# ENGINEERING RESEARCH REVIEW 2014

South Dakota State University
*Jerome J. Lohr College of Engineering*

## Dear Colleagues,

**Welcome to the 2014 edition of our Engineering Research Review.**

University research is rapidly moving from an era where individual researchers are making solo contributions to a time where major advances are being made by teams of researchers. These teams are often not simply multiple investigators from a single core discipline, but are more likely to consist of a group of investigators whose expertise spans from engineering to physical/biological sciences to soft sciences, such as psychology and sociology. This year, our research review emphasizes collaborative research in the Jerome J. Lohr College of Engineering.

One of the key ways in which we have encouraged collaboration has been through speed networking events that connected our researchers with those of other colleges. Already, several interactions are underway that came out of those brief five-minute meetings.

In this issue, you will see examples of how our researchers are involved with collaborative projects. For some groups, such as our mathematical modeling and statistics group, this is a central part of who they are. In other cases, unexpected collaborations have formed such as the engineering solution to a Mayo Clinic patient-care problem. Other collaborations are becoming more commonplace such as the relationship between statistical analysis and genomic data. I hope you will find the articles in this issue both informational and motivating.

While research performance as measured by collaboration is quite positive, when measured by awards and expenditures our efforts are lower than last year as shown by the accompanying charts. We continue to operate in an environment in which federal research funding is harder to obtain. Our funding has diversified from last year in that FY14 federal funding was 79 percent of our expenditures as opposed to 83 percent the year before. However, in an absolute sense, awards are down slightly from last year, while expenditures decreased to a larger degree as the last of our federal earmark monies are gone.

Our goal for this coming year will be to continue to encourage diversified funding opportunities and new collaborations as we pursue research that is aligned with the mission and resources of our college.

Dennis Helder, Ph.D.
Associate Dean for Research
Distinguished Professor of Electrical Engineering

# ENGINEERING RESEARCH REVIEW 2014

## CONTENTS




**SOUTH DAKOTA STATE UNIVERSITY**
OFFICE OF ENGINEERING RESEARCH
Daktronics Engineering Hall 309, Box 2222
Brookings, SD 57007

**www.sdstate.edu/engr/research**
Phone: 605-688-4372
Fax: 605-688-4969
dennis.helder@sdstate.edu

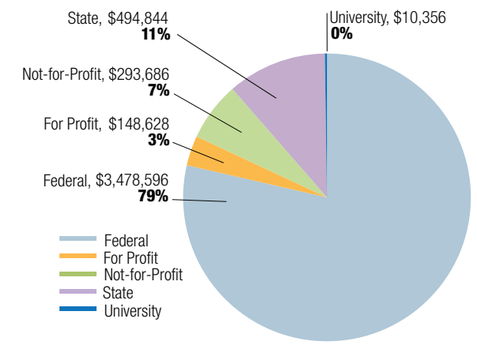


President of South Dakota State University:
David L. Chicoine

Christie Delfanian, *Content Coordinator/Writer*
Virginia Coudron, *Graphic Design*
Emily Weber, *Photographer*

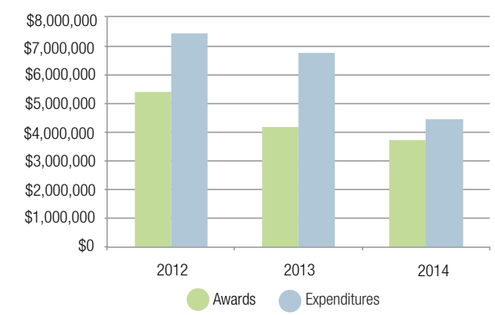
This publication is published by the Office of University Marketing and Communications


### FY2014 COE EXPENDITURES




In FY 2014, more than $6.7 million in funding was expended to support Jerome J. Lohr College of Engineering research projects. This funding is classified in the pie chart by the originating source.

