engineering news
School of Engineering
FALL 14
SANTA CLARA UNIVERSITY

DEAN'S MESSAGE

Here at Santa Clara University, memories of a summer well spent always add to the excitement that naturally comes with fall and the advent of a new academic year. So, as we welcome a new class of Bronco engineers, we take a look back at the work our students and faculty have been doing the past few months and shine a light on some of what is new to SCU engineering.

In this issue of *Engineering News*, you will read how some of our faculty members spent their summer working to enhance students' learning experiences through improved pedagogy and the art of teaching, as well as by taking SCU engineering beyond our campus to Jesuit and Catholic institutions in India and Uruguay.

Other articles feature student outreach in partnership with The Tech Museum of Innovation in San Jose, field robotics research, new courses in Big Data, and a multi-disciplinary team's efforts to advance the field of autonomous, solar-powered transportation.

For the faculty and students of SCU engineering, it was a most productive summer and the fall quarter holds great promise. Happy reading!

Godfrey Mungal
Dean
School of Engineering

Water, water, anywhere?

As the golden hills surrounding Santa Clara Valley crack and turn dusty brown in the driest year on record for many parts of the state, the subject of water is, naturally, on our minds here in California. According to Keith Schneider, senior editor of Circle of Blue, an independent, non-partisan journalism organization, "The California drought, now in its third year and apparently deepening, may develop into the most significant test in American history of the capacity of residents, farmers, businesses and governments to ensure a state's water security in the new era of climate change."

Edwin Maurer, associate professor of civil engineering and internationally renowned expert on climate change, agrees that this is a momentous time. Maurer explains that the ramp-up in heat resulting from global climate change makes droughts start earlier, last longer, and be more intense. "It's a complex picture, but especially in the southwest, that is going to be the case," he said. Intertwined with other factors such as snow on the ground for less of the year and the incidence of more wildfires, soils are drying out more which leads to hotter air. All these factors deepen the drought, and they are all becoming more intensified. "Roughly every ten years we experience a drought in California," he continued. "In the past, we've looked at it as something we need to deal with 'this year.' We need to think more seriously now about planning for reduced availability of water in the long-term rather than going into drought-response mode and then backing out once the rain starts to fall. We need to change the infrastructure so we don't panic every five to ten years."

Recharging California's groundwater and managing its use in a more conservative, concerted manner is an important step toward water solvency. "We use groundwater as a buffer when there is not enough surface water to serve our

Photo: Heidi Williams

No swimming, no diving … no problem in parched lakebeds like Chesbro Reservoir in Morgan Hill, California.

needs, but even in a wet year about forty percent of our water demand is satisfied by pumping it from our aquifers. Santa Clara Valley Water District does a good job of managing and monitoring its system, but in California's Central Valley there is no one authority in charge—no one monitors how much is pumped or where the levels are. Proposed legislation is working its way through to address a process for groundwater management and that would be a huge help."

For now, Maurer said, the big payoff comes from conservation. In the agriculture sector, 30 to 50 percent could be cut back by converting to drip or sprinkler irrigation rather than flooding. And farmers are experimenting with "managed stress"—intentionally depriving plants of water in a calculated way to produce a stronger crop. In the urban sector, the largest water usage is residential, with landscaping accounting for the biggest chunk (we do love our lawns in California!). Changing our aesthetics to favor native vegetation and implementing standards to mandate dual plumbing to use reclaimed water for flushing toilets could go a long way toward a more sustainable future.

"I always stress in my classes that we shouldn't point our fingers at others," said Maurer. "We all have our own challenges based on our unique geography and climate. We need to look at what works and how to implement those things. There are tons of interesting approaches being taken and a lot of healthy dialogs are happening."

Onboard with online

Frank Barone on campus at Universidad Católica del Uruguay

MOOCs, Massive Open Online Courses, are causing a stir in academia. But while the opportunity for reaching thousands of students who would otherwise not have access to higher learning appeals to faculty at a Jesuit university whose dedication to social justice and global engagement are cornerstones of its very existence, the nuts and bolts of how to enter this arena while still providing personalized education has been a challenge for the engineering professors at SCU.

