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IMPACT

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Drone Rangers: New Research to Extend Security, Functionalities

Multiple Stevens teams lead efforts to improve, defend and detect airborne and underwater drones

Five million consumer drones are shipped and sold worldwide annually. They're used for everything from photography and package delivery to sampling volcanic gases, underwater structure inspection, remote search and rescue, and surveillance of disaster areas.

But along with the explosive proliferation of unmanned robots come new security and privacy concerns.

Now drone security expert Hamid Jafarnejad Sani and other Stevens researchers are working to improve drones' capabilities, teach them to map and grasp, defend them from hacks — even detect drones with potentially malicious intent.

CYBERSECURITY ON THE FLY, DRONES WITH ARMS

Jafarnejad Sani and his team program situational intelligence and awareness into networked formations and systems of drones.

"We use control theory and machine-learning tools to identify and defend against cyberattacks, emphasizing high-dimensional visual data," he explains, including the development of novel detection, isolation and recovery algorithms to help fleets defend against and recover from hacks and attacks.

Jafarnejad Sani also collaborates with Stevens robotics expert Long Wang to design and test bio-inspired arms that attach to flying drones.

"Drones will one day be able to lift, grip, toss and do many other things that a human hand and arm can do," notes Wang.

The researchers recently demonstrated low-cost, lightweight manipulator arms for drones made with 3D-printed polymer components and nickel-titanium alloy cables.

MORE INTELLIGENT LISTENING, MAPPING

Another team works on the challenge of rapidly identifying unknown drones by analyzing their sound signatures.

Under the leadership of STAR Center and Maritime Security Center director Hady Salloum, the group has developed a Drone Acoustic Detection System (DADS) using a network of microphone arrays to detect and track drones. DADS leverages an algorithmic matching process to rapidly classify airborne objects at a distance.

"With drones now possessing intelligence and advanced capabilities, acoustic detection becomes a useful technological tool in the nation's defense posture," notes Salloum.

Stevens Institute for Artificial Intelligence (SIAI) director Brendan Englot is another leading innovator in the space.

His group's customized, AI-powered BlueROV2 autonomous explorer is the first to learn on the fly in a real-world marine environment. The robot utilizes an active algorithm coupled with sonar data to detect objects and surroundings, learning to map as it travels underwater.

NEW AI FOCUS: EMPOWERING DISABLED TECH USERS

Speech recognition, auto-translation and image-recognition AI have gone mainstream. Devices can now predict, with quite high accuracy, what we're seeing and what people are saying.

But for blind, deaf and other disabled users, these tools don't always work perfectly — and even small errors can be dangerous.

"A blind person's experience of an iPhone," says computer scientist Jonggi Hong, who joined Stevens in January 2023 to develop assistive AI and other technologies for disabled technology users, "is very different from a sighted one's."

WHEN OBVIOUS ERRORS AREN'T OBVIOUS

There are considerable gaps between rapidly evolving AI technologies and the needs of disabled users, Hong says.

Machine-learning datasets, for instance, meant for tech that serves blind users are inevitably built by sighted scientists.

But if a system or device trained on that data makes an error identifying an object in the street, on a web page or in a photo, there could be consequences. Even when image captions are obviously incorrect to a sighted user, a blind user may have little to no sense the description is inaccurate.

"Disabled users depend on the automatic decisions made by software and systems — and actually over-trust them, according to studies," Hong notes.

Now he has begun developing systems where blind users themselves explore images on devices, judging whether auto-generated captions are correct or not. It's vital, he stresses, to test systems directly with users for whom they're intended.

"We need to understand the unique challenges blind people have by giving them the technologies. When I build a system for blind people, I always use blind subjects to test it."

Stevens Co-Leads First Martian Copter-Dust Study

NASA, JPL, Space Science Institute collaborate

A Stevens researcher has co-conducted a pioneering study of dust disturbances by the rotorcraft that has explored Mars since 2021. The data generated will inform future planetary missions, exploration and sample retrieval.

