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INSTITUTE OF TECHNOLOGY
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IMPACT

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Saving Lives and Protecting Communities

When weather is dangerous, rescues are needed or the sea rises, Stevens provides predictions, warnings, data and climate change research

Last year, in the U.S. alone, bad-weather events cost hundreds of lives and nearly $100 billion in damages. The warming climate is fueling more severe storms and, in turn, increased danger from storm surge and coastal flooding.

To help prepare and defend, Stevens is building some of the most advanced flood-advisory and ocean-monitoring systems in the nation to warn communities, save lives and protect property.

LIFE-SAVING ACCURACY

The Stevens Flood Advisory System (SFAS) — which very accurately forecasted Hurricane Sandy's record flooding in 2012 — is part of that mix, while a companion tool known as NYHOPS monitors the New York metropolitan region's notoriously swift, complex and dangerous ocean and river currents.

Local, regional and federal officials all depend upon this data.

When a US Airways jet went down in New York's Hudson River in 2009, the Coast Guard immediately turned to Stevens to determine how to secure and move the disabled aircraft. When boats are lost or adrift, or passengers have gone overboard, Stevens is again a primary emergency resource: Its predictions are tapped more than 1,000 times each year by search-and-rescue operations.

"[Stevens'] model remains our only consistently reliable model for one of the busiest maritime environments in the nation," notes Commander Matthew Mitchell, policy chief for the Coast Guard's Office of Search and Rescue. "It was used in more than 300 search-and-rescue responses in the last 12 months, saving or assisting [in saving] nearly 700 lives."

COMPUTATION, COMMUNICATION ARE KEY

Stevens launched NYHOPS in 2004, after placing sophisticated sensors and weather stations at various points around New York Harbor, Newark Bay and in the Hudson and East rivers. Three years later, the university added new models to the mix, rolling out the SFAS to forecast how high the Atlantic Ocean and its estuarine rivers would rise during hurricanes, winter storms and heavy rains.

The systems, with support from state and federal funding, are periodically updated; today they're powered by more than 200 sensors and draw on an array of leading weather models to calculate regional wind, ocean, river and flood dynamics.

All this information is communicated — quickly — to local authorities during crises.

"Davidson Lab provides us tactical information on the risk of coastal flooding that we use for decision-making and hazardous-weather preparations," notes Sal Kojak, a director in the Port Authority of New York & New Jersey's emergency management unit.

Stevens also works closely with communities, including New York City, to predict and defend against climate change. Driven effects including sea level rise, which is gradually consuming coastal properties and pushing cities underwater.

AI TO MONITOR THE NATION'S RIVERS AND STREAMS

NOAA, USGS fund Stevens image-analysis tech

Two Stevens researchers will develop computer vision-based systems to monitor flow in some of the nation's estimated 3.5 million miles of riverway. The U.S. Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA) have awarded $870,000 to professors Maroune Temimi and Kaijian Liu to leverage a network of USGS river-based cameras for public safety and benefit.

Knowing a river's state is critical for accurate flood forecasting and emergency management, as well as water quality assessment, irrigation and drought management and recreational safety. River streamflow — the speed and volume of water flowing through a given location — continually changes, affected by phenomena including weather, climate, snow melt, obstructions, sediment and erosion.

Standard methods for observing flow still mostly involve manual rulers or automated electronic gauges that must be regularly checked, then compared against historical measurements. But approximately 500 USGS stations are equipped with cameras capturing still or video images of waterways at regular intervals. It's *this* data Stevens will tap.

The pair will develop a computer vision-based system that determines river conditions from camera and video imagery. Learning networks will be trained to perform automated segmentation of captured image frames, inferring and estimating water velocity, levels and flow in more or less real time. The system will be especially useful during floods and storm surges, when monitoring of rising waters in real time is critical, they note.

