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wisconsin engineer

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14TH ANNUAL PHOTO CONTEST

FEATURED ON PAGE 14

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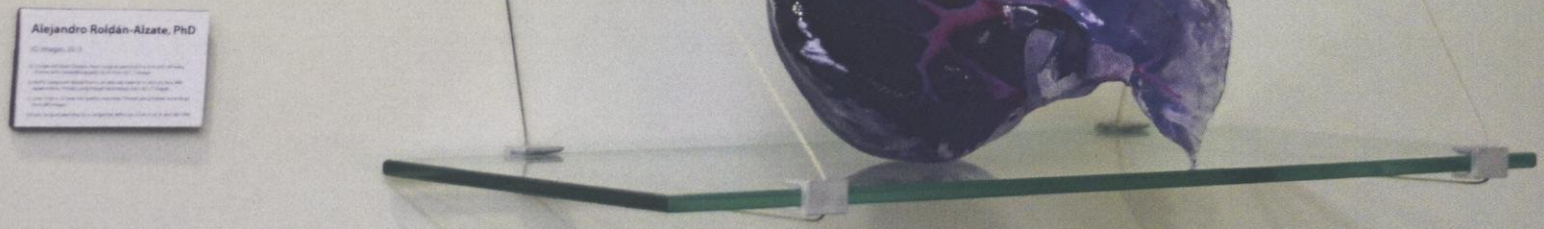
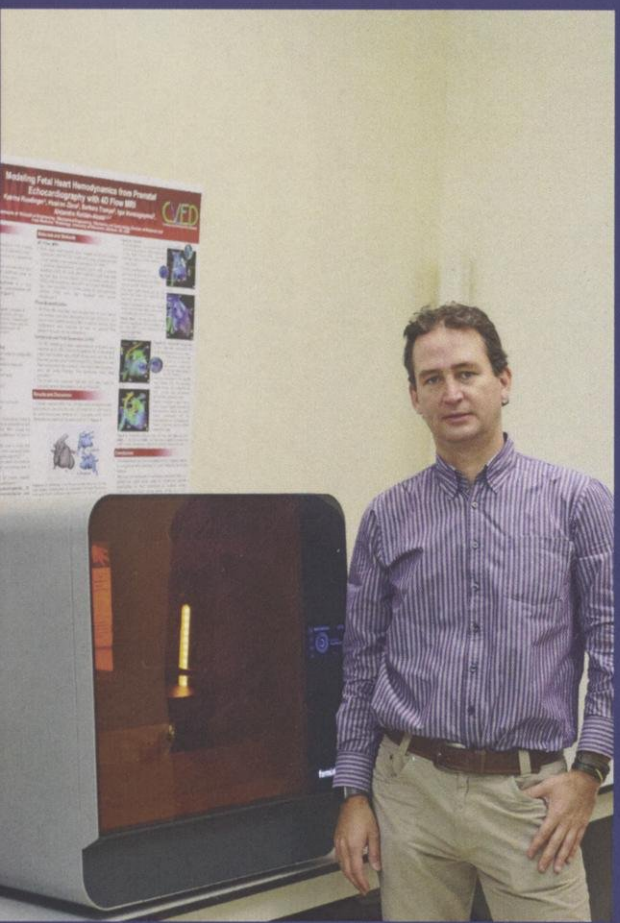


3D PRINTED MODEL OF A LIVER

WRITTEN BY
SYDNEY POLZIN



PROF. ALEJANDRO ROLDAN ALZATE

Over 40,000 children all over the world are born with a variety of heart defects that are often complicated to visualize, difficult to understand, and delicate to fix. Surgeons have very little room for error in open heart surgery to fix such defects, especially during the first few years of life. Alejandro Roldán-Alzate and his team developed a method of 3D-printing model hearts with these specific defects.

Roldán-Alzate has been a faculty member in the mechanical engineering and radiology department at UW-Madison since 2015. His current research focuses on fluid dynamics in the human body using medical imaging and engineering tools, such as computational fluids and experimental fluid dynamics. This research is applied to other fluid dynamics problems in the body, such as bladder voiding for individuals with diabetes, prostate obstruction, or after childbirth deliveries. However, Roldán-Alzate's research began by focusing on heart defects in children and adults.

"Most of my work has been centered on congenital heart disease, so kids that are born with malfunctional hearts or blood vessels," Roldán-Alzate says.

The origin of Roldán-Alzate's idea to 3D-print models began with attempts to understand the Fontan Operation, a surgical procedure in which blood is rerouted to get proper oxygenation in the lungs.

"Babies are [sometimes] born with one of the ventricles in the heart not working properly, so surgeons have to come up with an idea on how to optimize the fluid dynamics of the heart. The Fontan just reroutes the blood in places so it can be pumped efficiently," Roldán-Alzate says. "That's how we started working with models - how we brought 3D printing into this field… [Doctors] have the images but they cannot make a good 3D model of it in their heads… It started showing promising tools to train surgeons and how to approach this surgery."

"PARENTS HAVE THE HEART OF THEIR BABIES 3D-PRINTED AND THEY SEE WHAT'S WRONG AND WHAT'S GOING TO BE FIXED." -ALEJANDRO ROLDÁN-ALZATE

Since this approach gave optimistic results, Roldán-Alzate continued to further develop these models to help kids with a wide variety of heart defects. In addition to helping doctors and surgeons understand how to execute the surgery, 3D-printed models also teach families about what exactly is wrong with their child's heart and how the surgeon plans to fix the issue.

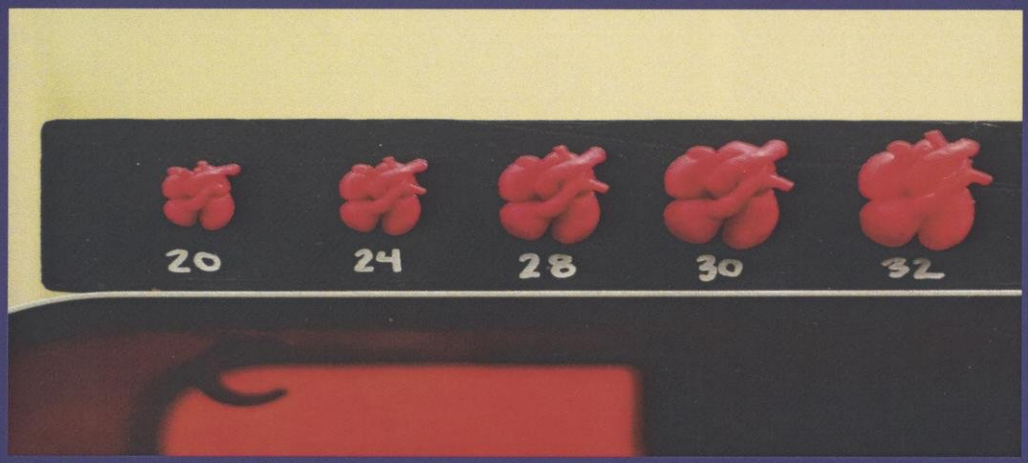
"With the echocardiography performed on those kids when they're fetuses, we 3D print those models and use them to teach the families what it is that the heart is failing on… In that way, parents have the heart of their babies 3D-printed and they see what's wrong and what's going to be fixed," Roldán-Alzate says. "We also 3D print it in a way that we connect it to a pump and we simulate what happens by measuring flow with MRI….We would like to understand how the flow works so we connect that to a pump and we get it to work….That's one of the main aspects of the lab as well is how can we translate immediately to healthcare."