### FY2014 COE AWARDS AND EXPENDITURES

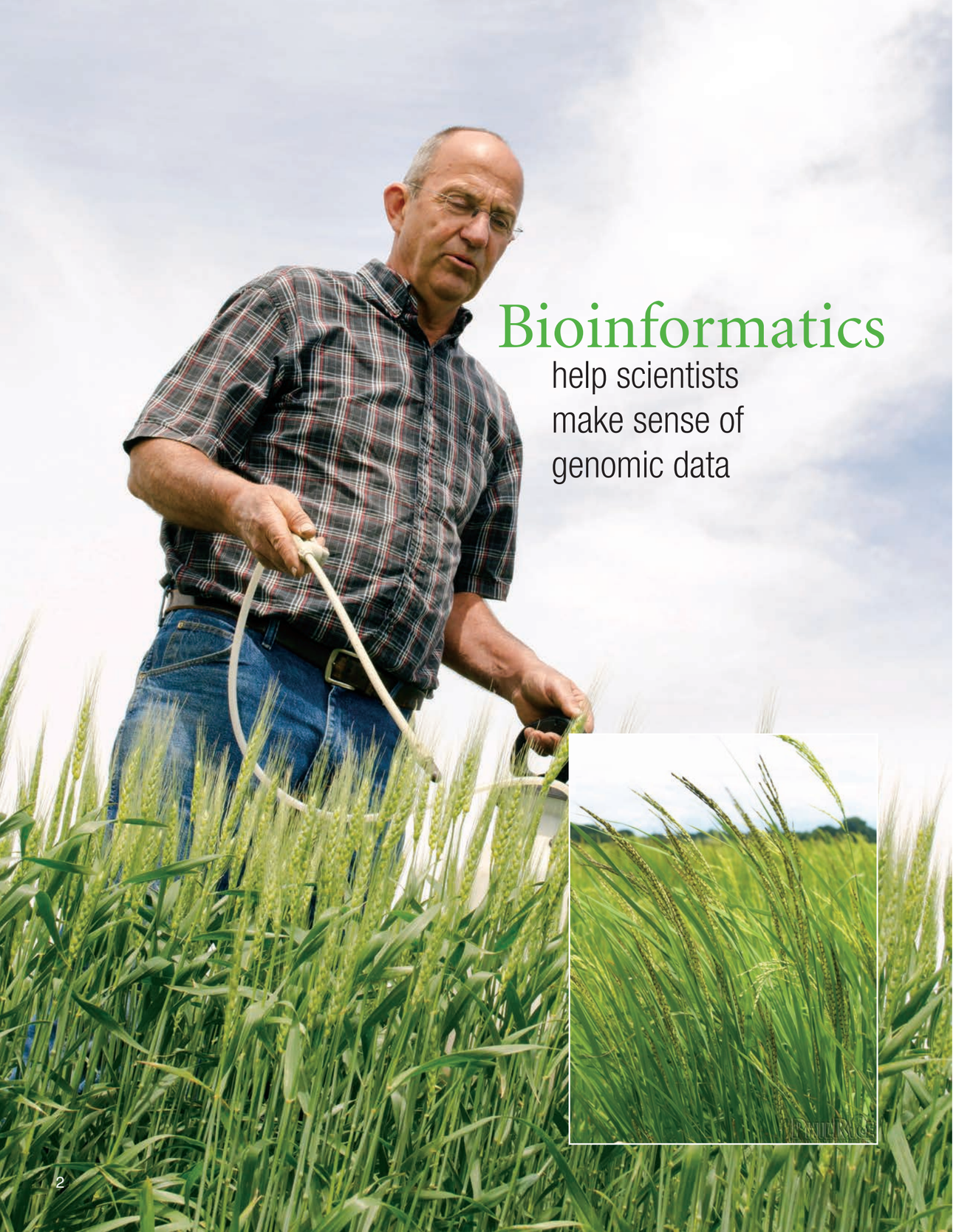



Awards represent external monies received by the Jerome J. Lohr College of Engineering during the fiscal year from July 1 through June 30. Expenditures are the externally generated dollars that were spent to conduct research, outreach and education projects during the fiscal year.

### FY2014 EXPENDITURES BY DEPARTMENT

| | |
|---|---|
| Civil & Environmental Engineering/WEERC | $909,625 |
| Electrical Engineering & Computer Science | $706,027 |
| Engineering Extension | $572,162 |
| Construction & Operations Management | $20,344 |
| Engineering-Office of Research | $686,329 |
| Mathematics & Statistics | $390,164 |
| Mechanical Engineering | $665,269 |
| SD LTAP | $476,190 |


1000 copies printed by SDSU Office of Engineering Research at $0.00 each EG056 8-14



# Bioinformatics

## help scientists make sense of genomic data

It's like looking for a needle in a haystack. Scientists searching for the gene or gene combination that affects even one plant or animal characteristic must sort through massive amounts of data, according to associate professor Xijin Ge of the mathematics and statistics department.

"Biologists used to study one gene at a time, but now they can look at tens of thousands of genes at once," Ge said. Just one experiment to analyze gene expression can produce one terabyte of sequence data. "That's a little beyond many biologists' comfort zone."

He leads the bioinformatics research group, which provides the expertise that plant and animal scientists need to "make sense of the genomic data." Ge, who has been at SDSU since 2007, started bioinformatics work with cancer genomics at the University of Tokyo.

"Incorporating bioinformatics into our department's research portfolio allowed us to conduct and collaborate in research of clear relevance to the university, state and region," according to math and statistics department head Kurt Cogswell.

Through funding from the Agricultural Experiment Station, the bioinformatics group helps SDSU plant and animal scientists uncover how genes and proteins affect cell functions.

### Setting up the experiments

Typically, scientists consult with Ge when planning their studies. After examining what they want to investigate, the researchers decide which techniques should be used to obtain data and develop a plan to analyze the data.

"It's critical to have the statistician and biologist working together," noted plant science professor Fedora Sutton, who worked with Ge on identifying gene interactions that account for freeze resistance in winter wheat. "He is able to say, based on statistical rules and regulations, how an experiment should be designed."

Using the same technique on one sample is not enough, Sutton pointed out. Multiple samples must be grown under the same conditions and then analyzed to have biological replicates. Ge explained that experiments must be designed to gather biological, rather than technical, replicates.

Once the technique to gather data is chosen and a plan of data analyses is created, Ge said, "we can figure out how many replicates are needed."

### Analyzing megabytes of data

"Bioinformatics is an important tool to zoom in on the target gene networks," said Xing-You Gu, who collaborated with Ge to identify genes that are associated with seed dormancy in weedy rice.

Weeds survive adverse environmental conditions because of strong seed dormancy, Gu explained. "To devise new weed management strategies, we need to understand the molecular genetic mechanisms of seed dormancy."

Gu used a map-based cloning strategy and then Ge applied bioinformatics tools, such as statistical tests and clustering, to find the candidate genes. This task involved looking at 30,000 to 40,000 genes, which can produce 3 to 4 million data points, according to Ge.

To determine which genes are responsible, Ge must first eliminate those data points that contain noise and then "focus on the reliable signals because we're looking at so many genes." Sometimes nearly half the data are eliminated.

### Visualizing gene expression

Ge uses data-mining algorithms to find patterns of interest to the scientists. Typically, Ge's analysis produces a visual representation of the data that is statistically significant.

One of Sutton's visuals was a heat map depicting gene expressions that were increased or upregulated in red, those that were shut down or downregulated in green and those unaffected in black. This allowed her to identify six genes as potential markers, which will then help breeders develop more lines of freeze-resistant winter wheat.

"We are trying to explain what's going on in the cell," Ge said. "We have to make the data tell a story."

After identifying the genes, the researchers "want to piece together the jigsaw puzzle and figure out the common characteristics of the affected genes," Ge explained. "This will allow us to identify the subsystems, or pathways, that are regulated."

### Comparing to model organism

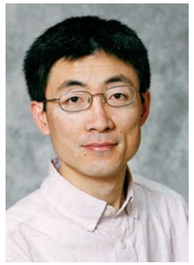
Ge's team often needs to bring in additional data and information from many sources to test various hypotheses. Arabidopsis thaliana, a member of the mustard family, serves as the model organism for cell and molecular biology studies. Thus, it also serves as a roadmap to uncovering the functions and pathways in other species, noted Ge.

Plant scientists then take these results and interpretations and then design experiments to confirm their findings.

To facilitate bioinformatics work, Ge and a team of graduate students sifted through 700 papers and 40 websites to collect recent genomic information on Arbidopsis thaliana. That data is compiled at http://bioinformatics.sdstate.edu/arapath/ for the scientists.

"It's very important to work as a team," Ge added. Through collaboration with the bioinformatics group, SDSU scientists can utilize cutting-edge genomic technologies efficiently to improve crop and livestock production.