"Offering a class fully online goes against the grain of what we do here; for me, a hybrid works," said Aleksandar Zecevic, professor of electrical engineering and associate dean of graduate engineering programs. Last winter, Zecevic offered a hybrid version of ENGR 343, Science, Religion, and the Limits of Knowledge, at St. Xavier's College in Kolkata, India, recording seven of the ten lectures for online viewing and presenting three in person. "For this course, I start with the science that we all agree on. Beginning from a place of shared understanding opens the topic of religion and allows people to question their own common sense." Zecevic finds these ground-laying lectures are easily handled online, but when the subject matter turns to more controversial topics such as miracles and pluralism, he likes to be there, in person, to enable a fully interactive dialog. "It makes a huge difference that I am there; it is much more effective than a purely online class. Without exception, students noted in their evaluations that the interactive piece was the most valuable component of the course. That's what is unique about how we teach here at SCU—the personalized interaction with the students."

Seeing it work so well in Kolkata has opened doors, and SCU recently signed a three-year Memorandum of Understanding with St. Xavier's College in Mumbai, India. Zecevic will be offering the course concurrently for students in Kolkata and Mumbai next winter, and this fall he is teaching a joint class for students in Santa Clara and Uruguay, presenting in-person lectures at each location.

South America was also the destination for Department of Engineering Management and Leadership chair Frank Barone last summer. Universidad Católica del Uruguay is starting an Engineering Management Program of their own, and they asked Barone to offer EMGT 380, Introduction to Systems Engineering, to their students. He traveled to Montevideo, presenting the first two lectures there before moving to a live online format.

"Though I wasn't teaching the course at SCU at the time, I wanted to do my class live," Barone said. "It was nice to meet the students in person first before giving the rest of the lectures remotely. We got to know each other, which enabled better interaction throughout the course." Homework assignments and exams were handled via email; office hours were a little more flexible, to say the least. "I was available twenty-four hours a day to answer questions," said Barone with a smile.

"The students were excellent," he added. "They understood the concepts and did a great job on their group projects. I was happy to learn that everything we could do at SCU could be done with a class online. It's valuable for universities to be able to add to their curriculum in this way, and it enhances the experience for students—they get a different point of view from those in other countries."

Also commenting on the benefits of taking Santa Clara engineering on the road, Zecevic said, "It's not about making more money; it's about taking the things we do that are interesting and different and bringing them to different parts of the world. This opens doors and brings great visibility to Santa Clara. And having our students interact with peers from some of the top schools worldwide is a tremendous experience. Santa Clara engineering is being taught on three continents now, I'd love to see us in Europe one day."

TEACHING THE TEACHERS

Photo: Heidi Williams

Robert Marks (left) helps with an experiment during the teachers' workshop.

> *"For the first time, [students] were all immediately able to understand one of the concepts that has traditionally been a stumbling block for at least half the class."*
>
> *— Robert Marks*

It's a common problem: you go to a workshop, learn some exciting new methods for doing what you do in a more innovative and effective way, but when you step back into your workaday world, you find the changes you'd like to make require too much work, so the ideas and intentions are pushed aside.

The same thing can happen to university professors who try to integrate new methods into an "old-school" lecture style of teaching; even if they had time to redevelop a class, trying out new methods in front of students can be intimidating. So last summer, in an effort to turn intentions into successes, the School of Engineering incentivized faculty to learn and put into practice some new teaching techniques. The plan: faculty would attend teaching workshops and practice sessions and would receive supplemental pay to rework one of their own courses and implement it in the coming year.

Partnering with SCU's Faculty Development Program, participants attended a two-day workshop to see how technology could enhance learning in and out of the classroom. They also learned how to write effective learning objectives and how to reinforce concepts through "active learning." A supplemental workshop, devoted specifically to engineering, included a demonstration class led by master teacher Dr. Allen Estes, head of the architectural engineering department at Cal Poly, San Luis Obispo. In the demo, Estes played music, got people out of their seats to participate in an experiment, called on each class member by name, and kept everyone engaged in the learning process—giving the professors a perfect example of how they could run their own classes.

Participants were then given time to rework one of their classes before reconvening to practice teaching in front of their peers; their performance was videotaped and written assessments were provided. After a few days of tweaking based on the assessment, they taught for each other again, and were once more videotaped and assessed. Participants agreed that the demo class and practice sessions were crucial components in the workshop's efficacy.