Beyond creating models for the heart, Roldán-Alzate and his team started creating models for other parts of the body, such as bones, to improve surgical techniques. Evolving technology allows them to continue to develop this technology in new and innovative ways.

"With the advancement of technology currently we have a lot of children that can still live a relatively normal life after those repairs, which was not possible several decades ago because there were not the same resources," Roldán-Alzate says. "Trying to understand what's wrong with each condition motivates us to develop new things."

Roldán-Alzate has helped eight children through his new technology, which he assures is the best part of the entire process. 3D-printed models of the heart open up future opportunities for these kids.

"Kids are resilient," Roldán-Alzate says. "They walk in not being able to do much and they are miserable after they get surgery because they have open chest and connected to many tubes and the heart was up for a while, but then you hear that a month later they came for check-up and they're just running around and everything is working out fine and you see that families are happy. Having that impact is much more rewarding than any publication or anything like that."



3D PRINTED HEART OF AN INFANT AT DIFFERENT WEEKS OF PREGNANCY

PHOTOGRAPHER:
HRIDYESH (RAD) TEWANI

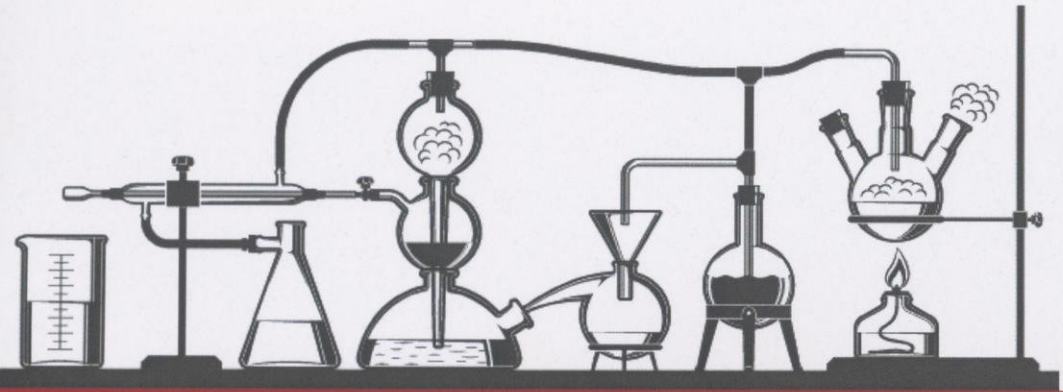
GRAPHIC DESIGNER:
JADEN SIM

CATALYSIS FOR TOMORROW

CATALYSIS HAS BEEN SPEEDING UP REACTIONS TO MAKE PRODUCTS WE USE DAILY FOR YEARS,FROM FOOD TO GAS TO PLASTIC CONTAINERS. UW-MADISON'S PRESTIGIOUS CHEMICAL ENGINEERING DEPARTMENT IS AT THE FOREFRONT OF IMPROVING CATALYTIC TECHNOLOGIES FOR OTHER IMPORTANT LONG-TERM GOALS: CLEAN ENERGY AND REDUCING CLIMATE CHANGE.

WRITTEN BY
SARAH GEROVAC

Catalysis, the process of accelerating the rate of chemical reactions, has been a focal point of scientific research for many decades. In the 21st century, catalysis continues to contribute to the manufacturing of 90% of the products we encounter daily, from modified foods, to gas for your car, to the majority of manufactured consumer products. How else can it contribute to a better future?



One UW-Madison faculty member of the chemical and biological engineering department, Professor Manos Mavrikakis, discussed with me the potential for his work on catalysis to contribute to an environmentally friendly world. His research team previously developed and now uses a methodology based on microkinetic and molecular modeling. During this process, they work iteratively with the elementary steps of a chemical reaction - calculating from quantum mechanics binding energies of reactants, products, and reaction intermediates. From this information, they can infer the decoration and shape of the catalyst's active sites when the reaction is taking place. Their models can help decipher what separates a good catalyst from a bad one for a given reaction and eventually develop better performing catalysts. This process lends itself toward improving the efficiency of catalysis in specific reactions, like electrochemical and thermal energy-generating reactions.

In terms of electrochemical reactions, Mavrikakis discussed the potential for these electrocatalysts in relation to renewable energy. "As electricity from renewable sources becomes cheaper, people are trying to use it to drive reactions," says Mavrikakis. "Catalysis for efficient energy production is at the core of catalytic systems that we choose to work on." As the efficiency of electrochemical reactions is increased, the ability of electrocatalysis to become a sustainable process fueled by renewable energy will increase as well.

Besides electrocatalysis, Mavrikakis also noted the potential for thermal energy-related catalysis in working towards a greener future by reducing the harmful effects of greenhouse gases like carbon dioxide and methane. "If we can capture CO2 where it's being produced and transform it into a useful liquid such as methanol... we can have an impact on the global community," says Mavrikakis. Using catalysis will improve the process of liquifying carbon dioxide and turning it into a fuel while simultaneously reducing the effects of greenhouse gases in the atmosphere.

As for where his research will end up, Mavrikakis believes we will continue to see the effects of the research conducted at UW-Madison for decades to come. "We are working as a community... I would argue that it's a long-term type of work," says Mavrikakis. "At the University, the chemical engineering department has been a post of excellence for 70 or more years now." Mavrikakis credits his colleague, celebrated catalysis researcher Professor James Dumesic, along with scholars such as late Profs. Robert Bird, Warren Stewart, Edwin Lightfoot, and Olaf Hougen for the success at UW-Madison in chemical engineering.

Mavrikakis explains that UW-Madison's chemical engineering department can "generate new technologies and jobs that feed back into the economy of Wisconsin." However, he believes that his work in catalysis in the future of renewable energy and reduction of the effects of climate change go beyond Madison and even the state of Wisconsin. His research has a worldwide scope, and as he explains, "if other countries don't do it too, it doesn't help. The entire humankind needs to work together and commit to controlling climate change." Catalysis is already an important part of our everyday lives, and as we continue to improve efficiency in processes like electrocatalysis and thermal catalysis, it can become an even bigger part of improving our world.

"AS ELECTRICITY FROM RENEWABLE SOURCES BECOMES CHEAPER, PEOPLE ARE TRYING TO USE IT TO DRIVE THE REACTION ... CATALYSIS FOR EFFICIENT ENERGY PRODUCTION IS AT THE CORE OF CATALYTIC SYSTEMS THAT WE CHOOSE TO WORK ON."

- PROFESSOR MANOS MAVRIKAKIS

PROF. MANOS MAVRIKAKIS WITH A MODEL OF AN ORBITAL

PHOTOGRAPH BY HRIDYESH TEWANI
GRAPHIC DESIGN BY JADEN SIM

Speeding up CRISPR's Path from Benchtop to Bedside

UW Madison researcher Krishanu Saha is working on bringing the revolutionary gene editing-technique CRISPR to the public's life.

Graduate student Dan Cappabianca inspects light-sensitive cells in Dr. Saha's lab.

Written by: Mingshuang Wang

In the last decade, headlines surrounding the therapeutic potential of CRISPR have been dazzling the public. This revolutionary gene-editing technique has ignited the hopes of healthcare professionals and patients alike in tackling genetic diseases. However, the question remains: who will benefit from CRISPR and how soon? The Somatic Cell Genome Editing (SCGE) Consortium sponsored by the National Institute of Health is working collaboratively to answer this question, along with Krishanu Saha, professor of biomedical engineering at UW-Madison, who is co-chair of the SCGE consortium.