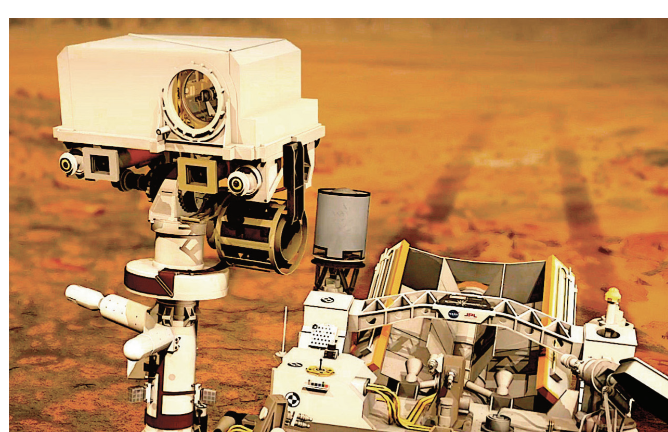
Working with the Jet Propulsion Laboratory and the Space Science Institute, mechanical engineering professor Jason Rabinovitch — who previously worked with NASA on missions for Mars, Jupiter and Saturn, including testing of craft-landing parachute dynamics — used advanced image-processing techniques to extract information from video captured during six flights of the *Ingenuity* rotorcraft by the *Perseverance* rover upon which it is based.

By identifying variations among video frames and the light intensity of individual pixels, the team calculated the size and total mass of dust clouds kicked up as *Ingenuity* took off, hovered, maneuvered and landed. The group determined that *Ingenuity* disturbed approximately four pounds of dust each time it flew — much more than would be generated by an equivalent helicopter on Earth.

"When you think about dust on Mars, you have to consider not just the lower gravity but also the effects of air pressure, temperature, air density — there's a lot we don't yet fully understand," says Rabinovitch.

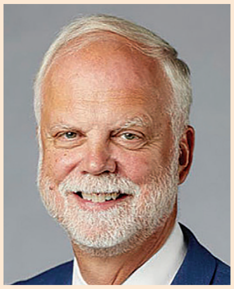
The modeling is important because dusty environments obscure the clarity both of imaging systems and solar panels that power missions. Dust might also degrade certain mechanical parts of rovers and spacecraft. Improved understanding of dust dynamics could help extend future missions by keeping solar panels operational longer and making it easier to land delicate equipment safely on dusty surfaces. The research may also offer new insight into the role of wind and wind-carried dust in weather patterns and erosion on Earth.

The work was reported in the *Journal of Geophysical Research: Planets* in December 2022.



DON'T *ALWAYS* KEEP IT SIMPLE

How the 3 C's — complexity, collaboration and centers — can lead to more powerful research outcomes



During my first months getting to know Stevens' growing research enterprise, I have been gratified to encounter a community of scholars, students, leaders and staff firmly committed to research toward social benefit. This is clearly an institution devoted to its students and to generating applicable, real-world solutions to some of our most pressing technological questions.

Stevens may be smaller than most U.S. research universities, but it is outsized in its intellectual and innovative impact — there's a reason we are seeing ourselves mentioned daily in publications such as *Forbes, The Washington Post, The Wall Street Journal* and on broadcast news.

I thank the university for inviting me to join as we make plans to continue our upward trajectory, building on a decade of very positive momentum.

Regarding the generation of research, I have gained a certain perspective from leadership roles at the Department of Energy, two of the nation's public state universities and two national labs. And one thing I have learned is that there's an important role for embracing complexity.

What do I mean? Societal challenges are evolving at a dizzying pace, and it can be paralyzing when individuals and institutions don't understand how they have agency amidst all this complexity and change. But a research university can be a deeply important and exciting place when it embraces these challenges by developing new ways of both working internally and partnering.

However, taking on these numerous challenges — from cybersecurity, climate change and clean energy and cost-effective healthcare to financial literacy, reliable infrastructure and societal bias and discrimination, to name just a few — will require a more complex, matrixed approach than many in academia have traditionally been familiar or comfortable with. Universities will need to learn to work together more closely on campus, and with fellow institutions, than ever before.

FOCUSED, COLLABORATIVE CENTERS CAN POWER INNOVATION

At Stevens, the creation of powerful interdisciplinary research centers within the university has worked to help break down silos, drawing broadly on the best elements of faculty and student ingenuity across schools, departments, fields and experience levels.

Both in combination and on their own, centers can create an environment in which students become embedded in the research enterprise very early in their academic careers, helping to create both foundational knowledge discovery and practical solutions as undergraduates.

The 2018 creation of the Stevens Institute for Artificial Intelligence (SIAI), which includes participation from every program and department on campus, is a good example. AI is exploding — both its promise and positive applications, as you will read in this issue, as well as the pitfalls and potential rogue uses. It will take informed, intelligent conversations and collaborative research among many different colleagues and students to keep up. That's why we created a center.

What is even more exciting is that research centers *themselves* join forces at Stevens. Stevens centers such as the NSF Center for Research toward Advancing Financial Technology (CRAFT), the DoD-sponsored Systems Engineering Research Center (SERC) and the pathbreaking Center for Quantum Science and Engineering are all poised to advance their missions in even *more* impactful ways by joining forces with the talents of SIAI on selected high-impact projects with significant societal benefit.