'Nervous Systems' for Infrastructure

NSF awards $1.2M to Stevens, Illinois to develop smarter fiber-optic sensors

A Stevens duo will be part of a new effort with the University of Illinois to develop, test and deploy smart, intelligently connected sensors in buildings, bridges and other infrastructure.

Researchers Yi Bao and Kaijian Liu will co-investigate "Mutualistic Cyber-Physical Interaction for Self-Adaptive Multi-Damage Monitoring of Civil Infrastructure" during a three-year project sponsored by the National Science Foundation.

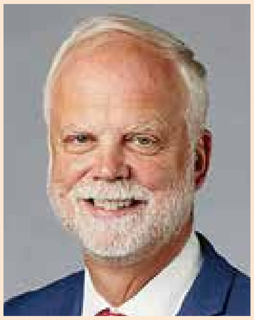
While methods exist to monitor civil infrastructure, sensing some types of potential damage — corrosion, cracking, separation and scaling — can be cost-prohibitive. The teams will work to develop systems that intelligently leverage single-point sensors to monitor multiple damage indicators and their progression.

"In the same way a dense sensory nerve system covers every inch of the human body," explains Bao, "we want to use a multi-functional fiber-optic sensor that can measure multiple types of damage at once to provide detailed data on infrastructure damages.

"This playbook could be applied not only to the same structure but also to different structures."

"The goal is to predict different types of damage in terms of what, when, where and how they'll happen, as well as how they'll spread over space and time," adds Liu. "We envision a monitoring system that can adjust and optimize its settings as needed to predict and detect multiple types of damage."

UNDERGRADUATE RESEARCH CULTIVATES STUDENT SUCCESS — AND PERSONAL GROWTH



University leaders and administrators typically focus on the high-level outcomes of research: high-impact journal publications, funding awards and other sponsorship, commercialization, licensing. We are no different at Stevens, which has enjoyed record growth in both external research support and internal research spending over the past decade.

Our research benefits society, aids in faculty recruitment, fuels commercialization efforts and provides life-changing experience for thousands of master's and Ph.D. students.

But another facet of research also deserves the spotlight's shine: the work conducted by our remarkable undergraduates. Undergrads participate very actively in Stevens' leading-edge research and frequently publish work in prominent journals alongside our faculty. Here are a few examples:

- Senior Dariya Baizhigitova searches for new therapeutic candidates, working closely with one of our faculty leads on drug discovery. She recently published in *Inorganic Chemistry*.
- Penelope Halkiadakis investigated gene therapies for rare mitochondrial diseases as an undergrad, co-publishing in the *Journal of Translational Genetics and Genomics*; she's now interning with a professional sports team you'd recognize while she also obtains a medical degree.
- Recent graduate Samantha Weckesser ideated and built a cargo container–scanning AI system now being studied for use by the Coast Guard. (Read more about Sam in this issue.)

Stevens also hosts an annual Innovation Expo each April, during which hundreds of senior teams present pathbreaking research and innovative devices, products and services, many in collaboration with key government or industry partners. Expos have featured thousands of remarkable innovations over the years — a touchless brainless scanner, an aerial drone that can swap batteries in midair, a portable concussion detector — designed *entirely* by undergraduates.

It's not just the quantity and quality of this research, innovation and scholarship that makes you sit up and take notice. It's the *personal transformation* taking place as students go through the scientific process. That's one reason Stevens recently created a new Director for Undergraduate Research role.

Research experiences help our students develop technical skills and soft skills for the career marketplace — more than 96% of the Class of 2023 received a job offer or graduate-school placement within six months of graduating. And this research also builds personal worth, surety and agency in a fast-moving age presenting new and complex challenges daily.

We need to encourage undergraduates' next great ideas now, mindful that they will soon be moving society forward with innovations we can't even yet imagine. Integrating (and supporting) research within undergrad curricula is an important first step.

Enjoy the spring and summer!

