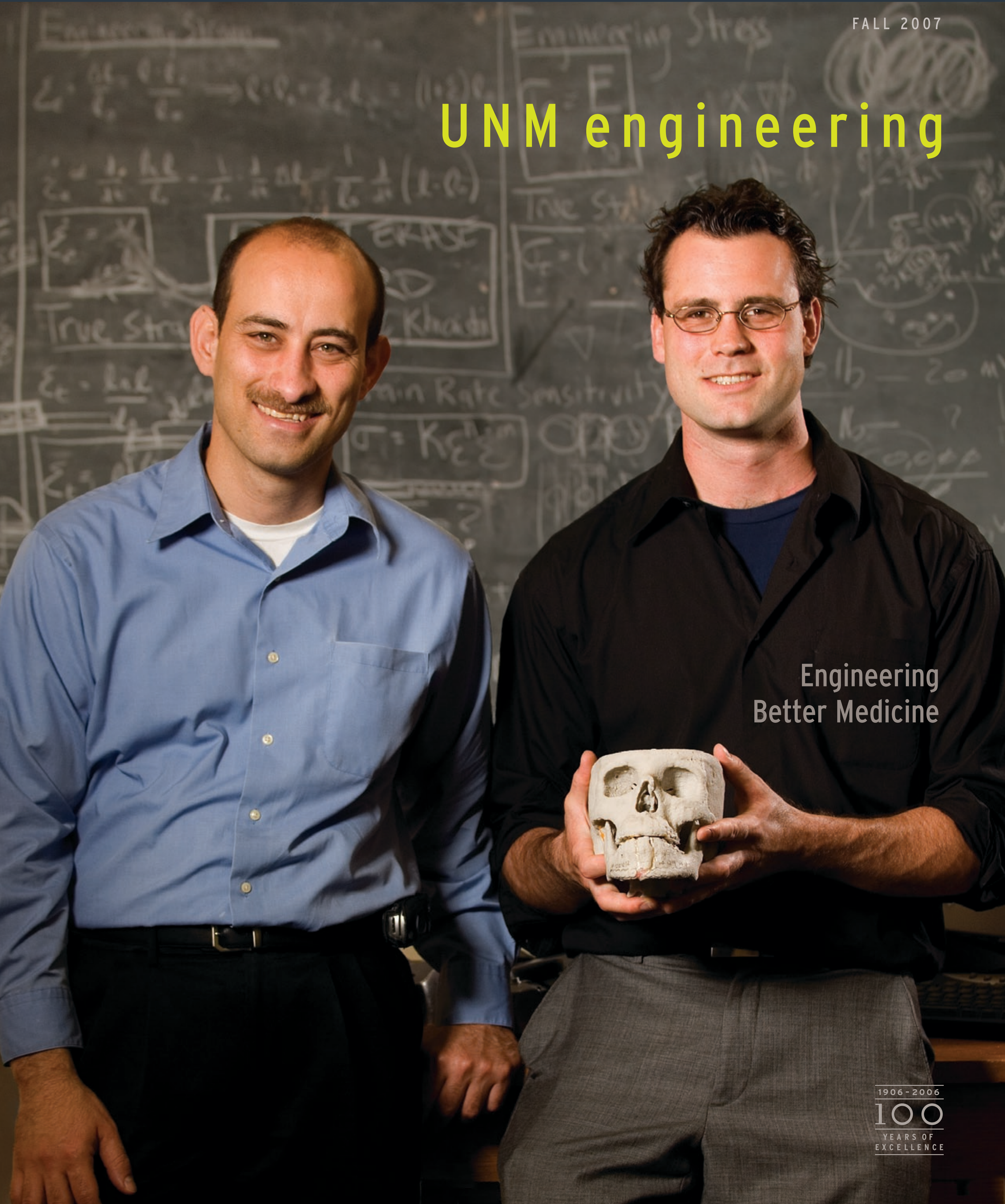
THE UNIVERSITY OF NEW MEXICO SCHOOL OF ENGINEERING

FALL 2007

UNM engineering



Engineering Better Medicine

1906-2006
100
YEARS OF
EXCELLENCE

From the Dean

Collaborations and Innovations

Solving today's complex biomedical problems necessitates collaboration among engineering, computer science, and the life and health sciences. UNM's top-ranked medical school, distinguished biology department, innovative research centers, and our own School of Engineering provide a vibrant environment for teams to jointly explore and solve biomedical challenges.

In this issue, you will read how UNM collaborators cross disciplines and campuses to make significant contributions. A surgeon frustrated with jaw implants for corrective jaw surgery turns to mechanical engineers, who design tougher, more pliant plates. A researcher trained in engineering bridges helps doctors heal injured ligaments and broken bones. Computer scientists work along with doctors and biologists, using computational geometry and powerful algorithms to create software that improves cancer treatment. At a neuroscience research center, teams are investigating how brain imaging can unlock clues to better diagnosis and treatment techniques for schizophrenia.

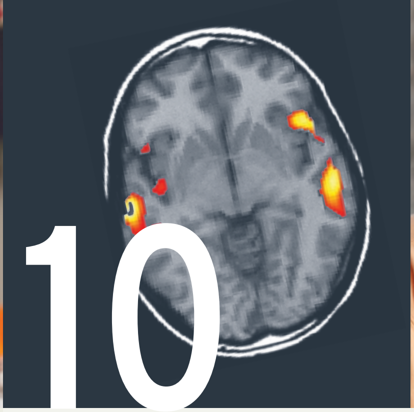
These collaborations and the School's increased research funding reflect the growing emphasis on biomedical engineering at UNM. Partnerships with industry and government laboratories are ongoing and expanding. New educational and research programs have been developed. High school outreach programs, undergraduate research opportunities, internships, and graduate research assistantships are increasing. Next year, a new state-of the-art facility, the Centennial Engineering Center, will accommodate the School's expansion and serve as the home for the Center for Biomedical Engineering, which has received $8 million in grants since its founding two years ago.

Interdisciplinary collaborations represent an important dimension of diversity. Engineers, computer scientists, biologists, and medical researchers have different academic training, perspectives, vocabularies, and ways to solve problems. Those *differences* are precisely the source of excitement, creativity, new insights, and innovation that these alliances can produce. The challenge is having to deal with the attendant complexity. There must be a shared commitment to the team's work and project goals, as well as an openness to crossing the barriers of individual backgrounds and beliefs. It is a process of bridging multiple cultures that involves learning to speak other "technical languages," and appreciating the different materials and tools each individual brings.