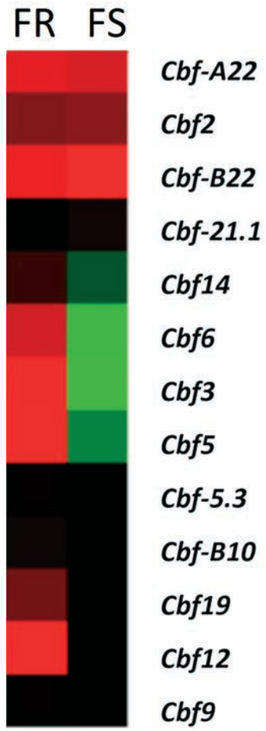
**www.sdstate.edu/mathstat/bioinformatics/index.cfm**




Xijin Ge

Associate Professor
Mathematics and Statistics

Xijin.Get@sdstate.edu

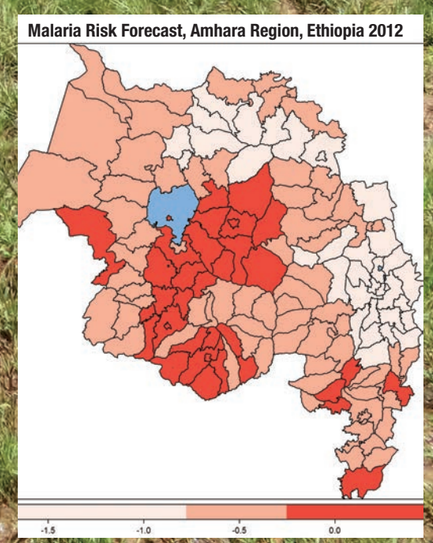




**Opposite:** Research associate Steve Kalsbeck sprays fungicide on winter wheat test plots near the Young Brothers Seed Technology Laboratory. By analyzing the genetic makeup of specific parts of the plant, scientists can look at how environmental conditions can affect gene expression.

**Inset:** Weedy rice may hold the genetic key to dormancy, but to unravel those secrets, plant scientists need the assistance of bioinformatics experts.

**Left:** A heat map shows in red those gene expressions that have been upregulated, in green those that have been downregulated and in black those which remain unchanged. This map helped plant scientist Fedora Sutton identify six genes associated with freeze resistance in winter wheat.

# Maps help public health officials fight malaria, West Nile Virus




When it comes to describing a complex system, a picture is worth a thousand words—and may also help save thousands of lives. Thanks to research at SDSU, public health officials can use satellite data to anticipate outbreaks of West Nile virus in South Dakota and malaria in the highlands of Ethiopia.

Yi Liu, associate professor of electrical engineering and computer science, collaborated with senior scientist Michael Wimberly of the Geospatial Sciences Center of Excellence to create a Web atlas that gives public health officials a "heads-up" as to where and when mosquito-borne diseases might strike.

Researchers combine remote-sensing data—including temperature and rainfall—with sophisticated software modeling to predict when conditions are ripe for vector-borne diseases, which are transmitted to humans through blood-sucking creatures. Having an advanced warning system helps put the resources people need to deal with diseases such as malaria, where they are needed most.

### Building a software framework

The collaboration began in 2009 when Wimberly asked Liu to help build a Web atlas with which his team could disseminate their maps. Using her experience as a software engineer, Liu and her students developed the framework of the Web atlas to support specific products. One such product allows Wimberly and his team to use the framework to post their maps to http://globalmonitoring.sdstate.edu/projects/eastweb/, which is part of Epidemiological Applications of Spatial Technologies or EASTweb.

Six undergraduate students and four graduate students have worked on the project over the last five years. The team has continued to "resolve issues that crop up and also enhance the software," Liu said.

"Yi is an excellent leader of software-development teams. She can effectively identify key user needs, use creativity in designing software and solve technical problems that arise while continuing to upgrade and improve her products," Wimberly said.

### Improving product performance

Wimberly and his team used to rely on ArcGIS, a common commercial software program and Python programming code to make the maps available online. "They didn't have a product to handle the entire process," Liu said.

Liu and her students studied what had been done to get "a good picture of the typical way of processing the images." After one year, Liu and her team automated the process of downloading online remote-sensing archives and processing them. This enabled scientists to compute and summarize environmental indices, which can then be saved to a database.

The computer science team replaced Python code with Java programing language, but retained ArcObjects, a component of ArcGIS. Java provided what Liu called "a nice user interface," but "the performance was not stable."

Supported by a Joseph P. Nelson scholarship, undergraduate Isaiah Snell-Feikema replaced ArcObjects with the Geospatial Data Abstraction Library (GDAL), an open source product in summer 2011.

"The performance is great," Liu noted. "We improved the execution time to 1/10th of what it was before."

However, the interface still used one piece of third-party software—a Moderate Resolution Imaging Spectroradiometer, MODIS, re-projection tool. When computer science graduate student Jiameng Hu took over the project, she replaced that module with a GDAL product to increase performance stability and reliability.

"The open-source approach yields a more robust software application that is more stable and easier to modify than earlier versions that were dependent on commercial geographic information science software libraries," commented Wimberly.

### Making framework accessible

Last summer, Liu and her team modified the software code so it can handle different online archive formats. "We're dealing with multiple institutions that aggregate data from different satellite missions," Wimberly explained.

The U.S. Geological Survey Center for Earth Resources Observation and Science archives data from Landsat and MODIS missions. Other data, such as global precipitation, are available through the Goddard Space Flight Center. These data are archived in a variety of file formats.

"The software now allows us to plug into these different archives and easily set up the technical details for the particular file format and access methods," Wimberly noted. Scientists can easily pull weather data from one place and vegetation indices from another.

"We made a framework so if the product changes, our system can automatically handle it," Liu added.

That will be especially important when they begin a new NASA-funded project called Advancing Collaborative Connection for Earth System Science (ACCESS), which will make EASTweb more customizable and available to more end users, according to Wimberly. More scientists "will be able to use remote-sensing data in epidemiological research and develop their own forecasting systems," he said.

As a result, public health officials will have access to more tools with which they can anticipate other types of vector-borne disease outbreaks and subsequently reduce mortality rates worldwide.

