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Stronger, sustainable concrete with seawater.

Steerable robotic needles for lung biopsies.
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also wants to integrate electroencephalogram technology to show not only brain perfusion—how blood flow correlates to changes in thought—but also areas of stimulation related to movement and emotion.

Because basic ultrasound beams bounce around inside the skull, no useful imagery makes it out, and next-generation brain imaging has eluded medical doctors and scientists for decades.

Only now have the technologies aligned to make it possible, said Byram, whose lab is affiliated with the Vanderbilt Institute for Surgery and Engineering.

“The goal is to create a brain-machine interface using an ultrasound helmet and EEG,” he said. “A lot of the technology we’re using now wasn’t available when people were working on this 20 or 30 years ago. Deep neural networks and machine learning have become popular, and our group is the first to show how you can use those for ultrasound beam-forming.”

The applications, he said, are endless. At the basic level, it could allow for images at least as clear as those doctors are accustomed to seeing of the heart or uterus. Ultrasound technology for the brain could produce real-time images during surgery, identify where certain feelings or actions stimulate brain activity, and even create the ability to control software and robotics by thought.

“We expect the portable ultrasound helmet prototypes will resolve ultrasound image quality problems, and the new integrated algorithms will lead to new techniques for both understanding brain activity and using it to interact with computers,” Byram said.

Computational power also plays a significant role in Grissom’s NIH project. Until recently, the science has outpaced the ability of traditional tools and techniques to capture brain activity at a finer scale.

Ultra-high field MRI now can detect brain activity in areas as small as 1 to 2 millimeters. But at such levels background “noise” from magnetic pulses compromises image clarity and accuracy.

Using parallel coil arrays, the new RF coil design and improved algorithms will extract higher quality data that translates into higher resolution images, as small as 6/10 of a millimeter.

The difference is significant. Functional MRI uses changes associated with blood flow to measure brain activity because cerebral blood flow and neuron activation are linked. Recent neuroscience research has shown what unfolds in the brain – in space as well as in time – takes place at a much smaller scale than previously thought.

“We have not been able to perform MRI at fine enough scales to take advantage of these new insights,” Grissom said.
BUILDING SOCIAL VALUES INTO THE IoT

An ambitious new international, interdisciplinary project will develop and test the concept of incorporating social norms, policies and values into the basic architecture of smart devices. “The fusion between people, computing and the physical environment is becoming so deep that it is getting harder and harder to tell them apart,” said Janos Sztipanovits, E. Bronson Ingram Professor of Engineering and one of four principal investigators on the five-year project.

The $4 million project is funded through NSF’s PIRE program.

“Science of Design for Societal-Scale Cyber-Physical Systems” will develop prototype policy-aware systems in three domains: connected vehicles, including self-driving cars, smart grid energy systems, and unmanned aerial vehicles. “It is not surprising that societal tensions are developing,” Sztipanovits said. The evolution of the Internet of Things creates winners and losers. Take route-planning apps. Individual drivers win with reduced commute times. Society, as a whole, wins because the system helps balance overall traffic flows. But those who live on neighborhood streets that now experience increased traffic lose.

“How do we resolve conflicts like this?” Social norms vary greatly. In the U.S., for example, people are much more suspicious of government than big business. In Europe, the reverse is true. People generally view big companies as evil and government as benign, Sztipanovits said. “Unless we adopt a new approach, these different social norms will be hardwired into the evolving systems,” he said.
SMART GRID PLATFORM JOINS LINUX FOUNDATION ENERGY PROJECT

Vanderbilt School of Engineering will contribute both deep expertise and a platform for smart grid applications to a new effort by The Linux Foundation to advance open source innovation in the energy and electricity sectors.

Through LF Energy, The Linux Foundation will host the platform and related projects, providing a hub for multi-vendor collaboration to help seed an open source ecosystem.

Vanderbilt was the initiative’s first academic partner. LF Energy also has support from Europe’s largest transmission power systems provider, a network that represents 43 transmission system operators from 36 countries, and the Electric Power Research Institute, whose membership represents 90 percent of annual electric utility revenue in the U.S.