We were inspired by all those profiled in this issue. We hope you are, too.

Joe

Joseph L. Cecchi
Dean of Engineering



Points of Pride

- Starting Fall 2007, the **School of Engineering**, in partnership with the UNM Division of Continuing Education, introduced a series of short courses for engineering and technical professionals. Ranging from one to five days in length, the short courses are taught by SOE professors and other experts, who present practical theory and application.

- UNM Assistant Professor of Chemical and Nuclear Engineering **Dimiter N. Petsev** was co-author of an article published in *Nature Materials* (March, 2007) exploring various types of miniature semiconductor diodes floating in water that act as self-propelling particles when powered by an external alternating electric field.

- Professor and Chairman of the Department of Civil Engineering **Arup Maji** has been appointed to chair the Aerospace Division of the American Society of Civil Engineers. He will oversee the ASCE technical committees on Advanced Materials and Structures, Aerodynamics, Dynamics and Controls, Space Engineering, and Construction, and Field Sensing and Robotics.

- Computer Science graduate **Dino Dai Zovi** (BS, 2002) was featured recently on SearchSecurity.com as a security researcher worth watching. Dino discovered a Java-based vulnerability in QuickTime to win a $10,000 prize in the CanSecWest MacBook Pro hacking contest. The vulnerability was disclosed responsibly to Apple and has been patched.

- Electrical and Computer Engineering Professor **Edl Schamiloglu** chaired the highly successful 2007 IEEE Pulsed Power and Plasma Science Conference June 17–22 at the Albuquerque Convention Center. 1,200 engineers and physicists from 34 countries attended, many seeing New Mexico for the first time, and about 130 registrants attended the open house at ECE's laboratory facilities.

- Mechanical Engineering Professor **Marc Ingber** has been appointed Program Director for Particulate and Multiphase Processes in the Division of Chemical, Bioengineering, Environmental, and Transport Processes of the National Science Foundation. The appointment is expected to be for two years.

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Tariq Khraishi and Scott Lovald are developing plates designed to cut corrective jaw surgery time and post-operative complications almost in half.

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THE DOCTOR AND ENGINEER WILL SEE YOU NOW

Engineers and doctors collaborate to improve medical techniques

Dr. Jon Wagner enters a brightly lit surgery suite and examines his patient's broken jawbone. Then Wagner selects a three-inch long, thick titanium plate from an orthopedic implant kit and measures the plate against his patient's jaw line. Too big. He selects another plate. Still too big. And another. Too small. Once Wagner finds a plate that fits, he begins the painstaking process of bending and shaping the hard metal to match the contours of the patient's face. Finally, he screws the plate into the broken bones and finishes the surgery. The process, which can take well over three hours, is difficult and expensive considering operating room costs exceed $2,000 an hour.

Wagner has earned a M.D., a D.D.S. and is associate professor in the Division of Plastic Surgery at the UNM School of Medicine's Department of Surgery. He knew there had to be a better way.

Tariq Khraishi and Scott Lovald are developing plates designed to cut corrective jaw surgery time and post-operative complications almost in half.

> The fun, but challenging part of working with doctors is that they have different proficiencies than engineers. We talk about the same things, but we describe them in different terms.
>
> Tariq Khraishi

He hypothesized that the smaller, easier to attach plates he used to fix other facial fractures would work on the jaw. But could the plates withstand the powerful forces in the jaw? Wagner and his colleagues conducted their own tests to find out. "We were simulating a jaw using levers and beams and then applying pressure until the plates broke. It was pretty rudimentary experimentation," says Wagner.

Searching for Sophisticated Solutions

With no definitive answers from their tests, the doctors turned their sights across campus to the Mechanical Engineering Department and Tariq Khraishi, associate professor of mechanical engineering and expert in materials science and fracture mechanics. Khraishi and graduate student Scott Lovald, '06 Manufacturing Engineering, MBA, were the perfect partners for Wagner's team. "Collaborating across campus has been such a novel concept," says Wagner. "I would still be doing archaic studies, but with the engineers it quickly became a very sophisticated problem-solving pursuit."

Stryker Leibinger, a medical implant manufacturer, funded the multidisciplinary team's research with a $150,000 five-year fellowship. It was the largest fellowship donated directly to the Mechanical Engineering Department and the first to be dedicated to biomechanics research. The first fellowship recipient was graduate student Victor Caraveo in 2006, followed by Julie Kimsal in 2007. Both have been studying the effect of different bite forces and fracture locations, including fracture surface friction, on fracture healing and fixation.

Before Khraishi and Lovald could begin their research, the doctors and engineers had to learn each other's processes and jargon. "The fun, but challenging part of working with doctors is that they have different proficiencies than engineers," explains Khraishi. "We talk about the same things, but we describe them in different terms."

From Medical to Mechanical

After learning about the anatomy of the jaw and Wagner's hypothesis, the engineers created a three-dimensional digital model of the jaw based on CT scans from an actual patient. The model replicated the jaw's parabolic shape, the various forces exerted upon the jaw, and the exact material qualities of the different tissue and bone types in the jaw. The modeling process required two software programs and months of meticulous work.

Then the team used the model to analyze how well different types of plates stabilized jaw fractures. The jaw's complex movement and materials required a robust analysis tool. Khraishi had just the thing: finite element analysis, a technique that solves engineering problems in complex structures. "Basically, you take one impossibly complicated problem and break it up into a number of reasonably complicated problems," explains Khraishi. "By knowing how the part behaves, you can understand how the whole behaves."

Khraishi and Lovald used finite element analysis to quantify bite force, muscle movement, stress on the screws that hold the plates in place, and finally how different plate designs stabilized

Christina Salas (left) is working towards her M.Sc in biomechanics with Mahmoud Taha, assistant professor, Civil Engineering Department. Both are collaborating with Thomas Decoster, MD, professor, Department of Orthopaedics, UNM Hospital and Dr. Deana Mercer, MD, Resident Physician Department of Orthopaedics, UNM Hospital.

fractured bones. Their results confirmed Wagner's hunch: the smaller plates were strong enough to stabilize most jawbone fractures. In addition, the team showed that the smaller plates would cut surgery time and post-operative complications almost in half.

The team is now publishing papers on the research and Wagner is promoting the concept of using smaller plates to other maxillofacial surgeons. Inspired by the findings, Lovald started a company to market his new, smaller plate designs. *(See sidebar.)*

"I may have stopped pursuing this idea without the engineers," says Wagner. "The cross-campus collaboration has made all the difference in the world."

