THE UNIVERSITY OF UTAH

DECEMBER 2010 UTAH ENGINEERING

The Brain Speaks

ENGINEERS DECODE WORDS FROM BRAIN SIGNALS

LEFT: Bradley Greger, assistant professor of bioengineering

BELOW: An array of 16 microelectrodes is arranged in a four-by-four array and shown next to a quarter. University of Utah researchers placed two such microelectrode grids over speech areas of a patient's brain and used them to decode brain signals into words. The technology might someday help severely paralyzed patients "speak" with their thoughts.

PHOTO CREDIT:
Spencer Kellis,
The University of Utah

In an early step toward letting severely paralyzed people speak with their thoughts, University of Utah engineers translated brain signals into words using two tiny grids of 16 microelectrodes implanted beneath the skull but atop the brain.

"We have been able to decode spoken words using only signals from the brain with a device that has promise for long-term use in paralyzed patients who cannot now speak," says Bradley Greger, assistant professor of bioengineering. Because the method is in its early stages of development, he says it will be a few years before clinical trials could be conducted.

"The accuracy of identifying words from brain signals needs improvement, but we have shown the information is there," says Spencer Kellis, a doctoral student in electrical engineering who designed the algorithm, or step-by-step technique, that allowed researchers to read the brain signals.

The research team placed the microelectrodes over speech centers in the brain of a volunteer with severe epileptic seizures. The patient already had a craniotomy—temporary partial skull removal—so doctors could place larger, conventional electrodes to locate the source of his seizures and surgically stop them.

Using the experimental microelectrodes, the team recorded brain signals as the patient repeatedly read each of 10 words that might be useful to a paralyzed person: yes, no, hot, cold, hungry, thirsty, hello, goodbye, more and less. Later, they analyzed which brain signals represented each of the 10 words. When they compared any two brain signals, they could distinguish brain signals for each word 76 percent to 90 percent of the time. >>

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When they examined all 10 brain signal patterns at once, they could pick out the correct word any one signal represented only 28 percent to 48 percent of the time—better than chance (which is 10 percent) but not good enough for a device to translate thoughts into words spoken by a computer.

"We've proven these signals can tell you what the person is saying well above chance," Greger says. "But we need to be able to do more words with more accuracy before it is something a patient really might find useful."

This project is an example of the power of interdisciplinary research that is prevalent in the U's College of Engineering. In addition to Greger from bioengineering and PhD student Kellis from electrical engineering, the study involved Richard Brown, dean of the College of Engineering, and Paul House, assistant professor of neurosurgery. Another coauthor was Kai Miller, a neuroscientist at the University of Washington in Seattle.

LEFT: Spencer Kellis, PhD student in electrical engineering

Nonpenetrating Microelectrodes Read Brain's Speech Signals

The study used a nonpenetrating microelectrode that sits on the brain without poking into it. The "microECoGs" are a small version of the much larger electrodes used for electrocorticography, or ECoG, to detect abnormal electrical activity in patients with severe epileptic seizures.

Last year, Greger and colleagues published a study showing the much smaller microECoG electrodes could "read" brain signals controlling arm movements. Because the microelectrodes do not penetrate brain matter, they are considered safe to place on speech areas of the brain—something that cannot be done with penetrating electrodes used in experimental devices to help paralyzed people control a computer cursor or an artificial arm. EEG electrodes used on the skull to record brain waves are too big and record too many brain signals to be used easily for decoding speech signals from paralyzed people.

Translating Nerve Signals into Words

In the new study, each of two grids with 16 microECoGs spaced 1 millimeter apart, was placed over one of two speech areas of the brain: First, the facial motor cortex, which controls movements of the mouth, lips, tongue and face. Second, Wernicke's area, a little understood area tied to language comprehension and understanding.

