Computer Vision: Teaching A.I. to See
Research in object tracking, video analysis attracts partners including Google

Stevens research clusters have recently achieved significant advances in the field known as computer vision — the use of artificial intelligence to “see” and track objects, people and scenes.

Now collaborators, including Google, are joining the university’s effort.

Computer scientist Xinchao Wang works to develop algorithms that track objects and scenes in greater depth. He began by devising a system to analyze live basketball footage and track individual players, movements, passes and shots along with data on angle and force. The technology was later licensed to a California firm, where it now helps power the NBA’s analytics software.

Wang also uses machine-learning methods to track human activities such as operating room procedures, the movements of cells, and the locations and motions of people and objects at transit stations and garages — important for safety and security technologies.

“Once you have accumulated enough tracking data and trained a learning model to recognize threatening behaviors,” he notes, “you can teach the machine to identify potentially suspicious poses or actions just as they are happening.”

Wang has even used deep learning to create higher resolution videos by checking groups of neighboring frames for familiar shapes, patterns and movements. A similar approach helps sharpen the images produced by the curved lenses in security cameras.

Wang’s collaboration with another Stevens researcher, Enrique Dunn, is attracting industry interest as the duo develops systems that can automate and perform scene, person and object tracking in real time. That work has broad applications to autonomous transportation and disaster response, among other challenges.

Augmented reality, assisted driving
Stevens researcher Philippos Mordohai works to enhance the renderings produced in augmented reality (AR) applications and games. He received recent support from Google to continue the research.

Mordohai also experiments with mobility technologies. In one recently concluded, NIH-supported project — “NRI: An Egocentric Computer Vision based Active Learning Co-Robot Wheelchair” — his team mounted cameras on a motorized wheelchair. Deploying machine learning on various sets of terrain, the system anticipates the driver’s next likely moves and assists with driving. The goal: to help patients with limited upper-body mobility to navigate more easily.

“There’s already an impressive body of work here in this field,” says Stevens computer science chair Giuseppe Ateniese, noting that researchers have gone on to assume lead roles in computer vision at firms such as Microsoft and Adobe. “And it’s only growing. We’ll continue to work hard to innovate in this area.”
Researchers Create ‘Quantum Lock’ Prototype

Stevens researchers Yuping Huang, Lac Nguyen and Jeeva Ramanathan have created a new prototype quantum lock that may foreshadow the next super-secure tools to protect networked devices and sensitive data.

The lock, which works via the university’s quantum communication network, could bring secure privacy to homes, offices, medical facilities, financial institutions, defense agencies and data centers.

“Quantum applications will soon change both the internet and the Internet of Things (IoT),” predicts Huang, who directs the university’s Center for Quantum Science & Engineering and worked with graduate students Nguyen and Ramanathan on the project.

In the prototype system, a camera attached to a physical lock obtains facial data. As that happens, a dedicated laser also generates and splits two entangled photons, separating and routing them apart: one to the lock and one to a server in a remote location.

As the photons are detected at either end of the transaction, private, one-time encryption keys are generated and shared between the lock and the server where facial-recognition computations and matches are performed. The facial data are then transmitted, using those keys, to the server; if a match is obtained, a command is sent to open the lock via the same encryption.

“If this scales up as we believe it will, eavesdroppers would in theory be nearly powerless to sneak into the connected networks of devices that permeate our lives and manage much of our personal data,” concludes Huang.

Smart Insoles to Aid Diabetic Care

Stevens has signed an agreement to license patented technology to a New York City health technology firm developing a graphene-based sensing system to assist diabetes patients.

The firm, Bonbouton, is developing a “smart” insole to passively monitor the feet of diabetic patients. The technology is based in part on research conducted by Stevens graduate Linh Le Ph.D. ’15, now CEO of the Manhattan-based venture.

Built-in sensors in the device harvest skin temperature, pressure and other data, wirelessly sending it to a tailored application for analysis and action. The system can provide early warning of forming infections and ulcers, which frequently develop in diabetic patients’ feet due to damaged blood vessels.

“We are excited to see the future development of Bonbouton as it brings the technology forward to improve the lives of patients,” notes David Zimmerman, the university’s director of technology commercialization.

Le’s firm will also partner with MetLife to determine if the insoles might provide better preventative care and reduce the number of radical surgeries required for diabetic patients.

ATTACKING ‘DEAD ZONES’ AT THE SOURCE

Supported by NOAA, Stevens researcher Dibyendu Sarkar is developing novel methods to capture the excess nutrients that cause red tides, ocean dead zones and algal blooms on lakes.

His innovations include a new filter material fitted into storm drains (pictured), an iron- and aluminum-based mulch of recycled treatment byproducts that removed up to two-thirds of phosphorus in tests, and a floating platform of vetiver grass that removes nitrogen, phosphorus and other contaminants from bodies of water.
I want to begin by taking a moment to thank Dr. Mo Dehghani, who until August served as Stevens’ Vice Provost for Research, Innovation and Entrepreneurship.

