STEVENS INSTITUTE of TECHNOLOGY
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IMPACT

The research newsletter of Stevens Institute of Technology Spring 2020

Smart Infrastructure for a Greener Future

Stevens-developed materials self-heal, cleanse the air, reduce carbon footprint

In an era of warming temperatures and tightening carbon footprints, innovative new materials and sensors being developed in Stevens labs could point the way to smarter infrastructure.

The materials may also help mitigate soil and groundwater pollution — and slow the process of climate change — while reporting back on their stability in real time, a crucial advance for safety.

"We are obtaining very exciting results," says researcher Yi Bao, who collaborates with faculty member Weina Meng on the work.

Remarkable new materials

One newly engineered Stevens material — an MCC (multifunctional cementitious composite) — can actually self-heal. As the MCC cracks, its composition enables a chemical reaction to occur moisture in the air reacts with particles in the compound, forming a gel-like material.

Later, as the MCC cures, it hardens and retains load-carrying capacity. Fibers and other proprietary ingredients in the material's composition keep cracks from propagating or widening.

"Conventional concrete is brittle under tension," Bao explains. "Even when you reinforce with steel, it cracks or corrodes. Weather, earthquakes, tornadoes, floods or fires are all threats. We set out to create something improved."

The new MCC may also scrub pollutants from the air, via a photocatalytic effect. Greenhouses gases react with the new material and the ultraviolet light in sunlight to form harmless by-products such as nitrates that can be reused as fertilizer.

In cities where air quality is a major challenge, this could be a life-saver: Bao's team discovered the material converts 80% of harmful nitrous oxides into inert substances within minutes under sunlit conditions.

As a bonus, the material appears to be safer and more fire-resistant than standard concrete. In laboratory tests exposing it to flames as hot as 1,600 degrees Fahrenheit, the MCC formed long, oval channels through which flames passed.

High-tech sensors, advance warning

In a related effort, Bao develops thin, light-powered sensors that can take the pulse of structures continuously, enabling rapid analysis and action before dangerous failures occur. A distributed fiber optic sensing system currently in development can be embedded in concrete, wound around steel bars, attached to wood or strung along other surfaces.

"These are not like current sensors, which only measure data at a single point," Bao notes. "A network of these distributed sensors is more like the human nervous system, continuously measuring the condition of the structure at every point, and reporting back trouble spots immediately."

The sensors are composed of multi-layer optical fibers, manufactured with high-purity silica and cladding that efficiently reflects light for distances of up to 100 miles. The system measures and reports variables including material temperature, load, strength and deformation throughout a structure or expanse of pavement, uploading in real time.

The team is also working to develop algorithmic systems that can rapidly extract insights and send alerts when materials appear to be compromised.

"Our long-term vision is to develop smarter structures that transform planning and performance," Bao says. "In concert with smarter materials, novel types of sensors will be critical for the safety and management of a smarter, greener infrastructure."

INSIDE HIGHLIGHTS:

stevens.edu/research

Quantum Advance Produces Ultra-Sharp 3D Imaging

A Stevens research team has demonstrated an experimental new 3D imaging system that uses light's quantum properties to create images up to 40,000 times crisper than some current technologies enable. The work potentially paves the way for super-high-resolution medical imaging, satellite mapping and autonomous vehicle sensing.

The work, led by physicist Yuping Huang, was described in the journal *Nature Communications* in February.

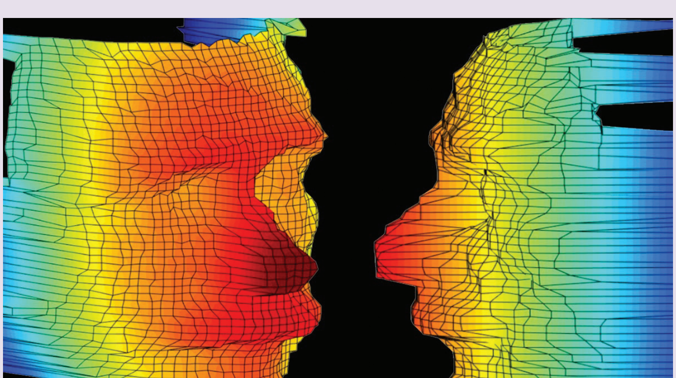
Huang's team addressed a longstanding limitation of LIDAR, a scanning and sensing technology that uses lasers aimed at and reflected off distant targets. Background light sources such as ambient sunlight complicate LIDAR imaging, preventing higher resolution.

