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IMPACT

THE RESEARCH NEWSLETTER OF STEVENS INSTITUTE OF TECHNOLOGY FALL 2023

A 'Smart Stethoscope' for Hearts, Arteries, Pregnancies

Wearable microphones and AI can spot potentially life-threatening health conditions

Heart-valve degradation and blocked arteries are silent killers. Nearly 10 million people in the U.S. are estimated to suffer from heart-valve disease, and a similar number from peripheral arterial disease (PAD). Yet both conditions often present few to no symptoms.

Stevens professor Negar Ebadi, a National Science Foundation (NSF) CAREER award winner and recent visiting faculty member at the Stanford School of Medicine, and Arash Shokouhmand, a research scientist specializing in AI at Stevens, have devised a new technique to detect these diseases earlier. The team is developing a "smart stethoscope" system coupling recordings from compact, high-tech microphones worn on the body with sophisticated AI

"If we can diagnose diseases and disorders non-invasively," says Ebadi, "with the same or greater accuracy, it's a win-win."

HEARING A SILENT THREAT

Angiography can be used to diagnose PAD, but the technique requires threading a catheter into arteries and associated risks.

Instead, Stevens' researchers — working in collaboration with StethX and Sorin Medical — take recordings with a specially designed, high-precision wearable contact microphone strapped to a patient's arm, leg or chest as the patient rests for a few minutes. The setup captures cardiovascular-induced vibrations and sounds on the body.

Then it's time for the AI to kick in. Auditory data picked up by the microphone — the sounds of blood flowing through arteries in the limbs — is fed into a 50-layer-deep neural network of algorithms and coefficients that mimic doctors' assessments of blood-flow. (Shokouhmand has dubbed this filter a multi-stream-powered vision transformer, or MSPViT.)

Ebadi and Shokouhmand gave the system a test in 2022 using recordings taken from 74 PAD patients and 21 healthy subjects. The system proved to be 96% to 99% accurate at separating confirmed cases of PAD from healthy patients, validating the concept. Findings were reported in the *IEEE Journal of Biomedical and Health Informatics* in January 2023 [Vol. 27, No. 1].

Ebadi and Shokouhmand are also applying the technique to the prediction of heart-valve disease — the first researchers to do so. The pair took five-minute recordings from 58 valvular heart disease patients and 52 control subjects, then processed, "denoised" and classified those recordings for predicted severity of valve disease by running them through a neural network of algorithmic filters.

This time the system was 92% to 97% accurate at distinguishing hearts with potential issues from healthy organs. Findings were reported in *IEEE Transactions on Biomedical Engineering*.

The researchers will continue developing iterations of the tools, Ebadi adds — including a proposed system for classifying potential fetal health risks sensors worn on pregnant mothers' abdomens.

INSIDE HIGHLIGHTS:

stevens.edu/research

QUIETER, GREENER FERRIES FOR THE GALÁPAGOS

Stevens helps reimagine sustainable transport in a sensitive ecosystem

Ecuador's four inhabited Galápagos Islands are connected by ferries that run twice daily from a hub port on Santa Cruz Island. Powerful Pacific waves, however, make for rough seas during the two-hour trips between islands, particularly during winter. Up to 40% of passengers experience seasickness.

Government officials have tapped Stevens faculty and students for help to smooth those journeys — and reduce their carbon footprint.

Professor Raju Datla works with Ecuadorian university ESPOL (Escuela Superior Politécnica del Litoral) to design and test new ferry hull designs, including a twin-hulled, catamaran-style ferry developed at Stevens.

Inside the university's Davidson Lab, the group — including a trio of undergraduates — spent the 2022-23 academic year testing 1:9 scale models of proposed hulls in a sensor-rigged wave tank under a wide variety of conditions. Fewer acceleration spikes (which cause seasickness) were produced by the twin-hulled Stevens design, they learned, and that data will be weighed as part of Ecuador's decision-making.

To address the environmental footprint of the ferries, currently powered by gasoline engines, greener power sources for propulsion are also being studied such as hydrogen fuel cells and lithium batteries. That determination will depend partly upon which hull design is selected.

"Our collaboration with this Stevens student team and faculty has been so valuable," notes Ruben Paredes, an ESPOL faculty lecturer directing the project.

Deciphering the Physics of Super-Fast Travel

Navy commits nearly $1 million to Stevens effort

New York to Tokyo by air in just one hour? Perhaps someday, says the U.S. government, which has committed nearly $1 million to Stevens research at the leading edge of understanding the physics of vehicles traveling at supersonic and faster speeds.

