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NJIT

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From the Senior Vice Provost for Research

Photo: Oscar Mascandaro

Those of us steeped in STEM tend to think of problem-solving in primarily technological terms: a longer-lasting battery, a sturdier vaccine, a more agile exoskeleton. Yet it's become clear that the extraordinary challenges we're tackling, from moderating climate change, to building resilient public health infrastructure, to improving our data analytics and communications capabilities, require more from us.

One of the bluntest lessons of the COVID-19 pandemic is the complexity not just of the coordinated health care response, but also of effectively communicating it. That so many people are seemingly impervious to valid data, from politically motivated disbelievers, to unwitting consumers of falsehoods, to marginalized populations lacking access to information at the best of times, came as a shock. Worse still, where science fails to take root, we pay in lives.

The experience of the last three years is a clanging wake-up call — one that requires us to re-examine our role as researchers in securing the trust and backing of the people whose lives we are dedicated to improving. It should inform our approach to every existential challenge we face.

Our principal job remains: to collect more and better data, to use it to develop models that help us understand the present and plan for the future, and to devise technologies that put practical, accessible solutions into effect. One of the researchers profiled in this issue of the magazine, for example, is developing a timed-release mRNA vaccine that can potentially be freeze-dried to extend its shelf life.

However, success in tackling systemic threats such as pandemic readiness, global warming and targeted misinformation will depend on a web of motivated and productive partnerships among distinct groups: scientists, nimble enterprises and a workforce able to translate inventions into tools, informed policymakers and, perhaps most important, engaged communities that share an understanding of the problem and feel confident the remedies will benefit them.

It was in the spirit of forging these alliances — and spurring new partnerships and thinking — that representatives from these groups, including researchers from different regions of the country, gathered late last year at the inaugural forum of NJIT's chapter of the National Academy of Inventors, titled "Sustainable Societies and Climate Change: The Quest for Sustainable Global Solutions."

Robin Leichenko, co-director of the Rutgers Climate Institute, argued wisely that including affected communities in climate action planning at the design stage is the best guarantee policies are "not voted out at the next election."

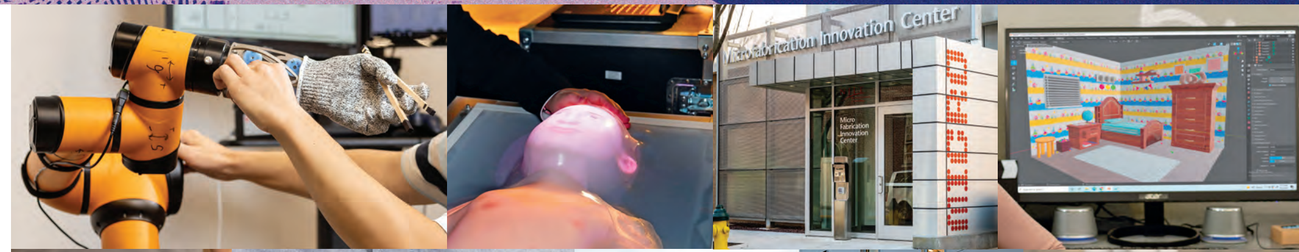
NJIT's Michel Boufadel unveiled a "Community Intrinsic Resilience Index" that evaluates a county's ability to prepare for, respond to and recover from a disruptive event. His model assesses and helps communicate the impact of various levels of stress, such as the severity of a storm, on four key areas that affect everyday life: transportation, energy, health and socio-economics.

In this issue of the magazine, we focus on the growing dependence of people on machines, what I call our co-evolution. But if we are to earn the public's trust in them, we must be vigilant. With the rise of machine learning and advanced data analytics, the ethics and trustworthiness of data-driven approaches, exemplified by artificial intelligence, become paramount. It is essential that we have a clear understanding of conflicts of interest built into data-gathering and the means to remove bias.

To advance the public's trust and ensure our own integrity, we launched a Center for Ethics and Responsible Research in 2021 to ensure a campuswide culture of ethical STEM that permeates NJIT's educational and research-related programs, as well as faculty research, including scrutiny of emerging technologies and their potential impacts. Ethics in Engineering courses, for example, require students to meet with local residents about issues in the built environment that affect them, such as the balance between luxury and affordable housing and the placement of hazardous waste remediation facilities. It is our job as educators to make sure that the scientific and technological workers of the future understand the cascading implications of failing to set and maintain ethical standards.