All my best,

Ed Synakowski
Vice Provost for Research & Innovation

Improving Treatments for Cystic Fibrosis

Stevens, with Columbia and Vanderbilt, develops life-like lung tissue to test new therapies

Cystic fibrosis (CF) is a crippling disease. While remarkable combinations of medicines have recently emerged, greatly improving a prognosis, treatment can cost more than $300,000 annually.

The search for genetic and other therapies continues, but there's a problem: Animal models don't always accurately capture the human lung's responses to medicines.

"It's challenging to develop drug molecules that work," concedes Stevens professor Jinho Kim, a leading lung expert recently awarded $590,000 by the Cystic Fibrosis Foundation to work alongside Columbia and Vanderbilt universities and develop a better protocol. The team will create a realistic "bioreactor" that closely simulates CF's course in the lab environment. The system will use lung models at three different scales: a miniature model of a lung airway; a more complex model utilizing animal material; and a whole-lung model integrating human lung tissue rejected for transplant. Each model will also incorporate a new bioartificial mucus the team is developing.

"Our goal," says Kim, "is to make the artificial CF mimetic lung system function as closely as possible to CF patients' lungs, so we can more efficiently test different drug molecules."

The concept also holds potential to aid in testing novel therapies for cancers and currently untreatable brain disorders, he adds.

An AI for Epilepsy, Sleep Apnea

Stevens researcher collaborates with Yale, others

More than 50 million people worldwide are diagnosed with epilepsy. Technologies exist to detect seizures, but most are time-consuming and power-consumptive.

"We need quicker detection, within the first one to two seconds of an event," says Stevens professor Md Abu Sayeed, who has collaborated with Yale University and others to develop AI-powered systems that can spot seizures quickly by parsing electroencephalogram (EEG) brain-electricity data.

KEEPING ONLY THE BEST DATA

To improve detection, Sayeed created new algorithmic processes that greatly shrink the amount of brain-wave data needed for a quick but robust analysis.

The centerpiece algorithm, specially tailored to the challenge of sorting brain-wave pulses, is known as PEM (for "pulse-exclusion model"). PEM recognizes characteristic patterns that occur during seizure activity, including certain types of high-amplitude electrical discharges, while weeding out extraneous signals.

In experiments with PEM and other techniques, Sayeed's group pared out up to 85% of patient EEG data, retaining only the most useful portions. After building a leaner hardware and testing the AI on data collected by MIT and Boston Children's Hospital, their detection of a spot episode of epilepsy was as accurate as the best existing AI-based systems — only much quicker. Flagging of seizures happened within an average of just one second, among the quickest detections in the scientific record. The University of North Texas collaborated on those investigations, reported in *Springer Nature Computer Science* [Vol. 4, No. 5].

Sayeed is also beginning development on a system to deliver medication to epilepsy patients instantly when seizures are detected.

In still another project, with Eastern New Mexico University, he is creating systems that analyze the heart's electrical activity to detect sleep apnea. A deep neural network is being trained on electrocardiographic data recorded during known sleep apnea episodes to develop detection algorithms. Promising early work on that system was presented at IEEE's annual International Conference on Artificial Intelligence, Blockchain, and Internet of Things last year.

NEXT-GEN RADAR WILL SEE AROUND CORNERS

NSF funds Stevens RF sensing project

Radar that can see around corners, inferring what is behind objects or otherwise hidden? It's not out of the question as new, more intelligent techniques emerge.

Stevens professor Hongbin Li has been granted $600,000 by the National Science Foundation to expand the power of radio-frequency (RF) sensing. RF sensing is becoming more pervasive; global WiFi standard IEEE802.11bf, arriving this year, will enable devices to function as portable radars capable of sensing surroundings and determining the positions of nearby objects.

However, the technology currently does not work well — sometimes not at all — through solid objects. Li aims to leverage RF sensing in a revolutionary way, with an assist from AI and special materials, to "look" around corners. His techniques employ reconfigurable intelligent surfaces (RISs): thin, flat multi-layered structures packed with circuitry and lined with reflective materials.