**www.globalmonitoring.sdstate.edu/projects/eastweb/**

Yi Liu

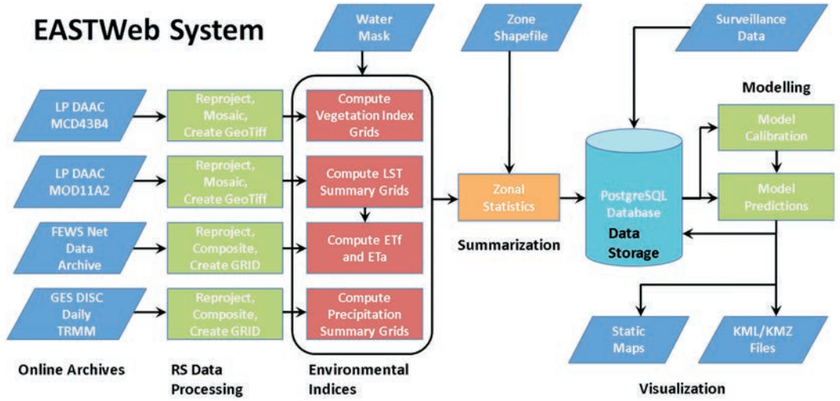
Associate Professor
Electrical Engineering and Computer Science

Yi.Liu@sdstate.edu

**Opposite:** Sampling mosquito larvae in a seasonally flooded pasture in the Amhara region of Ethiopia will give senior scientist Michael Wimberly, of the Geospatial Sciences Center of Excellence, left, and research scientist Gabriel Senay, of the U.S. Geological Survey Earth Resources Observation and Science Center, some of the data they need to help predict outbreaks of malaria.

**Inset:** The map of the Amhara region in Ethiopia in 2012 showed public health officials the risk of malaria outbreaks. Associate professor Yi Liu developed two applications—the EASTWEB application to download and process the earth observation data and the software framework to develop the Web-Atlas for disseminating the maps—to make this possible.

**Below:** The flow chart illustrates how data is downloaded and processed using the EASTWEB application.



# North Dakota-South Dakota engineers develop materials, components for solid-state cell phone

A lighter, more durable solid-state cell phone. That's the dream and the design challenge taken on by SDSU mechanical engineering professor Zhong Hu and North Dakota engineering researchers.

The wireless device's functionality will be the same, but "the focus is on the form factor," explained principal investigator Benjamin Braaten, an assistant professor at the North Dakota State University Electrical and Computer Engineering Department. The researchers hope to combine the phone's circuitry, screen and enclosure into one material.

Their research project is supported by a one-year $30,000 grant from the Inter-institutional Collaboration Fund. The associate deans for research at NDSU, SDSU and the University of North Dakota pooled their resources to provide this seed funding to encourage cross-disciplinary cooperation on joint research projects.

"The whole idea is to come up with a material that integrates the electrical and mechanical properties—strength, mechanical dampening, moisture resistance—with the electromagnetic properties needed for wireless communication," Braaten said.

Hu and SDSU graduate student develop the materials from which Braaten and UND associate professor of electrical engineering Sima Noghanian will construct electronic components—switches, antenna, filters and microwave circuits. The team also includes NDSU associate professor of industrial and manufacturing engineering Val Marinov and UND assistant professor of technology Isaac Chang.

**Taking on the Challenges**

Before the researchers can achieve their goal, they must address three fundamental design challenges, Braaten explained. First, they must figure out how to embed electronic components into the material while preserving its strength.

The second challenge is "how do we connect these circuit components in a manner similar to a printed circuit board?" Braaten said. "Maybe we don't." The electrical engineers hope to enable the circuitry with magnetic fields.

The third component and the primary focus of the seed grant is wireless communication. This involves "the antenna and manipulating the electromagnetic waves for wireless communication," Braaten explained. To do that, the researchers will "embed microelectromechanical system, or MEMS, devices into the composites and control their behavior with the magnetic field."

**Developing metamaterial**

Hu's task is to develop a multilayered engineered material, known as a metamaterial, with unique electromagnetic properties. An upper and lower conduction layer will induce the signal and then transmit it to the receiver. The middle layer needs to resonate to be responsive without being conductive, Hu adds, "yet it cannot be completely insulating or there will be no signal. It has to be something in between."

He has experimented with combinations of nanoparticles, short glass fibers and/or carbon fibers suspended in a polystyrene matrix as the dielectric material. "The fiber and polymer give strength, while the nanoparticles provide the magnetic response," Hu explained.

He adds nanoparticles at levels ranging from 1 to 5 percent of the fiber/polymer mixture. "Smaller particles can be more uniformly distributed and the signal is generated more uniformly," he said.

Hu is also considering woven carbon fiber with epoxy and unidirectional carbon fiber with polyether ether ketone, commonly known as PEEK, which are both used for aerospace applications. These are then combined with conductive materials—copper or paint with carbon fiber—for the transmission wire.

Using the spectroscopic ellipsometer in the SDSU Microstructure Characterization Lab, Hu measures the amplitude and polarization of reflected light, from which he can deduce the materials' optical and electric properties, composition and structure to determine its suitability for this application.

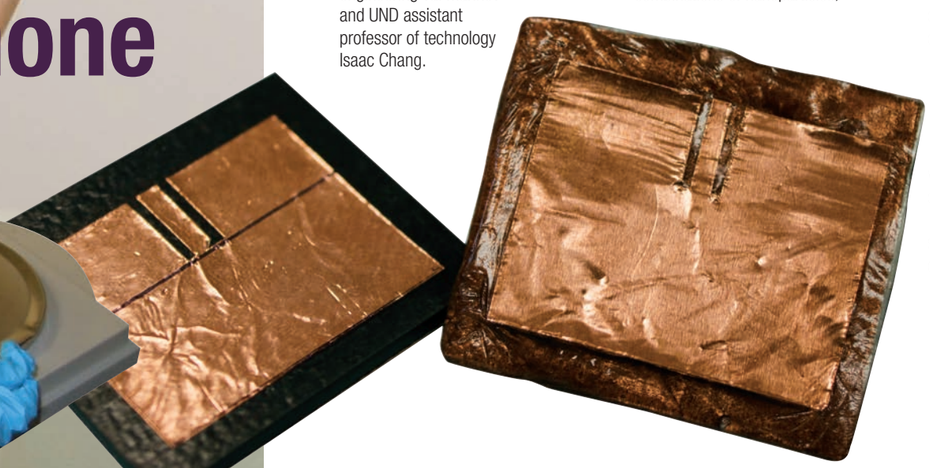
Then he sends selected samples to UND, where Noghanian and her team evaluate their electromagnetic properties. At NDSU, Braaten develops switches from the materials Hu provides.