Robert Marks, mechanical engineering academic year lecturer, put his knowledge to use immediately, adjusting how he taught thermodynamics during the summer session. Rather than trying to implement all the new techniques at once, Marks started with creating clear learning objectives and building activities into his classes. "I found I was able to cover more information by adding activities, and student learning improved. For the first time, they were all immediately able to understand one of the concepts that has traditionally been a stumbling block for at least half the class." Marks also now incorporates both equations and graphical illustrations in his board notes to address students' different learning styles. "It was a very productive workshop," he said; "there are a lot of things to work on, a lot of techniques to perfect, but the tools really are helping me to improve my teaching. Much of what took place in a traditional classroom still goes on, but adding a demonstration, calling on students more often, and implementing some of these changes definitely makes a difference and changes the mood in the classroom."

MORE POWER TO THESE SUMMER SCHOLARS

For two months this past summer, one graduate and 10 undergraduate engineering students were paid by the School of Engineering's Latimer Energy Lab to design and build a prototype of a solar-powered, autonomous vehicle and wireless charging station. "We are in the midst of a revolution that will affect our lives dramatically," said Tim Healy, lab director and professor of electrical engineering. "Electric vehicles will dominate transportation, and energy storage will change everything. If our students have a leg up on these technologies, career opportunities will be wide open."

Photo: Heidi Williams

Mike Wagner (center, in yellow shirt) gets a demo of the solar-powered car and charging station from the Latimer Energy Scholars.

Knowing that those in this groundbreaking field need a thorough understanding of how multiple engineering disciplines work together, Healy included the issues of solar power collection, controls systems, energy storage, wireless charging, and autonomous vehicles into the challenge. He provided minimal constraints or guidelines on how to tackle the challenge, but met with the team regularly to check their status and offer assistance. "My role was not to mentor, but to enable. They really were very independent, and that was fine with me," he said. The students—Fred Feyzi, Stan Whitcomb (computer science and engineering), Brad Ydens (electrical/computer science and engineering), Alejandra Huitron, Danny Mendoza, Peter Roguski (electrical engineering), Drew Azevedo, Ryan Greenough, Mike Rudolf, Peter Stephens, and David Swan (mechanical engineering)—quickly got to work devising a plan of attack.

"We split up into teams: control, electronics/docking station, platform, and sensors. The first weeks were research overkill—reading things we may or may not need, but getting background. We didn't know where we were supposed to go or what parts we would need; it took a month for us to figure out which battery would work," said one of the scholars. But soon the platform team had the vehicle built using purchased items and components they'd created in the School of Engineering's Maker Lab; the sensors team had ruled out using parallax range finders or ultrasonic sensors in lieu of a photo resistor sensor and four ping sensors; and the control team set to work on GPS communication and efficient operation of the autonomous car. Meanwhile, the docking station/electronics group was figuring out appropriate battery sizes for the car and charging station and how to manage the power loss inherent in wireless systems.

Concerned that the team take a break from the project occasionally—it was summer, after all—Healy established an unconventional rule: every Friday afternoon the team (still on the payroll) had to get out of the lab and go out and do something. Though it wasn't stipulated that they do something together, they did. Hiking, trying new food at a Mongolian restaurant, and visiting the Intel Museum together built camaraderie. "Our Fridays off built team chemistry," one student said. "It was awkward at first but we became very close." This bond helped the team persist through difficulties.

"There was a lot of push/pull with the project; it seemed like we would get one thing to work and another would go the other direction. Dr. Healy helped by reaching out to engineers from National Instruments, Linear Technology Corporation, and Texas Instruments. They came in and offered suggestions, gave us boards to play around with, and showed us how to make the wireless charging more efficient. The guys at TI had worked on the Google car, so it was really cool to learn from them."

At the end of eight weeks, the team showed off their solar-powered autonomous car and wireless charging station to Mike Wagner '69 (it was his and wife Jolon's generous donation that led to the establishment of the Latimer Energy Scholars Program in 2011), sharing their enthusiasm for the experience and for the future of autonomous vehicles. "Right now, it's just barely an idea, but it could get very big very fast," said one team member.

The team sent Dr. Healy a postcard from their Friday afternoon visit to the Intel Museum.

