STEVENS INSTITUTE of TECHNOLOGY
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IMPACT

The research newsletter of Stevens Institute of Technology Spring 2022

Understanding Threats and Civil Defense in a Modern Nuclear Age

Stevens develops data-driven tools, communications strategies around global weaponry

Recent global tensions have rekindled public curiosity and concern about nuclear weapons, non-nuclear weapons and their potential impacts on population centers.

To assist planners and the public in understanding modern threats and civil defense practices, Stevens researchers have developed data-powered simulations, surveys and behavioral analyses.

Public data, powerfully programmed

Professor Alex Wellerstein uses declassified defense data to help visualize and understand nuclear and non-nuclear risks more precisely, creating and managing two popular software simulation tools that depict the devastating power and destructive potential of the world's vast nuclear and non-nuclear arsenals.

One tool, NUKEMAP, can graphically simulate a nuclear detonation anywhere in the world, supplying visualizations of blast zones, mushroom clouds, fallout plumes and fatality and injury estimates superimposed upon digitally mapped renderings of cities. Users test scenarios for a wide range of weapons, from compact "backpack" explosives to large-scale thermonuclear weapons such as the hydrogen bomb.

Visits to NUKEMAP increased ten-fold during the initial phases of Russia's invasion of Ukraine — to as many as 150,000 per day — as concerns rose about potential use of nuclear weapons.

A companion simulation tool, MISSILEMAP, does much the same for long-range missiles, producing instant visualizations of predicted target range, accuracy and explosive power.

When designing the tools, Wellerstein didn't need to develop the foundational mathematics. That was previously done by the U.S. government decades ago, through detailed postwar studies of detonations at Hiroshima and Nagasaki, Japan, the Nevada Test Site and in the Marshall Islands. The work was later declassified as open data.

"These calculations were daunting for the computing machines of the 1960s, but now easily run in a modern web browser," he explains.

Nuclear fears, better civil defense

The work is timely: a 2020 survey by Stevens political scientist Kristyn Karl and psychology professor Ashley Lytle found Americans still believe nuclear war is a 50/50 possibility in their lifetimes.

A related project, headed by Wellerstein and Karl and supported by the Carnegie Foundation, has worked to develop more effective communications strategies aimed at conveying sound civil defense practices — how to best evacuate or shelter during and after a proximate nuclear detonation, for example — using modern forms of digital media, social media, art and graphic design.

INSIDE HIGHLIGHTS:

stevens.edu/research


Avoiding Space Objects, Through Smarter AI

Defusing 'Fake News' on Social Media


Greener Power Grids for the Future

INNOVATION APPLIED

Filtering 'Forever Chemicals' from Drinking Water

A novel, Stevens-innovated filter medium made from recycled wastewater byproducts may offer protection against harmful chemicals seeping into the nation's drinking water.

That's the conclusion of Stevens research published in the *Journal of Hazardous Materials Letters* [Vol. 2, 100034].

"This is an important public health challenge, and we may have achieved proof-of-concept for a scalable, environmentally friendlier solution," explains environmental engineering professor Dibyendu Sarkar, lead investigator for the effort.

Chemicals that can last 1,000 years

The U.S. Environmental Protection Agency (EPA) recently announced an effort to more closely monitor perfluoroalkyl and polyfluoroalkyl chemicals, a class of more than 4,000 related manufactured substances collectively known as PFAS.

Because of their unusual structure and strong chemical bonds, PFAS chemicals degrade extremely slowly; some forms are believed to remain in soil and water as long as 1,000 years before breaking down. In the human body, PFAS substances may persist for as long as eight years.

A growing body of research suggests the chemicals can raise cancer risk and the potential for liver damage, kidney damage and infertility even when ingested in very small quantities.

Sarkar, working with postdoctoral fellow Zhiming Zhang and researchers at Montclair State University and Michigan Technological University, has designed a filter made from residuals produced incidentally by municipal treatment plants as they process and disinfect wastewater with aluminum-based salts.