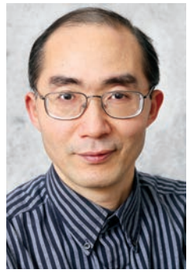
**Strength by collaboration**

Researchers at all three universities are eager to work together and willing to share their resources. This spirit of cooperation has led to what Braaten calls "multiplying the lab base through our collaborators."

Noghanian agreed: "We know each other's expertise and language." As the researchers prepare a proposal for further funding, she said, "the reviewers can see a history of us working together. This shows that we can produce results."

"Collaboration makes the research stronger," noted Hu. "We can cover the entire system, the whole package."





Zhong Hu

Professor
Mechanical Engineering

Zhong.Hu@sdstate.edu

**Opposite:** Graduate student Xiaohui Ji examines a specimen on which she will evaluate the optical transmittance. She and mechanical engineering professor Zhong Hu are developing a dielectric material using various combinations of nanoparticles, glass fibers and/or carbon fibers suspended in a polystyrene matrix.

**Inset:** Precisely measuring the polystyrene capsules is the first step in developing a dielectric material that may one day be used to make solid-state cell phones.

**Left:** The sample on the left uses carbon fiber in the matrix, while the one on the right uses magnetic nanoparticles to improve the material's signal-absorbing properties and increase the absorbing wave bandwidth. Copper tape on the outside of the samples is used for signal transmission.

EARLY-STAGE

# BREAST CANCER

## Mastectomy or lumpectomy: Statisticians uncover major reason behind cancer survivors' **choices**

"Some just wanted to get it over with and get back on the tractor" said Nancy Fahrenwald, describing the resiliency of South Dakota women diagnosed with early-stage breast cancer.

A survey of South Dakota women early stage breast cancer survivors showed that 43 percent of the 1,093 respondents chose mastectomy rather than lumpectomy. All were diagnosed and treated within the last five years.

However, Nancy Fahrenwald, dean of the SDSU College of Nursing, pointed out "according to research evidence, survival rates are considered equal," making both surgical treatments viable options. So why are these women choosing the more invasive surgery?

To identify which of the nine independent variables was the major decision-making factor, Fahrenwald turned to associate professor Chris Saunders of the mathematics and statistics department. His background in epidemiological statistics includes predicting whether certain cancer types will respond to a given treatment based on their RNA expression profiles.

Logistic regression analysis allows a statistician to analyze a data set with one or more independent variables that determine an outcome, explained Saunders, who tackled the task with graduate student Danica Ommen. The statistical analysis was made possible through a $2,500 grant from the Rural Health Research Center at SDSU, which emphasizes interdisciplinary collaboration.

### Narrowing data sets

After completing special training mandated by the Health Insurance Portability and Accountability Act of 1996, known as HIPAA, Ommen faced the challenge of dealing with two types of data—categorical and numerical.

Parameters—such as stage of cancer, education level, rural status code, the treatment choices the respondents considered and which treatments the women discussed with their doctors—were categorical, Ommen explained. The other variables such as age, income and miles to the treatment and surgical centers from the women's homes were numerical.

With Saunders' guidance, Ommen scaled these discretized categories into numerical values to move them from the nursing statistics software, SPSS, into the statisticians' analytics program, SAS, and then into R programming language to do the regression analysis.

"It works better because of the way the R package is set up," she noted. Once Ommen had everything in SAS, the software program turned the data into a CSV file, which R can read.

When doing regression analysis, any missing data points will skew the data, Saunders explained. Consequently, he and Ommen narrowed the analysis to the 550 complete data sets. Then she broke those into four subgroups based on treatments discussed with their surgeons—only mastectomy, only lumpectomy, both and those who didn't remember.

### Identifying significant relationships

Though previous studies led nursing researchers to hypothesize that rural women opt for mastectomy because of distance, Saunders said, "Distance did not account for a significant amount of the variation in treatment choices."

The logistic regression analysis yielded two decisive factors—whether the woman discussed both options with her surgeon and the stage of her cancer. Ommen also noted two interactions of low significance with regard to whether the surgeon discussed both options—age and income.

When Ommen and Saunders discussed these findings with Fahrenwald, the researchers decided to focus only on those respondents whose surgeons discussed both lumpectomy and mastectomy as options. "Those are the ones that might have been influenced by other factors," Ommen said.

The statisticians verified the logistic analysis using a reverse stepwise procedure for regression and concluded that the most significant factor to predict treatment choice is the stage of the woman's breast cancer.

Among the 415 women who considered both options, 109 were at Stage 0, 186 at Stage 1 and 120 at Stage 2. The majority of those at Stage 0 and Stage 1 chose lumpectomy, 57.7 percent and 65.6 percent respectively, which shows that a statistically significant relationship was observed, Ommen explained.

However, the women with Stage 2 cancer had a tendency to choose the more surgically extensive treatments with nearly 58 percent opting for mastectomy, according to Ommen.

"Because the categorical table [for the cancer stage subset] is very sparse, the likelihood structure becomes unstable," Saunders pointed out. Consequently, the next step is to use a Bayesian averaging technique, which will give the results "more stability and robustness and achieve the nominal significance level researchers desire."

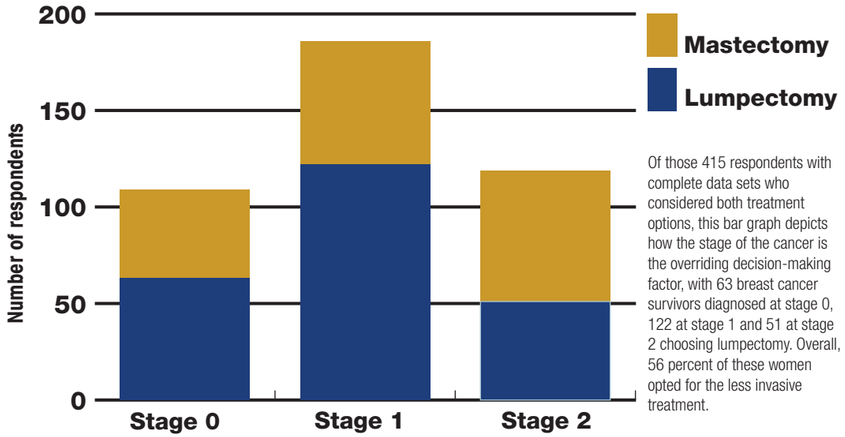
"Statistics were not meant to be innovative but to provide an answer that is robust and rigorous," said Saunders, who views statistics as a supportive discipline. "Getting the disciplines together means you get a better product."