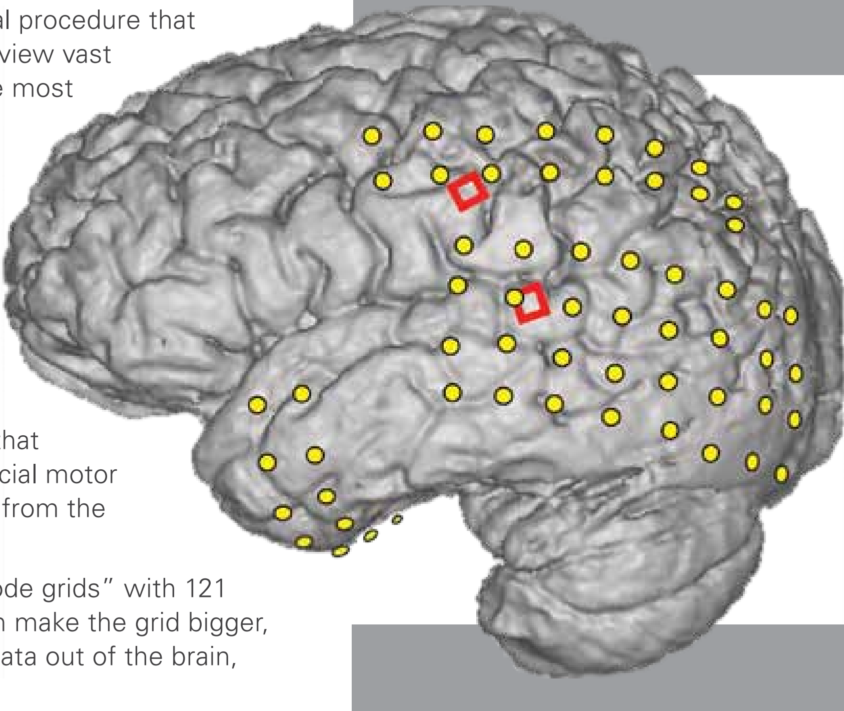
Researchers told the epilepsy patient to repeat one of the 10 words and recorded brain signals via the two grids of microelectrodes. Kellis had written the software code that allowed researchers to analyze the brain signals using a method called principal component analysis (PCA), a mathematical procedure that makes data easier to understand. "PCA will allow you to view vast amounts of information and let you look at the data in the most meaningful way," says Kellis.

The researchers looked for patterns in the brain signals that correspond to the different words by analyzing changes in strength of different frequencies within each nerve signal. The researchers were most accurate —85 percent—in distinguishing brain signals for one word from those for another when they used signals recorded from the facial motor cortex versus 76 percent accuracy when using signals from Wernicke's area. When the team selected the five microelectrodes on each grid that were most accurate in decoding brain signals from the facial motor cortex, their accuracy in distinguishing one of two words from the other rose to almost 90 percent.

"The obvious next step is to do it with bigger microelectrode grids" with 121 microelectrodes in an 11-by-11 grid, Greger says. "We can make the grid bigger, have more electrodes and get a tremendous amount of data out of the brain, which probably means more words and better accuracy."