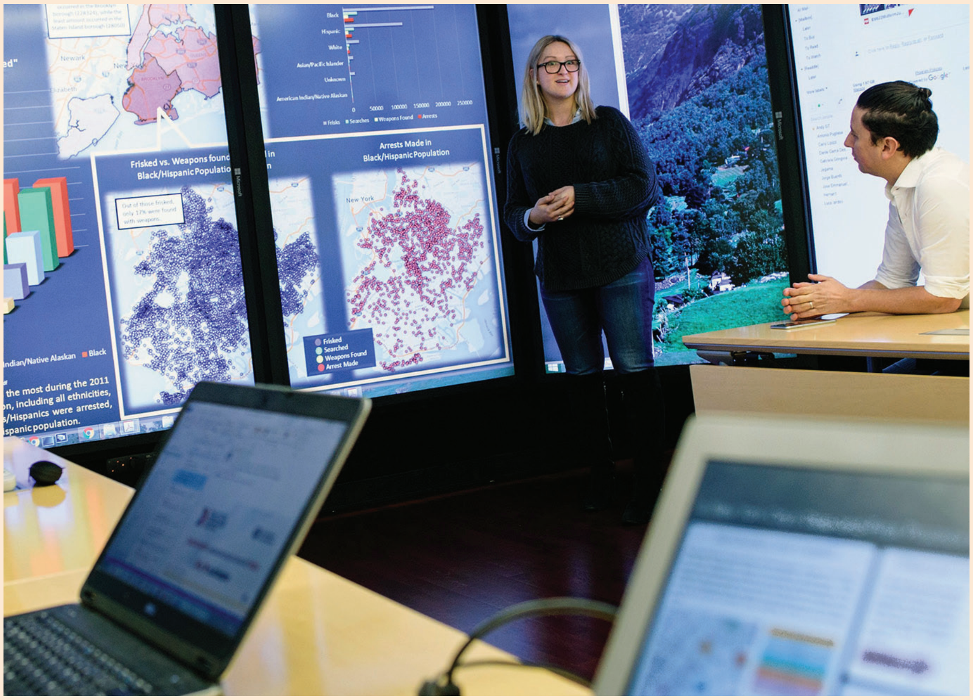
On a campus that already buzzes with excitement, leveraging the power of these centers can help bring us a long way toward meeting our highest obligation as a research university: graduating students who enter the workforce possessing an enhanced sense of agency and the confidence and technical skills to help navigate and lead our nation through increasingly complex, disruptive times.

Please enjoy reading this issue of IMPACT and do not hesitate to get in touch with me if you are interested to learn more about Stevens' research, collaborate with us or visit.

Enjoy the spring!

All my best,

Edmund Synakowski
Vice Provost for Research and Innovation



Safer Bridges, Through Smarter AI

New method integrates big data from multiple sources, learning and analyzing with more predictive power

Nearly 80,000 U.S. bridges now require replacement, according to the American Road & Transportation Builders Association. But predicting bridge deterioration is challenging, says Stevens civil engineering professor Kaijian Liu, because deterioration "is affected by a multitude of factors."

Now Liu, in collaboration with professor Nora El-Gohary from the University of Illinois at Urbana-Champaign, has developed an AI that integrates multiple data streams related to bridge health and analyzes them using the tools of artificial intelligence.

MORE DATA, ANALYZED MORE DEEPLY

Current U.S. bridge assessment and maintenance practice mostly relies on the National Bridge Inventory (NBI), an annual Department of Transportation-mandated evaluation that classifies bridges into broad categories.

"Bridges with similar geometric, structural and construction characteristics could have distinctive deterioration patterns," notes Liu. "NBI ratings alone probably do not sufficiently capture and differentiate the deterioration patterns of seemingly similar bridges."

To improve assessment and prediction, Liu and El-Gohary drew in additional, multi-year data from sources including inspection report notes and bridge traffic data from a cooperating state's transportation department. The researchers then added publicly available data on temperature, precipitation and other weather factors at bridge locations to the mix.

Next they created and trained a recurrent neural network AI system to learn bridges' evolving conditions and correlate changes with the data, predicting future condition assessments.

During an early test, the team assessed more than 2,600 bridges in Washington state — and the AI accurately flagged potential future issues about 90% of the time, 15% to 20% more accurately than existing methods. The method is particularly accurate at assessing bridges already assessed to be in poor condition, note the investigators.