When used to test-filter water with a pH of 3.0 in Sarkar's lab, more than 97% of PFOAs and more than 99% of PFOS (two sub-classes of PFAS chemicals) were adsorbed by the material.

Patent applications for the filter material are being prepared, says Sarkar, and research will continue.

Defusing Fake News

Stevens teams with MIT, Penn, others to develop social strategies, lie-detection tech

A tidal wave of misinformation is inundating media and social media airwaves. But recent Stevens collaborative research suggests new strategies and technologies can work to limit the spread of bad information.

Stevens business professor Jingyi Sun, with colleagues at the University of Pennsylvania, University of Southern California, Michigan State University and University of Florida, analyzed thousands of Facebook posts on COVID vaccine information made between March 2020 and March 2021.

The team examined discussions and reactions to identify specific interactions that changed social media users' perceptions of, and engagement with, the misinformation.

When fact-checkers dispute or debate false information online, they found, repeating the false claim during the process of disputing it appears to open readers' minds more effectively. Ignoring the false claim, however, produced negative emotions in readers.

"This finding offers some evidence that fact-checking can be more effective in triggering engagement when it includes the original misinformation," wrote the authors, who also discuss and suggest strategies for combatting misinformation.

The research was published in the *Harvard Kennedy School Misinformation Review*.

Another Stevens team is designing an experimental AI-powered system that detects misinformation dispersed via social media with a high degree of accuracy.

Professor K.P. Subbalakshmi and graduate students Mingxuan Chen and Xingqiao Chu scanned more than 2,500 public news stories about COVID-19 vaccines published during the initial stages of the pandemic, scoring each for truthfulness.

The team then cross-indexed and analyzed nearly 25,000 social media posts discussing those stories to determine how each social media actor supported or refuted news known to be truthful or deceptive.

In early tests, the system has been nearly 90% successful at predicting and separating COVID-19 vaccine fact from fiction on social media.

The group will next integrate video and image analysis into its algorithmic system to further increase accuracy.

How Collaboration, Clustering and Cooperation Have Enabled Stevens' Growing Research Enterprise

I'm pleased to report Stevens' research enterprise remains on a strong upward trajectory. Research funding broke consecutive records during the past two academic years, and on the basis of awards received to date during the current academic year, we anticipate Stevens will surpass those levels and once again achieve a record high, for the third consecutive time, by the time the fiscal year concludes in June.

The growth in research activity parallels the upward momentum of Stevens as an institution. The new, beautiful buildings adorning campus, the increases in undergraduate and graduate applications and enrollment, and the annually stronger and more diverse classes of incoming students and talented new faculty all confirm how Stevens is a university on the rise. As we all know, success breeds further success. Increased research funding enables recruitment of top graduate students, whose presence helps attract and retain top faculty. This in turn leads to widening recognition of a university with high research activity, and the cycle renews itself.

Continued long-term growth, of course, requires navigating issues of budget or space. As we work to build and maintain state-of-the-art research facilities with unique experimental capabilities here at Stevens, our campus — nestled within the compact, vibrant city of Hoboken — continues to expand, but within fixed geographic boundaries.

To maximize available resources, then, the team use of lab spaces by faculty has been key to our successful growth. In planned "research clusters," faculty working in similar areas share equipment, students, safety obligations, stipends — and ideas. It is truly a team effort at Stevens. Faculty recruitment reflects this commitment to a team experience, as well: many newly hired faculty teach or research across multiple disciplines that complement existing faculty experience and strengths.

As a faculty member with 42 years of service to Stevens, I deeply appreciate this tremendous team effort as we move closer to designation and recognition as a major research university. It is no longer about "publish or perish," but rather about "collaborate and grow," and Stevens' research-cluster model is demonstrating daily how sharing and collaboration are realistic, achievable and beneficial goals. I am extremely proud of this faculty's vigorous, unselfish and productive efforts as we continue to grow in both size and impact.