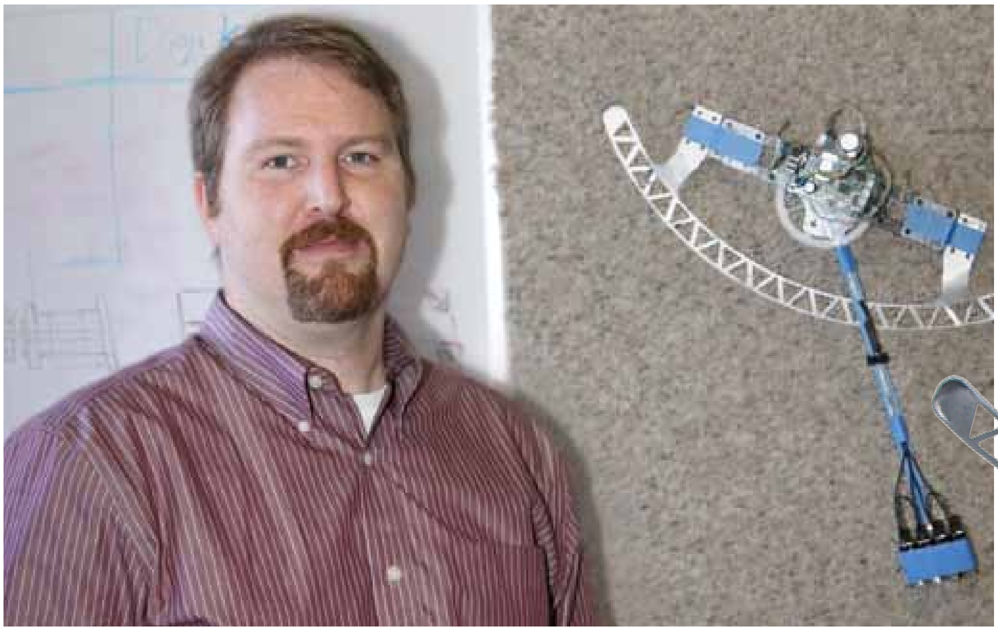
BELOW: This magnetic resonance image (MRI) of an epileptic patient's brain is superimposed with the locations of two kinds of electrodes: conventional ECoG electrodes (yellow) to help locate the source of his seizures, and two grids (red) of 16 experimental microECoG electrodes used to read speech signals from the brain.

PHOTO CREDIT: Kai Miller, University of Washington



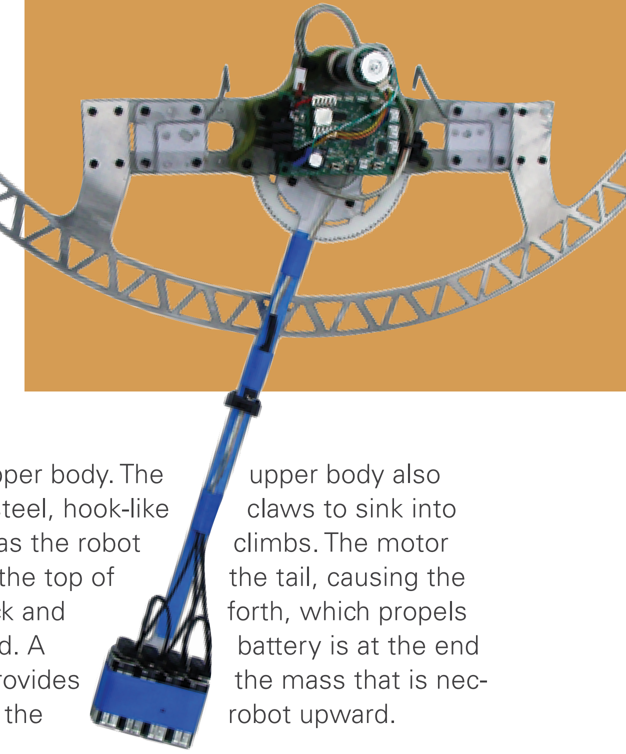
Robot Climbs Walls

POTENTIAL USES: SURVEILLANCE, INSPECTION, MAINTENANCE



LEFT: William Provancher, assistant professor of mechanical engineering, stands next to the ROCR Oscillating Climbing Robot he and his colleagues developed.

BELOW: Another view of ROCR.



Wielding two claws, a motor and a tail that swings like a grandfather clock's pendulum, a small robot named ROCR ("rocker") Oscillating Climbing Robot scrambles up a carpeted, 8-foot wall in just over 15 seconds—the first such robot designed to climb efficiently and move like human rock climbers or apes swinging through trees.

"While this robot eventually can be used for inspection, maintenance and surveillance, probably the greatest short-term potential is as a teaching tool or as a really cool toy," says robot developer William Provancher, assistant professor of mechanical engineering.

"Prior climbing robots have focused on issues such as speed, adhering to the wall, and deciding how and where to move, but ROCR is the first to focus on climbing efficiently," Provancher says.

One previous climbing robot has ascended about four times faster than ROCR, which can climb at 6.2 inches per second, but ROCR achieved 20 percent efficiency in climbing tests, "which is relatively impressive given that a car's engine is approximately 25 percent efficient," he says.