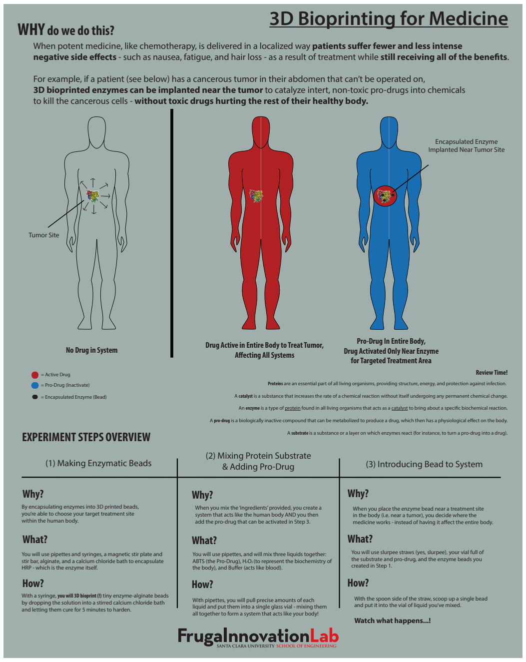
Bioengineers bring 3D tech to The Tech

The School of Engineering's Frugal Innovation Lab (FIL) has teamed up with The Tech Museum of Innovation in San Jose, California, and their partners NASDAQ OMX and Accenture to present a series of Social Innovation Workshops showcasing some of the exciting ways technology is being put to good use for social benefit. In four sessions this year, FIL staff and SCU engineering faculty and students create a fun environment of interactive learning in The Tech's basement (which is used to teach all sorts of engineering or tech-based projects) for teenagers to explore topics as varied as sustainable building materials and techniques, solutions for detecting water pathogens, and mobile phone apps that can improve lives of people in disadvantaged communities, locally and globally.

July's workshop focused on 3D Printing for Humanity. Here, 40 teens selected through The Tech's Young Innovators Scholarship Program participated in a number of hands-on activities, one of which was led by Department of Bioengineering Assistant Professor Prashanth Asuri and students Sabrina Cismas, Jeffrey Kunkel, William Leineweber, Casey O'Brien, and Mallory Williams. Participants were briefed on how engineers are using 3D printing to mitigate the negative side effects of cancer treatment on patients by delivering a pro-drug (a biologically inactive, non-toxic agent that can be metabolized to create a drug) to the entire body and then implanting 3D bioprinted enzymes near the site of the tumor to catalyze the pro-drug into a biologically active chemical compound that will kill the cancerous cells in that particular area without harming the rest of the body.

To demonstrate this concept to the attendees, SCU students created a simplistic rendition of an *in vivo* system on a laboratory benchtop. "A main goal of the experimental set-up was to mimic tumor site conditions so that students could tangibly grasp the role of enzymes in a targeted drug treatment," said Cismas. Teens were introduced to lab safety guidelines before donning lab coats, gloves, and goggles. Once outfitted, they used tools of the trade (pipettes, syringes, magnetic stir plate, et cetera) to 3D bioprint tiny enzyme-containing alginate beads. Then, in a glass vial meant to represent the human body, they created a substrate, mixing two solutions that characterized the blood and biochemistry of the body with a pro-drug. Finally, using a Slurpee straw, the budding bioengineers spooned a single enzymatic bead into each of their vials. What the students didn't know was that the substrate contained a colorimetric agent, so when they introduced the enzyme bead to the solution containing the pro-drug, the activation of the pro-drug to a drug was immediately apparent when the liquid changed from clear to a blue color.

"The experiment was well received and the kids asked a lot of good questions—some about how this is being done now, which is hard to answer since the process is still in research; but they were engaged and grasping the concept," said Kunkel. Participants took the experiment even further by investigating how outcomes changed by making the beads without the enzyme, and by adjusting the amounts of the various solutions, or experimenting with extrusion of the beads. "I learned I like teaching. They were so happy to learn something new, and it made me happy to see them learning," said O'Brien.



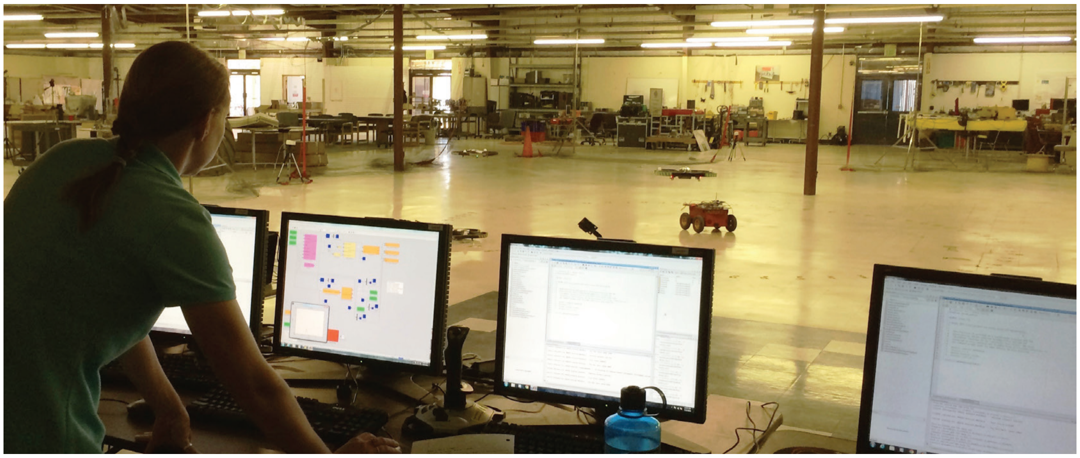
This poster took participants through the how and why of the 3D printing drug delivery experiment.