Dilhan M. Kalyon
Vice Provost for Research and Innovation

Probing a Medication Misuse Puzzle

Novartis-Stevens project examines cancer patients who skip meds

According to the World Health Organization, just 50% of patients worldwide take their medications properly. Many skip doses or discontinue courses of medication altogether — potentially shortening their life expectancies.

Stevens professor Onur Asan, an expert in medical systems, has been awarded a grant from pharmaceutical manufacturer Novartis to try to understand why.

His exploratory project, "Exploring Nonadherence Factors in Cancer Oral Chemotherapy," will specifically examine breast cancer patients who have been prescribed post-surgical endocrine therapies. Working with Novartis, Asan will analyze anonymized data from the company's proprietary databases, using both quantitative and qualitative approaches to identify the various factors, risks, facilitators and barriers that impact women's use of prescribed oral cancer medications.

He hopes the research will lead to more effective methods of communicating the critical importance of medication adherence for cancer patients.

"With over 250,000 new cases of invasive breast cancer diagnosed last year and more than 3 million survivors, better support is needed to help women adhere to prescribed adjuvant endocrine therapies," explains Asan. "Non-adherence requires innovative solutions."

Eyes on the Skies

Stevens-developed AI to guide space-object surveillance takes top prize in DoD challenge

Objects crashing back to Earth from low-level orbits are increasingly in the news, and the planet is also continuously orbited by hundreds of thousands of pieces of space debris — each a speeding bullet to working satellites and spacecraft.

Now Stevens researchers have created prize-winning artificial intelligence to track the changing paths of objects and avoid potentially fatal collisions.

Optimizing tracking, in real time

By 2050, there may be 50,000 satellites circling the Earth, a 2,000% increase from the 2,500 currently deployed.

There are also half a million large, small and microscopic pieces of space debris in Earth orbit, moving at speeds of up to 16,000 miles per hour — everything from tiny meteorites, discarded gloves and paint chips to entire satellites and rocket stages that have malfunctioned, disintegrated or collided.

To keep an eye on the skies, a network of planetary telescopes and radars is constantly fixed on about 20,000 known space objects, tracking them through the sky daily and noting deviations. These systems, however, do not adjust rapidly and also were not built to accommodate a rapid increase in satellite launches and quantities of space debris.

Electrical and computer engineering professor K.P. Subbalakshmi, in collaboration with former Stevens professor Rajarathnam Chandramouli, designed a proposed AI-based system that continuously optimizes the ways in which these Earth-based sensors work in concert to anticipate and warn of collisions.

The AI works by deciding, in real time, which telescopes and radars observe which areas of space and which objects, adjusting those assignments on the fly as it processes all objects' changing movements and predicted paths.

In early tests, the system has been at least 60% more efficient than current methods of observing and predicting orbital objects and took top prize among all university entries in the 2021 U.S. Space Force-sponsored Hyperspace Challenge.

Brain 'Wear and Tear' Causes Cognitive Decline

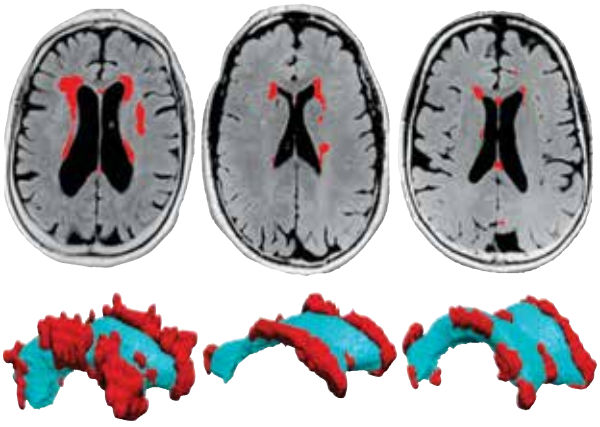
New work from Stevens researchers has revealed how lesions arise in the brain's white matter and can lead to cognitive decline. The work highlights the importance of considering the brain as a physical object continuously undergoing mechanical strains.