The collaborative work will provide "statistically rigorous justification for the relationships that are leading to perceptions that rural community members are choosing mastectomy," Fahrenwald said. That will then help formulate public health policies to encourage patient-centered treatment decisions where options are provided and women make an informed choice and are highly satisfied with that choice.

Chris Saunders

Assistant Professor
Mathematics and Statistics

Chris.Saunders@sdstate.edu




Of those 415 respondents with complete data sets who considered both treatment options, this bar graph depicts how the stage of the cancer is the overriding decision-making factor, with 63 breast cancer survivors diagnosed at stage 0, 122 at stage 1 and 51 at stage 2 choosing lumpectomy. Overall, 56 percent of these women opted for the less invasive treatment.

# Crash reporting helps reduce fatalities, improve roads on TRIBAL LANDS

Native Americans are four times more likely to die in a motor vehicle crash than the general population, but many of those tragic accidents are never recorded in a transportation database, according to associate professor Xiao Qin of the civil and environmental engineering department.

A 2005 South Dakota Department of Transportation study showed Native Americans accounted for 25 percent of the state's motor vehicle fatalities, but 64 percent of the crashes on tribal lands went unreported. Crash reports are essential for obtaining state and federal funds to improve roads and promote safety in these communities.

Dave Huft, manager of research at the South Dakota Department of Transportation, noted "the motivation for the research came from the tribes," who found they needed crash reports to justify safety-improvement projects. Without these reports, the people were even having difficulty getting reimbursement from insurance claims.

Efforts to increase crash reporting rates have made South Dakota a model for other states, according professor David A. Noyce, director of the Traffic Operations and Safety Laboratory at the University of Wisconsin, Madison. He and Qin are looking for ways to improve crash reporting nationwide.

## Surveying tribal officials

Through a $200,000 grant from the National Cooperative Highway Research Program, principal investigator Noyce has collaborated with Qin and three other research partners to identify barriers to crash reporting. The national study was prompted by and modeled after South Dakota's research project.

Beginning in July 2011, the researchers developed a survey that was distributed through two Native American organizations to officials on nearly 250 reservations with at least 240 miles of highway. They received 48 fully completed questionnaires from 15 states, with Wisconsin, South Dakota, Alaska and Minnesota accounting for half of the returned surveys. In addition, a number of partially completed surveys were included in the final analysis, as they provided additional information in selected sections of the research.

Based on the responses, the researchers created a guidebook, including a self-assessment tool and strategies for building relationships among tribal authorities and state officials that will facilitate record-keeping.

Qin went to transportation conferences—including the annual South Dakota Tribal Transportation Safety Summit—to gather information regarding barriers to crash reporting. He talked to officials from nine of the 11 reservations in South Dakota.

"It was challenging to obtain information," Noyce said. Because the reporting duties can be spread across tribal leaders, "we had to talk to many different people to get a holistic view." However, the researchers also admitted that respondents were concerned about how the information would be used, something that also affects accident reporting.

"If there is a crash involving a DUI, for instance, tribes do not go after it," Qin explained, because they don't want the victim to be punished twice—in tribal court and by the state. Most states want to know where and when a crash occurred and its severity, rather than the names of the parties involved, Noyce explained.

## Establishing cooperative relationships

Building a strong relationship between the tribes and the Department of Public Safety has been crucial to South Dakota's success. The guidebook includes a memorandum of understanding that South Dakota state transportation and public safety officials use to establish a collaborative relationship with tribal governments.

Richard Greenwald, former highway safety director for the Oglala Sioux Tribe at Pine Ridge, noted that once the tribe was assured that the information would be used to help them, "the relationship with the state became stronger."

Nationwide, Qin found crash reporting was not a standard practice on tribal lands, and lack of staff, resources and training made recordkeeping difficult. Noyce explained those records ranged from handwritten notes to the use of sophisticated computer software.

## Improving highway safety

Greenwald, who is now a police officer at the Oglala Sioux Tribe Department of Public Safety, brought electronic recordkeeping to Pine Ridge. The S.D. Department of Transportation provided free Traffic and Criminal Software, or TraCS, and trained tribal police to use it.

The data allows them to pinpoint location, date, time and weather conditions when a crash occurs, according to Pine Ridge Highway Safety Director Ken Franks. He finds TraCS easy to use, even without training, and reports are complete because the system won't accept the report until it's complete. "It's much easier than the paper form."

"Over the last two years, our fatalities have been the lowest in history," said Franks, pointing to major improvements on U.S. Highway 18 that runs across two reservations in southern South Dakota. Crash reports helped them pinpoint problem areas and then get the funding to "widen the road and take out some hills and blind curves."

In addition, Greenwald said the community has become vested in the effort through public safety programs in the schools that use the Lakota language and artwork.

"We are even educating people from other reservations," he commented, through the yearly Lakota National Invitational.

Testimonials like this are what will help other tribes see the value of crash reporting. "The Dakotas are leaders in this area," said Noyce.

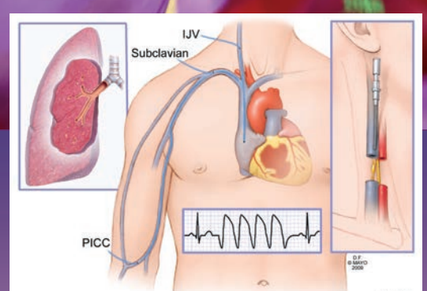
Documenting crashes will help tribal and state transportation officials secure critical resources to prevent accidents and save lives in Native American communities across the nation.

Xiao Qin

Associate Professor
Civil and Environmental Engineering

Xiao.Qin@sdstate.edu

# Operations management expert, Mayo Clinic researcher help improve health-care delivery for patients with BLOOD POISONING




An estimated 15 to 30 percent of Americans diagnosed with sepsis, or blood poisoning, will not survive, according to a benchmark study in the May 2013 issue of Critical Care Medicine. In 2009, the Centers for Disease Control and Prevention labeled septicemia as the 11th leading cause of death nationwide.

To care for these patients, health-care professionals recommend completing a series of care processes called the sepsis resuscitation bundle within six hours after diagnosis. However, only half of sepsis patients receive all elements of care needed within the recommended six-hour window, according to Dr. Yue Dong, assistant professor of the Mayo Clinic College of Medicine in Rochester, Minnesota. Research studies have shown that treatment delays can cause poor patient outcomes and higher associated health-care costs.

