world food choices.”

---

**Jacqueline Snow, Ph.D.**

Joined the University in 2013

**Research interests:**

- Object perception
- Real-world objects
- Functional magnetic resonance imaging (fMRI)
- Neuropsychology

Director of the Jacqueline C. Snow Object Perception Laboratory

National Institutes of Health R01 Grant Recipient

Before joining the faculty in the Department of Mechanical Engineering, Assistant Professor Yiliang “Leon” Liao worked for Caterpillar, where he was part of a team focused on designing more effective manufacturing processes to produce the massive yellow machines we see on worksites across the world.

These days, Assistant Professor Liao focuses on the little things in life.

The Little Things

“If you opened your smart phone, you would see that it has tiny features that are integral to its functioning,” Liao said. “One of my research objectives is to figure out how to produce those small features as efficiently as possible. This is advanced manufacturing.”

Traditionally, manufacturing has been performed with the use of metal tools to cut, drill and press pieces to a specified size and form. But there are limitations to conventional manufacturing techniques.

“Manufacturing is hamstrung by the limitations of the tools themselves,” Liao said. “Traditional tools get too hot or lose integrity upon repeated use, and there are very real limitations to the kinds of tasks they can perform. In a world where new products are produced with increasingly complicated—and small—components, these limitations are not acceptable.”

The goals of advanced manufacturing are clear: to utilize new manufacturing processes that are energy efficient, highly effective, and capable of performing small, complicated tasks, and to enhance the durability of the goods produced.

All of these goals are possible with the use of a laser beam.

Assistant Professor Yiliang Liao’s grand challenge:

AIDING INNOVATION THROUGH ADVANCED MANUFACTURING

Yiliang “Leon” Liao, Ph.D.

Joined the University in 2014

Research Interests:

- Laser materials processing
- Laser-assisted advanced manufacturing
- Micro/nanoscale manufacturing
- Mechanical/physical property enhancement
- Integrated computational materials engineering

Oak Ridge Associated Universities (ORAU)
Ralph E. Powe Junior Faculty Enhancement Award Recipient

visit http://wolfweb.unr.edu/~yliao/
The Laser Beam

“The laser beam is easy to control, it applies a high density of energy in an extremely localized spot, and it is capable of performing processes that are geometrically far more complicated than those traditional tools can perform,” Liao said. “As we improve manufacturing processes, we will see better, more durable products manufactured with greater energy and financial efficiency.”

But Liao’s immediate goal is not merely to bring a product to market. He does not have a new cell phone design he hopes to introduce, nor does he have a new tractor he wants to produce. Instead, he sees his work as a way of enabling the ideas of a wide swath of entrepreneurs and businesses to reach the market.

“As we continue to refine our techniques, we see greater opportunities for localized manufacturing in nano- and micro-scales,” Liao said. “More importantly, the laser beam is capable of performing scalable manufacturing jobs, which means it can be applied to fabricate large quantities of nano- and micro-features in a large area.”

In practical terms, this means that companies and entrepreneurs who have an idea will be able not only to produce a prototype at a competitive rate but will also have the leverage to fulfill larger orders more quickly thanks to the work Liao is doing.

A Nevada-Specific Advanced Manufacturing Enterprise

With a team of graduate and undergraduate mechanical engineering students in the Advanced Manufacturing Laboratory, Liao is at the forefront of an important field of study for the University. As the institution continues to grow, it is doing so strategically, enlisting faculty and staff to utilize its position as a nexus of knowledge to develop new economic opportunities for our community.

Of the potential for advanced manufacturing in the state, Executive Vice President and Provost Kevin Carman said, “Our goal is to cultivate a Nevada-specific advanced manufacturing enterprise, allowing the University to continue to grow technologies and manufacturing methods that improve the world while bolstering and diversifying the state’s economy.”

Professor M. “Saiid” Saiidi’s grand challenge: BUILDING SAFER, MORE DURABLE BRIDGES

When Foundation Professor M. “Saiid” Saiidi was a boy, a powerful earthquake hit near his home. Houses were reduced to rubble, and the fear of aftershocks was strong enough that he and his neighbors chose to sleep out in the open that night, for fear that their homes might topple.

This seminal experience led Saiidi to a career developing innovative materials and methods for constructing buildings and bridges, in particular, to ensure that they not only survive earthquakes but remain usable afterward.

An Interdisciplinary Approach to Addressing “Knowledge Gaps”

In his lifelong quest to improve bridge construction and performance, Saiidi has found that having a comprehensive knowledge of his field is only the starting point. One must also understand what is not known—“knowledge gaps,” as he calls them—in one’s discipline and look to other fields to fill in those gaps.

“What you are looking for when you approach a problem in your field is the gaps in knowledge—what don’t we know, what aren’t we doing that we could be doing?” Saiidi said. “For me, finding the solutions for these knowledge gaps often comes from looking to other fields, looking at other materials, techniques, and ideas they have implemented and seeing if they could be adapted to the construction of bridges that retain their integrity even after earthquakes.”