Khraishi is also using finite element analysis to help other medical teams. Using his expertise in fluid mechanics, Khraishi is helping doctors in the Department of Neurosurgery (Dr. Howard Yonas and Dr. Christopher Taylor) evaluate blockages in the carotid artery that runs from the heart into the brain. He's also working with the Department of Orthopaedics and Rehabilitation (Dr. Robert Schenck, Dr. Thomas Decoster, and Dr. Deana Mercer) to improve the process of fixing bone fractures in the arm and leg.

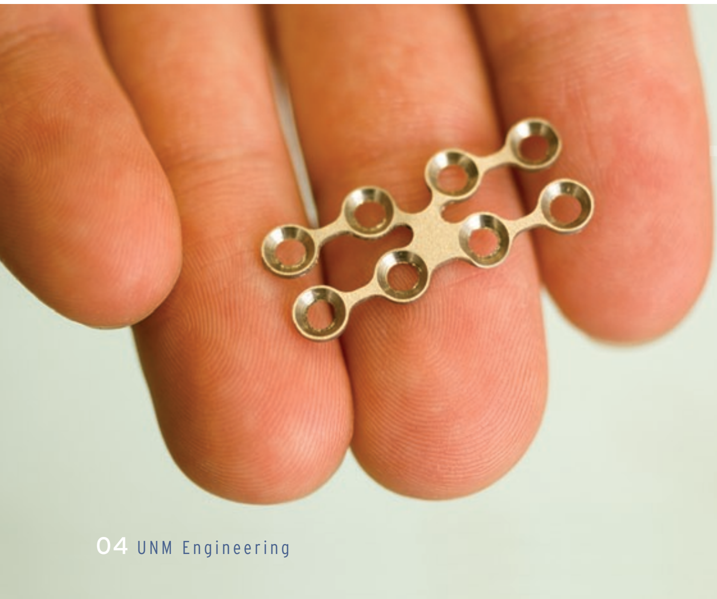
A Fuzzy Approach to Healing

Like Khraishi, Mahmound Reda Taha, assistant professor of civil engineering, is using his expertise to advance medicine. But Taha is approaching the challenges from another perspective and applying the tools he uses for engineering bridges to help doctors heal injured ligaments and broken bones.

In 2006, Taha completed a two-year research collaboration with the UNM School of Medicine Department of Orthopaedics and Rehabilitation, where he used fuzzy logic to model knee ligaments. Fuzzy logic is a technology that applies a mathematical framework to processes or situations—like biology—that are inherently imprecise or ambiguous. "We use fuzzy logic because it helps us quantify things that aren't crisp," says Taha. "The concept of healing is pretty difficult to capture and quantify. We see a lot of value in using fuzzy logic in biomedical engineering because of the unclear boundaries and the difficulty of quantifying engineering values for biomechanical problems," he adds.

Prior to Taha's research, knee ligament models didn't address the complexity of how the ligaments work. Using a fuzzy model, Taha and his students showed that tissues in the knee ligament don't all stretch at once. Some tissues stretch to handle the initial load and then, as the stress increases, additional fibers in the ligament are called upon. That's a critical-and fundamental-finding for researchers who want to engineer better artificial ligaments. says Taha. "Knee ligaments have very specific/intelligent behaviors, and without studying those behaviors we cannot make effective artificial ligaments," he says.

Taha received the Oakridge Associated Universities Ralph E. Powe Junior Faculty Enhancement Award for the work and he was the first to publish a paper on the use of fuzzy



Engineer and Entrepreneur

Scott Lovald's graduate research was more than a degree requirement; it was his inspiration to become an entrepreneur. During his graduate fellowship study on the stability of orthopedic implants used to fix jawbone fractures, Lovald ('06 Manufacturing Engineering, MBA) discovered that plate designs used in the jaw hadn't changed in more than a century.

That's when research became opportunity. In spring 2006, Lovald and his business partner, Ryan Smith ('06 Management systems to model biological tissues in the *Journal of Biomechanical Engineering.*

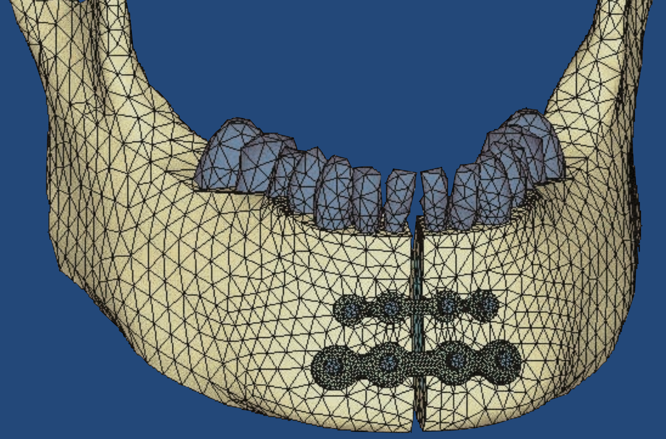
Fixing Bones with Bridge-Building Tools

Recently, Taha started another biomechanics research collaboration with the orthopedic surgeons at the School of Medicine. The team is studying femur fractures in patients with osteoporosis and evaluating which methods of fixation, or stabilization of the fracture with a metal plate, can be more effective. "Femur fractures in patients with osteoporosis or poor bone quality are challenging," says Deana Mercer, resident physician in the Department of Orthopaedics at the SOM. "The current technology does not work well in some situations due to problems with capturing enough bone to stabilize the fracture." Mercer says collaborating with Taha is strategic because his expertise in load transfer in structures is complementary to the orthopedic surgeons' focus on human body biomechanics.

Taha is using an innovative new engineering modeling technique to simulate osteoporosis in bones in finite element models and then analyze fixation options. "Our research might show that of all the options, only one or two methods are appropriate for patients with osteoporosis," says Taha. With only a small part of the research complete, Taha says he's already seeing good initial results.

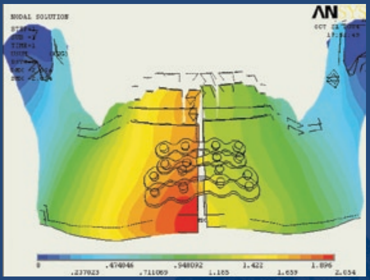
The value of collaborating with the SOM is two-fold, says Taha. "We get to address issues of clinical relevance with solutions that have a direct impact on people's lives—and that is extremely satisfactory for me," he says. "And multidisciplinary research brings people together that think differently and speak different scientific languages. By doing so you can see things other people can't, and that is key to innovation."