"The brain is susceptible to wear and tear in vulnerable areas," explains professor Johannes Weickenmeier. "Especially in an aging brain, we need to look at its biomechanical properties to better understand how things can start to go wrong."

Mapping pressures

Most people develop lesions in the brain's white matter — known as deep and periventricular white matter hyperintensities — by age 60. When lesions accumulate and grow, they can lead to cognitive impairments ranging from memory problems to motor disorders.

Using MRI scans from healthy subjects, Weickenmeier and colleagues at New York University's Grossman School of Medicine and Eindhoven University of Technology developed complex models of each subject's brain. The team then mapped the strains placed on the linings of fluid-filled chambers deep in each brain as pressure pulsed through subjects' cerebral spinal fluid.



Hyperintensities, they found, tended to occur in areas that had stretched more to accommodate pressure changes of that circulating fluid. As those areas wear thin, the fluid can leak into the brain and cause lesions.

This suggests mechanical loads and pressures are major contributors to the onset of brain disorders and cognitive decline, says Weickenmeier, underscoring the need for healthy behaviors such as exercise and the avoidance of harmful substances.

"The cell wall that lines the ventricles wears out over time, like a balloon that's repeatedly blown up and deflated," he explains. "These stresses aren't uniform. They're defined by the geometry of the ventricle, so we can predict where failures will occur."

The research was published in *Scientific Reports* [11, No. 21956].

NEWS & NOTES

Xiaofeng Qian's theoretical work on quantum wave-particle duality was named one of the top physics breakthroughs of 2021 by *Physics World*.

Kathrin Smetana received an **NSF** CAREER award for her project, "Randomized Multiscale Methods for Heterogeneous Nonlinear Partial Differential Equations;" **Jinho Kim** received an CAREER award for his project "Biomechanics of Tension-Induced Lung Tissue Fracture and Subsequent Pulmonary Air Leak;" and **Annie Xian Zhang** received a CAREER award for her project, "Investigation of Thermal Transport in Moiré Pattern Structured Materials to Push the Extremes of Thermal Modulation."

A Stevens proposal to optimize selection of sustainable corporate research projects was awarded first place in **Siemens'** Tech for Sustainability Campaign challenge.

Xiaojiang Du was selected as an ACM Distinguished Member by the Association for Computing Machinery**.**

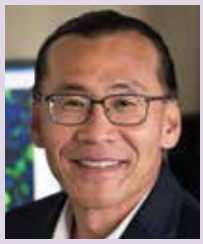
Raviraj Nataraj co-authored "Hand Dominance in the Performance and Perceptions of Virtual Reach Control" in *Acta Psychologica* [223: 103494].

Dibyendu Sarkar began work on a multi-university, $1.6 million **NOAA**-sponsored project to explore green infrastructure and mitigation of stormwater runoff into rivers, lakes and oceans.

Amber Benezra co-authored "Chasing Ghosts: Race, Racism, and the Future of Microbiome Research" in the American Society of Microbiology journal *mSystems* [Vol. 6, No. 5] and authored "Microbial Kin: Relations of Environment and Time" in *Medical Anthropology Quarterly* [Vol. 35, Issue 4; pp. 511-528].

Weina Meng received a New Jersey Department of Transportation award of $780,000 per year for four years to collaborate on high-performance concrete research.

Yanghyo Kim received funding support from **Northrop Grumman** for his project "D-Band Wireline CMOS Tx and Rx for Digital Beamforming Array."



Woo Lee and two former students received an **Edison Patent Award** from the Research & Development Council of New Jersey for their U.S. patent "Graphene-based Films in Sensor Applications."

Hang Liu received a **DOE/Lawrence Berkeley National Lab** award for his project "GPU-Based Parallel Symbolic Factorization and Ordering in SuperLU-DIST."

Lei Wu was selected as a Fellow of the Institute of Electrical and Electronics Engineers **(IEEE)**.

Insider Silence: A Sign of Stock Decline?