During a sabbatical at Mayo Clinic, professor Huitian Lu of the SDSU Department of Construction and Operations Management met Dong, who is also a patient safety researcher at Mayo Clinic Multidisciplinary Simulation Center and the Multidisciplinary Epidemiology and Translational Research in Intensive Care group. After learning about computer simulation's potential to improve the care process beyond medical education, Lu began collaborating with Dong to identify bottlenecks in the sepsis resuscitation delivery process.

## Examining resuscitation process

Sepsis is the most common cause of death in intensive care units, according to the National Institutes of Health. The body's immune response to fight the infection triggers inflammation that restricts blood flow and leads to multiple organ failure.

The health-care team's goal is to return the patient's central venous oxygen saturation level to at least 70 percent within six hours or less, Lu explained. If that doesn't happen, "the patient mortality will be high—the first six hours are critical."

One graduate student worked on the project through a $7,500 grant from the SDSU Research and Scholarship Support Fund.

From a health-care perspective, certain evidence-based procedures need to be done in six hours and that matrix is used to measure performance, according to Dong. Individual care processes are not routinely tracked.

## Analyzing system design

Lu worked with Dong to analyze the problems from a system design perspective considering factors such as scheduling and workflow, rather than solely focusing on treatment itself. Then he applied root cause analysis to examine the existing processes and identify sources of delays.

"This is a statistical methodology used in systems engineering, which I am applying to health-care delivery operations" Lu said.

The researchers used data from 200 sepsis cases and examined 15 key processes within the sepsis resuscitation bundle. They relied on observations, electric medical records with time stamps and the provider's best estimation to determine how much time each task consumed.

For instance, Dong explained. "We'd ask the nurse, if you order a blood draw, how long does it usually take?" In this case, the answer was 5 to 10 minutes.

Using these numbers, the researchers built a computer model, which they verified using real data. "It was not perfect because we lacked detailed process data, but it was good enough for the statistical analysis we were doing," Lu said.

## Pinpointing bottlenecks

Through discrete event simulation, Lu pinpointed the tasks that took the most time. "Then we compared them using statistical methods to analyze their sensitivity," Lu recalled. "If the specific task time was reduced by 1 to 2 percent, how much would it affect the six-hour threshold?"

Lu's simulations showed that bottlenecks occurred with X-ray, lab work and placement of a catheter into a central vein, usually in the neck. Specifically, 20 minutes could be saved by having an experienced critical care fellow insert the catheter.

Other research has shown that early placement of the central line catheter increases survival rates.

Overall, Lu reported that the changes in six areas can reduce the total average patient treatment time by 31.8 percent, improving the sepsis resuscitation bundle compliance rate from 50 to 71 percent.

"Completing the procedures in six hours will give the patients the best chance of survival," Lu pointed out. But unlike a manufacturing situation, the outcome also depends on many unpredictable individual patient variables.

## Improving delivery system

Although these changes have only been tested through computer simulation, Dong recognizes the potential Lu's statistical analyses have to improve delivery efficiency. "Health care is at a crossroad," he noted, and applying system engineering metrics to health-care delivery can help maximize return on investment and improve patient outcomes.

"This, in itself, is a good learning experience," he said. The challenge will be "to bring the stakeholders beyond our groups—physicians, nurses and pharmacists—together earlier to help build better models and facilitate process change."

Dong sees engineering-based systems integration as having an impact beyond sepsis and critical care to improve patient care.

Huitian Lu

Professor
Construction and Operations Management

Huitian.Lu@sdstate.edu

**Opposite:** Using a systems engineering approach, bottlenecks in the sepsis resuscitation bundle—a series of care processes performed on patients suffering from blood poisoning—were identified. Those areas included placement of a catheter in a central neck vein, left, and X-ray.

# ISEE

## supports grant development

Universities must lead the national charge to inspire students to become engineers and scientists, but often researchers don't have direct ties to K-12 education—that's where associate professor Sharon Vestal comes in.

As director of the Institute for STEM (science, technology, engineering and mathematics) Education Enhancement, Vestal and other education experts help faculty make connections so their research impacts students and teachers. The institute, known as ISEE, became an official campus entity July 1, 2013.

ISEE is an outgrowth of Vestal's work with the National Science Foundation Robert Noyce Teaching Scholarship Program that encourages students majoring in mathematics and science to become teachers. Since 2007, the SDSU program has produced 44 math and science teachers. Faculty mentoring and outreach activities, including teacher workshops, are part of the support network for these graduates.

Nearly all federal funding agencies are interested in outreach and broader impacts, whether the project is directly linked to STEM education or not, according to Vestal. "We can help them with educational activities related to their research."

### Adding outreach element

Assistant professor Reinaldo Tonkoski of the electrical engineering and computer science dpeartment sought guidance from ISEE when he prepared a National Science Foundation Faculty Early Career Development Program proposal.

To illustrate the importance of alternative energy technologies, he proposed building a trailer containing a solar cell, mobile wind turbine and power converters. Tonskoski calls it "a microgrid in a box." This unit could be taken to area schools, farm shows and even a private residence or an electrical utilities company to illustrate how much energy could be generated from renewable sources.

"The education part of my proposal got [the reviewers'] attention," Tonskoski noted. "I am very thankful for ISEE's support in the development of a strong educational plan for my proposal."

He credited Vestal's experience at organizing activities tailored to K-12 teachers for saving him several weeks of proposal preparation time.

Associate dean of research Dennis Helder commended ISEE for helping researchers develop their outreach components. "Sharon has done a great job of making that part of the proposal development process easier."

Vestal explained that "communicating what they do at a level that is understandable to the average person" can sometimes be challenging for university researchers. That's where ISEE pedagogy experts can help.

### Advancing STEM in high schools

Civil engineering professor Suzette Burckhard, statistics associate professor Gemechis Djira and agricultural engineer Christine Wood are part of an interdisciplinary group of researchers who applied for a three-year, $150,000 U.S. Department of Agriculture grant to increase the number of women and minority students enrolling in university agriculture, science, math and engineering programs.

"Sharon was very supportive," said associate professor of plant science Thandiwe Nleya, who spearheads the agricultural sciences component with plant pathologist Emmanuel Byamukama.