The CRISPR-Cas9 system is derived from bacterial pathways to resist external viruses, majorly consisting of guide RNA and Cas9 complex. Once the CRISPR-Cas9 system enters the cells, the guide RNA would locate the target DNA, and then the "editor," Cas-9 enzyme, would cut the target DNA. "Researchers can simply replace the guide RNA for the specific target gene," Saha says. "Compared to other genome editing techniques, CRISPR shows remarkable simplicity and modularity," Saha says. "CRISPR's high efficiency motivates a number of researchers around the world, and labs are working on various types of disease with their interest."

Cappabianca prepares an agarose gel, which will later be used for electrophoresis.

On June 28, 2021, Intellia and Regeneron, the pioneering biotechnology companies in developing CRISPR genome editing, published the phase one clinical trial results of in vivo CRISPR therapy for the protein misfolding disorder ATTR. Researchers directly inject the CRISPR-Cas9 system to volunteer patients intravenously. For the first time, the clinical data indicate considerable efficacy and safety of in vivo CRISPR editing. Meanwhile, clinical trials in blood sickle disease, cancer, eye disease, and neuro diseases are also underway and show promising results.

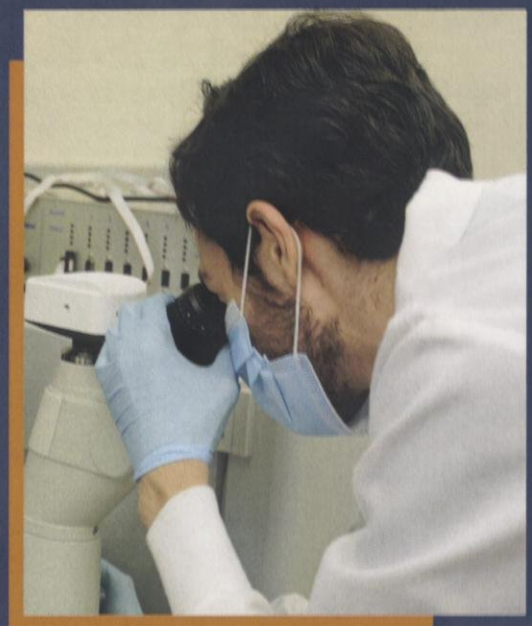
Despite CRISPR's safe and effective profile thus far, the clinical trials are still in the early stages, with a long road ahead to bring this technology to the public. With this in mind, the NIH launched the SCGE program, bringing together engineers, biologists, and clinicians to accelerate the process of bringing genome editing techniques to bedside therapeutics, with a significant focus on the CRISPR system.

"The common goal of the SCGE consortium is to apply genome editing technology to many types of disorders," Saha says. "Not just in brains, livers, infectious disease, but any disease that might arise."

The SCGE consortium includes labs across the U.S. and Canada. "One of our mandates is to share all data and tools as broadly as possible. We have a common toolkit," says Saha. "If people have new applications in mind, for example, editing particular cells in lung for cystic fibrosis application, they might be able to go to the toolkit, find the editor that would address that particular sequence, and the delivery system that delivers the editor into the lung efficiently." By sharing resulting data with the public, the SCGE consortium enables other researchers to make use of their already-developed tools, which reduces the time and cost in developing gene editing techniques.

To realize the high standards of efficiency, efficacy, and safety of gene editing tools required by the FDA, the consortium must overcome several technical challenges. First, it must improve the editor delivery system. How well the gene-editing tool performs depends largely on how well editors can reach the target genes without causing toxicity. The delivery systems most used in gene editing include viral vectors and nanoparticles, each with its own advantages and disadvantages.

"The viral vectors have additional risks, not only in immunogenetics potential when the body recognizes the capsid as a foreign protein, but also, the gene sequence of the virus can be integrated into human's genome. For some cell types, it's not a problem. However, in high doses, it has been considered a serious safety concern," Saha says. "The beauty of having non-viral strategies, for nano-capsules in particular, is that its polymer coating can be degraded soon after the delivery system enters the cytoplasm. They will not lead to unexpected gene editing." However, nano-capsules have limited space for editors, which hampers its ability to become an efficient delivery method. To find the most efficient and safe option for different diseases, the consortium has twenty ongoing projects to customize the delivery platforms.



Cappabianca examines the cells through a microscope.

Cappabianca prepares an agarose gel, which will later be used for electrophoresis

Graphic Design by Angel Salas
Photography by James Ballard

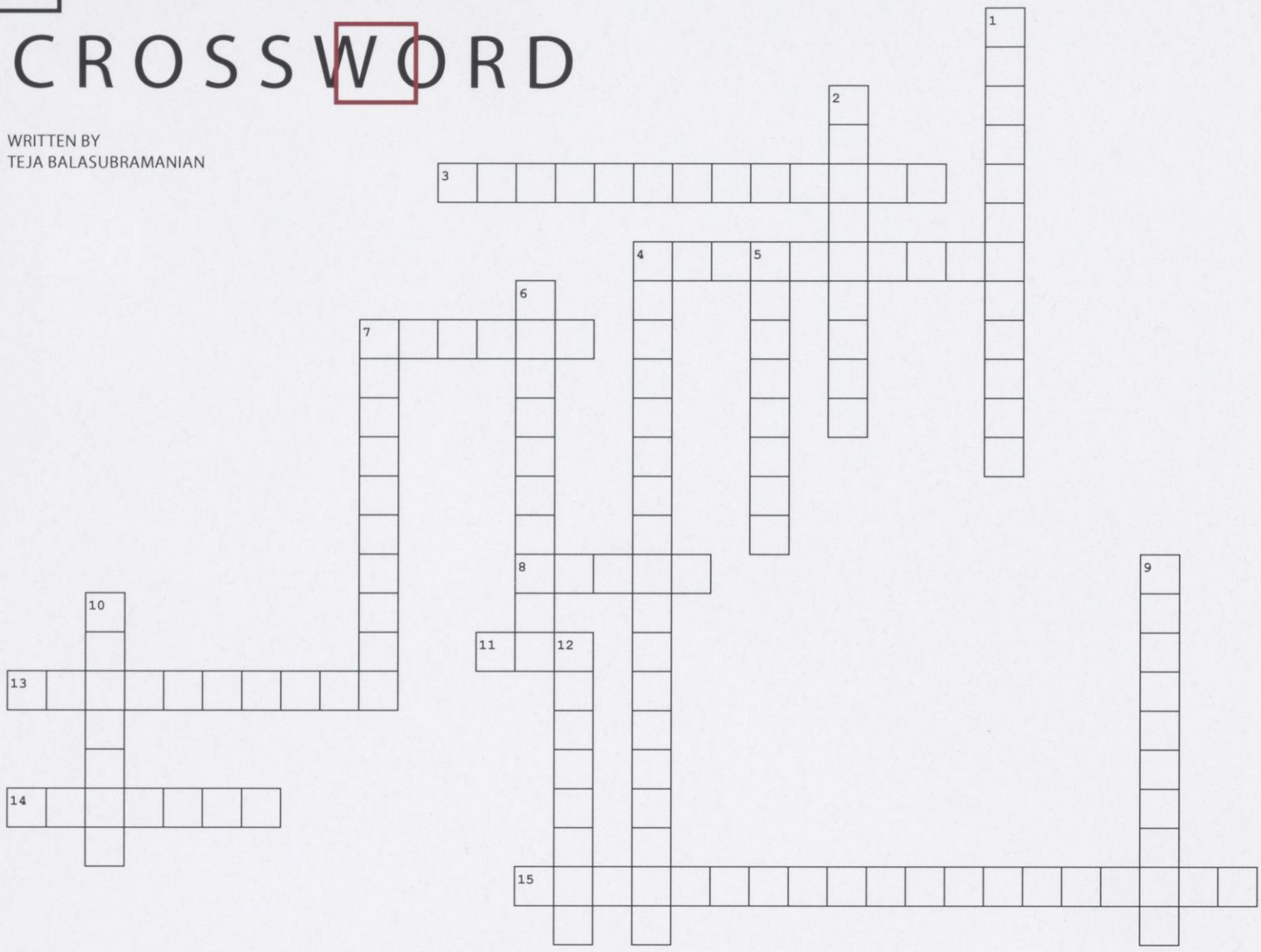
The consortium is also working to reduce off-target effects, considered a salient safety concern of gene editing. "For CRISPR particularly, there are twenty bases in cell genome that researchers intend to cut out. However, there are frequent spots where there are nineteen, for instance, the same bases," Saha says. "In such a case, editors would have both on-target and off-target cutting. The important task now is to understand the biological effects of off-target modification for a specific disease."