We intend to back this initiative with data. Joining with members of the National Ethics Project from Harvard, Stanford and the University of South Florida, center director Britt Holbrook's team is building an evidence-based method for determining an institution's commitment to ethics and ethical education. With funding from the National Science Foundation, we're examining how well institutional messaging that describes NJIT's commitment to ethics aligns with students' experiences in and out of the classroom. We look forward to sharing the results.

Atam P. Dhawan
Senior Vice Provost for Research
Distinguished Professor of Electrical and Computer Engineering



Machines Like Us

Arm in arm, humans and machines trek into the future. The U.S. Department of Veterans Affairs has committed to providing an exoskeleton to every eligible veteran with a spinal cord injury who wants one. Humanoid robots are being developed as human avatars for remotely controlled jobs, such as emergency responders, caregivers and repair workers. In less conspicuous ways, the range of technologies designed to expand human capabilities, from the physical to the cognitive, is ever widening.

What will determine their success is a focus on the human: creating machines that amplify, rather than replace. In his Life Sciences Motion Capture Laboratory, Saikat Pal, for example, measures the movement of people and exoskeletons, both together and independently, to see how the two interact and to get a deeper sense of the physics behind how a human walks in a robot. So much depends on getting it right. Damyane Evely, a paraplegic who took 1,100 steps in Pal's lab last year, described the outing as both a physical and an emotional high. "Just to stand, to have an eye-level conversation, makes it worthwhile."

APPROXIMATING HUMANS TOCABI, a nearly 6-foot-tall robot whose programming and 33 degrees of freedom give it strikingly human capabilities, such as skill at charades, also smiles, blows kisses and toasts companions. The goal, says industrial designer Mathew Schwartz, a member of the TOCABI team, is to make a real-world robot that looks and moves in an understandable way to integrate with peoples' daily lives.

Electrical and computer engineer Cong Wang focuses on the "physical intelligence" of robots designed to perform everyday tasks. He is currently building a "chopstick robot" with two electromechanical fingers that are sufficient to do many jobs — one finger to serve as a brace and platform, the other to slide forward and backward and move sideways or vertically.

In designing a physical-virtual patient to train medical and nursing students, informatics researcher Salam Daher incorporated computer-generated facial expressions that use controllers to imitate muscles. Her simulators allow them to test for reactions — tug on the eyelids, listen to the heartbeat, localize temperature and even talk to the patient.

Murat Guvendiren develops biomaterials that would enable the production of fully functional, human-scale tissues and organs to replace failed ones. To date, bioinks, hydrogels seeded with live human cells that are 3D-printed in the lab, cannot fully mimic the dynamic properties of native tissue, such as changes in stiffness and biochemistry.

AMPLIFYING HUMAN SENSES Endowed with machine listening, smart acoustic sensors are the auditory sibling to computer vision, able to distinguish individual sounds, record how often they occur and measure how loud each one is. Informatics researcher Mark Cartwright works on networks that monitor, analyze and mitigate urban noise pollution.

Tao Han, director of NJIT's Ubiquitous Networking and Intelligent Computing System Lab, is developing a decentralized system of networked cameras, each with embedded hardware and software, that can be trained to recognize what they're seeing in real time and respond appropriately.

In measuring a building's energy usage and indoor environmental quality, architect and senior designer Hyojin Kim analyzes a test house's long-term energy performance, while also determining how occupant comfort is impacted by energy efficiency improvements and building system changes.

Architect Vera Parlac reimagines the function of building walls in favor of surfaces that are not still, but responsive to inhabitants. Inspired by soft robotics, Parlac builds systems that integrate shape-changing materials, such as soft pneumatic, or inflatable, "muscles" made of silicone, to create movement.

INTEGRATING THE REAL INTO VIRTUAL REALITY Informatics researcher Margarita Vinnikov develops immersive virtual reality platforms to study driver behaviors in precisely rendered simulations. Working with the New Jersey Transportation Planning Authority, she is currently creating programs to teach young people the dangers posed by distractions such as ringing phones, text notifications and unsecured objects rattling around a moving car.