Nick Parziale, who studies the ways atmospheric gases move around quickly traveling objects and create heat and friction that are a major barrier to speed, received the support from the Office of Naval Research (ONR) for his project "Turbulence Quantities in Supersonic and Hypersonic Flows."

EXPLORING AN ULTRA-THIN, BUT CRITICAL, LAYER

Parziale's work focuses chiefly on the micro-thin, chaotic environment of the so-called "turbulent boundary layer": the 1/25th-of-an-inch-thick envelope of gas surrounding very high-speed vehicles as they move through the air.

"The state of the boundary layer can dictate a vehicle's capability," he explains.

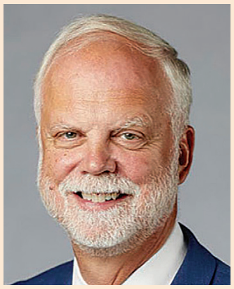
Vehicles with more turbulent boundary layers display higher drag and heat transfer, requiring added thrust from their engines, more onboard power and added thermal protection.

To explore the micro-physics of those constant interactions and the influence shapes and surfaces have on them, the team makes repeated, precise measurements of the turbulence in supersonic and hypersonic air flows to collect data on pressure, heat transfer, friction drag and current velocity.

Parziale's lab array includes the unique Stevens Shock Tunnel: a 60-foot, custom-developed instrument capable of testing basic model shapes in simulated air flows at speeds of up to Mach 6, or about 4,600 miles per hour. The experiments require coordinated timing and communication down to an accuracy of 50 billionths of one second.

The data acquired, says Parziale, then inform complex turbulence computations that empower designers to innovate shapes, surfaces and materials used in developing new aircraft for optimum speed, safety and energy use.

HOW ENGAGING CORPORATE PARTNERS ENHANCES UNIVERSITY RESEARCH



It's often said that a rising tide lifts all boats, and in the world of research that is certainly the case. In recognition of this, growing corporate partnerships is a key goal of Stevens' comprehensive new strategic plan for the university's next decade of growth and progress, *Stevens 2032: Inspired by Humanity, Powered by Technology.*™

Forging these partnerships helps ensure that Stevens research will swiftly make an impact, and enables Stevens faculty and students to gain a keener awareness of the research needs and opportunities that can affect lives *now*.

Stevens already possesses a legacy of close collaboration with industry. Defense contractor L3Harris, for example, supports student design project work. The energy group PSEG bolsters renewable-energy research and diversity programming. The American Bureau of Shipping committed a significant gift to the renovation and realization of Stevens' ABS Engineering Center, home to key robotics labs.

Our neighbors on Wall Street frequently step up, as well, including Bank of America's recent flagship corporate membership in the Stevens-led Center for Research toward Advancing Financial Technologies (CRAFT). All these efforts enhance both the university's discovery activities and the student experience in real, tangible ways.

And this collaboration is a two-way street. Stevens' research to benefit society feeds back to corporate partners in the form of shared intellectual property, proof of concept studies, market research, innovative ideas and other fruitful interactions. These close relationships also provide our corporate partners with an inside track to new and promising Stevens student talent, as well as means to grow the knowledge and skills of their own employees.

For Stevens students, these engagements provide experiential learning opportunities centered on the needs of industry, exposing them to the ways their research and coursework can and will be applied during their careers.

Our renewed corporate-engagement efforts include the recent selection of a new Director of Technology Commercialization and New Ventures, Chris Snyder, who has already begun to forge new bonds with regional, national and global business and research communities. Under his leadership we will become increasingly active in patenting, licensing, commercialization and entrepreneurial activities.

If you are interested in collaborating with us as a corporate partner, please do not hesitate to get directly in touch with Chris (csnyder2@stevens.edu) and with the university's senior director of corporate, government and community relations, Greg Townsend (gtownsen@stevens.edu). We look forward to working with you.
Enjoy a healthy and productive fall!

All my best,

Edmund Synakowski
Vice Provost for Research and Innovation

NASA, JPL Fund Beneathground-Radar Project

Future missions to the moon or planets will certainly explore subsurface environments; before probing, however, they will need to see into those surfaces.

Stevens professor Yanghyo "Rod" Kim has been awarded $360,000 by NASA's Jet Propulsion Laboratory (JPL) to design a radar system that can penetrate soil, stone and snow, providing clearer images of what lies beneath.