Taha adds that this collaborative research lays the groundwork for his ultimate goal: creating a large biomechanics program at the SOE, which means even more talented engineers will use their knowledge and insight to solve medical problems. ✦



Above: an image showing the finite-element mesh used in the computer model of a dentate mandible. Each mesh element is shaped like a tetrahedron. Also shown are two band plates bridging a symphyseal fracture.

Below: A contour plot of the nodal displacements or movement of the jaw under biting action showing the strains that the bands experience



Technology), entered a UNM business plan competition with their idea for a company that would design and market more stable, less intrusive orthopedic implants. They won the competition and $28,000, which they used to start their company, Satyrne.

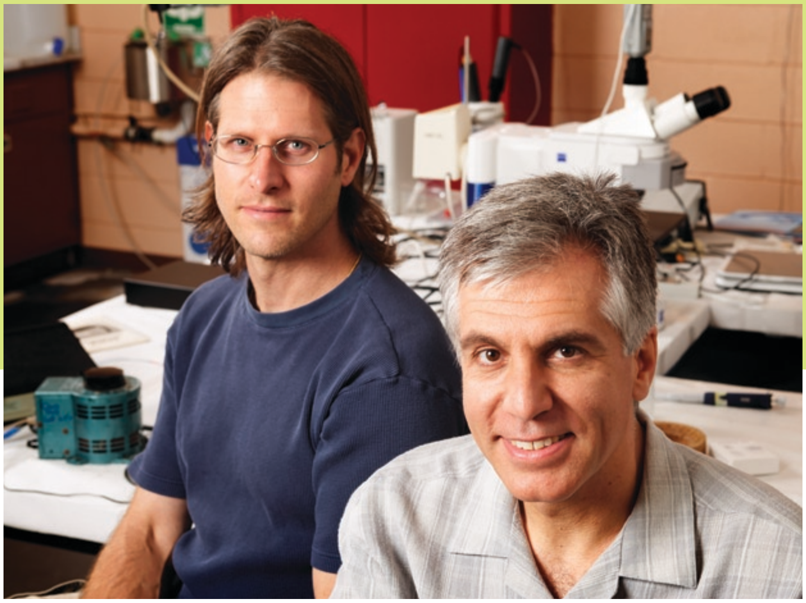
The partners are now promoting the company full time and searching for start-up funds. Ultimately, they'll need $1 million to $2 million to move into full production. Lovald is also finalizing Satyrne's nine new plate designs. "For the first time, plates have been designed from a mechanistic perspective to provide more stability and less volume," explains Lovald. The titanium plates, which feature cross bars for better load sharing between screws, are the smallest, most stable plates in the industry, according to Lovald. Satyrne's first plate design has been patented and is now going through FDA approval.

Ultimately, Lovald and Smith hope to enter a strategic partnership with a larger orthopedic implant manufacturer or have another company acquire Satyrne. In the meantime, Lovald says, building the company is the chance of a lifetime. "It's a great feeling knowing that our small project is coming to fruition and sustaining itself," he says. "We're passionate about this because we know we have a product that can do some real good." ✦

CENTERED ON SUCCESS

CBME FOSTERS BIOMEDICAL ENGINEERING RESEARCH AND EDUCATION AT UNM

A test tube made of water. A “Post-It note” of cells. A diagnostic device smaller than a human cell. Sound futuristic? Actually, they’re in development now at the Center for Biomedical Engineering. Established at the School of Engineering in 2005, the CBME is an interdisciplinary center that coordinates research activities in biomedical engineering (BME) among engineers, clinicians, and biologists. The CBME is also a strategic first step toward the ultimate goal of providing a full range of BME educational opportunities at UNM. The center has already fostered research among disciplines and with the high-tech industry, has hired faculty, and developed an outreach program for K-12 students. Each of those efforts supports the CBME’s goal of improving New Mexico’s educational, research, and economic environment.



Dimiter Petsev, assistant professor of chemical and nuclear engineering, and Jeremy Edwards, assistant professor of molecular genetics and microbiology and assistant professor of chemical and nuclear engineering, have been collaborating through the CBME for a year and a half.

In just two years, the center has received $8 million in grants. "We've already produced a 17-to-1 return on the university's investment," says Gabriel Lopez, director of the CBME and professor of chemical and nuclear engineering and chemistry. "We're really proving that this kind of collaboration can be achieved here at UNM."

Here's how some CBME researchers are engineering better medicine:

Droplets of DNA

Imagine a billion glass test tubes lined up, row after row, in a gigantic laboratory. Now, shrink that picture. *Way* down. Dimiter Petsev, assistant professor of chemical and nuclear engineering is using his expertise in microfluidic devices to fabricate miniaturized test tubes made of water droplets. Jeremy Edwards, assistant professor of molecular genetics and microbiology and assistant professor of chemical and nuclear engineering, plans to use billions of these tiny test tubes to develop a fast, inexpensive way to sequence the DNA of patients with different cancers or even an individual's entire genome.

Each tiny drop, about ten microns in diameter, is loaded with a small fragment of DNA and a bit of reactant. Then, the droplets are suspended in an oil emulsion and used for tests. Once the droplets are floating in the emulsion, Edwards uses a chemical process to break the droplets open. He reads the biochemical results emanating from streams of these broken "test tubes" using a customized microscope, one of only two in the world. The collaboration, which also involves researchers at Harvard University, is organized by the CBME and is part of the National Science Foundation Partnership for Research and Education in Materials: UNM/Harvard Partnership for Leadership in Biomaterials.

Petsev's challenge is to fabricate these minute droplets in a uniform size and shape. With input from Harvard researchers, Petsev has achieved very fast production of highly uniform droplets using microfluidic devices formed using a process called soft lithography. Through this process, a network of channels 10-100 micrometers deep and wide can easily be formed in a silicone rubber material. Petsev then bonds the printed polymer channels on a glass slide and uses pressure or electric fields to force oil and water through separate channels. The droplets form where the channels intersect. Petsev's next challenge is perfecting the process of loading the DNA fragments into the droplets.

Petsev and Edwards have been collaborating through the CBME for a year and a half. Petsev says access to the CBME facilities has been critical, but the opportunity to collaborate is most important. "There's an exchange of information and ideas here which is very beneficial for our multidisciplinary work." Edwards agrees. "I have an engineering background but I don't have the ability to make microfluidic devices. With engineers like Dimiter bringing their skills to the table, we can achieve our goals."