RF technology could have applications for health, safety and security including surveillance, fall detection, location monitoring and as a navigational aid. It is also privacy-preserving.

"An RF device only sees echoes of an object, not the object itself," he notes. "Unlike a camera, it cannot view your body."

STEVENS, UCLA TO DEVELOP 'METABOLIC AI'

The U.S. Department of Energy (DOE) has awarded Stevens professor Pin-Kuang Lai $525,000 to develop new AI in collaboration with UCLA researchers that advances our understanding of metabolic engineering.

Lai will work to develop models that untangle the complex chemical reactions occurring within biological organisms, particularly microbial systems, in an effort to uncover new therapeutic pathways and environmental interventions.

Leveraging techniques from the field of computer vision, Lai will develop models to calculate the flow of individual metabolic reactions through organisms, a fundamental first step in understanding disease processes. UCLA will assist in the simulation of biochemical reactions and in generation of the large datasets required to train Lai's AI models.

The work could aid in the development of novel medications and shed new light on the effects of toxic contaminants.

NEWS & NOTES

Four faculty received **National Science Foundation** (NSF) CAREER awards: **Shima Hajimirza** *(photo)*, for her thermal properties project "Precise Mathematical Modeling and Experimental Validation of Radiation Heat Transfer in Complex Porous Media Using Analytical Renewal Theory Abstraction-Regressions;" **Philip Odonkor**, for his energy project "Evaluating Cooperative Intelligence in Connected Communities;" **Christopher Sugino**, for his acoustics project "Non-Local Metamaterials and Metasurfaces for Next Generation Non-Reciprocal Acoustic Devices;" and **Johannes Weickenmeier**, for his brain science project "Biomechanical Characterization of Periventricular White Matter and Its Age-Related Degeneration."

Xiaojun Yu received $410,000 from the **NIH** for a collaborative project with the **University of Connecticut**, "Ionically Conductive Polymeric Materials and Grafts for Nerve Regeneration."

The **PSEG Foundation** awarded Stevens a **$1.45 million** grant to establish the **Stevens Center for Sustainability**. The Center will develop educational programs and novel research addressing climate change, toxics reduction, renewable energy, environmental justice and other key sustainability challenges.

Adam Overvig received a $450,000 Young Investigator Program award from the **Air Force Office of Sponsored Research** to support his project "Nonlocal Metasurfaces for Spectro-Spatial Control of Light."

Kwahun Lee co-authored "Ligand Separation on Nanoconstructs Affects Targeting Selectivity to Protein Dimers on Cell Membranes" in *Nano Letters* [2024, 24, 1, 519–524] with collaborators at **Northwestern University**.

Yong Zhang and **Rahul Khade** co-authored "Mechanistic manifold in a hemoprotein catalyzed cyclopropanation reaction with diazoketone" with collaborators including **Oxford**, **Cornell**, the **University of Texas** and the **University of Rochester** in *Nature Communications* [14: 7985, 2023].

Dibyendu "Dibs" Sarkar and **Sameer Neve Ph.D. '22** co-authored "Valorization of Spent Vetiver Roots for Biochar Generation" in *Molecules* [2024, 29(1), 63] with collaborators at **City College of New York** and **Michigan Technological University**.

Yudong Yao and collaborators including **Northeastern University** published "Dermoscopic Image Classification Using Attention Mechanism and Ensemble Learning Approaches" in the proceedings of the *2023 IEEE International Conference on Big Data* [2023, pp. 4424-4431].

Cheng Chen publishing "Galaxy morphology classification using VGG16" in the *Journal of Physics: Conference Series* [2023: 2580, 012023].

Army Commits Up to $15M for Quantum, AI

Bridging the gap between lab and field systems

Stevens Institute of Technology has secured a five-year contract with a $15 million ceiling aimed at revolutionizing the applications of quantum technologies in practical, real-world scenarios. The project, funded by the U.S. Army, focuses on bridging the gap between laboratory demonstrations and field-deployable systems.