To confront this challenge, the group — including master researcher Ivan Dickson, senior scientist Yong Meng Sua and doctoral researchers Patrick Rehain, Bharathwaj Muthuswamy, Jeevanandha Ramanathan, Amin Shahverdi and Shenyu Zhu — trained very fast dual laser pulses on objects, channeling and detecting single reflected photons using specialized optical filters and algorithmic techniques including a novel method known as quantum parametric mode sorting (QPMS).

Unlike noise-filtering techniques that rely upon software-based post-processing, QPMS inspects an incoming light stream's quantum properties, filtering it so that only photons with matching quantum properties returning from the target are registered by the sensor. Non-relevant, noisy photons are simply ignored.

Even when metallic mesh screens were placed in front of target objects in experiments, the resulting processed image information obtained by the new Stevens system were highly accurate and largely noise-free.

Promising potential applications on the near horizon range from medically safer imaging of the human eye's retina using very faint laser pulses to deep-space communications normally contaminated by the sun's radiance.



STUDY: AMERICANS FEAR NUCLEAR ATTACK

New Stevens research suggests Americans worry greatly about nuclear incidents. The survey, conducted by political scientist Kristyn Karl and psychologist Ashley Lytle, queried nearly 3,500 U.S. subjects. Respondents assigned roughly 50% probability to a nuclear threat during their lifetimes; urban Americans and women assessed the likelihood higher than male or rural counterparts, while increased media consumption correlated with increased apathy about the risks among younger subjects. Analyses were reported in the *International Journal of International Communication* in January.

Mission: Software Without Bugs

AI powered Stevens-Yale system aims for 100% detection

Software crashes, freezes and malfunctions are not only inconvenient; for airplanes, autonomous vehicles, medical devices, and other devices and system, they can have deadly consequences.

Stevens researchers, in collaboration with Yale University, are developing automatic verification tools that could render software crashes nearly obsolete.

Headed by Stevens professors Eric Koskinen and Jun Xu, the system both checks to ensure that programs run correctly and also uses algorithms to determine whether it's possible for a given software to produce undesirable outcomes.

"What we're aiming for is a 100% guarantee that you'll never encounter a bug," explains Koskinen. "With the explosive growth of systems and software in areas such as healthcare, aviation and transportation, it's vital we develop practical techniques to make computer-controlled systems bug-free and safe to use."

The collaborative team uses artificial intelligence to rapidly model the differences among different versions of a program to mathematically prove that the program is bug-free. The method utilizes so-called temporal logic: rather than reading millions of individual lines of code checking for simplistic errors, the new algorithms examine the software's behavior over time, modeling and iterating every possible outcome as a test.

The work is supported by the U.S. Office of Naval Research.

150 Years of Research Innovation — and Counting

Stevens Institute of Technology is a private and co-educational institution that was created by the act of the New Jersey legislature in 1870 — so this issue of IMPACT welcomes you to the 150th anniversary of Stevens.

Considering that I joined Stevens in 1980 (originally to teach in academic programs that Stevens ran in North Africa), I am fortunate to witness first-hand the incredible changes that have taken place at Stevens during about 30% of its entire history, including the very significant increases in numbers of students and faculty as well as a sharper focus on research and technology development in areas of true societal need and national defense.