Heather Canavan, assistant professor of chemical and nuclear engineering, (left) and chemical engineering graduate student Jamie Reed (below left), collaborate with Angela Wandinger-Ness, professor of pathology at the School of Medicine in developing smart surfaces for cell analysis.

Solution: Smart Surfaces

Angela Wandinger-Ness, professor of pathology at the School of Medicine, needed a better process for one facet of her research. Heather Canavan, assistant professor of chemical and nuclear engineering, had the perfect technique. The CBME brought them together in a successful research collaboration.

Wandinger-Ness studies cells and how therapeutic drugs interact with them. Her goal is to analyze single cells and measure protein levels on their surface using a flow cytometer, a machine that measures particles in a streaming fluid. Currently, Wandinger-Ness uses enzymes to remove cells from surfaces like Petri dishes, on which they are grown. Then she places them into suspension, where they can be analyzed by flow cytometry. Her concern is that the enzymatic process destroys some of the proteins she wants to study.

Canavan's new technique is a perfect fit. She studies "smart surfaces," thermoresponsive polymers with properties that change based on environmental cues like temperature or electrical field. By growing cells on these smart, flexible surfaces, Canavan can create clumps of cells that peel off like a Post-It note, or even isolate single cells that pop off the polymer without changing their structure.

The researchers' ultimate goal is to create an off-the-shelf device that Wandinger-Ness could use to allow accurate cell analysis. Canavan says the research wouldn't have been possible without the CBME. "Gabriel Lopez made the initial connection between the two sides and the CBME provided financial support," says Canavan. "There was both an intellectual and financial contribution that was very significant."

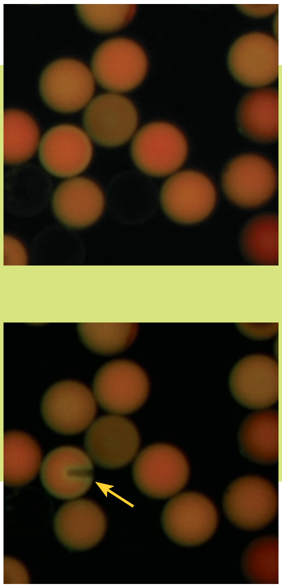
One Bead, Two Innovations

Two sides of campus, two disciplines, two goals, one shared interest: microscopic beads. Gabriel Lopez and Larry Sklar, professor of pathology at UNM's School of Medicine, are collaborating on fluorescent biosensors that use tiny, protein-coated beads the size of a human cell. While their research goals are different, it's a strategic collaboration because the researchers share an interest in the microbiosensors and in biochemistry. "It's technically a natural fit and our work is nicely complementary," says Lopez. The two researchers, along with Tione Buranda, research assistant professor in the Pathology Department, have shared a series of five-year grants during their twelve-year collaboration.

Sklar uses the beads for drug discovery, coating them with a specific protein and suspending them in a fluid that he wants to test. By running the suspension through a flow cytometer, Sklar can evaluate the reaction of the proteins on the surface of the beads with those in the solution. Using this process, Sklar and Buranda can screen molecules involving more than a dozen molecular interactions that contribute to cancer, infectious diseases, and inflammatory diseases. Sklar says collaborating with engineers at the CBME moves the team closer to its goals. "An engineer's skill set is complementary to those of a biomedical scientist," he explains. "One of the biggest factors is the different types of materials that we use for building sensors or instrumentation. Engineering students have different interests in technology than biologists, including materials, fluidics, automation, electronics, and computers."

Lopez and his team use the beads to create diagnostic assays. They make chip-based, microfluidic devices by packing thousands of the protein-coated beads into tiny glass capillaries. Lopez injects a fluid, for example a blood sample, into the bead-packed channels. When he exposes the channels to a laser, the beads that are attached to specific proteins fluoresce, indicating the presence of a toxin or disease marker in the liquid. Lopez and his team are currently testing such devices, using samples from patients with respiratory infections. The devices have already successfully detected several different viruses in one small sample. ✦

Tione Buranda, research assistant professor in the Pathology Department and Gabriel Lopez, director of the CBME and professor of chemical and nuclear engineering and chemistry, have shared a series of five-year grants during their twelve-year collaboration.



Above: Confocal scanning laser fluorescence microscopy image of mesoporous silica particles filled with rhodamine dye (red) and encapsulated by fluorescent lipid bilayer (green). Bottom image shows one particle (arrow) which has been partially bleached for measurements of diffusive fluorescence recovery.

Vince Calhoun, Director of Image Analysis and MRI Research at the MIND Institute

HEAD DETECTIVES »

UNM ENGINEERS INVESTIGATE THE MYSTERIES OF THE MIND

Photo: John Yost, Marble Street Studio

With its high ceilings, displays of modern art, and expansive views, this gleaming building certainly doesn't look anything like your typical detective office. Then again, your typical gumshoes don't work here. These special investigators aren't searching for clues to a crime; they're trying to crack a much more difficult case: how the mind works.

This modern HQ for these high-tech detectives is The MIND Institute, a non-profit neuroscience research center just north of UNM's main campus. Multidisciplinary teams at the institute collaborate with researchers around the country and use the latest imaging technology to sleuth for new ways of understanding human behavior, especially mental illness.

Collaborating to Find Clues

One of the head detectives is Vince Calhoun, director of image analysis and MRI research at The MIND Institute and associate professor of electrical and computer engineering at the School of Engineering. With his background in biomedical engineering and years of experience working with psychiatrists at The Johns Hopkins University School of Medicine Department of Psychiatry as well as Yale

University, Calhoun is uniquely qualified to apply engineering approaches to an investigation of how the brain works. The MIND Institute is a perfect match for his special qualifications. "The MIND is one of the few centers of its kind in the country," says Calhoun. "What's unique is its focus on mental illness and the fact that it has all of this excellent technology in one place."

Calhoun is also adept at creating successful collaborations between engineers and psychiatrists, who have distinct approaches to research. "I've seen good ideas from engineers go to the point of a paper and then stop because the engineer doesn't know how to address questions of relevance in psychiatry. And psychiatrists don't understand how to read an engineer's paper," explains Calhoun. "So, I've learned how to work with psychiatrists, but think about things from an engineering perspective."