The research was reported in the *Journal of Computing in Civil Engineering* [36(5): 04022023].

STUDY: BLACK CEOS ADD VALUE IMMEDIATELY

Hiring a Black CEO can lead to a significant financial benefit for companies, according to a new Stevens study co-conducted with the University of Georgia's Terry College of Business.

The findings suggest that a median-sized firm appointing a Black chief executive might see, on average, a boost of more than $44 million in market cap relative to a similar-sized firm appointing a white CEO.

The researchers analyzed nearly 5,000 CEO appointments over a two-decade period from 2001 to 2020, discovering that company stock prices and market capitalization rose if those companies announced newly appointed Black CEOs.

Companies' average cumulative abnormal returns – returns beyond expected normal market returns over the following three-day period – increased 3.1% in firms appointing Black CEOs, compared with an average 0.91% decrease in return in a comparative sample of companies appointing white CEOs.

The authors also noted that, of the nearly 5,000 new CEO appointments analyzed during the 20-year study, only 57 involved Black executives.

"Our study suggests that Black CEOs face a higher bar for advancement than white CEOs as they climb the corporate ladder, resulting in their being that much more prepared to lead," noted Ann Mooney Murphy, a Stevens business professor and co-author of the study.

The work was published in *Strategic Management Journal* [2022; 1–20].

$1.3M AWARD FROM DOD TO TACKLE PFAS

Stevens environmental engineering professor Dibyendu "Dibs" Sarkar has received approximately $1.3 million in support from the Department of Defense for his project "Green Remediation of Per- and Polyfluoroalkyl Substances in Soil and Water."

These so-called PFAS chemicals accumulate and persist in soil and sediments, aquatic environments, plants, animals and even humans for decades.

During the project, Sarkar will utilize drinking water treatment residuals, a non-hazardous type of solid waste generated at drinking water treatment plants, to develop a cost-effective, environmentally friendly method of treating soil and water contaminated with PFAS and other contaminants such as lead at military sites.

NEWS & NOTES

Matthew Libera and **Hongjun Wang** received $1.3 million in support from the **National Science Foundation** (NSF) toward their project "Collaborative Research: GCR: Infection-Resisting Resorbable Scaffolds for Engineering Human Tissue." The work will include colleagues at Binghamton University, City College of New York, Syracuse University and the University of Pennsylvania Veterinary School.

Raviraj Nataraj, Elnaz Banan Sadeghian and **Jie Shen** were selected to receive **NSF CAREER** awards. The prestigious awards support five years of investigation into focused topics by promising early-career investigators.

Nataraj's project, "Personalizing Sensory-Driven Computerized Interfaces to Optimize Motor Rehabilitation," will examine the use of **virtual reality-based therapies** for motor rehabilitation, particularly after spinal cord injuries, utilizing augmented sensory feedback customized for individual patients to enhance their treatment outcomes.

Banan Sadeghian's project, "Multitrack Read Channel Designs for Modern Two-Dimensional Magnetic Recording," will pursue the development of efficient noise prediction, synchronization and symbol detection algorithms to support modern and future generations of two-dimensional magnetic recording, an emerging technology that dramatically increases the data density and **storage capacity of disk drives**.

Shen's project, "Robustness, Active Learning, Sparsity, and Fairness in Classification," will address fundamental questions in the algorithmic classification process and develop novel algorithms to tolerate data corruption, **ensure fairness in learning models**, among other applications.

Victor Lawrence and **Yu-Dong Yao** received $400,000 in **NSF** support for a collaborative project with **MIT, Columbia University** and **Nokia Bell Labs**. The project, "Resilient and Low-Latency Networks for Situation Awareness in the Factory of the Future," will run three years.

Ansu Perekatt and a team of Stevens student researchers authored "Single-cell RNA sequencing of dedifferentiating cells from a mouse model that display oncogenic plasticity: Implications in understanding colon cancer stem cells" for the American Cancer Society journal *Cancer Research* in December 2022.

Kristyn Karl and **Yu Tao** co-authored "Correcting overconfidence in online privacy: experimenting with an educational game" in the journal *Information, Communication & Society* in January 2023.

A New AI to Improve Antibody Development

Deep learning model to predict viscosity may accelerate therapeutic antibody design, delivery

Monoclonal antibody therapeutics are complicated to develop and manufacture. Pharmaceutical firms have long pursued a portable, home-based solution to deliver these medications, but it is challenging: most antibodies are too sticky to draw through conventional syringes, and their viscosity is very difficult to control during the research and development process.

Now Stevens researcher Pin-Kuang Lai has developed DeepSCM, a deep learning model to predict high-concentration antibody viscosity.