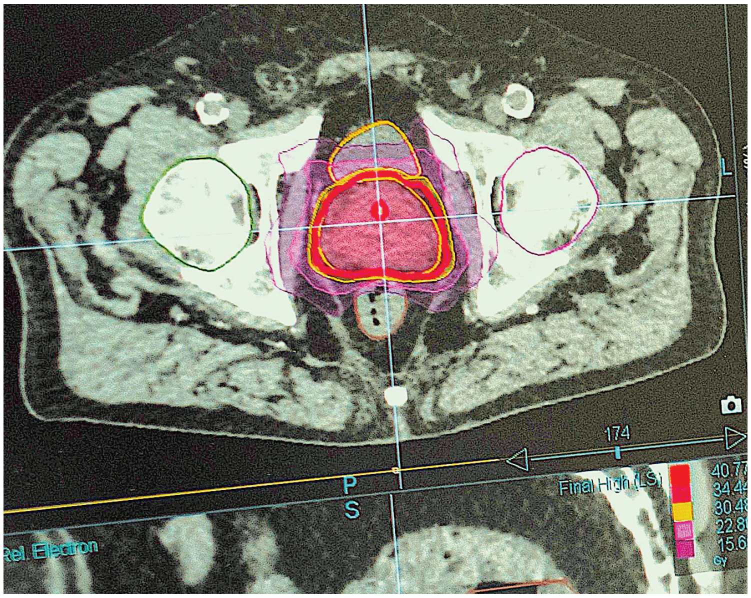
Kim's CMOS (complementary metal-oxide semiconductor) ground-penetrating radar will carry hardware-embedded artificial intelligence onboard to help guide its subsurface explorations. CMOS chips work well as sensors in space due to their high tolerance for noise, such as signal disturbances from electronics, stars and galaxies, notes Kim. They also use relatively little power.

The ground-penetrating component of the radar will enable detection of subsurface objects, revealing previously concealed layers and geological features, while the AI will allow sensors to adjust range in real time according to local conditions.

The system will also be able to detect subsurface water and ice, currently only detectable by drilling physical holes into the surfaces of planets or moons.

"This is noninvasive technology," explains Kim. "We can scan without mechanical or physical drilling."

After designing the basic functions of the system, the radar's detection capabilities and other environmental testing will be performed at JPL in California.



An AI for Sharper Images

New systems will aid medical diagnosis, food inspection, cancer research

A host of rapidly evolving imaging technologies has improved the odds of catching dangerous diseases before they become deadly. But good tools to interpret those images have lagged behind.

Now the rise of artificial intelligence has changed the game. Stevens professor Yu Gan — with the support of the National Science Foundation, National Institutes of Health, NVIDIA, Burroughs Wellcome and others — is using AI to sharpen images and bring out hidden signs of trouble.

Gan's main focus is atherosclerosis. Angiograms and other imaging tools give doctors a visual sense of whether arteries are calcified, but AI-based methods can obtain more accurate 3D internal views of the heart's chambers and blood vessels. NSF recently granted Gan a five-year, $600,000 CAREER award to develop algorithms that produce quicker, sharper, lower-cost analyses of the images produced by optical coherence tomography, histological microscopy and MRI systems.

In a dedicated lab, his team photographs and scans pathology samples, then trains deep-learning networks on the data to spot at-risk patients in groups of healthy ones.

"We are looking for arterial plaques in images where they appear indistinct," explains Gan. "The software will bring out disease patterns that were not visible at first."

The group also investigates the use of AI to facilitate cancer detection. Working with Germany's national cancer research center, DKFZ, Gan's team investigates cancers at the cellular level and recently co-authored a group paper in the leading cancer journal *Cancer Cell* [2023: 1, 1–12].

In addition, the U.S. Department of Agriculture recently awarded Gan's lab support to develop an imaging and algorithmic system with applications to food evaluation and inspection. That proposed system would assess the freshness of produce and dairy products — and detect potentially hazardous objects embedded in them — from images.

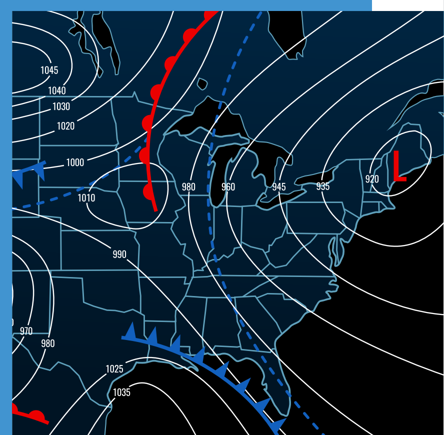
IMPROVING SHORT-TERM WEATHER FORECASTS

Stevens-NOAA project evaluates leading models to inform better accuracy, future systems

A Stevens research team evaluating short-term "nowcast" weather-forecasting tools has determined that they can be highly effective — when used in the right situations — but also improved.