> » THE MIND INSTITUTE IS ONE OF THE FEW CENTERS OF ITS KIND IN THE COUNTRY. WHAT'S UNIQUE IS ITS FOCUS ON MENTAL ILLNESS AND THE FACT THAT IT HAS ALL OF THIS EXCELLENT TECHNOLOGY IN ONE PLACE.
>
> Vince Calhoun

Detecting Differences

Calhoun leads a multidisciplinary team investigating how brain imaging can unlock clues to better diagnosis and treatment techniques for schizophrenia, which affects 3.2 million Americans. The team is using brain scans to look for indicators of the disease. They're also creating powerful new tools to analyze the data they collect.

Using high tech imaging systems, including magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), and electroencephalography (EEG), the team is searching for biomarkers, or measurable changes in the brain that indicate schizophrenia.

Calhoun uses the imaging tools to collect brain scans while subjects perform simple memory or auditory tasks. Each image type yields different information about how the brain works. For instance, fMRI provides a dynamic view of blood flow in the brain, while EEG picks up electrical fields created when neurons fire in the brain. By comparing images from a control group with those from a group of patients with schizophrenia, the researchers can see differences in how the brain works. Those differences could point to possible biomarkers for the disease.

Calhoun and his team are also developing better ways to analyze and synthesize all of the data from hundreds of patients who have had multiple images made during numerous tests. Calhoun already has an analysis toolbox online. Now he and his team are developing more robust tools to first analyze each data type independently, and then to conduct "data fusion," analysis of combinations of images, such as fMRI and MRI, or EEG, fMRI, and MRI. "The goal is to combine the information in a way that gives us a better ability to look for differences in the brain," explains Calhoun. The National Institutes of Health is funding his data fusion study with a $1.5 million grant. His approach, called joint independent component analysis, decomposes the high dimensional data into a smaller set of independent parts. The different types of data are grouped together in the algorithm, and Calhoun then uses an approach based upon information theory to identify which parts of this massive decomposition are the most informative about differences between patients and healthy controls.

Cracking the Code

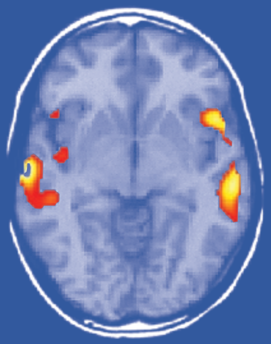
Calhoun is not alone in his investigation. Terran Lane, assistant professor of computer science, is also on the case. Lane, too, is investigating data fusion and is just starting to develop a sophisticated joint probability model that can combine the different types of data.

Lane is collaborating with Vince Clark, associate professor of psychology and scientific director of The MIND Institute, to study networks in the brain. "We're trying to understand how different regions of the brain influence each other and send messages to each other," says Lane. "The goal is to untangle the story and pull out a network." Lane receives data directly from MIND researchers and loads it on to computers in the Computer Science Department. Then comes the real challenge: the brain's complexity and the immense amount of data involved make teasing out relevant networks very difficult. "It's as if I gave you a list of how many telephone calls enter and leave every building on the UNM campus without telling you who they came from or went to. Then, I asked you to tell me who called who," explains Lane.

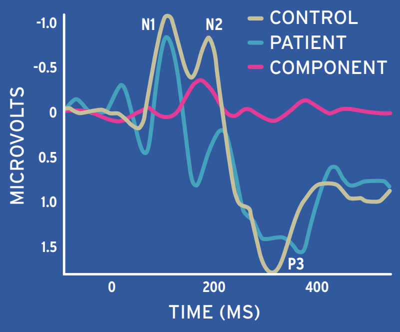
Lane is cracking the code using powerful machine learning and statistical techniques. While his tools are decidedly high-tech, he's based his process on a probability theorem, developed in the 18th century, called Bayes' Rule. Using only a small fraction of the available data, software based on Bayesian networks can scan the brain images for possible networks, learn about the data as it goes, and use that information to improve the ongoing analysis process. Lane and senior doctoral student John Burge have created an in-house version of Bayesian network software that includes anatomical and hierarchical information about the brain's structure as it evaluates the structural and temporal data collected by MIND researchers. Lane filters results from the software to improve the statistical confidence, then shares his findings with neuroscientists at The MIND Institute, who provide input and context on the results. "It's a feedback loop. We give them results and they give us back new data and new questions to ask. Hopefully, from this process we'll gain neuroscience consequences and computational consequences," says Lane.

Lane's research, funded by a three-year grant from the National Institutes of Health, is at its midpoint. The team is currently evaluating some new networks extracted by the software. "In the 20 years that I've been studying the human brain, I have watched the tools for data acquisition become far more sophisticated, while our methods of analysis have remained very simplistic. We only understand about 10 percent of the data we collect; the rest is obscured by its complexity," says Clark. "One of my goals for The MIND Institute is to support the work of scientists like Vince Calhoun and Terran Lane, who can develop more sophisticated methods for analyzing brain data. Their algorithms have already produced a flood of new insights into the kind of data that has been available to us for years, but couldn't be analyzed using available methods."