Upon entering architectural historian Burcak Ozludil's virtual model of the women's ward of the Toptasi Insane Asylum in Istanbul, visitors walk through a vast open-air courtyard where patients mingled under the elements after meals, before climbing a staircase leading back to their rooms around a corridor secured by iron bars. To understand evolving treatments of madness in the late 19th-century Ottoman Empire, she says, it's vital to know how patients moved through the institution.

Historian Louis Hamilton uses virtual models of a public shrine before and after its restoration, and eye-tracking software to monitor "visitor" responses to both. He's interested in how changes in the urban fabric may have unintended effects on religious practice, and the implications for the restoration of heritage sites and community development going forward.

CREATING A MORE RESPONSIBLE AI Cognitive neuroscientist Niccolo Pescetelli focuses on expanding our collective intelligence capabilities, while identifying the bias-filled algorithms that hamper them. Pointing to his research showing that common search engines diminish the diversity of information that groups can forage online, he proposes a new model: algorithms that do not just optimize click-through rates and advertisement customization, but offer content that enriches, and for people on all sides of a debate, a window into something new.

Xiaoyang Xu is developing a controlled-release mRNA vaccine that can be stored longer and at higher temperatures than the current jabs.

Mediating the Immune System With Durable, Timed-Release Vaccines

Developed at lightning speed and with breathtaking success, the mRNA vaccines targeting SARS-CoV-2 are a marvel of modern science. Their shortcomings primarily involve distribution: They require ultra-cold chain logistics, suffer from a short shelf life and show reduced stability during storage and transportation.

In a bid to devise a sturdier, more accessible generation of vaccines, chemical engineer **Xiaoyang Xu** is developing a nano-sized delivery vehicle for gene-based medications that can be stored much longer and at higher temperatures than the current mRNA jabs deployed against the virus, including by freeze-drying.

His shot is composed of millions of polymer-encapsulated mRNA nanoparticles that release their payloads — genetic code that instructs cells to create proteins that mimic disease antigens, prompting an immune response — over time. In the case of vaccines, a controlled release — faster or slower on demand, or in stages — could potentially eliminate the need for two doses.

In early tests, Xu's COVID vaccine successfully delivered the SARS-CoV-2 spike gene and generated strong spike-specific antibody titers and non-allergy-related immune responses in mice, while lowering cellular toxicity. The drugs, once administered, were released over the course of eight days, peaking at two. The novel "particle-in-particle" structure of the mRNA carriers, which encapsulates smaller mRNA nanocomplexes within the relatively bigger polymer-based nanoparticle, facilitates the drug's controlled release by protecting the mRNA molecules from degradation by enzymes in the body, thus promoting the production of spike proteins.

Backed by a $1 million award from the Gustavus and Louise Pfeiffer Research Foundation, Xu's immediate focus is COVID-19, although theoretically any protein can be expressed by changing the mRNA code in his nanoparticles.

Indeed, his goal is to develop a platform with the potential to treat a multitude of diseases or different strains of the same disease. Cancer patients, for example, would particularly benefit from the long-term controlled release of mRNA to prolong antigen production, which could reduce the number of trips to the hospital for treatment.

Nucleic acid vaccines, he notes, represent an advance over live attenuated vaccines in protection from contamination in the manufacturing process and from the risk of causing disease in patients, as well as in their ease of design and speed of manufacture. However, their DNA/mRNA payload is fragile.

"More durable vaccines would be especially useful in rural and underdeveloped regions that lack the refrigeration capabilities, transportation technology and the capital to keep the vaccine stabilized and avoid waste," he explains.

One of his core innovations is to replace the fragile lipid casing of the current mRNA vaccines with a novel polymer he developed that, when formulated into a nanoparticle vaccine, can be freeze-dried and stored at -20°C/-4°F. The current formulations require extreme cold chain storage and transportation, with temperatures as low as -70°C/-94°F, to prevent the vaccine from spoiling.

In later experiments, Xu's lab discovered that a lipid-polymer hybrid nanoparticle improves upon his earlier formula by bolstering the stability of the drug carriers; they proved durable for at least six months of storage at -20°C with no loss of the nanoparticle-mediated antigen production efficiency after they were freeze-dried. The modified vaccines also successfully elicited spike-specific antibodies and Th1-biased T cell immune responses in immunized mice.