Provancher's collaborators include Mark Fehlberg, a doctoral student in mechanical engineering, and Samuel Jensen-Segal, a former Utah master's degree student now working as an engineer in New Hampshire.

At 12.2 inches wide, 18 inches long and weighing 1.2 pounds, ROCR is small and lightweight compared to some previous climbing robots. The motor that drives the robot's tail and a curved, girder-like stabilizer bar attach to the robot's upper body. The upper body also has two small, steel, hook-like claws to sink into a carpeted wall as the robot climbs. The motor drives a gear at the top of the tail, causing the tail to swing back and forth, which propels the robot upward. A battery is at the end of the tail and provides the mass that is necessary to swing the robot upward.

"ROCR alternatively grips the wall with one hand at a time and swings its tail, causing a center of gravity shift that raises its free hand, which then grips the climbing surface," Provancher says. "The hands swap gripping duties and ROCR swings its tail in the opposite direction."

ROCR is self-contained and autonomous, with a microcomputer, sensors and power electronics to execute desired tail motions to make it climb. "Its design mimics efficient natural and manmade systems," he says. "It mimics a gibbon swinging through the trees and a grandfather clock's pendulum, both of which are extremely efficient."

Provancher says ROCR is the first to set a benchmark for the efficiency of climbing robots against which future models may be compared. He says future work will include improving the robot's design and ability to grip walls of various sorts, such as brick and sandstone, and investigating more complex ways of controlling the robot —all aimed at improving efficiency.

Provancher is also lead author of a new study on touch-based directional devices that may help motorists and hearing-impaired people drive more safely. For more information on Provancher's research, go online to *http://heml.eng.utah.edu.*

New Home for Civil Engineering

We are pleased to announce the completion of the Floyd and Jeri Meldrum Civil Engineering Building as the new home of the Department of Civil and Environmental Engineering. The renovation was finished on August 24, 2010, and the dedication and ribbon-cutting ceremony (pictured below at left) took place on October 28, 2010.

The 14,500-square-foot addition to the former Energy and Minerals Research Laboratory brings together civil, environmental, and nuclear engineering faculty into adjacent space with a newly designed transportation operations center and environmental engineering labs.

The addition was designed for earthquake-safety and energy-efficiency to save tens of thousands of dollars annually in heating and cooling. The student-designed construction showcases sustainable engineering systems, materials and structural elements that saved more than 250 tons of greenhouse gases over conventional construction. The auditorium provides facilities for distance learning and communication training. A leadership center and a mentoring center provide a home for student organizations and tutoring opportunities. The Dunn Commons features an informal gathering space for students and professionals. The renovations are supported by a generous $3.3 million gift from alumnus Floyd Meldrum (pictured below at right with U of U President Michael Young) and his wife, Jeri.

NEW FACULTY HIRES

Orly Alter
Bioengineering and
SCI Institute

RESEARCH INTERESTS:
Using mathematical frameworks to model large-scale molecular biological data, such as DNA microarray data

Brittany Coats
Mechanical
Engineering

RESEARCH INTERESTS:
Characterizing linear and non-linear material properties of skull and brain tissue to identify injury tolerances in children

Mathieu Francoeur
Mechanical
Engineering

RESEARCH INTERESTS:
Near-field radiative transfer applied to thermal radiation, thermophotovoltaic power generation, and optical characterization of nanoparticles

Luis Ibarra
Civil & Environmental
Engineering

RESEARCH INTERESTS:
Structural engineering, performance-based design with emphasis on the collapse limit state, seismic risk assessment, and aging effects on structural performance

Rising Star Award

Chiao-ih Hui, who graduated with a BS in computer engineering from the Department of Electrical & Computer Engineering in 2002 and an MBA in 2005 both from the University of Utah, was recently named the "Rising Star" by the Women Tech Council, an organization that advocates for women working in Utah's high-tech sector. Hui was honored along with four other women at a banquet for their contributions to their communities and industries. They were noted particularly for working "in innovative ways to advance in their careers, affect positive change in the world in which they live, and influence and inspire a new generation of young girls."