“The power industry is increasingly realizing it has to rely on software and putting together the kind of software apps they need is not easy,” said Gabor Karsai, associate director of the Vanderbilt Institute for Software Integrated Systems.

“Having this software infrastructure and having it open sourced enables faster implementation yet delivers the kind of functionality existing systems cannot.”

Karsai, a professor of computer engineering, computer science and electrical engineering, also is principal investigator on The Resilient Information Architecture Platform for Smart Grid, or RIAPS, which provides core services for building effective, secure and powerful distributed software applications. RIAPS enables smart grid control software to run reliably, just as smartphone apps run on platforms like Android and Apple iOS that have become industry standards.

EXPERTISE IN AUTONOMOUS VEHICLES LANDS NEW PROFESSOR IN FAST LANE

In less than a year since joining the School of Engineering faculty, Dan Work cemented his reputation as an authority on one of technology’s hottest topics.

Work studies self-driving vehicles and traffic control. The associate professor of civil and environmental engineering has been tapped as an “expert voice” by tech publisher Axios. He partnered with a major U.S. auto manufacturer on a closed-track test that showed adding one autonomous car to a group of 20 with humans in control ended a typical stop-and-go wave, or “phantom” traffic jam, and reduced fuel consumption by 40 percent.

Though the experiment didn’t include the lane changes, merges or wide variations in vehicles that drivers experience on regular roads, future research will, Work said.

When he joined Vanderbilt in December 2017, Work brought his expertise on cyber-physical systems in transportation to a fast-growing city where traffic and transit are top issues. During his transition from the University of Illinois at Urbana-Champaign, he was named a Gilbreth Lecturer for the February 2018 National Academy of Engineering meeting. Connected World put Work on its list 2018 Pioneers, selecting him one of 10 Innovators of IoT (Internet of Things) under age 40.

And he’s been invited to give a talk on the future of transportation at The Royal Swedish Academy of Engineering Sciences in June 2019. The international conference will mark the Academy’s 100th anniversary.

He is already part of the Vanderbilt Engineering Center for Transportation and Operational Resiliency and collaborating with the Vanderbilt Institute for Software Integrated Systems, a global leader in CPS technologies.

“I’m deeply impressed by what Vanderbilt is accomplishing in this field and by the collaborative nature of the work that happens here,” he said. “Nashville is a rich landscape that is going to provide many opportunities to research and develop the latest transportation technologies.”
Research internship reaffirms undergraduate’s passion for rehab engineering

by Adrianna Johnson

When I came to Vanderbilt School of Engineering I knew I wanted to learn how to use my interests and talents to better the world by helping others. At a young age I discovered a knack for things mechanical and a love of physical problem solving. Finding a way to combine the two and improve the lives of as many people as possible became my dream.

Over the summer I worked with graduate students and post-doctoral scholars in the Center for Rehabilitation Engineering and Assistive Technology as a researcher in the lab of Assistant Professor of Mechanical Engineering Karl Zelik. I worked mainly with graduate student Matthew Yandell, whose focus is assistive exoskeleton technology, but I also helped others on human gait-related projects. I became IRB certified. With that important credential I could assist researchers with experimental protocols involving human subjects and data collection. During some preliminary trials, I even participated as a subject.

Testing and data collection are important components of this type of research. Processing and analyzing the data is critical, too, and I worked with researchers to turn testing outcomes into meaningful results for use in scholarly papers as well as to support and direct subsequent testing.

And I did get out of the lab, which is so vital for studying human motion. Visiting with a prosthetist, I saw the complexities involved in fitting prosthetic limbs and learned best practices for fitting research devices to subjects.

Those graduate students and postdocs, working in labs that have made great advancements in the fields of human gait research and exoskeleton devices, are living my dream. Witnessing the amazing findings and innovations that arise from interaction between the human body and creative mechanical devices reaffirmed my desire to help those with mobility impairments and my passion for engineering.

As a rising sophomore, this research experience was an incredible opportunity, which the Clark Scholars Program made possible for me. My summer was exciting, educational and challenging in the best ways possible. I know it will be a key stepping stone in my engineering career and an experience I will never forget.