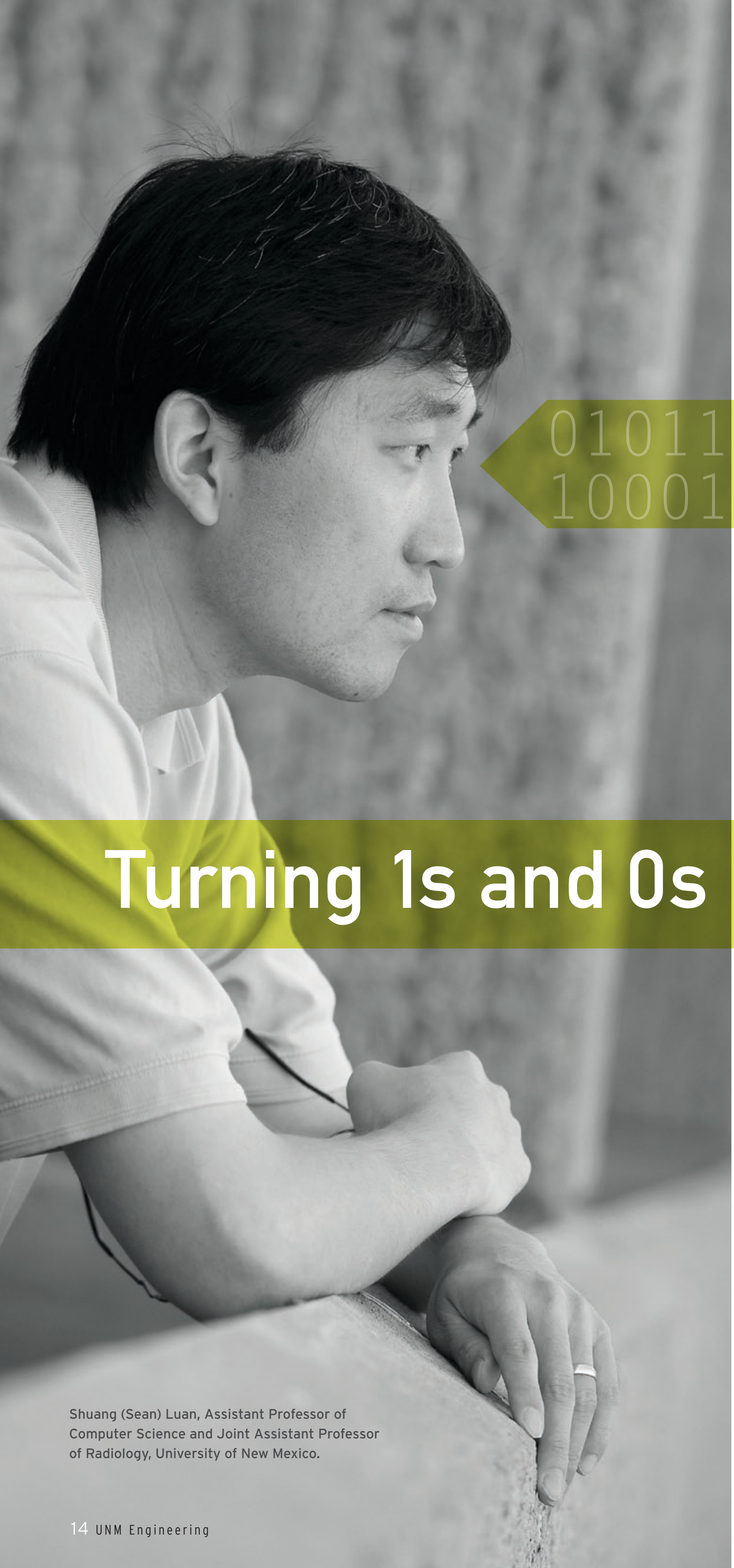
With clues, collaboration, and cutting-edge technology, UNM's head detectives are piecing together answers that will not only unlock the mysteries of the mind, but could also improve millions of lives. ✦



A joint analysis was performed to identify a component showing linked electrical changes as measured by electroencephalography (EEG) and blood oxygenation changes as measured by functional magnetic resonance imaging (fMRI) during the presentation of infrequent sounds, called an auditory oddball task. The pink curve (below) provides information about 'when' and the orange colored regions (above) provide information about 'where' the brain activity is different in patients versus controls.



Turning 1s and 0s Into Hope



Shuang (Sean) Luan, Assistant Professor of Computer Science and Joint Assistant Professor of Radiology, University of New Mexico.

Working alongside doctors and biologists armed with laser beams and microscopes, UNM researchers Shuang Luan and Terran Lane wield complex computer codes of 1s and 0s to fight disease. Luan and Lane, both assistant professors of Computer Science, study bioinformatics, the use of computers, software, and databases to solve biological questions.

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Luan is interested in the interface between computer science and radiation oncology. "You need committed collaborators in medicine and the background in the theory of computer science to design algorithms to solve these problems," explains Luan. "We have both here at UNM. And our department makes interdisciplinary research a priority." Collaborating with researchers at UNM and across the country, Luan is working on three cancer-related bioinformatics projects.

New Dimensions in Cancer Treatment

Luan helped develop two software programs to improve linear accelerator-based (LINAC) cancer treatment. LINAC, the most common radiation device, uses a precisely positioned beam to irradiate cancerous tumors. Multileaf collimators, or moveable "leaves," placed under the beam, shield healthy body parts from the radiation. Accurately positioning the beam and the leaves is challenging when the tumor is located in a moving body part like the lung.

Luan collaborated with researchers at University of Maryland, University of Notre Dame, and UNM Radiology to develop new four-dimensional treatment techniques that optimize the leaves and synchronize the angle of the beam with the body's movement. The team used computational geometry and powerful algorithms to create the program.

Gamma knife treatment uses focused beams of radiation to treat brain tumors. The Automatic Patient Positioning System (APS) on the Elekta Leksell Gamma Knife® 4C System makes dynamic Gamma Knife radiosurgery possible. Photos courtesy of Elekta, Atlanta, GA, www.elekta.com.

> "You need committed collaborators in medicine and a background in the theory of computer science to solve these problems. We have both here at UNM." Shuang Luan

In a second LINAC project, Luan and researchers at the University of Maryland and University of Notre Dame pioneered another treatment optimization technique. Normally, LINAC machines use up to 13 individual beams of radiation positioned at different angles to treat a tumor. Using computational geometry, the team developed Single ARC Dose Painting Therapy, treatment planning software that moves the beams around the patient, continuously delivering radiation from all possible directions. Luan says results are excellent. "Treatment time can be as much as 80% shorter and we can deliver a higher dose of radiation to the tumor and less to the surrounding structures." The team has filed a provisional patent for the technique.

Gamma knife treatment uses focused beams of radiation to treat brain tumors. Again, using powerful algorithms, Luan and his research partner at University of California at San Francisco developed software that optimizes the beams, turning them into a relative brush that "paints" the contours and volume of the tumor with radiation. The dynamic process covers the tumor faster and more evenly. Ultimately, the software could be incorporated into a treatment planning program. A provisional patent has also been filed for the technique.

Improving cancer treatment is a long way from the theoretical work Luan had planned to pursue. His goals changed the day he saw how his work could heal. "I'll never forget the first day they used my algorithm to treat patients," says Luan. "I was nervous, but it worked. That's when I decided to make it the focus of my career."

Probing RNAi

Like Luan, Terran Lane is using his computer science expertise to conduct bioinformatic research. One focus of Lane's work is ribonucleic acid (RNA), which is closely associated with DNA. While DNA contains the code for cell growth, RNA acts as the "middle man," controlling the flow of genetic information between DNA and the proteins it ultimately produces. Many researchers believe understanding RNA will dramatically improve disease treatment and genomic research.