In 2002 Hui joined L-3 Communications — the sixth largest defense company in the United States — as a software engineer and has held several engineering positions including lead systems engineer for the Littoral Combat Ship Systems. She is currently a program manager in charge of the development and manufacturing of the communications and control system on "The Shadow" — a small unmanned plane program currently used by the U.S. military in Afghanistan and Iraq. In 2005, Hui was named the youngest "Rising Star: Top 40 Under 40" by Utah Business Magazine.

Hui is involved in efforts to help expose young women to careers in engineering, science and technology. She is a past president of the professional section of the Society of Women Engineers (SWE) from 2002 to 2007. She currently serves on several national SWE committees. Hui also works with the Young Alumni Board and the Women's MBA Alumni Association at the U of U.

"Many young girls and students just don't know about engineering career paths, which are very fulfilling, challenging and interesting," Hui says. "I have an interest in letting them know about opportunities they could have."

Manoranjan Misra
Chemical Engineering

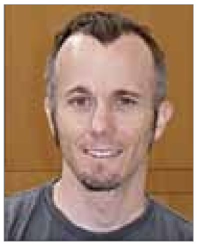
RESEARCH INTERESTS:
Photoelectrochemical hydrogen generation, hydrogen storage using CNT and titania composites, materials for high-temperature nuclear reactors, nanotube and nanowire devices

Bart Raeymaekers
Mechanical Engineering

RESEARCH INTERESTS:
Ultrasonic sensor technology for energy and biomedical applications; magnetic recording technology

Thomas Schmid
Electrical & Computer Engineering

RESEARCH INTERESTS:
Wireless embedded systems architectures, including the hardware-software boundary, and how changes on one side influence the other



David Schurig
Electrical & Computer Engineering

RESEARCH INTERESTS:
Metamaterials, self-adjusting assembly and method for close tolerance spacing, transformation-optical devices of reconfigurable optical devices, and electromagnetic cloaking method

Haori Yang
Civil & Environmental Engineering
Nuclear Engineering

RESEARCH INTERESTS:
Detector design and development, radiation imaging and monitoring systems, waste assay techniques, nuclear instrumentations and control systems

$5M GRANT TO STUDY CO_2 STORAGE

Brian McPherson, associate professor of civil and environmental engineering, was recently awarded a $5 million grant from the U.S. Department of Energy to evaluate rock formations in Utah and nearby states to find the best sites to store carbon dioxide underground. The goal is to reduce carbon emissions in the atmosphere that are released from power plants and other industrial emitters. McPherson's team is looking for sites far from population centers and earthquake fault lines. McPherson, who is also a member of the University of Utah's Energy & Geoscience Institute, says there is at least 50 years worth of storage capacity in the earth's subsurface.