Clark Scholars  A $15 million gift in 2017 from the A. James and Alice B. Clark Charitable Foundation established the A. James Clark Scholars Program at the School of Engineering. Each year a cohort of 10 students is chosen from the incoming first-year class, and sophomore Adrianna Johnson was in the inaugural group. The program, part of Opportunity Vanderbilt, provides scholarship support to exceptional students with financial need and from underrepresented backgrounds. It emphasizes engineering excellence, business acumen, service learning and leadership—characteristics that the late A. James Clark embodied and wished to cultivate in others. Clark was the president and CEO of Clark Construction.
Testing a self-setting resin to improve sustainability of wind turbine blades

In the U.S. alone, wind power avoids the carbon pollution of more than 28 million cars. The "carbon cost" of a typical commercial wind project repays itself in six months, displacing fossil fuels and producing no carbon emissions for decades.
This composite materials technology is exciting because it closes the loop on sustainability in wind energy.

Doug Adams

But wind power has its costs. The resin that makes 150-foot fiberglass turbine blades strong and durable needs a great deal of time and energy to cure. When the blades reach the end of their lifespan of 20 or 25 years, very little of the material can be recycled.

That problem has a solution in sight, and Vanderbilt engineers are playing a key role. The Laboratory for Systems Integrity and Reliability has tested a new recyclable resin that cures at room temperature and allows the fiberglass blade itself to be recycled.

This new resin by Arkema, called Elium, creates its own heat and cures without creating flaws in the fiberglass. Resins that have been in use destined turbine blades for the landfill.

“This composite materials technology is exciting because it closes the loop on sustainability in wind energy,” said Doug Adams, Daniel F. Flowers Professor and Distinguished Professor of Civil and Environmental Engineering.

“What better application to look at than wind power, where energy and sustainability are foremost in our minds?” he said. “It’s a grand challenge in composites manufacturing.”

Adams is director of LASIR and chair of the Vanderbilt’s Department of Civil and Environmental Engineering. The challenge, he said, made an ideal project for the Institute for Advanced Composites Manufacturing Innovation, a consortium of industry, government and academic institutions aimed at improving composite materials manufactured for use in turbines, cars, compressed gas storage tanks, airplanes and even sporting goods.

At LASIR, Adams, staff engineers and mechanical engineering graduate student Christopher Nash tested the resin’s self-setting properties using infrared imaging on a nine-meter demonstration blade. They also produced an algorithm for use in setting up the process on the commercial production lines.

Arkema showcased the Elium blade at JEC World in March 2018. Elium is a liquid thermoplastic resin that can be processed with the same manufacturing methods as a thermoset liquid resin. Thermoplastic resins may reduce manufacturing costs and time as well as increase sustainability. Thermoset resins take energy and time to cure but cannot be reheated, which renders components that use them non-recyclable.

As the wind industry grows and wind turbines age, using more sustainable materials increases in importance. The U.S. has more than 54,000 active industrial-scale turbines, each with three blades, and thousands more on the way. The IACMI has a five-year goal of 80 percent recyclability for the composite structures of wind turbine blades.
Researchers in the race to produce safe, powerful and affordable solid-state batteries have two routes – develop new materials or reengineer existing materials. Assistant Professor of Mechanical Engineering Kelsey Hatzell and her group are tackling the latter by uncoupling physical and chemical transformations within batteries to identify failure points.

And then fixing them.

Hatzell’s team tested Lithium lanthanum Zirconium Oxide or LLZO. The garnet-type material shows great promise for solid-state batteries due to its high Li-ion conductivity and compatibility with Li metal.

“This is a paradigm shift in energy storage,” she said. “These results can potentially inform materials design for the next generation of all solid-state battery systems. The results concluded that the presence of voids or connected pores led to a higher failure rate.”