"As the research continues, the applications of this technology will extend well beyond use in chemotherapy," said Asuri. "But for now, we introduced to the students how 3D printing technology could be used to interface biomolecules or biological entities with synthetic materials and the possibilities this could bring to promote human health and medicine."

"The level of subject matter that these middle and high school students are able to engage with is incredible," said Elizabeth Sweeny, FIL director of programs and partnerships, continuing, "What excites us about these workshops is that it gives a direct conduit for students to harness their skills and intellect to build, use, and explore technology for societal benefit."

Robotics students stay busy at the lake and in the lab

Photo: Heidi Williams



Jasmine Cashbaugh puts the drones through their paces at the RSL's facility at Moffett Field.

Summertime … and while the living might not be easy, it's not too shabby for the team in the Robotic Systems Laboratory (RSL). For years, this world-class field robotics program has had undergraduates, master's, and Ph.D. students running satellite missions for NASA and conducting research in partnership with the Monterey Bay Aquarium Research Institute. And now they are beefing up their operations in Lake Tahoe, adding drones to their fleet of aquatic vehicles that have been actively researching and mapping the geology of the lake for more than a decade in partnership with the U.S. Geological Society and University of Nevada, Reno.

In June the team headed to Tahoe to test a prototype fleet of AUVs (autonomous underwater vehicles), demonstrating the ability to control the formation of the robots, which may ultimately support tasks such as oil well inspection and environmental cleanup. They also tested a new prototype of an ROV (remotely operated vehicle) made from hobby-class electronics and outfitted with a sonar tracking system and cameras to give a view of the lakebed to the crew on the RSL's boat—Christopher Kitts, lab director and associate professor of mechanical engineering, Ph.D. student Michael Neumann '03, Mike Vlahos '14, and Kristin Berbawy, a teacher at Fremont's Irvington High School who has interned with the team the past two summers as part of IISME (Industry Initiatives for Science and Math Education). Berbawy credits Kitts with helping her get a robotics course off the ground at Irvington last year.

Another friend of the RSL, Lloyd Droppers (who works at an astronautics start-up) was in one of the lab's kayaks, helping with retrieval and management of the ROV's tether, and Ph.D. student Jasmine Cashbaugh was on shore hoping the wind would die down long enough to get her drones in the air. (Sadly, it didn't happen that day.)

The ROV was performing admirably until Vlahos noticed the gauge was registering 96 percent humidity; the robot was pulled up out of the water for a quick inspection, and a leak was spotted coming from the plug in a donated piece of equipment—a setback that couldn't be mended with the zip ties, clamps, cable, or any of the other various and sundry items kept aboard that might be utilized for a quick fix. "As they test these prototypes and put new equipment in the water, the students encounter a lot of unexpected challenges. We learn far more than we wanted to learn," said Kitts with a laugh as the day's mission was called to a halt.

When the team returned to the Bay Area, Cashbaugh resumed her research at the RSL's facility at Moffett Field's NASA Ames Research Park. She is determining how best to control a group of quadrotor drones to fly autonomously in formation following a Pioneer Landrover. Positioning them around a testbed area marked with electrical tape to delineate the angle of separation between each robot, she tests them in a range of separation angles to find the ideal configuration for tracking a moving object to produce the best overall picture. Cameras mounted on the front of the drones send location data to a control computer, which uses Simulink and Matlab to compute drive commands and then transmits instructions to individual computers that run the aircraft. All tests are videotaped as she moves the robots around the field. It's a painstaking process but Cashbaugh said, "The project is going well. I've gotten a lot of the math worked out, and the results I get from using two or three drones can be applied to larger groups of robots."