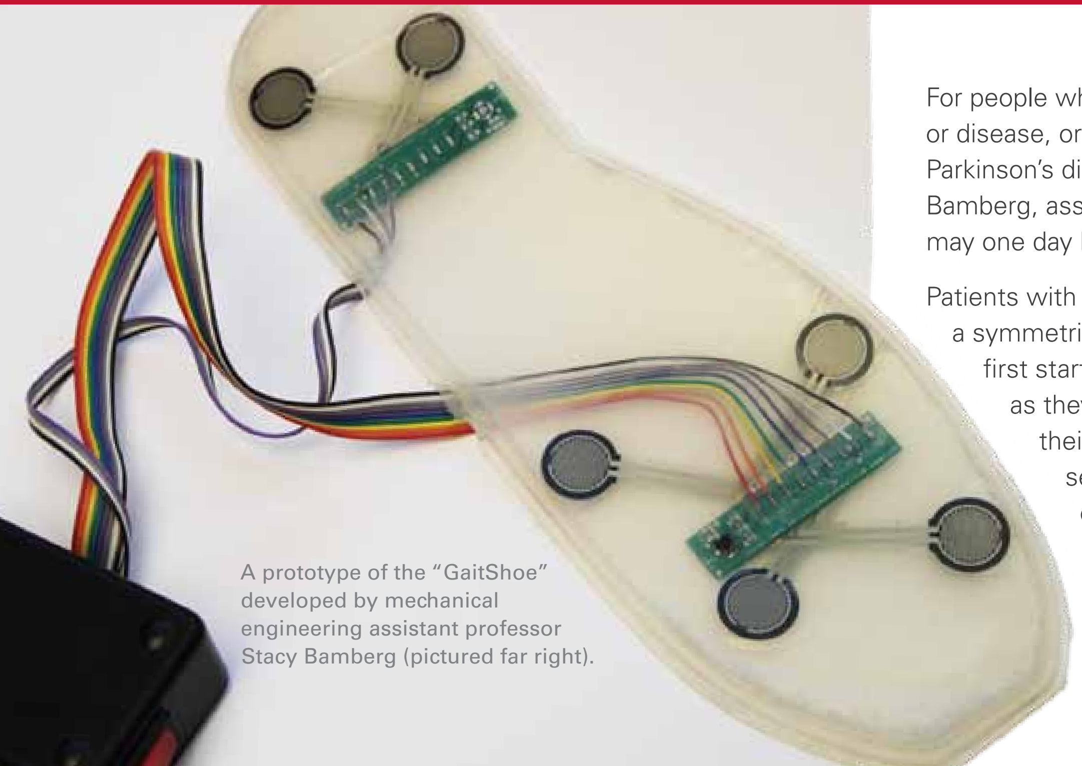
SOCIETY OF PETROLEUM ENGINEERS AWARD

Milind Deo, professor of chemical engineering, recently received special recognition for his contributions to petroleum engineering by the Rocky Mountain North America Region of the Society of Petroleum Engineers (SPE) International. The award was for his work in Reservoir Description and Dynamics. The SPE Regional Technical Awards acknowledge SPE members who make "significant technical and professional contributions to the worldwide oil and gas industry and to the petroleum engineering profession and exceptional service to the Society."

DARPA AWARD: EXTREMESCALE SUPERCOMPUTING

The University of Utah is part of a group of companies and other universities that has been awarded a four-year, $25 million research grant from the Defense Advanced Research Projects Agency (DARPA), to develop graphics processing unit technologies for a new generation of "extremescale" supercomputers that are 1,000 times more powerful than today's fastest supercomputers. Mary Hall, associate professor in the School of Computing, is heading the U of U group whose role is "to contribute to the programming model design and compiler technology for the proposed architecture." Hall is also the recipient of a new Distinguished Scientist Award from the Association for Computing Machinery.

Technology Commercialization at the U



A prototype of the "GaitShoe" developed by mechanical engineering assistant professor Stacy Bamberg (pictured far right).

For people who have undergone amputation from trauma or disease, or who suffer from paralysis from stroke or Parkinson's disease, a new "shoe" designed by Stacy Bamberg, assistant professor of mechanical engineering, may one day help them regain the ability to walk normally.

Patients with prosthetic legs have difficulty maintaining a symmetrical (or natural and balanced) stride. When they first start wearing artificial legs, patients may limp as they learn to walk placing only limited weight on their prosthetic legs. Over time, a limp can cause serious health consequences because the opposite natural limb must take the brunt of unequal weight distribution. Gradually most patients learn to properly balance weight between the natural and prosthetic limbs, but the damage may already be done.

SCI HELPS NEW BUSINESSES DEVELOP SOFTWARE

University of Utah faculty develop a wealth of software, and they now have a resource, the Software Development Center, that will help them organize, refine and make software more commercially viable. The center is a joint effort between the Scientific Computing and Imaging (SCI) Institute and the U's Technology Commercialization Office, which manages intellectual property on campus. By working with established programs like the successful SCI Institute, the center will provide a much-needed central agency to drive software development projects across campus. SCI is an international research leader in the areas of scientific computing, visualization and image analysis.