The natural DNA repair mechanism of cells can also be problematic in gene editing therapy. Once the Cas9 complex cuts the DNA double strands, the cell's innate DNA repair pathways can be triggered, generating genetic variances that could cause cancer. To avoid this, the consortium is further developing the CRISPR mechanism. Instead of using the Cas-9 enzyme, which is used to cut DNA strands, researchers attach another type of enzyme, which could change the single base on target DNA to edit the gene without breaking the DNA strands and inducing the DNA repair mechanism. The major challenge for this base editing technique is that the additional enzyme attached to the CRISPR system requires a larger delivery system, which is another bottleneck. "If it can be efficient enough, the base editing technique opens up a number of applications in cell types that are not amenable to traditional editing using DNA double strands break," Saha says.

Considering the rigorous requirements for safety and efficacy, realizing the application of CRISPR as widespread therapeutics for disease still requires further efforts. As the SCGE consortium's work increasingly steps on the public stage, it would arguably become strong momentum for the academics, industry, and other institutes to advance CRISPR. The joint efforts from all these organizations broaden the possibility for gene editing techniques in more and more treatment areas.

ENGINEER'S CROSSWORD

WRITTEN BY
TEJA BALASUBRAMANIAN



Across

3. Engineer that merges engineering and ____ science to sustainably build, design and operate infrastructure
4. Kind of engineer designs ____ wires and ____ poles (one word)
7. If you graduate from UW engineering, you are a ____ engineer. Hint: think school mascot!
8. Engineer that designs and builds tunnels and bridges
11. Abbreviation of tutoring services offered by the College of Engineering
13. This type of engineer might enjoy building robots or experimental cars
14. This engineer's job is to ensure an item is of good ____
15. What "source of water" does not work outside Engineering Hall?

Down

1. Type of engineer that makes tools and machinery for farms
2. Engineer that develops ____ that can help conserve energy or make high-resolution screens
4. This engineering major focuses on forces and the resulting deformations, accelerations, motions, vibrations and other action that they cause
5. Which engineer develops and designs ____ manufacturing processes (think flue, drugs and food)?
6. Kind of engineer studies Earth's origins, composition and evolution
7. Kind of engineer makes advances in technology for health
9. Kind of engineer that redesigns and hospital's emergency department workflows
10. Type of engineer studies the fission and fusion of atoms
12. Engineering discipline that focuses on the design, development, and managment systems that process, store, and convey informations

Answers: 1. Agricultural, 2. Materials, 3. Environmental, 4. Electrical, Engineering Physics, 5. Chemical, 6. Geological, 7. Badger, Biomedical, 8. Civil, 9. Industrial, 10. Nuclear, 11. ULC, 12. Computers, 13. Mechanical, 14. Quality, 15. Descendant Fountain

GRAPHIC DESIGN BY LUCAS BARTEL

INTERFEROMETRY
THE FUTURE OF UNDERSTANDING THE UNIVERSE ... THROUGH MAGIC?

FROM THE SMALLEST PARTICLES TO SOME OF THE LARGEST FORCES IN THE UNIVERSE, RADIO ASTRONOMY IS A DRIVING FORCE FOR MAKING DISCOVERIES.
BUT INTERFEROMETRY, AN EXTENSION OF RADIO ASTRONOMY, ADDS ANOTHER LAYER OF DISCOVERY THROUGH A COMBINATION OF TECHNOLOGY, COMPUTING, AND MAGIC?

WRITTEN BY
LUCY STEFFES

When the idea of a professional astronomer comes to mind, perhaps the first thing one pictures is a person sitting in a rural area in the middle of the night, squinting through a telescope, hoping to find some new star, planet, or asteroid. While this is certainly the case for the occasional astronomer or student enjoying a clear weekend, the story of radio astronomy and interferometry looks quite different. With its roots deep in the UW-Madison physics department, beginning with UW-Madison alumnus, Karl Jansky, who built the first radio telescope in 1928, radio astronomy has spread across the planet to explore the universe from the smallest particles to the largest driving forces of cosmology.

In the aftermath of World War 2, the United States found itself with a plethora of technicians full of knowledge of radio technology and communication, yet with no further use for their knowledge. As the United States began to look around the world in the early 1950s, they realized that they were falling behind when it came to radio astronomy infrastructure. By the early 1960s, the National Radio Quiet Zone had been established and the National Radio Astronomy Observatory (NRAO) had set up shop in Green Bank, West Virginia. At the heart of this 26,000 square mile zone, most forms of modern technology are restricted to listen for the whispers of the universe.

Interferometry in the United States was first explored at the Green Bank Observatory, and is further explained by scientist Dr. Will Armentrout. Armentrout works in mapping star-forming regions in the Milky Way using data from various interferometers across the globe. Interferometry, Armentrout explains, "is a technique of combining signals from disconnected antennae to form a larger aperture that is

THE GREEN BANK TELESCOPE, THE WORLD'S LARGEST FULLY MOVABLE STRUCTURE, AND WHAT WILL EVENTUALLY BE PART OF THE NGVLA

the size of the furthest distance elements." Armentrout further states, "your telescope does not have to be filled the entire way from the left side to the right side. You can now build telescopes the size of continents." This method allows for telescopes to be built with elements several hundred meters apart up to several thousand miles apart, being limited only by the size of the Earth. It is even possible to place an antenna in space with a second dish on the ground to further increase the effective size of the aperture.