We are proud of the research and technology development accomplishments of our faculty and students. Some of these research accomplishments are highlighted in this issue of IMPACT: projects to protect the New York City region from floods, develop fuel cell-based technologies to enable drones to stay aloft longer, develop improved treatments for brain illnesses and disorders and develop a new understanding of how stem cells differentiate as functions of substrate geometries relevant to more viable stem-cell therapies; smarter infrastructure initiatives; the development of automatic verification tools to minimize software crashes; the building of AI methods to map the functions of bots; and new technologies for helping Alzheimer patients and imaging via quantum technologies.

To learn more, please visit our website (**stevens.edu/research**) and contact us about partnership opportunities at **201.216.8911** or **mgutier1@stevens.edu**.

All my best,

Dilhan M. Kalyon, Ph.D.
Professor and Interim Vice Provost for Research, Innovation & Entrepreneurship

Stevens Launches Brain Research Center

First biomechanical effort to investigate neurological disorders, treatments

A pathbreaking new Stevens research center will produce multidisciplinary brain research to inform improved treatments for concussions, dementia, Alzheimer's disease, Parkinson's disease, stroke and other associated disorders.

The university's Center for Neuromechanics is the first in the nation to examine the function, structure and health of the brain, spinal cord and peripheral nervous system from mechanical and engineering perspectives. Mehmet Kurt, a leading national expert in concussion science, serves as founding director.

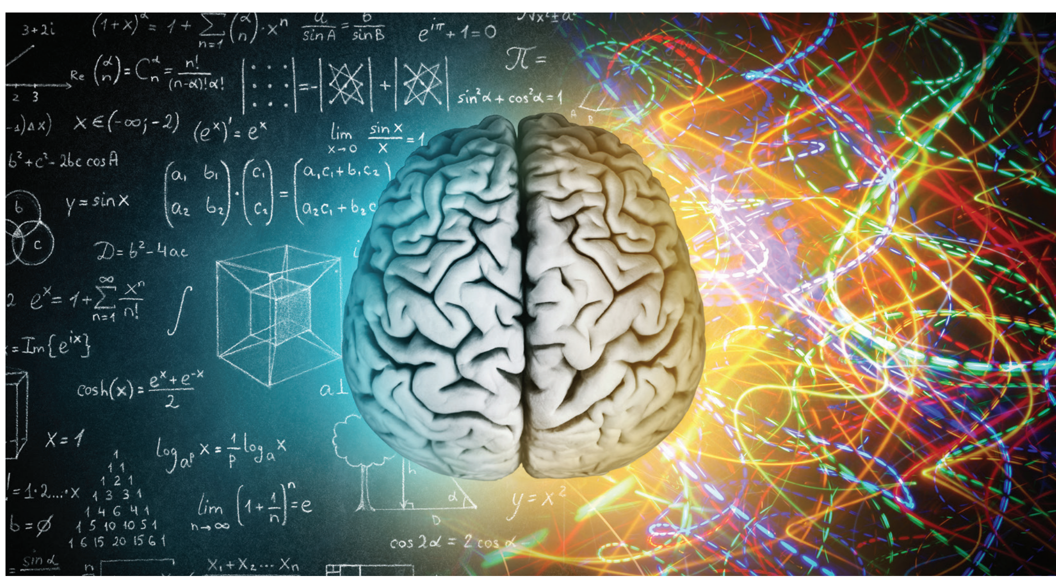
Kurt's own laboratory supplies athletes with wearable sensors to better understand the biomechanics of head movements and head impacts. His team works to understand how the brain responds mechanically to impacts and how to avoid, reduce or treat potential damage with improved helmet designs, enhanced imaging and better therapeutic strategies.

Studying Parkinson's, cancer, stroke

Another Stevens team housed within the center will continue studying the accumulation of harmful proteins and resulting loss of brain volume characteristic of dementia, Parkinson's and related diseases. Tapping into medical imaging data, the group has modeled and visualized these proteins spreading through the brain over time in novel ways. The goal: earlier disease diagnoses.