At the heart of this project, led by Yuping Huang, professor of physics, lies the development of a cutting-edge computing platform for quantum information processing and artificial intelligence.

Unlike conventional AI systems relying on graphics processing units, Stevens is pioneering the use of hybrid photonics and microelectronics neural networks. By harnessing nanophononics and quantum optics circuits, Stevens aims to significantly reduce power consumption and eliminate the heat generated during AI computations. This innovative approach not only enhances efficiency but also paves the way for practical applications of AI in diverse fields.

A key objective of the project is to quantify and assess the true advantage of hybrid neural network realization, which brings together expertise from six different disciplines: physics, mechanical engineering, chemical engineering, electrical engineering, computer science and mathematics.

Huang, who is also the director of Stevens' Center for Quantum Science and Engineering, emphasized the importance of transitioning from devices that work in the laboratory to more practical tools that can be used in the field.

"We need to host these technologies outside of the lab, which requires expertise beyond physics," he said.

Huang's team aims to develop advanced quantum technologies and integrate them with modern AI methods for defense systems. The emphasis is on innovation and the demonstration of practical technologies with superior size, weight and power (SWAP) parameters.

By harnessing compatible quantum and integrated photonics techniques, the project aims to create SWAP-friendly devices and systems that operate at room temperature, ensuring superior compactness and portability. These advancements would provide a clear path to scalable production and deployment, leading to revolutionary impacts in various sectors.

ABOUT STEVENS

Stevens Institute of Technology is a premier, private research university in Hoboken, New Jersey, overlooking the Manhattan skyline. Since its founding in 1870, technological innovation and entrepreneurship have been the hallmarks of Stevens' education and research. Academic and research programs spanning finance, computing, engineering and the arts expand the frontiers of science and leverage technology to confront the most challenging problems of our time. Stevens is home to two national centers of excellence as well as leading-edge scholarship and research centers in disciplines such as artificial intelligence, including the Stevens Institute for Artificial Intelligence (SIAI); business and finance, including the Center for Research toward Advancing Financial Technologies (CRAFT); energy and sustainability, including the Stevens Center for Sustainability (SCS); health and medicine, including the Center for Healthcare Innovation (CHI); quantum science and engineering, including the Center for Quantum Science and Engineering (CQSE); and urban and coastal resilience, including the Davidson Laboratory.

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Containing Disaster: AI to Spot Hazardous Cargo

Undergraduate research project blossoms into Coast Guard-endorsed startup

Worldwide, hundreds of fires take place on cargo ships or containers annually, costing lives and causing millions to billions of dollars' worth of damage. A 2020 fire in a California port destroyed a $1.2 billion vessel; a 2023 ship fire in New Jersey burned for a week and killed two firefighters.

Now recent Stevens graduate and current master's student Samantha Weckesser is addressing this challenge with AI — and the Coast Guard is listening.

SMART SCREENING, BASED ON DATA

A flood of 7 million containers flows through the metro New York region annually, checked by a handful of human inspectors. Some containers pose hazards for various reasons, including leaks, flammable or toxic substances and live batteries.

Since inspectors can't open every container, the challenge becomes deciding which ships to board and which containers to open.

That's where Weckesser's AI comes in.

In 2021 she began performing analytics on cargo data, working with fellow undergrad Andrew Narvaez to sift through a government database spanning 20 years and 60,000-plus containers. The duo eventually demonstrated the concept of AI-assisted inspections to the Coast Guard, which responded by offering Weckesser a summer internship and beginning to integrate those concepts into inspections.

Weckesser later updated the tool, developing a Python-driven AI called Calypso that analyzes historical violation and compliance data to make highly intelligent predictions. Ships' countries of origin, individual shippers' track records and cargo types all help the AI steer inspectors to potentially risky vessels and containers.

As discussions continue with the Coast Guard, Weckesser has co-launched a startup called Homer with Narvaez and Stevens faculty member Matt Wade to refine, commercialize and market the system. The group expects to release a public product soon.