Recently, biology researchers discovered a cellular process, now called RNA interference (RNAi), that can be used to stop malfunctioning genes from producing bad proteins. Lane is conducting RNAi research with immunologists in the UNM Biology Department and the Center for Evolutionary and Theoretical Immunology. He uses algorithms to create models of chemical probes that connect with RNA and stop the process of protein production. "We're designing these RNAi probes to target specific RNA and disrupt them, while creating as few side effects as possible," explains Lane. The challenge is how to design the short interfering RNA probe (siRNA) so that the probe targets a specific malfunctioning gene or protein without disrupting beneficial ones. The powerful algorithms help the researchers evaluate all the possible variations in the structure of the probe.

It's early in the research, but Lane and his team have made one important find. "Some of the early work in the area assumed that everything was highly specific and you didn't have to worry about side effects," explains Lane. "But we predicted computationally that you're likely to have side effects unless you work to design probes that are free of side effects." The team already developed one algorithm that other RNAi researchers can use to design more effective drugs with fewer side effects. It's clear that with their bioinformatic research already yielding results, Lane and Luan are turning computer codes into hope. ✚

Alumni Profile: **Robert I. Solenberger**

ENGINEERING SURGICAL INNOVATIONS

Whether you address him as "Dr. Robert Solenberger" or "Colonel Robert Solenberger," you'll be talking to an outstanding surgeon and highly decorated military officer who has helped heal thousands of lives with his own hands and through his medical innovations.

Robert Solenberger, a native of Oakland, California, graduated from the University of New Mexico in 1965 with a degree in chemical engineering and had a successful engineering career. But things changed after he developed walking pneumonia and a serious disability during Officer Candidate School. Inspired by the doctors and nurses who not only helped him but treated soldiers wounded in Vietnam, he soon had a different goal. He decided to pursue medicine. He received his M.D. in 1974 from the University of Maryland School of Medicine, completed his surgical residency, and went on to fellowships in pediatric surgery at the John Hopkins Hospital in Baltimore, Maryland and the University of Texas Medical Branch in Galveston. Solenberger's long career included appointments at several army medical centers, most recently as Chief of the Department of Surgery at Carl R. Darnall Army Medical Center at Fort Hood, Texas, the largest Army base in the world.

Solderberg's training at UNM provided a valuable foundation for his career as he used his engineering skills to develop many important medical innovations. "I learned about methodologies, the systematic examination of subjects, separating facts from fiction, and how not to be afraid of thinking out of the box," says Solenberger of his engineering experience at UNM. In 1982, he developed a three-pronged treatment for ruptured appendicitis that is still considered the gold standard today. In 1995, Solenberger coordinated the delivery of twins who were born attached from the breastbone down, sharing one pelvis and three legs. He helped lead the 70-member surgical team that transformed the twins' lives with five medical breakthroughs. The successful operations gave both girls the ability to walk and to bear children.

Giving Back

"My UNM professors advised us to never forget that learning is followed by leading and teaching others and sharing, and your learning process has to go on forever," says Solenberger. He stays busy following their advice. Solenberger continues to practice medicine as the only pediatric surgeon at the Carl R. Darnall Army Medical Center. He is on the teaching faculty at two medical schools and runs an emergency room training program at Fort Hood that has produced residents with the highest ER board certification scores for the past six years.

During his career, Solenberger has authored articles for medical journals and has been affiliated with numerous professional organizations. He has also received several distinguished awards for his exemplary military service and exceptional dedication to his profession. Solenberger frequently travels to combat zones around the globe to patch up Purple Heart recipients because, "as long as they're out there doing what they're doing, I should be there too." ✚

New Faculty

Chemical and Nuclear Engineering

Cassiano de Oliveira Professor
Throughout his research career, de Oliveira has specialized in unstructured finite element techniques, high-performance computing and advanced solution methods applied to radiation transport and radiative transfer and also to multiphase flow, electro-seismics and global ocean circulation. Most recently he was a professor at the Nuclear and Radiological Engineering Program within the George Woodruff School of Mechanical Engineering of the Georgia Institute of Technology.

Civil Engineering

Rafiqul A. Tarefder Assistant Professor
Tarefder's research interests include characterization and modeling of pavement materials and system, mechanistic pavement design, geotechnical applications related to transportation systems, numerical modeling at multiple length scales, neural networks, and nanoscale measurements in geo-paving materials. He received his Ph.D. from the University of Oklahoma.

Giovanni C. Migliaccio Assistant Professor
Joining the CE department in Construction Engineering and Management, Migliaccio's areas of expertise include innovative procurement, project management, sustainability and design-construction integration. He completed his Ph.D. at the University of Texas at Austin.

Andrew J. Schuler Assistant Professor
A recipient of the NSF CAREER Award, Schuler brings his expertise in biological wastewater treatment, nutrient removal, agent-based modeling, sedimentation, and the application of molecular methods to the expanding UNM Environmental Engineering faculty. He received his Ph.D. from the University of California at Berkeley.

Computer Science

Joel Castellanos Lecturer
Castellanos' background includes working as a senior software engineer subcontractor to Lockheed Martin and teaching college and high school math, science and computer science. He received his MS in Computer Science from UNM.

Joseph Kniss Assistant Professor
Kniss is currently conducting research on high quality, interactive visualization of extremely large-scale 3D datasets from science and medicine. His work also focuses on the visualization of 3D image data for visual representation of uncertainty and decision-making using visualization tools. He looks forward to developing strong interdisciplinary collaborations within science, medicine, and industry. He received his Ph.D. from the University of Utah.

Jedidiah Crandall Assistant Professor
Crandall's research interests include systems, security, and malware. His main area of research is to understand Internet worms and the exploits that they use to propagate so that computer scientists can automatically capture and analyze them. He received his Ph.D. from University of California, Davis.

Electrical and Computer Engineering

Rafael Fierro Associate Professor
Fierro's interests include hybrid and embedded systems, coordination of multiagent systems, optimization-based cooperative control of unmanned aerial and ground vehicles, mobile sensor networks, and robotics. He received his Ph.D. from the University of Texas-Arlington and was an assistant professor at Oklahoma State.

Nasir Ghani Associate Professor
Ghani's research interests include cyber-infrastructures, optical networks, protocols, traffic engineering, survivability, network virtualization and services, performance evaluation, simulation, and stochastic modeling. He received his Ph.D. from Ontario's University of Waterloo and has held senior positions in industry.

Jamesina J. Simpson Assistant Professor
Simpson is interested in computational electromagnetics theory and applications, especially finite-difference time-domain (FDTD) solutions of Maxwell's equations. Her research topics range from near-DC to light, and include modeling the Earth-ionosphere waveguide and optical interactions with living tissues. She received her Ph.D. from Northwestern.

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