Solid-state batteries are desirable for all-electric vehicles and other applications where energy storage and safety are paramount. Lithium-ion batteries typically contain a liquid organic electrolyte that can catch fire, but the fire risk is eliminated with a non-flammable electrolyte such as LLZO. Replacing liquid electrolytes with a solid organic like garnet also potentially lowers the cost by increasing battery life.

Hatzell’s novel research tracked structural changes in LLZO after realistic charging and discharging events using synchrotron X-ray tomography at Argonne National Lab.

The American Chemical Society’s Energy Letters published Hatzell’s findings, “The Effect of Pore Connectivity on Li Dendrite Propagation Within LLZO Electrolytes Observed with Synchrotron X-ray Tomography,” online in March 2018. It was among the most read ACS Letters articles that month.
DATA SCIENCE INSTITUTE BRIDGES DISCIPLINES AND SCHOOLS AS RESEARCH, TRAINING HUB

Data science is revolutionizing academic fields and emerging as a discipline that provides critical training for students at all levels and interests to create a competitive advantage in their future careers.

Vanderbilt’s new Data Science Institute will promote data-driven research in all schools and departments and add courses in data science for undergraduate and graduate students. An initial goal is to design and launch a professional master’s-level degree program in data science.

The institute also will support university-wide coalitions since data is becoming the core for research and insight for a broad set of academic disciplines. That support extends to resources for faculty, students and researchers to help spark dramatic advances in academic discovery.

“In research, there’s often a problem of recognition,” said Padma Raghavan, vice provost for research and professor of computer science and computer engineering. “Data science can filter out the distracting information and reveal the essential. Over the next decade, data science is estimated to have a significant impact across all sectors of the economy, from transportation, manufacturing and construction to health care, urban living and more.”

The institute is co-directed by Douglas Schmidt, associate provost for research development and technologies and Cornelius Vanderbilt Professor of Engineering, and Associate Professor of Physics and Astronomy Andreas Berndt.

“We are building a foundation to meet current and near-term needs of data-driven efforts that span research, education and other application domains at the university and beyond, and evolve data science as a trans-institutional discipline that can meet the future needs of data-driven scenarios,” Schmidt said.

“And, prepare data-savvy students to shape our future.”

Sources used in the study

- Google’s My Activity and Takeout tools, which describe information collected during use of Google’s user-facing products
- Data intercepted as it is sent to Google server domains while Google or third-party products are used
- Google’s privacy policies, both general and product-specific
- Other third-party research that has examined Google’s data collection efforts

About the study and the author

Digital Content Next, a trade group, commissioned Cornelius Vanderbilt Professor of Engineering Douglas Schmidt to conduct the research. Schmidt is a professor of computer science and computer engineering, associate provost for research development and technologies, and co-director of the Vanderbilt Data Science Institute.

The study, “Google’s Data Collection,” was made available to the public at Schmidt’s request. Visit https://digitalcontentnext.org/blog/2018/08/21/google-data-collection-research/ to download the report.
A little nudge goes a long way in activating killer T cells

Vanderbilt engineers have made a significant leap toward developing killer T cells to attack cancer tumors with far less evidence of disease than long believed – using a nudge so small it can’t be seen without advanced microscopy.

“'We can, for the first time, pick the closer on the baseball team who can reliably pitch fastballs,' Lang said. ‘Which T cell do you pick? Which one do you put back into the patient to fight their disease? Maybe you get lucky and pick the right one. With these new tests, we can measure the interaction under the native, energized state. The good news is these cells are extremely sensitive. We've been able to trigger them with as little as two molecules.'

The work by Vanderbilt University Professor of Chemical and Biomolecular Engineering Matt Lang, Yinnian Feng, Ph.D. '18, and their Harvard University collaborators changes what researchers look for in activating T cells for immunotherapy. Now, the task is finding T cells that demonstrate strong binding potential when they're flung ever so gently at damaged cells.

Scientists studying the body’s cancer-fighting T cells have faced a serious hurdle: Cultured in the lab, T cells sit at equilibrium, waiting to bump into cancerous cells. Once inside the body, however, they become motorized little bloodhounds and seek out infected cells.