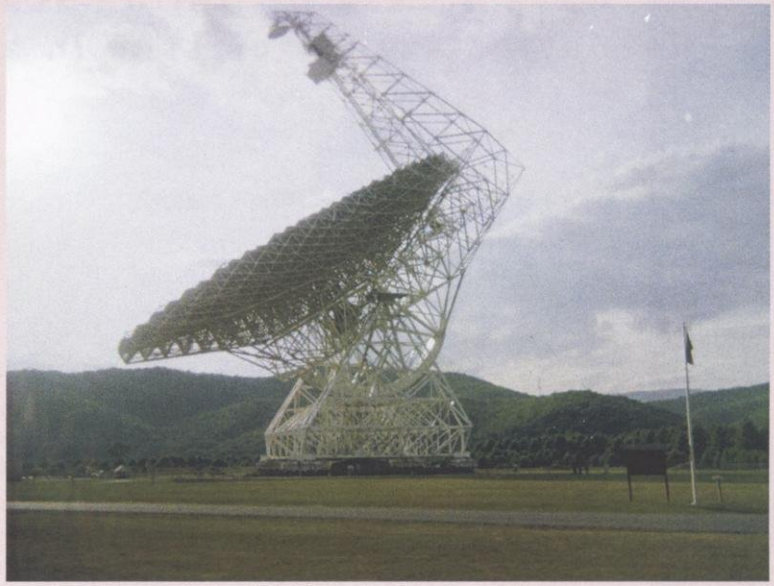
So why on this telescope, (often called Earth) could this be useful? When looking at the benefits of interferometry, a larger effective diameter, and thereby a larger aperture made possible by the multiple antennae, dramatically increases the resolution. Increased resolution makes it possible to see smaller objects and differentiate between small objects that are close together. Armentrout also states, "one thing that interferometers are great at doing is producing images." Single dishes only produce spectral lines, while the multiple dishes of an interferometer allow for maps and detailed images of smaller bodies, such as stars and planetary nebulae, to be produced.

"YOU CAN NOW BUILD TELESCOPES THE SIZE OF CONTINENTS."
- DR. WILL ARMENTROUT

While UW-Madison itself does not own any interferometers, there are smaller sized radio telescopes for student access and for teaching located in the astronomy department's Washburn Observatory and off campus at the Pine Bluff Observatory. Aside from teaching in radio astronomy, researchers at UW-Madison have shares and designated research time at large, international interferometers and radio telescopes. These include the Very Large Array (VLA), located in the deserts of Socorro, New Mexico, and several other individual radio antennae across the world, such as the Atacama Desert in Chile and the Appalachian Mountains of West Virginia.

Students and professors alike at UW-Madison use data collected by interferometers on a regular basis. Maps are made of detections of molecules in different regions of the galactic plane to indicate regions of potential star formation. The relative abundances of different atoms and molecules in various environments and stages of stellar evolution are also studied using data from interferometers.

Looking into the future of radio astronomy, the United States is moving forward with a project called the Next Generation Very Large Array (ngVLA) to create an interferometer across the entirety of North America that would increase the power of the VLA by a factor of 10. The core of the ngVLA would be at the VLA, with spiral arms extending into Arizona, Texas, and Mexico, and a large baseline of other dishes spread from Hawaii to the Caribbean.



THE GREEN BANK TELESCOPE

While astronomers can confirm that interferometry is in fact, not a product of magic, rather the result of advanced science and data processing, there is no denying the power or remarkability of this technology. The development of interferometry and the continuing advancement of technology in radio astronomy in general continues to push the field forward faster than ever before. Telescopes to this size also increase the rate of national and international collaboration, not to mention the recent influx in use of Zoom daily. Perhaps the real magic is in how the increase in the size of telescopes only makes this planet we call home smaller.

DESIGN BY LUCAS BARTEL

PHOTOGRAPHY BY LUCY STEFFES

ENG101: Intro to Survival Skills

Have a Case of Online School Syndrome? Learn how to navigate your classes in a post pandemic world!

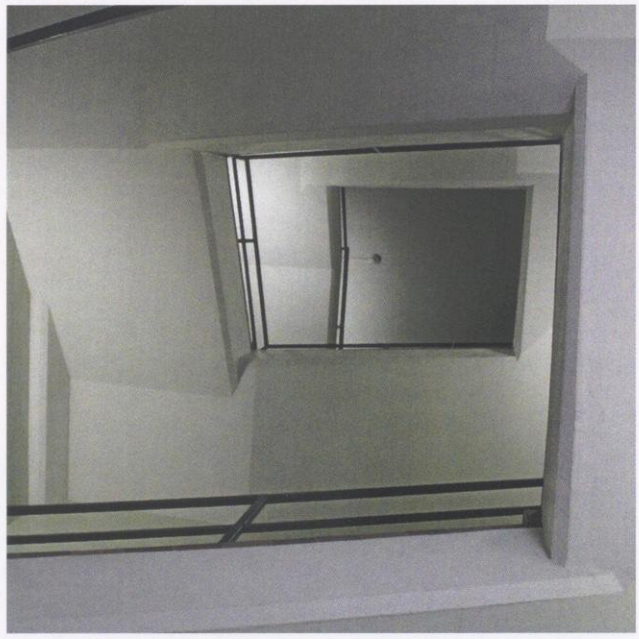
WRITTEN BY
ISABELLE EGIZIO

Welcome to the College of Engineering!

With UW-Madison returning to in-person classes this semester, thousands of college students just like you will once again swarm the campus – many for the very first time! Whether you are a first-year, second-year, or third-year freshman, this semester will not be without its obstacles. Between navigating the engineering campus and attending in-person classes for the first time, you will learn to overcome the challenges of attending college during a global pandemic.

For three classes of students used to paying full tuition for online classes, the constant rush of traveling across campus may present some problems. Long gone are the days where you could sleep until 10 minutes before your class started and join Zoom while still eating breakfast. Now, you may find yourself oversleeping and running up Bascom Hill to make it to your 8:50 a.m. calculus lecture. Even if you somehow manage to arrive on time, never underestimate the time it takes to find your room number – be prepared to spend an extra 15 minutes walking down the same hallway in the Mosse Humanities Building or staring at the directory map in Engineering Hall. If you happen to be particularly unlucky, you may find yourself navigating the basement of 1410 Engineering Drive. Better fit for the set of the next Stranger Things season, this modern dungeon is the reincarnation of your childhood nightmares. Instead of finding the next Demogorgon, these rooms house the college-equivalent human test subject: a sleep-deprived 5th year engineering student.

Beyond navigating the depths and hidden treasures of the engineering campus, the full freshmen year experience also includes managing your classes. With syllabus week over

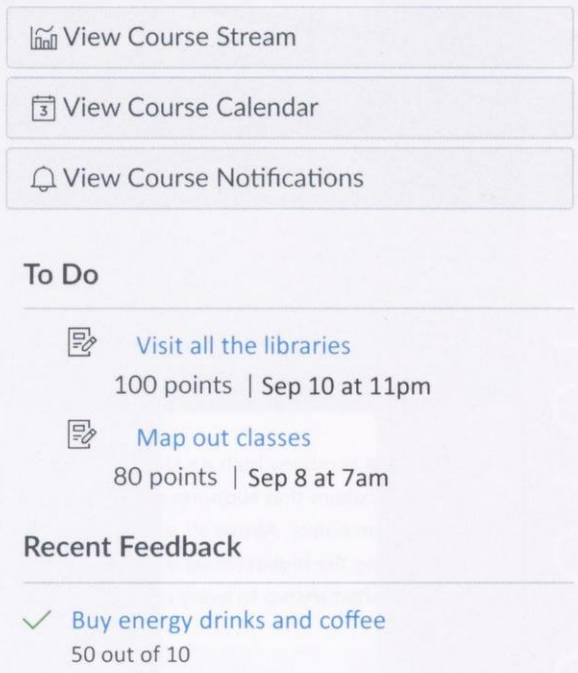


BASEMENT OF ENGINEERING HALL

as soon as it started, welcome your newfound love for caffeine as you strive to turn in all of your homework before the 11:59 p.m. deadline. Make sure to stock up on Red Bull, 5 Hour Energy, and every freshman's favorite drink, Bubbl'r, because these essentials will be your homework lifelines! Even when you finish your assignment more than five minutes before the deadline, DuoPush may make it difficult to see the Canvas confetti when it locks you out of your account for the second night in a row.