In the future, the particle-in-particle structure will also enable vaccine designers to load multiple mRNA codes into a single particle to generate different antigens, including those for SARS-CoV-2 variants. Similarly, the ability to quickly design a flu vaccine that protects against several strains would be hugely advantageous. Drug companies must now decide months in advance which strain they think will be circulating in the coming season, as the vaccines are so difficult and time-intensive to manufacture.

In developing the nanoparticles, Xu's team has tried more than 100 polymer formulations by tuning the materials used, their sizes and surface electric charges. They are studying the effects of various parameters on immune response and stability to optimize the formulations with translational potential.

Previous polymeric formulations were limited in their capacity to deliver mRNA and DNA. Through computer-assisted design technology, Xu's team has created a library of novel polymers that could deliver gene payloads effectively.

"The materials we use must also be nontoxic, or biocompatible, meaning they don't themselves trigger an undesired chemical or immune response, and degrade naturally after they deliver their package inside the cell," he adds.

Xu's nanoparticle platform is a continuation of his previous work on novel biomaterials and drug delivery systems, stemming from his investigations in Moderna co-founder Robert Langer's lab at MIT, where he was a postdoctoral researcher focused on obesity medicines.

In his Laboratory of Nanomedicine and Healthcare Biomaterials, he and his team are developing new technologies for medical applications in addition to controlled drug delivery mechanisms, such as targeted nanoparticles to deliver therapies to the brain. Their aim is to develop new methods to treat cancer, obesity and cardiovascular disease, among other disorders.

Bioprinting Rejection-Proof Organs

Murat Guvendiren

There is no sustainable cure at present for osteoarthritis, the most common chronic musculoskeletal disorder of the joints. And while joint replacements are successful treatments for older patients, they hold less promise for younger people, with failure in the long-term nearly guaranteed. Biomaterial engineers propose another solution: restoring the damaged tissue itself.

"Optimally, we would produce tissues and organs from a person's own medical images and cells to manufacture personalized materials that would not be rejected," says MURAT GUVENDIREN, an assistant professor of chemical and materials engineering. Backed by a National Science Foundation CAREER grant, he is developing biomaterials that would enable the production of fully functional, human-scale tissues and organs to replace failed ones.

To date, bioinks, hydrogels seeded with live human cells that are 3D-printed in the lab, cannot fully mimic the dynamic properties of native tissue, such as changes in stiffness and biochemistry. These properties take shape in the body's extracellular matrix during tissue development, disease progression and the healing process.

Guvendiren's bioinks are "cell-instructive" materials that train stem cells to differentiate into different cell types in the right sequence to create a functional tissue. Their hydrogel casing, which is composed of a polysaccharide found in nature, including the body, functions as a supportive matrix for the cells that is "cured" into the desired structure with blue light. It degrades as it is replaced by naturally produced extracellular matrix.

Bioprinting the interface between cartilage and bone is difficult, because the tissues are so different: bone is hard, has a unique architecture and is threaded with blood vessels; cartilage is soft and has none. The cells that compose each must be created in a precise sequence.

"Our goal is to investigate the ability of our smart bioinks to create a cell-instructive material to regenerate bone with built-in vasculature that will gradually transition into cartilage using adult human mesenchymal stem cells, which is not possible with conventional fabrication techniques," Guvendiren explains.

Decoding Drivers' Behavior on the Virtual Highway

Margarita Vinnikov analyzes drivers' behavior, including their attention to the roadway, as they virtually motor around urban and rural routes.

Being told that it takes five seconds to travel the length of a football field at 55 mph doesn't register quite as forcefully as looking up from a momentary peek at a cellphone to discover a truck braking directly ahead.

Providing those experiences memorably, while safely, to young drivers is the goal of a partnership between the New Jersey Transportation Planning Authority (NJTPA) and informatics researchers at NJIT, who develop immersive virtual reality (VR) platforms to study driver behaviors in precisely rendered simulations. Here, the program is designed to teach the dangers posed by distractions such as ringing phones, text notifications and unsecured objects rattling around a moving car.

NJIT students and others are now testing the first phase of the experimental system, designed to assess the fidelity, or realism, of the platform. Wearing VR headsets and gripping a virtual wheel, they motor at noon around a simulated city block, responding to traffic lights and pedestrians in crosswalks. Directional signals on the dashboard tell them when to turn.