"There's a great deal of biological and chemical knowledge about the brain at very small scales, but it requires mechanics to project what we know about the small, cellular level up to the scale of tissues and organs," explains Johannes Weickenmeier, another founding member of the center. "We know cells respond to forces, and that every cell takes on a shape informed by its mechanical environment. These are the sorts of questions we will be investigating."

Additional center efforts will examine surgical robotic design, stroke rehabilitation, tumor detection, pharmaceutical therapies at the blood-brain barrier and enhanced MRI techniques to diagnose brain malformations in children.



APPLIED SCIENCE

‘Fuel Membrane’ Tech Attracting Buzz

Patented energy source could allow small drones to stay aloft for hours

Inspecting skyscrapers, bridges, railroad track and tall structures in person is a time-consuming, potentially risky task. Small drones could serve as safer inspectors, streaming live video or storing still images for further analysis.

However, there’s a problem: even the best lithium polymer batteries currently available last only about 25 minutes before requiring a return flight to base to recharge.

Stevens materials scientist Ronald Besser has proposed a better idea: a novel, lightweight type of hydrogen fuel cell source built into the drone material itself that — if it proves viable and scalable — could disrupt battery tech and keep small drones aloft for one to ten hours.

Simultaneous form and function

Fuel cells typically consist of metallic containers, pumped full of hydrogen and oxygen. Within the devices, polymer membranes help convert the chemical energy of hydrogen into electrical energy.

Besser’s novel fabrication method removes the metal from the equation while retaining the flat, nearly two-dimensional polymer membranes, which still produce energy but can be formed into nearly any shape, including the exterior or interior surface of a drone.

In tests, Besser’s lab showed that just a ten-inch-square panel of the Stevens-developed ‘fuel membrane’ material can generate approximately 100 watts of energy: easily enough to power small lights or keep a very small drone aloft.

A patent is currently under review while an associated startup company, Hoboken Fuel Cell, begins conducting market research and outreach to potential investors and partners with support from Stevens and the National Science Foundation.

How AI Keeps Wikipedia Current, Accurate

First-of-kind study reveals bots’ role

Wikipedia has evolved into one of the largest repositories of human knowledge, maintaining accuracy and currency with the assistance of more than 130,000 volunteers — and, increasingly, an army of automated software tools that continually scour the website to update, repair and remind editors to keep current.

Stevens researchers recently examined these tools, completing the first known survey of the 1,600 or so software bots deployed by Wikipedia. The work was published in *Proceedings of the ACM on Human-Computer Interaction* (Volume 3, Issue CSCW).

Stevens business professor Jeffrey Nickerson led the five-member group, which deployed automated algorithms to map each bot’s function within the Wikipedia ecosystem. Those algorithms identified nine roles that bots serve, making millions of edits.

Particularly important, they learned, are so-called protector bots that search for and undo occurrences of vandalism. Also very important are advisor bots, suggesting where editors should turn their attention next for ongoing maintenance.

Business professor Feng Mai, undergraduate researchers Christopher Albano and Neev Vora, and Ph.D. student Lei Zheng also contributed.

$4.9M AWARD TO PROTECT NYC REGION FROM FLOODS

Stevens’ Davidson Laboratory was awarded a $4.9 million contract from the Port Authority of New York and New Jersey over five years to continually produce four-day meteorological ensemble-based high resolution storm surge forecasts for New York and New Jersey infrastructure sites. Lab director Muhammad Hajj, faculty researchers Raju Datla, Jon Miller, Philip Orton and Reza Marsooli and research engineer David Runnels will serve as primary investigators.

The project’s scope includes performing all computations in the cloud, continuous updating of topographical changes, improved performance using machine learning, and installation and maintenance of observation stations and communication networks.

NEWS & NOTES

Jae Chul Kim received $300,000 in research support from **LG Chem** to advance the fundamental understanding of energy storage stability in lithium metal batteries. Leveraging Stevens' expertise in ceramic-polymer nanocomposite processing, the project aims to make batteries lighter, smaller and longer lasting for electric vehicles.