Under Dr. Dehghani’s guidance, research awards to the university have increased significantly. He created and supported this publication. And he strengthened the research culture at Stevens immeasurably. We would like to express our gratitude for Dr. Dehghani’s leadership in these efforts.

I am pleased that Dr. Dilhan Kalyon has agreed to serve as Interim Vice Provost and I am grateful to him. Dr. Kalyon is an Institute Professor and is well known for his stewardship of Stevens’ Highly Filled Materials Institute (HfMI), which he has directed since 1989. He has received numerous awards for research excellence and leadership and was selected as a Fellow of the American Institute of Chemical Engineering in 2006.

He joins me in welcoming your feedback on IMPACT and our research activities as we continue to move forward and upward.

This issue of IMPACT focuses on the fast-growing area of artificial intelligence (A.I.). Stevens researchers are significant participants in the effort to discern useful patterns quickly from large sets of data and make accurate predictions about everything from tumor growth to criminal behavior to travel conditions. Our partners include MIT, IBM, Google, NIH and the NSF. The 2018 launch of the Stevens Institute for Artificial Intelligence (SIAI) further signaled our resolve to leverage A.I. technologies to solve pressing challenges and ensure a safer, healthier, more secure future.

In this issue you will learn about a number of impressive advances and investigations in machine learning and A.I. They include new ways of teaching autonomous vehicles to map unfamiliar terrain as they move; systems that track people, objects, behaviors and actions in real time; and a Stevens-designed A.I. that can detect insider trading and fraud.

In addition, you will learn about recent innovations in power grid management, quantum security and health monitoring, among others.

As always, we encourage you to learn more by visiting stevens.edu/research.

All my best,

Christophe Pierre
Provost and Vice President for Academic Affairs

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**UNDERGRAD INNOVATION**

**Student-Designed Stent, Mars Rover, Solar Boat**

Stevens undergraduates continued a legacy of research innovation in 2019 with projects including a potentially safer medical device, a rover that can sample Mars’ surface and help produce water for explorers or colonies, and designs for solar-powered watercraft.

One group of seniors developed a novel ureteral stent, working with one of the metro New York City region’s leading hospitals, Hackensack University Medical Center (HUMC). The device replaces the J-shaped coil at one end of a standard stent with a ring-shaped magnet covered with polymer material to slow the growth of painful calcium crystals and harmful biofilms.

Students Mithin Nair, Saarah Mohammedi, Alicia Galer and Anthony Fragale collaborated. HUMC will continue to refine the device, which has already earned a provisional patent.

- A Stevens competition team placed second overall in NASA’s annual Moons to Mars Ice Challenge, showcasing their innovative design for a proposed robotic system that can drill for ice samples and extract water from ice cores on the surface of Mars.

  The team’s design ranked first both for accuracy of ice core samples and clearest water produced. Fellow competitors included MIT and Carnegie Mellon University.

  James Furrer, Jonathan Bobkov, Dana Roe, Nicholas Sorrentino, Ann Collins and Arjun Krishna contributed.

- Stevens also placed third in the annual Solar Splash competition. The university’s lightweight, solar-electric motorboat placed second for 300-meter sprint speed, second for solar endurance, fourth in a slalom race and received special recognition for electrical system design.

  The craft’s systems feature upgraded, intelligent power management software. Victoria Davis, Melanie Valentin, Matthew Colacino, Justin Sitler and Meghan Hand collaborated.
Battling Blackouts

Researcher Lei Wu helps keep the power grid up and running

America’s power grid is formidable, sending half a trillion dollars’ worth of energy annually through some 7 million miles of transmission lines.

But the system by which the nation generates, stores and delivers energy was assembled piecemeal and is becoming increasingly vulnerable. Blackouts and outages cost the U.S. $150 billion annually; with electric consumption expected to double in 30 years, the challenges of optimizing the grid have grown more urgent.

Stevens researcher Lei Wu is using artificial intelligence to try to minimize breakdowns, overloads and power shortages.

“We can’t rebuild the grid,” notes Wu. “But we can redesign and optimize the tools that control and operate it.”

Wu develops models to simulate and understand how the nation’s energy travels from point to point via power plants, transmission infrastructure and storage media. The group tackles challenges as diverse as the efficient apportionment of wind and solar power; the protection of power plants and power grids from cyberattack; and the use of electric vehicles for temporary power storage.

Wu will also begin exploring the design and deployment of microgrids: power systems that only span several buildings or blocks. He plans to create a pilot microgrid that can provide emergency power to hospitals and municipal facilities for a small Northeastern city during outages.

Detecting Insider Trading With A.I.

Algorithms spot potential fraud by scanning communications

A Stevens-Accenture collaboration is building A.I. that appears to reliably spot insider-trading chatter and other potentially illegal behavior before it escalates.

Working with the Fortune 500 firm, researchers Rajarathnam “Mouli” Chandramouli and Koduvayur Subbalakshmi adapted their proprietary lie-detecting technology — which scans emails and other communications for signs of deception — to financial applications.

The researchers fed large quantities of both fraud-related emails and normal email communications into an artificial intelligence-based analytic engine as training data, directing the software to seek out insider-trading references.