"We're also collecting initial data on driver safety with eye-tracking devices embedded in the headsets that determine where people are looking when they're driving, especially in making turns," says **Margarita Vinnikov**, director of NJIT's Interactive Cross-Reality (iXR) Lab. "We gather information from the VR steering wheel that tells what portion of the road the person is looking at and the orientation of their vehicle while taking the turn. Did they, for example, approximate it well enough, and if not, why?"

In later stages of the study, the iXR Lab plans to complicate the road tests with unforeseen events, such as people suddenly crossing outside of the crosswalk when the driver's eyes are averted from his or her route by distractions in the car.

"Ultimately, we want to know how to detect unsafe habits and keep people on task. Drivers need to actively monitor where they're driving. The more they scan the environment, the better they drive," Vinnikov says. "In terms of steering, we also want to know where they're looking, such as at the horizon or more directly at the road in front of them. While making turns, do they look at the inner or outer part of the curb? At night, if their cellphone is illuminated on the dashboard, can they only see the outer part of the curb?"

For automobile manufacturers and policymakers, the information could help determine, for example, if and when automatic driving features take control of a vehicle.

The current project follows on the heels of an earlier collaboration with the NJTPA, in which Vinnikov and her team developed a VR tool to allow local officials and the driving public in a rural section of the state to virtually test a roundabout the agency had proposed as a replacement for a dangerous four-way intersection.

"The roundabout project gave us a rural setting that we can now compare to an urban environment, allowing us to measure the safety of roadway curvatures in different contexts," she says. "We also developed different environmental settings, so that drivers can test the roads in snow and rain and at nighttime."

The lab focuses on cognitive as well as physical tasks. The team is currently developing a VR platform for medical ontology databases that will help medical students and researchers learn the thousands of terms they're required to know, while exploring the connections among diseases, symptoms, treatments and involved organ systems.

Here, users walk among books that are connected to related ones by directional lines. A book on pulmonary diseases, for example, would be linked to lung-involved subcategories, such as COVID-19 and asthma, as well as to subsets of related information, such as virus variants or asthma in children. They can open a book using a pair of virtual hands or by shooting "rays" at it, and place it in a cart to read later with other books.

"Think of each term or concept as a book with definitions and descriptions on a shelf next to related ones. You can memorize a list, but it's better to see a picture. When we're asked to recall things, we see them in 3D, not as words on a list," Vinnikov explains. "Here, the viewer is not limited to a flat surface with a graph layout on a screen, but can literally walk through the knowledge structure in virtual reality."

The main beneficiaries of the system, she says, are people who want to understand the big picture, to see all of the possible connections and relationships among topics. More sophisticated researchers will also have the ability to create their own knowledge structures by cutting links and reordering them.

"In all of these projects," she notes, "my goal is to build VR platforms with realistic simulations to better understand human behavior and improve learning and training as a result."

Alert! The Physical-Virtual Patient Is Going Into Shock

Photo: Courtesy of Ravi Melaram

The boy's faint voice, rapid pulse and high temperature indicate a raging infection. While the doctor questions him calmly, a swift diagnosis is urgent. She presses on his finger and the blood flow returns too slowly. His breathing becomes labored as his lips take on a blueish tinge.

That decides it: sepsis, a life-threatening condition that will send the body into irreversible shock if untreated. The only disaster averted, however, was a poor review. The ailing 7 year-old is a physical-virtual patient and the doctor, masked and gowned, a medical student in training.

"Nurse trainees and medical students need lots of practice before they can safely treat real patients," explains SALAM DAHER, director of NJIT's Virtual Technology Applications Lab for Human Simulation, who designed the simulator, including the computer-generated facial expressions that use controllers to imitate muscles.

While the doctor-in-training aced the test, the real point of the exercise was to see whether she would accept this new training technology, notes Daher, who has designed a number of devices that use augmented reality and virtual content to simulate real-world conditions to enhance health care training.

"Mannequins have limited communication and can't change their appearance, making it difficult for caregivers to practice their bedside manner, for example. Humans can't simulate symptoms, such as changing physiology, at will," she notes. "The physical-virtual patients do both, allowing students to test for reactions — tug on the eyelids, listen to the heartbeat, localize temperature and even talk to the patient."