With late nights of doing homework, you'll be surprised how quickly midterm season approaches. For newcomers on campus, you'll find your fellow engineering classmates cramming for their next midterm one hour before the exam in the library. The library will become your second home during midterm week, so make sure to bring all of the essentials to get through those calculus practice exams. Even if you find yourself contemplating a major change at 1 a.m. in one of the study rooms, don't worry because we've all been there!

Once you pass all of your midterms, congratulations – you are now halfway through the term and get to repeat the entire process over again! Now, though, your commute to class consists of walking to classes during a blizzard and attending class in below-zero temperatures (who doesn't love winter in Wisconsin?) With only seven weeks left of the semester, you will be counting the days until winter break. By the end of the semester, you'll learn how to navigate the engineering campus, pass your in-person classes, and be one step closer to graduating in four years.



PHOTOGRAPHY BY ANNIE KRILLENBERGER

GRAPHIC DESIGN BY LUCAS BARTEL

2021 PHOTO CONTEST WINNERS

wisconsin engineer

OVERALL WINNER

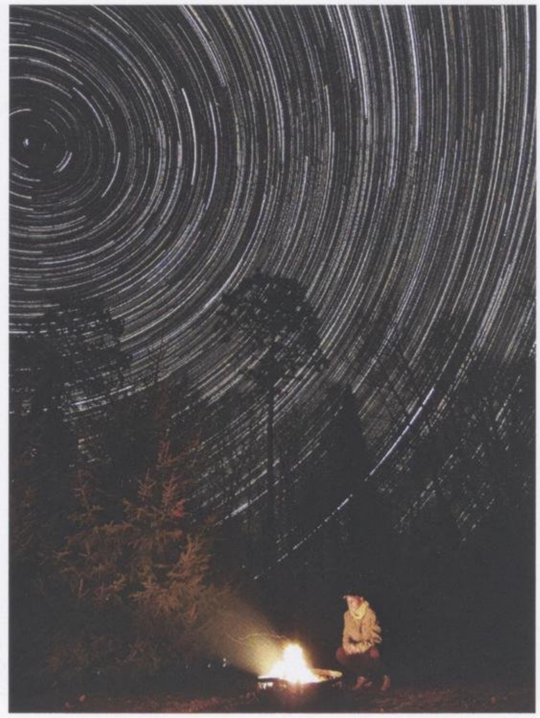
PRAIRIE STARS
KAITLIN MOORE

READERS' CHOICE

SUNBURST
HENRY FANG

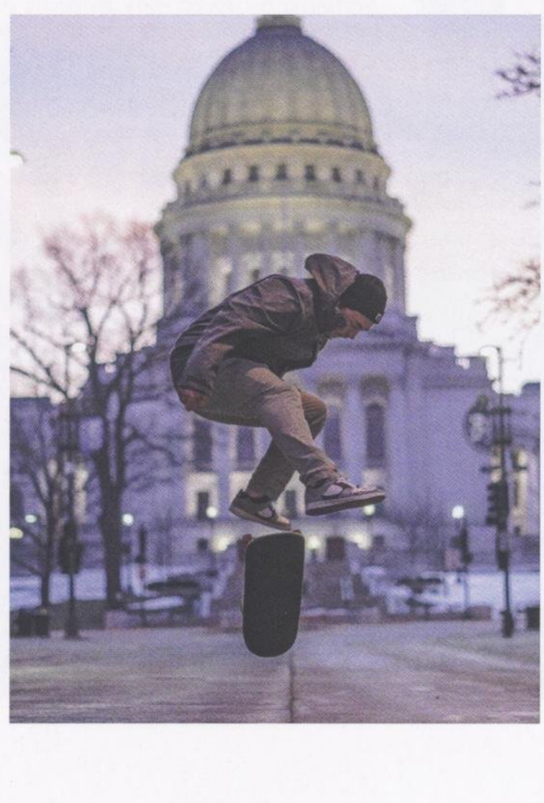
LANDSCAPE

AROUND AND AROUND AGAIN
BENJAMIN SPONG



CITYSCAPE

STATE STREET
SKATEBOARING SUNRISE
NICOLAS ALLEN



PORTRAIT

GLOW
BENJAMIN SPONG

STILL LIFE

TAKE A LOOK UP
KATIE ZETTEL

GRID-FORMING INVERTERS: A CRITICAL ASSET FOR THE POWER GRID

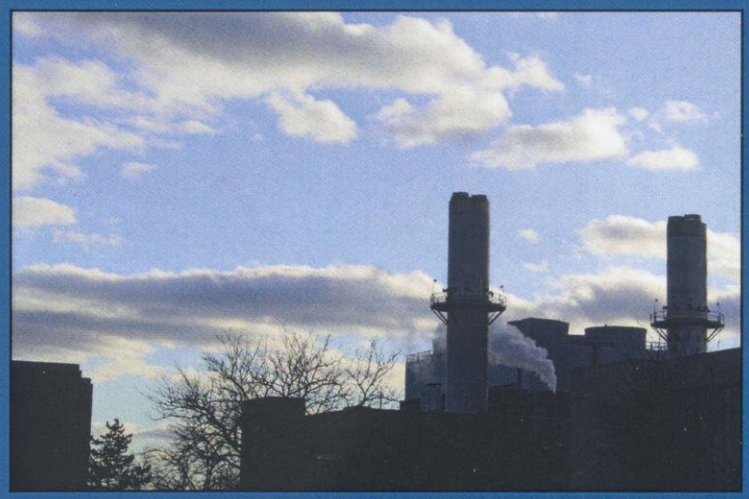
GRID-STABILITY IS IMPORTANT FOR MAINTAINING A RELIABLE SUPPLY OF POWER TO OUR HOMES. AS WE ADD RELATIVELY NEW POWER SOURCES SUCH AS SOLAR, AND WIND IN LARGE AMOUNTS INTO THE GRID, THE STABILITY OF THE GRID IS NEGATIVELY IMPACTED. TWO UW-MADISON PROFESSORS LOOK AT HOW AN ALTERNATIVE TECHNOLOGY FOR INTERFACING RENEWABLE GENERATION TO THE POWER GRID TO SOLVE THIS PROBLEM.

Written by: Vidit Agrawal

The power grid is a network connection responsible for providing power from big power stations to homes. Within the grid, power generation and load must be balanced to maintain reliable grid operation on time scales of milliseconds to seconds. As we are adding more renewable energy sources, power generation becomes variable due to uncontrollable natural factors, such as wind speed and sunlight intensity. This jeopardizes stability of the power grid and could cause the grid to fail and result in a massive blackout.

Professor Dominic Gross was among the first researchers to work on stability of power systems on the scale of milliseconds to seconds with massive integration of renewables and power electronics at ETH Zurich. He joined the department of electrical and computer engineering at UW-Madison to continue that research in the United States. The Department of Energy recently funded the UNIFI (Universal Interoperability for Grid-Forming Inverters) consortium in which Gross leads control research with 25 million dollars to evaluate and design grid-forming technologies at scale that address this problem. The consortium has experts from four national laboratories, twelve universities, and several multinational companies.

The Wisconsin Energy Institute on campus.