The algorithms quickly began picking out patterns and code words in conversation, among other signals, that appear to distinguish legitimate sales orders and other chatter from suspicious activity. The team is also developing tools to scan audio. Future iterations will factor in sentiments and emotions expressed in emails and calls, say the researchers.

NSF, NIH ADD $2.3 MILLION TO HEALTH DATA PROJECTS

Stevens researcher Samantha Kleinberg has secured an additional $2.3 million from the National Science Foundation (NSF) and National Institutes of Health (NIH). The support brings Kleinberg’s total funding on projects that leverage big data and enhance healthcare to $5.4 million.

In August, NSF awarded more than $918,000 to support development of computational tools to personalize care for patients with diabetes. The work, to be performed with Stevens colleague Onur Asan and Jesseca Marsh of Lehigh University, will also create training modules to educate clinicians about ways patient beliefs influence trust and decision making.

NIH awarded Kleinberg and New York University collaborator Andrea Deierlein $864,000 in August for a project focused on pregnant mothers at risk of gestational diabetes. Using patient-generated health data collected by such means as wearable activity monitors and meal-logging imagery, the team aims to identify risk factors and early-intervention targets.

NSF awarded Kleinberg $500,000 in September to continue investigations into causal inference aimed at improving the development of more useful artificial intelligence for patients.

“Humans don’t just use data like a machine,” explains Kleinberg. “They make decisions based on many things, including prior experiences and assumptions.”
Stevens researchers have developed a non-invasive device that could soon allow expectant mothers to hear their infants’ heartbeats in real time, at home — potentially providing earlier alerts to signs of trouble to physicians and parents-to-be.

Stevens professor Negar Tavassolian and graduate student Chenxi Yang collaborated with New York University’s Langone Medical Center on the work, reported in *IEEE Sensors Journal* 19(22). The device, which deploys the same onboard gyroscopes as a smartphone, records vibrations through a mother’s abdomen as an infant’s heart beats or a child kicks or moves.

The Stevens team’s previous work had demonstrated how chest vibrations can be used to track adult heartbeats. To filter out the masking effect of a mother’s body on fetal sounds, Tavassolian and Yang built a novel array of three distinct sensors, designing specific algorithms to isolate a baby’s unique heartbeat from surrounding signals.

In early tests on a small group of expecting mothers, the system detected fetal heart rates with roughly the same accuracy as fetal cardiocograms, which combine ECG readings with maternal contraction data.

The new system poses no risk to unborn children, say the researchers — a concern with ultrasound monitors, which produce heat and cannot be used for long periods of time. It is also far simpler, smaller, less expensive and more energy-efficient than current ECG or Doppler-based monitors.

A typical monitor system can weigh 10 pounds or more and only operate on battery power for several hours, notes Tavassolian, while the Stevens-developed device measures just one-half centimeter long and can run more than 24 hours before requiring a recharge of its 3-volt battery.

Next the team will work to create a more broadly useful sensor that integrates additional readings and patient feedback.
Self-driving vehicles, inspection robots and military drones all must move in unfamiliar spaces and places, learning on the fly, without becoming lost, disabled or drained of power.

And making maps of new places in real time is not as simple as it might seem.

That’s why a pair of Stevens research projects is teaching vehicles and systems to map new landscapes, streets and other spaces faster and more efficiently.

Leaner, more accurate mapping
Researcher Brendan Englot and former student Tixiao Shan Ph.D. ’19 (now a postdoctoral researcher at MIT) are taking two novel approaches to building better maps.

The first involves laser-based scanning technology known as LIDAR. Roving robots sporting LIDAR cannot always stay connected to GPS as they move — particularly indoors, underground or in remote areas. So the duo developed a system known as LeGO-LOAM (Lightweight, Ground-Optimized LIDAR Odometry And Mapping), first presented in 2018 at IEEE’s International Conference on Intelligent Robots and Systems.

The “lightweight” method tailors its assumptions and calculations to the problem of localization and mapping by developing a minimalistic algorithm that focuses on the most useful information and matches data across scans. The result: better maps, using less computing power. Even without any access to GPS or known map data, Englot and Shan discovered, the system can map several miles of new terrain with only very slight errors (less than one meter).

With MIT: A.I. to further enhance maps
Next the researchers added artificial intelligence to the process, enabling even higher-resolution, more accurate maps by moving vehicles.

In collaboration with MIT and supported by the National Science Foundation, the team has created new methods of using machine learning for mapping and rendering walls, barriers, roadside curbs and other hard boundaries.

The heart of the new system is a technique known as the Bayesian Generalized Kernel (BGK) method, which makes inferences to guess at missing data based on learned probabilities. While BGK has been around for a decade, Shan, Englot and Kevin Doherty ’17 (also at MIT) are the first to apply it to the mapping of structures and terrain on the ground.

Their specialized algorithms take a cloud of points from scan data, creating grid cells with height data and inferred elevations while drawing a rough map. Then the algorithms return for a second pass, filling in the remaining gaps by intelligently guessing using the BGK method — at lightning speed. A discussion of the method’s use for grid mapping appeared in IEEE’s Transactions on Robotics 34(4) in August.