Physicist **Svetlana Malinovskaya** received $375,000 in support from the **Office of Naval Research** for her project "Quantum-Enhanced FAST CARS for Remote Detection Using a Multi-Static Platform."

Hady Salloum, director of Stevens' **Maritime Security Center**, received $260,000 in support from the **Department of Homeland Security** and the **Pacific Northwest National Laboratory** to perform work related to vessel traffic service radar and maritime sensors.

The university created a new **master's degree program in robotics**, launching in fall 2020. The program will integrate studies in modeling, analysis, design and control with advanced applications of robotics technology.

Damiano Zanotto, **Huanghe Zhang** and **Yi Guo** published "Accurate Ambulatory Gait Analysis in Walking and Running Using Machine Learning Models" in *IEEE Transactions on Neural Systems and Rehabilitation Engineering* (Volume 28, Issue 1). The work proposes a new machine learning model for improving the accuracy of wearable devices that analyze motion.

Mahmoud Daneshmand co-authored "Fuzzy Deep Neural Learning Based on Goodman and Kruskal's Gamma for Search Engine Optimization" for *IEEE Transactions on Big Data* in January. The project proposes a new search engine optimization technique method powered by deep learning.

Stevens partnered with **Hugo Neu** to host a thought leaders' forum on climate resilience. Participants included former Maryland Governor **Parris Glendening** and Waterkeeper Alliance president **Robert F. Kennedy, Jr.**

Shucheng Yu received the Test of Time Paper Award during IEEE's 2020 Conference on Computer Communications for his paper "Achieving Secure, Scalable, and Fine-grained Data Access Control in Cloud Computing."

UNDERGRAD INNOVATION

Architecting for Alzheimer's; Safer Infant Sleep

Student R&D continues on two promising health applications

▶ Alzheimer's patients require specific care — and, perhaps, specific home architecture and technologies. Now five Stevens software and computer engineering students are working to develop a smart hub-based service that could make homes safer for these patients.

Michael Ameer, Jarod Holgado, Karun Sekhar, Kristen Tan and Jenna Wong created the Aging in Place Alzheimer's Care System (APACS), which would create both proactive and adaptive real-time interventions such as modulated ambient lighting during evening hours, when Alzheimer's patients require assistance transitioning from day to night, and automated tutorials that guide patients through difficult tasks.

A connected device would answer spoken questions about facts not easily recalled, while a planned beacon function could notify caretakers and family members when patients depart their homes suddenly or unexpectedly. Development will continue with additional undergraduate teams.

▶ Infant sleep has long been a serious medical concern: More than 10,000 children worldwide are estimated to die annually from sudden infant death syndrome (SIDS), believed to be caused by resting directly upon the face or stomach.

A pair of Stevens undergraduates are developing and testing a new mobile application product that leverages artificial intelligence to remotely alert parents to infants' potentially unsafe sleeping positions.

The flexible cribside device, known as Bira, would stream real-time video and still frames of sleeping infants to a cloud server, where trained algorithms would analyze the positional data for anomalies in real times. Crying volume and ambient temperature would also be sampled; instant alerts could be pushed to caregivers or parents.

Computer engineering students Jocelyn Ragukonis and Daniel Gural plan to involve pediatricians, unveil a prototype, begin wider tests and seek investment capital.

"We hope to find a way to ease parents' minds and free them from constantly checking a monitor all night long," says Ragukonis.

ABOUT STEVENS

Stevens Institute of Technology is a premier, private research university situated in Hoboken, New Jersey overlooking the Manhattan skyline. Since our founding in 1870, technological innovation has always been the hallmark and legacy of Stevens' education and research. A range of academic and research programming spanning business, computing, engineering, the arts and other fields actively advances the frontiers of science and leverages technology to confront our most pressing global challenges. Stevens is home to two national research centers of excellence as well as interdisciplinary research programs in artificial intelligence and cybersecurity; data science and information systems; complex systems and networks; financial systems and technologies; biomedical engineering, healthcare and life sciences; and resilience and sustainability. Stevens is currently in the midst of executing a 10-year strategic plan, *The Future. Ours to Create.*, which is growing and transforming the university, further extending the Stevens legacy to create a forward-looking, far-reaching institution with global impact.