The RSL already has customers clamoring for this technology. They are in conversations with SCU's Facilities Department to explore useful applications and have already conducted a test inspection of the University's extensive solar arrays, which may lead to identifying normal wear and tear as well as finding "hot spots" using an infrared camera. The team has also had the drones performing initial demonstrations of environmental monitoring, working with a Tahoe group to survey growth of the endangered Tahoe Yellow Cress plant, which often grows in spots that are not easily accessible. In addition to measuring the extent of growth, Kitts notes that the RSL's near-infrared camera could detect chlorophyll activity in the plant to gauge its health. "The potential for drones is tremendous," he said. "Another of our students is researching the use of drones for delivering medicine to remote villages in Africa. This is just the beginning of some very exciting work."

Photo: Kristin Berbawy

From left, Michael Vlahos, Lloyd Droppers, and Jasmine Cashbaugh at work on the sparkling waters of Lake Tahoe

BIG DATA—A BIG DEAL

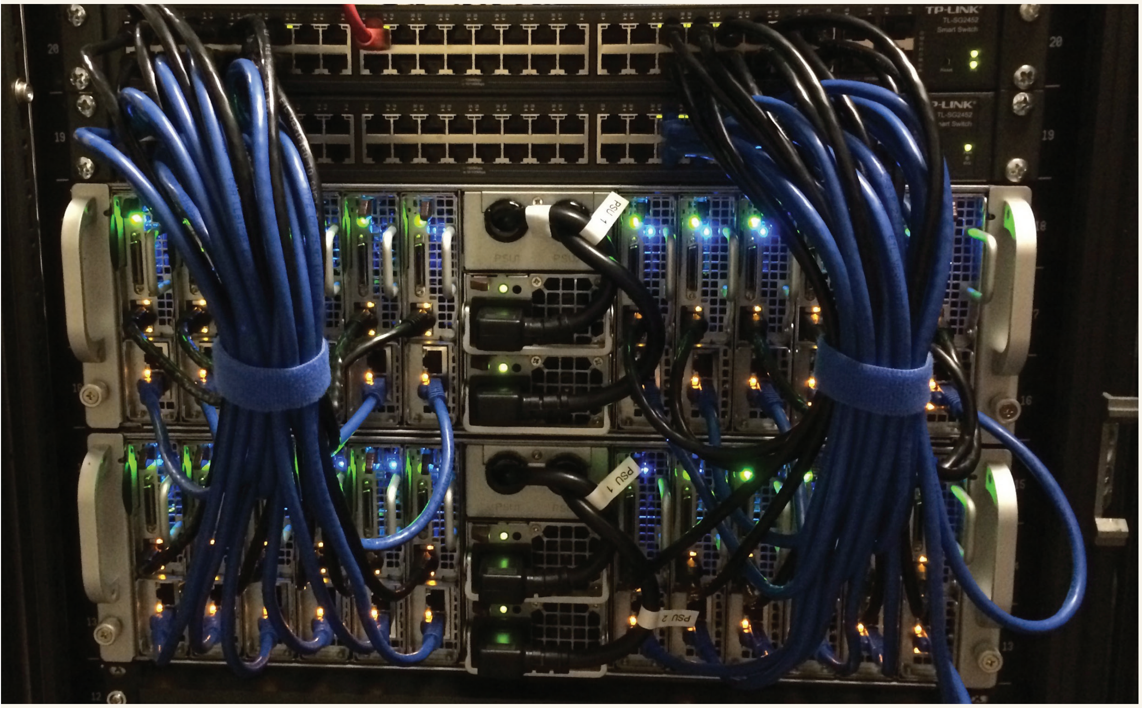


Photo: Heidi Williams

The School of Engineering's new Hadoop cluster handles Big Data using little space.

Tired of scrolling through your cable provider's seemingly endless television listings to find a program you want to watch? Well, my friend, those days are numbered. Just as Amazon or Google offer suggestions for products or websites based on your online history, soon your TV will discern your viewing preferences based on the programs you watch. How is this done? Through Big Data—a process where multiple computers work simultaneously to mine and make sense of vast amounts of data (we're talking terabytes and even zetabytes here)—and SCU's computer engineering assistant professor Yi Fang is helping to bring that technology to fruition, supported by a recent funding of $500,000 from Santa Clara–based TCL Research (TCL is the world's third largest television and fifth largest mobile phone manufacturer).