"This isn't just about whether you should take your umbrella with you when you go on a walk," explains Stevens hydrometeorologist Marouane Temimi, who worked with lead investigator Achraf Tounsi Ph.D. '23. "The forecasts that we're missing ... are needed to respond to storms, floods and other emergencies effectively."

Working closely with the National Oceanic and Atmospheric Administration, the team analyzed the agency's weather-radar systems to test the accuracy of seven widely used nowcasting algorithms across eight years of meteorological data from the metropolitan New York City region. The analysis included data from extreme events such as 2022's Hurricane Ida.



One key takeaway: different models perform better in different situations. So-called deterministic models push out predictions quickly and excel at providing guidance over the next few minutes. When more advance warning is needed, however, probabilistic models — which are more dynamic, factoring in changing temperatures and conditions within clouds — suit the task better.

Some probabilistic models particularly excel at predicting sudden, potentially dangerous torrential rainfall, but there's a cost to improved accuracy. Those models require significantly more computing power and take more time to generate predictions, cutting down on planning and emergency-response time.

To build an improved nowcasting model incorporating the best elements of existing systems, the team will next dig deeper to learn how and why higher-performing models succeeded.

The research was supported by the Port Authority of New York and New Jersey and published in *Environmental Modeling & Software* [Vol. 168: 105803].

NEWS & NOTES

The Stevens-led **Systems Engineering Research Center** received **$25 million** in funding from the **Department of Defense** to create a civilian training program for the nation.

Amazon announced a team of Stevens graduate students and doctoral candidates advised by **Jia Xu** finished second in the world in the **Amazon** Alexa Prize SocialBot Grand Challenge 5. The team's chatbot conducts long and detailed interactive conversations with users.

Jason Rabinovitch was one of six scientists selected to serve on the Venus Science Coordination group, a newly established joint committee of **NASA** and the **European Space Agency**.

Xiaofeng Qian and research assistant **Misagh Izadi '23** unveiled a connection between a 350-year-old theorem describing the movements of clocks and planets and the complex behaviors of light waves. The paper, "Bridging coherence optics and classical mechanics: A generic light polarization-entanglement complementary relation," was published in *Physical Review Research* [5, 033110].

Stevens-developed technology to **enable greater password security**, "System and process for generating passwords or password guesses," was granted **U.S. Patent** #11669612-B2 in June. The technology was developed in collaboration with New York Institute of Technology.

Stevens received **$4.5 million** in state and federal funding to enhance **supercomputing** and other resources that support the university's research in flood prediction, artificial intelligence and other areas.

Marouane Temimi and **Kaijian Liu** received **$870,000** from **NOAA** and the **U.S. Geological Survey** to develop AI to monitor flow conditions in the nation's rivers and streams from camera imagery.

Jing Chen co-authored "Does lowball guidance work? An analysis of firms that consistently beat their guidance by large margins" in the ***British Accounting Review*** [2023: 101219].

Philip Odonkor's startup venture Grid Discovery was selected as one of 12 to join the 2023 **TechStars** Alabama EnergyTech Accelerator, an incubator co-sponsored by the **University of Alabama** and other partners. Odonkor and a co-founder also received $120,000 in seed funding.

Better Brainstorming, Powered by AI

New system created with Columbia, Northwestern, Syracuse suggests novel ideas, questions

Press releases and anonymous tips or leaks to reporters are inevitably part spin, part fact. Journalists work hard to decide what's really a story and what isn't.

Stevens researcher Jeff Nickerson, as part of a multi-university team, has co-developed, evaluated and unveiled a new tool called AngleKindling to help reporters find more interesting angles and relevant context in the flood of information they receive.

"The tools of AI can be turned to positive or negative uses, and brainstorming is one of the positive use cases," explains Nickerson, an expert in human-computer interactions.

MORE IDEAS, MORE VARIETY

The team began by spending three months meeting with journalists, observing their processes for ideating stories from tips, press releases and other sources. The group also reached out to researchers at Northwestern University working on similar tools.

"We wanted to observe journalists working with AI tools," says Nickerson. "AI tools are different from other kinds of tools in that it can take time to figure out what they are capable of and how those capabilities can be applied."

The team then created and trained a new large-language model, using OpenAI's GPT-3 and directed prompts. The AI that emerged scans press releases and identifies both core facts and potential negative outcomes in the information. It also collects working links to high-quality news articles for background.

A follow-up study asked 12 professional reporters to use the tool as they worked with a set of press releases. The system proved both more useful and less time-consuming than existing brainstorming technologies.