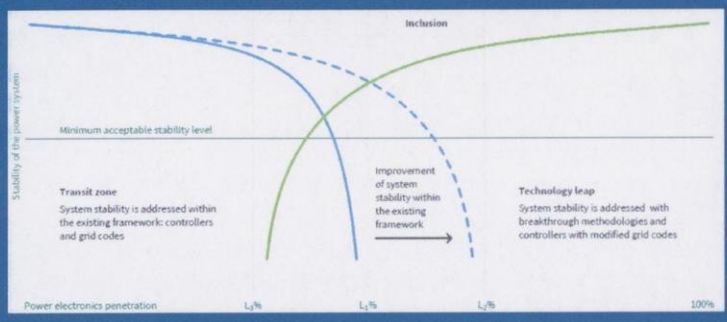


The smokestacks at the Charter Street Heeting and Cooling Plant.

Gross explains that the current grid is "built around the properties of conventional methods of electricity generation". Currently, grid-following inverters are used to interface renewables and do not contribute to balancing load and generation. This means we are not yet able to fully harness the advantages of renewable methods of electricity. Gross is helping develop and implement a new concept, the grid-forming inverter, which will provide the grid with more independence from big power stations and some level of autonomy.

Professor Robert H Lasseter, an emeritus professor in the department of electrical engineering at UW-Madison, was among the first to propose the idea of a flexible, autonomous microgrid. Lasseter is also part of the consortium as a member on the advisory board. "This consortium has brought the whole power industry into a focus on grid-forming inverters," says Lasseter.

Unlike grid-following inverters, grid-forming inverters autonomously balance the power system and provide grid support independently of conventional power stations. This characteristic is especially useful when dealing with energy sources like solar and wind that fluctuate. These fluctuations cause the power grid to be relatively unstable, as it needs to regulate power load and generation at very small-time intervals.



From MIGRATE Final Project Conference, Page 3

Deepak Divan, who was a professor in the department of electrical engineering at UW-Madison back in 1994, was among the first researchers to publish on the topic of grid-forming inverters, but the concept did not gain traction until the problem of decreased grid stability due to renewable integration became apparent in recent years. Grid-following inverters have been in use in power systems for decades. Lasseter has been pushing for more focus on grid-forming inverters for the past ten years, and this Department of Energy contract is a step in that direction. Right now, utilities are hesitant to explore changing the status quo because integration of grid-forming technologies into large-scale power systems and interoperability with existing equipment and paradigms has not received sufficient attention. Gross's consortium works towards removing that hesitancy.

"THIS CONSORTIUM HAS BROUGHT THE WHOLE POWER INDUSTRY INTO A FOCUS ON GRID-FORMING INVERTERS." - LASSETER

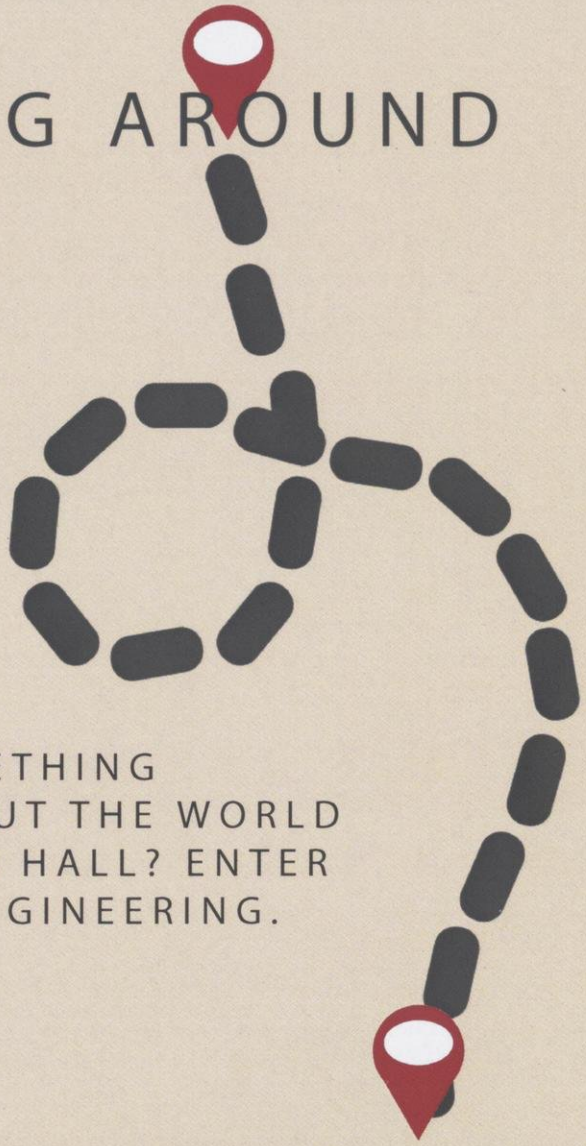
The solar panels on top of Gordon Avenue Market

Initially, the consortium will focus on how interoperability of grid-forming inverters can be ensured and seamless integration with prevailing operating practices can be achieved. Subsequently, the focus will shift to creating a whole new grid ecosystem to leverage the full potential of the grid-forming inverters.

The consortium believes that ultimately, the grid will use a hybrid solution of grid-forming and grid-following technologies to enable reliable and economically efficient operation of future power systems. Lasseter and Gross believe that the concept of big power stations will slowly fade away as renewables take over on the grid and will be replaced by smaller, renewable power stations heavily disrupting the way the power grids are developed. This consortium, and their work, is part of a bigger effort to increase the penetration of renewable energy sources in a power generation world.

Graphic Design by: Angel Salas
Photography by: James Ballard

TAKING ENGINEERING AROUND THE GLOBE: THE CERTIFICATE IN INTERNATIONAL ENGINEERING



HOW DO YOU GET A BUNCH OF 20-SOMETHING ENGINEERING STUDENTS TO THINK ABOUT THE WORLD BEYOND THE BORDERS OF ENGINEERING HALL? ENTER THE CERTIFICATE IN INTERNATIONAL ENGINEERING.

WRITTEN BY
BRIANNA FOTH

When you think "engineer," what's the first thing you think of? Perhaps problem-solver, creative thinker, and decent at math are all things that come to mind. But what about worldly? In an economy that is globalizing rapidly, many would argue that the fourth quality is now just as important as the first three. But how do you get a bunch of 20-something engineering students to think about the world beyond the borders of Engineering Hall? Enter the Certificate in International Engineering.

The Certificate in International Engineering is a 16-credit credential designed to get students to think about the larger world outside of the United States. The requirements include a minimum of six credits devoted to courses with a particular emphasis on the culture, history, geography, society, or institutions of a single country or region of the world. The certificate also requires students to live abroad in this particular region for at least five weeks, either to take university courses or to complete an engineering-related volunteer or work program. While language immersion is not the focus of the program, students can also count certain foreign language courses towards the certificate's 16-credit minimum.

Amanda Hammatt, Associate Director for Strategic Initiatives within UW-Madison's International Academic Programs department, is the main advisor for the certificate and has worked with students for over 10 years to help them plan their experiences abroad. "[The certificate] really exposes students to different ways to approach problems, issues, and challenges," Hammatt says. "It helps them become more aware of some of the cultural differences they might face on an international team, or even a colleague who sits next to them in an office who may be from a different country."

Hammatt also believes that having a deeper appreciation for cultural differences allows for better problem solving. "Whereas students who haven't had an international experience and haven't had additional exposure through these courses might see [cultural differences] as an obstacle… someone who's had this alternate experience may view that differently," Hammatt says.