"The next generation of TV will connect with the Internet," said Fang, "and it will know what has been viewed, will analyze the content of those programs to determine the users' preferences and taste, and will then make recommendations." Beyond simply helping us choose our shows, tomorrow's TV will offer information about the products, locations, and people featured in the video—where you can buy that shirt, what derailleur is on that bicycle, or whatever topics are trending on social media.

"There are many technical challenges," Fang continued. "The sheer volume of videos that are available demands that we have a way to quickly process images and dialog to recognize all those products, styles, locations, people, subjects.... We need the computer to understand what the program is all about and understand what you are most interested in. Our work is to try to pinpoint the exact information the user wants and provide it seamlessly."

Additionally, with funding from the School of Engineering, Fang recently helped install a Hadoop cluster of 24 computer nodes and 250 TB data storage in the SCU Design Center. Data that is too large to be housed on a single machine is divided up and sent to the different computers to process a particular portion, after which the results are aggregated. The cluster is available for use by any engineering faculty member and Senior Design student teams who need to process a huge amount of data. Fang is also using it to analyze more than one billion webpages—building an index, mapping between each word on every page in every language to help advance the search process. That's Big Data!

Fang's team also works with engineers and researchers from other Silicon Valley companies, such as Google, Microsoft, Yahoo!, Apple, and SimplyHired. "Through these collaborations, I am able to access real-world data to address challenging problems in Big Data, and my students have the opportunity to engage deeply with Silicon Valley technology giants," he said. "It's a real advantage to be in this location. We cannot just stay in our school; we need to talk with people in the field and have access to their resources. Companies we work with, and visit frequently, have thousands of machines to process huge amounts of data. There's no way a university can have so many machines and so much real-world data, so it is very helpful to be so close to those who do."

To keep up with the need for engineers trained in this field, a new Big Data track within the graduate engineering master's program has been established. Comprising three new courses, COEN 240 Machine Learning, COEN 241 Cloud Computing, and COEN 242 Big Data, the series takes students from theory to infrastructure to application. Fang has also developed a number of undergraduate courses addressing web information management, web search and information retrieval, and web technologies.

"This is an exciting new path for the School of Engineering," he said. "This field is interdisciplinary—not just for computer engineering—because data is generated very quickly in every discipline. We need computational tools to process, analyze, and understand data. I think there are many opportunities to help other disciplines solve their own challenges in managing and understanding data and putting it to use."

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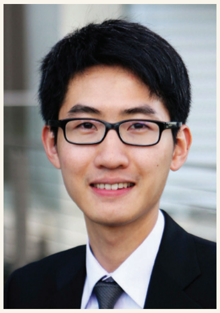

Talking fluid mechanics with mechanical engineering's newest faculty member, On Shun Pak, makes you recall the feelings you had when you first played with water as a kid, splashing in a pool. His passion for fluid mechanics is joyful and infectious.

Pak is fascinated by phenomena in fluids. "I'm particularly interested in the swimming of microorganisms—bacteria, or sperm, for example—and learning the physics that govern their motion. The way microorganisms swim in their environment is very different from the way we humans swim in water. If you put yourself in the microscopic world, you would have a hard time moving with your usual swimming strategies. It's remarkable that natural microorganisms can swim effectively in such environments to perform different biological tasks. If we can understand how nature designed these small-scale swimmers, we can use that information to design our own microswimmers—tiny robots to do amazing things like delivering drugs to targeted locations in our bodies."

Engaging students and helping them find their own fascination for the field is another passion of Pak's. "Fluid mechanics is such a funny subject; students can play with fluid all day long, and then they start to think about the phenomena and why fluid behaves the way it does. Soon they are contemplating the useful ways these behaviors can be put to use. It's fun to study the physics of fluids and learn about their engineering applications. "

Equally passionate about teaching and research, he feels at home with Santa Clara's model of the teacher-scholar. "Teaching is an art, and I am interested in the process: organizing the material, finding the best way to explain a difficult concept, and helping students get past a mental block. I am also recruiting graduate students to join my research, either on fundamental problems in fluid mechanics or on applications for biological systems. It depends on the students; we can tailor research to what they are fascinated by.

"Another reason I was drawn to Santa Clara is the mission component," he continued. "It inspires me to see how I can contribute to a more humane world as a teacher and scholar and hopefully inspire students to use their knowledge to change the world. That's the mission I have given myself."

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