Insiders and directors dumping stock in their own companies are widely recognized as signs of future revenue downturns or other adverse events. But a new long-term study led by Stevens business professor Ying Wu indicates insider *inaction* can provide strong predictive power, as well.

Wu, working with Cornell University professors David Ng and George Gao and California State University, Chico professor Qingzhong Ma, analyzed insiders and directors of nearly 2,000 publicly traded companies from 1990 through 2012.

"We theorize that directors and founders are trying to keep a low profile when they are aware of problems within a company," explains Wu. "Courts often use a public record of insider stock-selling as subsequent evidence that adverse company information was improperly concealed."

Indeed, the team discovered that when company directors did not sell their own holdings, returns subsequently dipped or underperformed.

"You would expect inside selling to tell you a company is headed downhill, but a lack of insider transactions may also tell you this."

The work was reported in *Management Science* in December 2021.

$5.9M DARPA AWARD TO STEVENS-LED AI TEAM

The Stevens Institute of Artificial Intelligence (SIAI), partnering with three fellow institutions, has received $5.9 million from the Defense Advanced Research Projects Agency (DARPA) to develop AI that can usefully guide humans through complex tasks. The project is titled "MILLY — Multi-Directional Loosely-Linked Archetype Models for Perceptually-Enabled Task Guidance" and will be headed by primary investigator Jason Corso and co-PI Enrique Dunn.

The team will work to develop artificial intelligence that learns procedures from combinations of visual and lingual examples — such as those included on YouTube or in instructional manuals — then use these learned models to develop interactive guidance for non-expert humans through complex tasks. The AI will continuously learn from multiple sources, map new tasks as they are presented and communicate with humans to understand knowledge gaps.

Co-investigators include Jeffrey Siskind of Purdue University, Joyce Chai at the University of Michigan and Chenliang Xu at the University of Rochester.

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.

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Greening the Grid

Stevens researchers design the next systems to power our homes and businesses more sustainably, reliably and equitably

The accelerating adoption of electric vehicles, wind and solar power, and better batteries will require the nation's power grid to adopt new infrastructure and IT. Cities and towns — even individual neighborhoods, homes and businesses — will connect to the grid of the future differently.

And this retooled grid will need to become more reliable and equitable than ever. Stevens researchers are anticipating these challenges by reimagining a more sustainable grid.

Plugging into the neighborhood 'microgrid'

In the United States, electricity is chiefly created by large facilities and at bulk scale. Step-down transmission systems and substations then move energy locally for distribution and consumption.

But these networks can break down when demand is high, causing blackouts and brownouts. Improved resiliency of grid nodes and linkages will be critical when upgrading the grid. In addition, renewable energy sources aren't always located near population centers.

One answer to these challenges, says Stevens energy expert Philip Odonkor, is to create "microgrids" within communities, placing generators, transmission lines and power storage facilities locally — all connected, monitored and networked intelligently.

To assist planners in siting microgrids, Odonkor has co-developed an AI-powered system, Grid Discovery, that inputs data such as population, climate, building stock and energy demand to determine optimal locations for local energy nodes.

"This is the future of the grid," he explains. "Intelligently locating significant numbers of regional, community-sized and neighborhood-sized sustainable energy resources."

The Department of Energy has awarded $2.5 million to support the projects to date.

Stevens researcher Junjian Qi earned an NSF CAREER award to study cascading failure and power system resilience, and additional NSF funding for a separate effort to develop systems that coordinate photovoltaic, local energy storage and intelligent microinverters.

"We can't rebuild the grid," concludes Wu. "But we can redesign and optimize the tools that control and operate it to develop a greener, more efficient system that can withstand and rebound from weather extremes."

Storage, demand management key

The nation's power distribution systems will also require more intelligent demand management and energy storage, says Lei Wu.

Wu develops algorithmic methods to optimize energy generated, stored, delivered and shed by local power stations. He also works with the University of Arizona to intelligently model, forecast and optimize water flow in an Oregon hydroelectric system by factoring in climate, rainfall and other variables.