Vestal met with the researchers when they planned their approach and then reviewed and helped them strengthen the proposal.

With Vestal's guidance, the researchers selected three high schools to target Native Americans, women, blacks and Hispanics—Sioux Falls Washington, Flandreau and Madison. During the academic year, these professionals will visit the schools to talk about their work and then will host students on campus during a summer workshop.

"The idea is to have someone who looks like them mentor them," Vestal added. "If you look at the big picture, the way to get students interested is to connect with the researchers."

University outreach and mentoring programs teach middle and high school students what engineers do and "give them a wider view of what's possible," said Burckhard, who has recruited minorities into engineering and science for 25 years. "We are trying to show them that it's not an impossible dream to become an engineer."

Through support from ISEE, university researchers can strengthen STEM education and motivate young people to pursue careers in science and engineering.

Sharon Vestal

Associate Professor
Mathematics and Statistics

Sharon.Vestal@sdstate.edu

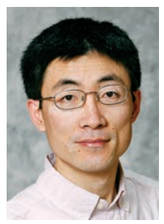
**Opposite:** Activities that bring the power of research to K-12 teachers and students are part of the outreach and broader impacts required for most federal funding applications. The Institute for STEM Education Enhancement helps researchers develop this key proposal element, which often involves teacher workshops.

# AWARDS

## Three engineering researchers receive awards

Qi Hua Fan

Qiquan Qiao



Xijin Ge

### Outstanding Researcher – Qi Hu Fan

For his work in thin films and plasma science, associate professor Qi Hua Fan of electrical engineering and computer science was named the Outstanding Researcher for the Jerome J. Lohr College of Engineering at the university's Celebration of Faculty Excellence. Last year Fan received the Pat and Jo Cannon Intellectual Property Commercialization Award.

Fan's patent-pending method for depositing nanoparticles on a substrate using a simple chemical process is licensed to Applied NanoFilms LLC, an SDSU spin-off company that is a part of the South Dakota Innovation Partners portfolio. A proof-of-concept grant from the North Central Regional Sun Grant Center supported in part by Applied Nanofilms allowed him to explore whether this technology can be used to deposit biochar onto thin films to decrease the cost of supercapacitors. Proof-of-concept grants allow researchers to show that their bio-based technologies merit a greater investment to bring them to the commercial marketplace.

Establishing connections with industry has helped Fan tailor his research to companies' needs. Through his previous work, Fan has established research partnerships with Xunlight of Toledo, Ohio, and Wintek of Ann Arbor, Michigan. Xunlight, a solar panel manufacturer, is investigating a material developed at the Center for Advanced Photovoltaics that may provide longer-lasting back reflectors. For Wintek, Fan is developing more efficient plasma processing techniques that will result in better-performing flat panel displays.

### F. O Butler Award for Research– Qiquan Qiao

Improving the efficiency of organic solar cells has been the focus of associate professor of electrical engineering Qiquan Qiao. Since he came to SDSU in 2007, he has established a lab devoted to studying organic electronic materials and devices. For his work, he received the F. O. Butler Award for Excellence in Research, which provides a $2,750 stipend.

In 2010, Qiao received the National Science Foundation Faculty Early Career Development award, given to support young faculty who demonstrate excellence in research and teaching. This has provided more than $436,000 during the last five years to advance his work.

In addition, he was the SDSU lead on a recently completed three-year, $750,000 NASA-EPSCoR grant collaborating with the South Dakota School of Mines and Technology, government laboratories and commercial entities to develop a photovoltaic materials research cluster in South Dakota.

In the last 10 years, Qiao has written 68 journal articles and done 118 presentations, posters and seminars. He has also written eight book chapters and is editing a book.

Qiao's research team is developing an interfacial layer that uses tunneling to provide a pathway for charge transport to increase the efficiency of organic solar cells. In addition, he seeks to combine solar cells and a lithium battery into a single unit that will both generate and store energy.

### Young Investigator – Xijin Ge

As the leader of the bioinformatics group, associate professor Xijin Ge of mathematics and statistics uses both computational and experimental approaches to study novel genes in mammalian genomes. Ge recently finished a five-year, nearly $850,000 National Institutes of Health research project.

His work has earned him the Jerome J. Lohr College of Engineering Young Investigator Award, which includes a monetary gift of $1,000 to support his research.

Ge, who has been at SDSU since 2007, started bioinformatics work with cancer genomics while doing doctoral work at the University of Tokyo. The field of study meshes computer science, statistics and biology. He continued to work on human genomics and breast cancer as a postdoctoral researcher at Northwestern University and NorthShore University HealthSystem until he came to SDSU.

Ge and a team of graduate students collected recent genomic information on Arbidopsis thaliana, a model organism for plant cell and molecular biology studies, from 700 papers and 40 websites. That data is available to scientists on the bioinformatics Web page at http://bioinformatics.sdstate.edu/arapath/. This knowledge base forms the foundation for interpreting large genomics data in the model plant.

Through funding from the Agricultural Experiment Station, the bioinformatics group helps SDSU plant and animal scientists discover how genes and proteins affect cell functions.

In addition, he is working with the Biochemical Spatiotemporal NeTwork Resource (BioSTNR), a South Dakota Experimental Program to Stimulate Competitive Research (EPSCoR) group that brings together scientists from SDSU, the South Dakota School of Mines and Technology and the University of South Dakota, as well as clinicians and researchers from Sanford Health and Avera.



## Grantswinship awards recognized

These Jerome J. Lohr College of Engineering faculty members secured or had research expenditures of $100,000 or more during the 2013 fiscal year: Nadim Wehbe, Jon Puetz, Xiao Qin, David Galipeau, Chris Schmit, Qi Hua Fan, Mahdi Farrokh Baroughi, Richard Reid, Qiquan Qiao, Teresa Hall, Sharon Vestal, Stephen Gent, Sung Shin and Fereidoon Delfanian. Not pictured are Ross Abraham, Venkateswara Bomissetty, Xijin Ge, Dennis Helder, Jung-Han Kim, Alex Moutsoglou, Mike Twedt and Ken Skorseth.

**SOUTH DAKOTA STATE UNIVERSITY**
OFFICE OF ENGINEERING RESEARCH
Daktronics Engineering Hall 309, Box 2222
Brookings, SD 57007

**www.sdstate.edu/engr/research**
Phone: 605-688-4372
Fax: 605-688-4969
Email: Dennis.Helder@sdstate.edu