His convolutional neural network can screen more than 1,000 antibodies simultaneously for thickness in seconds, with approximately 70% accuracy — faster and more accurate than standard means of distinguishing promising drug candidates from problematic ones.

CHARGING FORWARD TO BETTER PREDICTIONS

Lai began by considering the physical properties of antibody drug candidates.

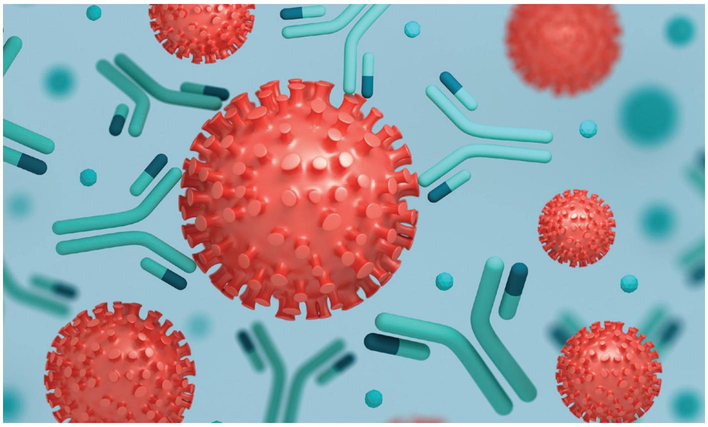
Certain regions of those protein molecules, known as variable fragment regions, are electrostatically charged — and the various positive and negative charges on those regions create either sticky substances (if adjoining regions' charges are opposing) or smooth-flowing ones (if the regions' charges are similar and repellent).

The extent and magnitude of those patches, converted into a metric known as an SCM score, help predict the likelihood a given drug candidate will prove too sticky to inject once it is manufactured.

Lai used a data set of more than 6,500 antibody variable fragment sequences to generate 3D protein structure models of each, running simulations to calculate individual SCM scores. Then he developed an algorithmic shortcut to learn from that process and detect patterns and rules to power predictions about *new* drug candidates' likely viscosity.

In one test run sampling 38 known therapeutic monoclonal antibodies, DeepSCM predicted the viscosity of the resulting products correctly in every case but one.

The research is described in *Computational and Structural Biotechnology Journal* [Vol. 20, pp. 2143-2152].



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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Office of the Vice Provost for Research and Innovation
1 Castle Point on Hudson
Hoboken, NJ 07030

Delivering New Pitching Biomechanics Research

Stevens research group unwinds pitchers' motions, analyzing data collected with MLB's grant support

Stevens biomedical engineering researcher Antonia Zaferiou and a growing team of graduate and undergraduate students are bringing new data-driven insights to sports science.

Using data collected with the financial support of a Major League Baseball research grant, Zaferiou's team examines how pitchers generate momentum and control body movement during their pitching motions.

Her group's research could help pitchers improve power and performance, while also potentially reducing their risk of injury. That's important in an era when many young pitchers experience pain or injury while throwing, and more than half of all major league baseball injuries occur to pitchers.

"We are trying to understand pitching biomechanics from the ground up," says Zaferiou, a National Science Foundation CAREER award winner.

LEG DRAG: KEY TO BODY ROTATION

Previous pitching biomechanics research has chiefly focused on body motion and linear propulsive forces.

But the Stevens project takes a different angle to understand body rotation.

In collaboration with Rush University, Zaferiou's team works with data sets collected by Rush with groups of high school and minor-league-level professional pitchers.

In one project, Stevens doctoral candidate Jun "Sam" Liu analyzes data collected from four minor-league pitchers who donned reflective markers and pitched off a force sensor-instrumented practice mound as motion-capture cameras recorded their movements in minute detail.

Rather than simply studying peak force, Liu zeroes in on the role of the legs in generating *impulse* as pitchers stride forward during their pitching motions, calculating the sum of forces or torques during the pitching motion.

He begins by finding the body's center of mass, examining how forces generate changes in linear momentum — a product of body mass and "center of mass" velocity. He then calculates changes in angular momentum, a measure of how quickly a pitcher's body mass rotates around the center of mass.

One key finding: a pitcher's back leg is critically important.

A pitcher's back leg typically drags behind the body during the forward stride. But this slight backward drag — which appears counterproductive — "actually facilitates the body's rotation in the direction of the pitch, increasing the speed of pitches," explains Liu.

That could inform coaching techniques, training, plyometric exercises and other methods to help pitchers develop power, coordination and body awareness while avoiding injury, says Zaferiou.