This is how Saiidi decided to utilize material—nickel-titanium—that is commonly used in aerospace and medical devices as well as consumer products such as frames for eyeglasses as a primary component in his revolutionary bridge-making techniques.

“For the past hundred years or so, we have built bridges and structures using concrete and steel. With modern research we have been able to make them withstand earthquakes without collapsing,” Professor Saiidi said. “This saves the lives of the people on and around these structures, but these materials don’t often survive earthquakes.”

The bridges we have been building with concrete and steel are sturdy, but they lose their capacity under strong earthquakes. The concrete spalls off when a bridge is hit by an earthquake, and the exposed steel rebar permanently bends.

Nickel-titanium, however, has enough give to accommodate the shaking inflicted during an earthquake, but it has the important additional feature of bending back afterward. Just like any pair of modern eyeglass frames.

From the Shake Lab to Seattle

“Bridges built with a modified concrete—using a combination of polyvinyl fibers—and with nickel-titanium bars instead of steel bars will not only survive an earthquake, but they will still be usable afterward. Unlike conventionally constructed bridges, they will not have to be hauled to the scrapheap after an earthquake,” Saiidi said. “We have proven that in the Shake Lab, and soon, in downtown Seattle, we will see the first bridge built with these materials erected.”

The Shake Lab Professor Saiidi mentioned is the Earthquake Engineering Laboratory housed on campus. Run by faculty and their undergraduate, graduate and post-doctoral researchers, the Shake Lab allows engineers like Saiidi to place structures—in this case, large-scale model bridges—on specially designed test beds to prove the concept of their work before implementing it in the real world.

With those tests proving Saiidi’s concept, the Federal Highway Administration and the Washington Department of Transportation have chosen to implement his work in the construction of a bridge on State Route 99 in downtown Seattle, slated to open in 2017.

“The Shake Lab was key to demonstrating that the concept behind these materials was sound,” Saiidi said. “Having proven the concept in the lab, we are able to bring our ideas out into the real world, where they will have the ability to save money, time, and most importantly lives.”

In recognition of Professor Saiidi’s life-changing and revolutionary ideas, techniques and materials, the University has honored him with the 2016 Established Innovator Award and the 2000 Outstanding Researcher Award.
Foundation Professor M. “Saiid” Saiidi has developed new materials and techniques to build bridges capable of withstanding earthquakes and remaining usable afterward. In recognition of his revolutionary ideas, the University has honored Professor Saiidi with the 2016 Established Innovator Award and the 2000 Outstanding Researcher Award.

In addition to their creative solutions to the challenges we face, faculty across campus provide a unique education for our students. As Vice President for Research and Innovation Mridul Gautam said, “Through their research, University faculty design solutions today, and through their teaching and mentoring, they prepare the next generation of leaders to face the grand challenges that we cannot yet foresee.”

We have highlighted a few professors whose work will change our lives and shape the world. In the following pages, you will meet more than 50 additional faculty members whose work spans the range of intellectual pursuit, each hoping to enrich our lives through their teaching, research and innovations.

M. “Saiid” Saiidi, Ph.D.

Joined the University in 1979

Research Interests:
- Earthquake engineering of bridges
- Large-scale concrete bridge testing
- Analysis and design of reinforced concrete structures
- Application of advanced materials in earthquake engineering

More than 140 research grants
More than 450 publications

visit > http://wolfweb.unr.edu/homepage/saiidi/
The ABCs of Bridge Construction

In addition to the new materials Professor Saiidi has developed to ensure the safety of bridges, he is co-director of the University Transportation Center on Accelerated Bridge Construction.

“Traditionally,” Saiidi explained, “bridges are built in phases that require down time between each phase. So, you lay the footing, then wait for the concrete to cure. Then you build a column and wait for the concrete to cure. Then, and only then, can you construct the surface of the bridge, which too will need to cure.”

This curing process can take months. This means that while the building of the parts might only take four to six months, the actual time it takes to go from beginning a bridge project to opening the bridge can be a year—or more. These delays increase construction cost and take a toll on the lives of those affected by the construction zone.

“The idea behind Accelerated Bridge Construction (ABC) is to utilize a parallel building process,” Saiidi said. “That is to say, we could construct the footing at the same time as the columns and at the same time as the sections of the bridge itself. They would then cure before going on site, and we would only need to fit the pieces together. We can do this. My patent for ‘deconstructable support column structures’ is part of this larger project in service of ABC.”

But the process raises its own set of concerns with respect to earthquake survivability and usability, because each of those components must be carefully fitted together. The points where these pieces come together are vulnerable during earthquakes. “Using the Earthquake Engineering Lab, we have actually been able to address these concerns too, building bridges with a technique I’ve developed that uses rubber to replace certain concrete components of the bridge.”

The Earthquake Engineering Lab was funded with $12.2 million from the U.S. Department of Commerce’s National Institute of Standards and Technology, $3 million from the Department of Energy, and $3.8 million from University and private donors.

for more, visit > http://wolfweb.unr.edu/homepage/saiidi/USDOT/index.html

Illustrated by Moses Achoka ’07 M.A.