Dante Fratta, an associate professor who teaches both undergraduate and graduate courses in geological engineering, recently became the new director of the Certificate in International Engineering. He believes that in a globalized world, having an international mindset is essential. "At the University of Wisconsin, we try to train the leaders, the engineers of tomorrow. So if we are going to do that, we will have to be able to engage in the world, and to be able to understand and be humble about our contributions and learn from the contributions of other countries," Fratta says.

Studying abroad as an engineer certainly comes with its

challenges, and both Hammatt and Fratta acknowledge that the process can seem daunting at first. "A lot of engineering students will come into my office, and they'll say, first thing: 'Despite the fact that studying abroad is going to set me back academically, I've decided that's okay, because I really want to have this experience,'" Hammatt recalls. "But often, they are pleasantly surprised when we walk through the equivalencies and they realize that they can take engineering courses abroad and fulfill requirements, and they learn that they actually aren't likely to get behind."

"But to be able to do that, you have to plan ahead," Fratta adds,

"AT THE UNIVERSITY OF WISCONSIN, WE TRY TO TRAIN THE LEADERS, THE ENGINEERS OF TOMORROW. SO IF WE ARE GOING TO DO THAT, WE WILL HAVE TO BE ABLE TO ENGAGE IN THE WORLD." - PROF. DANTE

whose biggest piece of advice for students is that they contact an advisor as soon as they figure out that they would like to go abroad. "I would recommend that if you're a freshman and you're thinking about it, start making plans in your freshman year."

Planning ahead isn't the only challenge that students have had to face in recent years. Just a few months into 2020, study abroad programs around the world began summoning back their students following a global surge in COVID-19 cases. UW-Madison fully cancelled all its spring and summer study abroad programs by early March.

"As you'd recognize, this has been very disruptive for everybody," Fratta says, recalling the duration of the pandemic. "I'm sure that your professors have been flexible in your classes; we have also had to become flexible with the certificate. Trying to maintain the spirit but being understanding of the constraints that we have been under the last eighteen months." Some of that flexibility has included allowing the option for students to enroll in virtual study abroad programs they can participate in from their own homes. It has also included greater flexibility around where students choose to focus their studies.

"For the certificate, we've implemented some exceptions during this time … for example, [students] can declare Europe as their focus for the certificate, but then they might do a virtual program that's focused on Japan," Hammatt says. "That's typically not allowed, but we were willing to do that to get through this challenging time."

Despite these challenges, both Hammatt and Fratta are optimistic about the coming months, as people continue to get vaccinated and booster shots become more widely available to the public. "[Study abroad programs] are slowly reopening to different places in the world. Mainly, right now, it's Europe, but we hope that as the world starts to control COVID, we'll be able to open this to other places as well," Fratta says. "But, while the academic programs are coming back strong, we still recognize that we have challenges."

Asked if there is anything else he would like students to know about the certificate, Fratta reiterates his earlier advice: "Plan ahead, plan ahead, plan ahead. Amanda is great, and I am willing also to talk with you if you're interested, so you can be able to think about all the steps you want to take to be able to complete all the requirements within the time of graduation. But again: plan ahead."

For more information about the Certificate in International Engineering, students can seek out its page on UW-Madison's virtual guidebook.

UW-MADISON 2015 SUMMER STUDY ABROAD TRIP TO CHINA.

DESIGN BY LUCAS BARTEL
PHOTOGRAPHY BY AMANDA HAMMATT

LIMITLESS DATA IN A LIMITLESS FUTURE

APPLYING DATA SCIENCE AND MACHINE LEARNING TO IMPROVE BUSINESS PROCESSES

WRITTEN BY
PRASOON TANDON

The root of all innovation, the pinnacle of all great advancements, the motivation for everything to come, may lie in the hands of the 21st century's most crucial resource: data. Advances in computing and communication technology, along with the growth that has occurred in the field of data science and artificial intelligence, have put society in a position to truly leverage data in unprecedented ways, impacting how we interact with our surroundings on a daily basis.

Two well-respected UW-Madison researchers stand in the midst of this movement, using the technologies of today to create what were once the ideas of the distant future. Dr. Raj Veeramani is the E-Business Chair Professor and holds joint appointments in the department of industrial and systems engineering in the College of Engineering and the operations and information management department in the Wisconsin School of Business. Dr. Shiyu Zhou is a Vilas Distinguished Achievement Professor of industrial and systems engineering. Their research focuses on applying data science and machine learning techniques to improve business processes and automation.

Rapid advances in computing and the sheer interconnectedness of society have created implications for our everyday interactions that are the focus of today's research. Everything from sensors in a factory machine to how we as consumers interact with businesses, both directly and indirectly, creates observable data for companies looking to improve decision making, machine productivity, and the overall business processes. Combining this data with decision science is the heart of Dr. Zhou and Dr. Veeramani's research. Conventional thinking suggests that data is purely composed of statistics and data that can easily be plotted on a coordinate plane. However, the existence of (and more importantly the handling of) unstructured data is one of the more advanced practices in the field of data science and machine learning. Comments, maintenance notes written by a technician, remarks written

by a customer service representative are just a few examples of "the rich and diverse set of data which are now available and cannot simply be modeled and studied like structured data," notes Dr. Veeramani.

Understanding unstructured data is important because it provides valuable insights to further enhance the capabilities of machines. Machines are primarily built

DR. SHIYU ZHOU (LEFT)
DR. RAJ VEERAMANI (RIGHT)

on understanding large quantities of data and improving pre-existing models and calculations, hence the term machine learning. Building relationships between different variables and categories of data, as Dr. Zhou notes, "allows for the creation of models that predict future behavior," thereby limiting error and improving business performance.

What goes into a given research project can vary depending on not only the kind of data Dr. Veeramani and Dr. Zhou are using, but also on the models that are already in place to address industry concerns. It's therefore vital for researchers in the field of data science and machine learning to begin with a specific problem that is yet to be addressed and then scale up such that it can reveal a greater industry concern. Talking to industry engineers might, for example, uncover existing problems with a machine coolant or belt functionality that is dramatically impacting production. This discovery then starts the process that eventually uncovers greater inconsistencies throughout the general industry, often requiring "newer models or building on existing principles to answer bigger questions," Dr. Zhou says.

The challenges that Dr. Zhou and Dr. Veeramani face after addressing a particular problem, however, are far greater than the plethora of information that must be analyzed. Understanding the data from an analytical standpoint poses a challenge in and of itself, because as Dr. Veeramani points out, "analysis isn't as simple as having an x-y coordinate and creating a model to show correlation [because there are simply too many] aspects that can influence a particular data set." Simply having access to data isn't enough to conduct thoughtful research, because the observations could be telling a story that isn't particularly relevant to the issue at hand. Compensating for the "heterogeneity and oftentimes the incompleteness of data," as Dr. Veeramani puts it, is a key aspect of their research. Only by pulling the correct information from what seems like an endless amount of data can one derive valuable insights.

> "WE NOT ONLY HAVE THE CAPABILITY TO UNDERSTAND WHAT HAS HAPPENED, BUT TO ALSO ANTICIPATE WHAT MIGHT HAPPEN"
> - DR. VEERAMANI

Using "pre-existing models is a beneficial starting point," as Dr. Zhou points out, but oftentimes there are limitations to such techniques. It isn't enough to solve problems for a particular issue or for a particular company. The most rewarding aspect of Dr. Zhou and Dr. Veeramani's research lies in the long term impacts this kind of research can have. "We not only have the capability to understand what HAS happened, but to also anticipate what MIGHT happen," Dr. Veeramani says. "Our aim is to extend the state of the art. To do things that could not be done before."

GRAPHIC DESIGN BY
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