▶ stevens.edu

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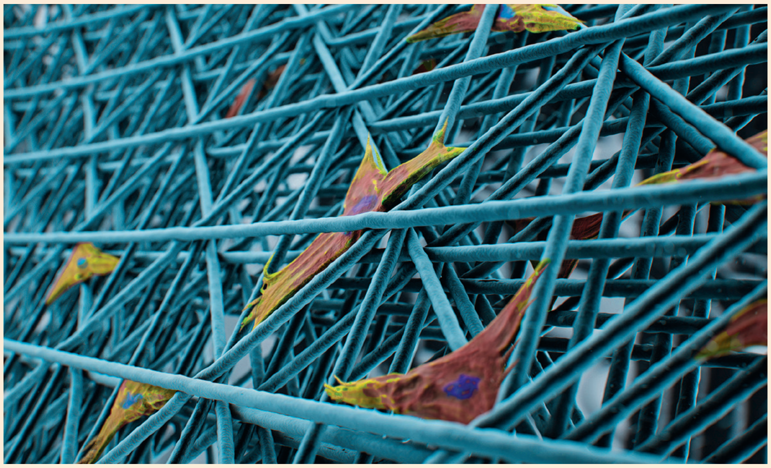
New Technique to Print Biomaterials, Insights into Programming Cell-Differentiated Function

A trio of Stevens researchers, in collaboration with MIT's Center for Bits and Atoms, have developed a new method of fabricating high fidelity, three-dimensional biomaterial substrates leveraging machine learning techniques to enhance 3D printing technology.

The research could pave the way for the additive manufacture of highly homogenous bioscaffolds, upon which more uniform, robust cell cultures possessing highly specific characteristics could eventually be grown.



The Stevens team included primary investigator Robert Chang; biomedical engineer Hongjun Wang; chemical engineer and current Vice Provost for Research, Innovation and Entrepreneurship Dilhan Kalyon; and postdoctoral researcher Chao Jia, working with MIT's Filippos Tourlomousis, Thrasyvoulus Karydis and Andreas Mershin. Investigations were primarily carried out at Stevens, in conjunction with Tourlomousis' doctoral thesis research at the university.

New insights into substrate geometry, cell differentiation

The new method uses melt electrowriting to weave patterns and build materials from tiny polymer strands as small as 10 microns wide — smaller than current standards by at least a factor of ten. Machine learning tools were used to classify and analyze large numbers of images of cell samples being grown on various types of printed microstructures in order to discover relationships between different fiber arrangements and the cells' growth patterns.

The best scaffolds produced by the team were highly homogenous when compared with non-woven structures, the researchers found — and the smaller scale achieved during fabrication approximates the scale of cells themselves, enabling investigation of the effects of the geometries of the fabricated structures on the morphology, growth and activity of cells at a scale of examination not previously attempted.

The work also produced a remarkable new finding: the type and rate of differentiation of cells seeded on lattice-like substrates depends upon the geometry of the substrate.

This suggests that the differentiation rate of cells can be controlled via choice of geometry of the substrate on which those cells are allowed to proliferate. These results are expected to have a significant impact especially on the development of stem cell based therapies.

Findings on fibroblasts used as a model cell system were published as a Stevens-MIT collaboration in *Nature Microsystems and Nanoengineering* 5:15, 1-19, under the title "Machine Learning Metrology of Cell Confinement in Melt Electrowritten Three-Dimensional Biomaterial Substrates," while results on mesenchymal stem cells obtained at Stevens were reported by Stevens researchers in a proprietary U.S. patent application.