Savvas Petridis, Lydia Chilton and Mark Hansen at Columbia University, Nicholas Diakopoulos at Northwestern and Kevin Crowston, Keren Henderson and Stan Jastrzebski at Syracuse University collaborated in the research, reported in the Association for Computing Machinery's *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (CHI '23).

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 — the Maritime Security Center (MSC) and the Systems Engineering Research Center (SERC) — as well as leading-edge scholarship and research centers in disciplines such as artificial intelligence, machine learning and cybersecurity, including the Stevens Institute for Artificial Intelligence (SIAI); biomedical engineering, healthcare and life sciences; complex systems and networks; data science and information systems; financial systems and technologies, including the Center for Research toward Advancing Financial Technologies (CRAFT); and resilience and sustainability.

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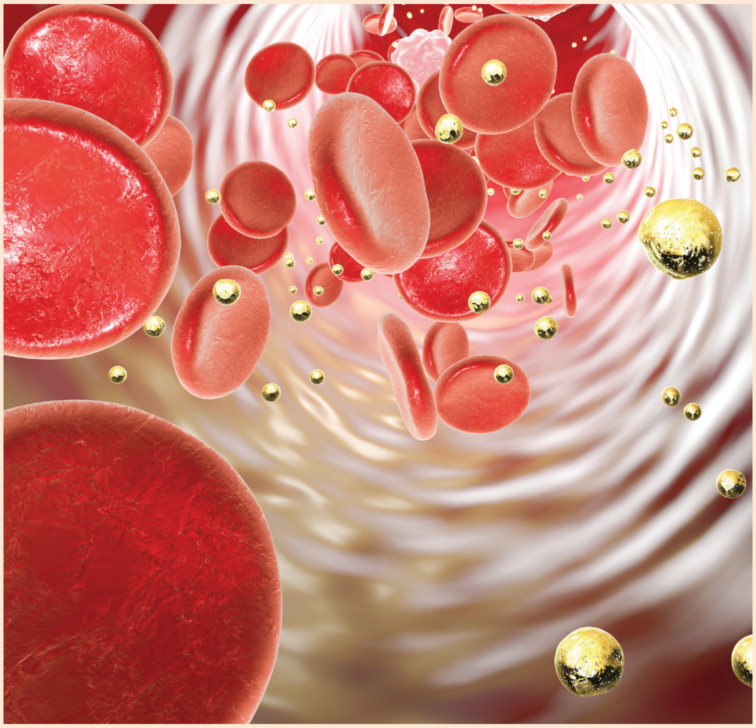
Delivering Therapies More Precisely to Tumors

Tiny parcels fashioned from gold nanoparticles show promise for precise, secure drug delivery

Most medications potent enough to kill cancer tumors also cause significant side effects; some may even do more harm than good. It's important to deliver medicines precisely and without leakage.

And there may be a promising new way to do it.

Stevens researchers, working with a leading New Jersey health system, have created an experimental system that uses sealed packages to deliver medications directly to tumors with remarkable precision — while also apparently reducing the potential for dangerous side-effects.



HITTING MORE TARGETS, 'COOKING' TUMORS

The team began by applying hyaluronic-acid coatings onto the outer surfaces of gold nanoparticles as a sealant. The result: an extremely stable particle that only gives up its payload once it has bound to specific receptors on the surfaces of lymphoma tumors.

"Gold is very stable, so it's the perfect material for drug delivery," explains Center for Healthcare Innovation Director Hongjun Wang, who leads the work in collaboration with Hackensack Meridian Health (HMH).

"Using this approach, we're able to deliver drugs much more precisely and get much better outcomes."

In recently completed animal studies, the group found lymphoma tumors responded markedly better to this drug-delivery method than it did to non-targeted treatments. Medications were delivered selectively with minimal leakage into the bloodstream, suggesting lower quantities could be prescribed.

The specially engineered gold nanoparticles also continued circulating in animal subjects' bloodstreams much longer than free-floating pharmaceutical molecules did. That could mean human patients may one day be able to switch to less-frequent regimens if the technology proves viable in clinical trials.

The early success of the system opens the door to a host of other potential clinical applications, adds Wang, including the use of gold nanoparticles as contrast agents to enable precise imaging of tumors and technologies that infuse the particles with light energy, "cooking" tumors from within.

Next the team will work to develop more sophisticated pore sealants that rely upon antibodies to target other, more difficult-to-treat tumors effectively as well.

"Our ultimate goal is to use this approach to target multiple myeloma and other cancers that are currently not curable," says Wang.

HMH clinician Johannes Zakrzewski collaborated on the work, which was reported in *ACS Applied Materials & Interfaces* [2023, 15, 5, 6312–6325].