SLC AND THE U IN 'BEST CITIES' LIST

Salt Lake City was recently chosen as the number five pick for "Best Cities for the Next Decade" by Kiplinger, a Washington, D.C.-based publisher of business forecasts and personal finance advice. SLC is noted for its educated workers, low cost of living and pro-business environment, as well as its beautiful mountain setting close to many ski resorts. The University of Utah, located in SLC, is also praised as "internationally recognized for its research" and as "a hotbed of new-business creation." Incidentally, the U of U is now ranked first in the nation along with MIT at starting companies from its research, according to the Association of University Technology Managers, which ranks public and private research institutions throughout the country.

A SHOE TO IMPROVE GAIT

Bamberg and her associates have developed a lower-extremity ambulatory feedback system, or "GaitShoe," to help patients walk normally faster. The device is a gel insole with force sensors fitted to the patient's artificial limb that measures the wearer's gait symmetry, wirelessly transmitting the data and providing real-time feedback to the wearer. The device beeps to tell a patient whether he is spending the proper amount of time on the prosthetic limb as he walks. The device can be programmed to help through each stage of the healing process. The next generation of the device will incorporate feedback corresponding to weight on each limb, so that patients can be directed to put less weight on the prosthesis up to full weight as the wearer's amputated limb heals.

Most rehabilitation centers currently lack the necessary tools to help new patients know exactly how much time spent or weight they are putting on their prosthetic limbs, says Bamberg. Plus, a lab is an artificial environment for relearning how to walk. "The shoe is meant to help people in a more natural environment, and it's affordable," she says. "You can wear it at home or wherever you would normally want to go and it will give you instant feedback." Bamberg now has a patent in progress for the device and is in the early stages of forming a company called Veristride to commercialize the technology.

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Seasons Greetings

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Skullcandy

From Ski Champ to Scholar

Being raised in Alaska, bioengineering student Katie Sciuto had always liked snow, but grew up involved in only a few winter sports. It wasn't until she watched the freestyle aerial skiing competitions on TV during the 2002 Utah Winter Olympics that her interest was piqued. Having practiced gymnastics since the age of five, Sciuto thought aerial ski jumping looked like a lot of fun.

After she graduated from high school, Sciuto's family moved to Spokane, Washington, where she spent a semester studying at Washington State University. "While I was there, I realized I had other dreams that I wanted to pursue as well as going to school, so I started working towards a way to do both," says Sciuto.

Sciuto heard about a nearby stunt school and enrolled in a three-week intensive program. After finishing the program, she went to an aerial ski camp in Lake Placid, New York, "to give my aerials dream a shot." For an individual who had never skied before, Sciuto struggled at first, but learned quickly. Her gymnastics skills helped her train in aerial jumping.

In 2004, Sciuto moved to Utah to continue her training and began to compete. In 2007, Sciuto was ranked 4th in the nation in freestyle aerial skiing. She also placed 8th in the U.S. National Championships. She joined the U.S. Freestyle Ski Team and continued training. But after a couple years, Sciuto decided to put skiing on hold to finish school.

Sciuto spoke with a friend about her future and her desire to continue her studies. The friend suggested the bioengineering program at the University of Utah. "I looked into it, and thought this is exactly what I want to do. I've always liked math and science and have done well in both," she says.

Now a junior in bioengineering, Sciuto is pursuing her degree while studying the effects of voltage-sensitive dyes on the electrophysiology of the heart under Steven Poelzing, a research assistant professor of bioengineering. Sciuto is also busy as co-chair of the department's undergraduate advisory committee. She hopes to involve other students and improve student interaction and mentoring.

Katie Sciuto, a junior in bioengineering, shown performing aerial ski jumps.

Sciuto is also working as a movie stunt woman and has performed stunts in almost a dozen movies filmed in Utah. She is a member of the Screen Actors Guild and was recently elected to serve on SAG's Utah Chapter Committee.

Although Sciuto is still determining what her future will be, she plans to finish her undergraduate degree and hopes to one day earn a PhD in bioengineering. "I'm keeping very busy and having a lot of fun in my bioengineering program and performing stunt work."