Feng and Lang performed their experiments using optical tweezers – highly focused laser beams – to pick up microscopic spheres and coat them with the same peptides found on diseased cells. They then placed the spheres onto T cells.

With no force, the T cells were thought to go about lackadaisically sniffing out one peptide, then another, then another in a process requiring hundreds or even thousands of binding events before the immune response was activated.

The team applied 10 piconewtons of force to the T cell, equivalent to the gravitational force exerted by dropping 1/1,000th of an eyelash. A special dye applied to the T cell immediately revealed an increase of intracellular calcium, which signals activation. Removing a peptide at a time and testing again, the researchers concluded the T cell can do its job when this tiny amount of force prompts contact with as few as two peptides.

The study involved more than 1,000 individual experiments aimed at triggering T cells given this humanly undetectable push.

“With the very precise microscopes we have, we saw a single binding event,” Lang said. “This project is telling us about the mechanism, about how the system actually works. It's basically saying that we're dealing with a mechanosensor that requires force to be activated.”

The work could inform design strategies for T cell therapies, said Dr. Christian S. Hinrichs, an investigator with the National Cancer Institute.

“In the emerging and very promising field of T cell therapy, these findings help us understand at a very basic level how therapeutic T cells are triggered to attack their targets,” he said.

The work, “Mechanosensing drives acuity of αβ T cell recognition,” was published in the Proceedings of the National Academy of Sciences, in late 2017. It was supported by NIH Grants R01AI100643 and SU2C-AACR-DT1314.
A wee nudge activates cancer-fighting T cells, based on research by Matt Lang, professor of chemical and biomolecular engineering, and lead author Yinnian Feng, Ph.D., ’18. Feng received the School of Engineering’s award for best research paper for 2017-18 for the work. A trapped bead (left) decorated with a pMHC ligand is placed on a T cell and pulled to facilitate recognition by the T cell receptor complex. (Illustration, Lang laboratory)
The study also successfully and simultaneously diagnosed a second biomarker, epidermal growth factor receptor (EGFR), in triple-negative breast cancer, a highly aggressive disease.
What started as graduate school research with steerable needles in blocks of gelatin could help pulmonologists more accurately reach sites in the peripheral lung to biopsy them.

A collaboration between that doctoral student – now Professor of Mechanical Engineering Robert Webster III; Dr. Fabien Maldonado a pulmonologist at Vanderbilt University Medical Center; and a colleague at the University of North Carolina received a $2 million National Institutes of Health R01 grant.

Engineering Ph.D. student Patrick Anderson also is deeply involved in the project. He was among several Vanderbilt Institute for Surgery and Engineering affiliates who gave technical demonstrations of works in progress during the 2017 VISE Symposium.

“The device combines multiple needles into a flexible structure,” said Anderson, who also was part of the first cohort to take part in a novel NIH-funded training grant for VISE research. “Normally a lung biopsy is an invasive procedure that goes through the ribs and is really painful for the patient.”

“We want to shrink the tools and make them really small,” Anderson said. “We connect them together and control them outside of the body using robot arms. The tools can be flexible or stiff depending on what you want to do with them and they can move in many different ways.”

Significantly, each tool is less than 2 millimeters in diameter, meaning patients will need only a bandage – not sutures – after the procedure.

Webster’s work on this dates back to 2004 when he began to design a beveled, steerable tip needle.

“We were just doing things in blocks of gelatin to see if we could get steerable needles to go where we wanted them to go. At the time, we had no idea that the lung was where this technology would be most useful for doctors —we were thinking about applications in the prostate and liver,” he said.

Once at Vanderbilt, Webster continued the work but needed a clinical collaborator to help advance the system.

Enter Fabien Maldonado, M.D., an interventional pulmonologist who commonly uses bronchoscopy to...
29% of the Class of 2018 studied or interned abroad for at least a month*

*Includes study abroad, exchange and overseas service learning programs

Innovation to Commercialization

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$1,135,542 Revenue generated from VUSE technologies

These figures were provided by Vanderbilt’s Center for Technology Transfer and Commercialization for the most recent fiscal year (July 1, 2017 through June 30, 2018).
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