A complex system of acoustic haptic devices, speakers, heaters, cameras and image projectors are contained in a box under the hospital bed. "The physical properties are critical," Daher adds. "We must be able to project images, but the soft skin can neither be transparent nor opaque. Finding the balance was an interesting process."

In several studies, students encountered strokes, sepsis, child abuse and measles.

"We found a high technology acceptance," Daher says. "The simulator succeeded in heightening students' perception of realism, and indeed, increasing their urgency to treat patients, compared to existing methods. Nursing students learned more. Adding this technology to traditional methods increased medical students' self-confidence in the diagnosis."

Walking With Paralysis

Strapped into an exoskeleton, Damyane Evely strode heavily back and forth across a 15-foot platform, taking an occasional peek at a monitor on the wall to survey his progress — and to silently marvel. It had been more than 15 years since his spinal cord was compressed in a motorcycle accident, landing him in a wheelchair. He was relishing his verticality.

Last December, Evely was the first person in the U.S. with a spinal cord injury to test the new, self-balancing Wandercraft Atalante, a third-generation exoskeleton with 12 degrees of freedom that is designed to more closely approximate human gaits than current models. He took 1,100 steps that day in **Saikat Pal**'s Life Sciences Motion Capture Laboratory, with a group of engineers, physical therapists, exoskeleton trainers and robot designers looking on. They wanted to know not just whether he could walk in it, but how naturally and safely.

Sections of both Evely's body, from his head to his toes, and corresponding points on the exoskeleton were tagged with reflective markers that light up under infrared sensors positioned around the lab. A network of cameras continuously recorded those movements, feeding the data into a specialized software program that displays an avatar on the monitor, while also recording the forces from the ground to determine their impact on joint rotations for both human and robot.

Using the markers, the researchers are able to track the 3D movement of each body segment with respect to a reference frame at the center of the platform. This allows them to calculate the relative movements of each body segment with respect to one another — the wrist to the elbow, the elbow to the shoulder, for example.

"We were measuring the movement of the human and the robot, both together and independently, to see how the two interact and to get a deeper sense of the physics behind how a human walks in the robot," says Pal, a biomedical engineer. "With the Wandercraft and other models, we also want to know how the device improves a host of health measures in different patient populations."

Damyane Evely, a paraplegic, was the first person in the U.S. with a spinal cord injury to test a new, self-balancing exoskeleton with 12 degrees of freedom that is designed to more closely approximate human gaits than current models. He took 1,100 closely observed steps that day in Saikat Pal's Life Sciences Motion Capture Laboratory.

Not being able to walk is just one of the problems that people with spinal cord injuries (SCI) face. Bone density and strength, bowel function, psychological state and cardiovascular health are among the many aspects negatively affected by losing upright ambulation.

"Taking 1,100 steps is very good exercise for people with SCI and great for their health," Pal says of Evely's session. "By the end, Damyane was sweating."

The U.S. Department of Veterans Affairs has committed to providing an exoskeleton to every eligible veteran with SCI who wants one. So far, the U.S. Food and Drug Administration has approved three devices for use, not including the Wandercraft. Pal is testing their safety.

"There are some negative impacts on weak bones, as is often the case with chronic SCI. Exoskeletal-assisted walking trials have reported fractures at the knee and ankle," he notes.

Backed by a $1.2 million grant from the Department of Veterans Affairs to evaluate individuals with SCI in the FDA-approved exoskeletons, Pal is developing methods to predict the risk of fractures by determining the mechanical competence of bone and forces brought to bear on the joints during exoskeletal-assisted walking. This grant is in collaboration with the James J. Peters VA Medical Center in the Bronx. Pal works closely there with William A. Bauman, M.D., director of the VA Rehabilitation, Research and Development National Center for the Medical Consequences of Spinal Cord Injury, and Ann Spungen, Ph.D., associate director of the Spinal Cord Damage Research Center and the principal investigator for its exoskeletal-assisted walking program.

"The human is the most important component of this system. We need to determine the forces they're experiencing at their joints so we can reduce them and minimize fractures," he says.

As they develop new and improved models, safety and fluidity will determine their success.

"We don't want people moving like Frankenstein. People who need these devices want to blend in with the crowd," says Pal. "We also recognize that the patient population is not generic. Two people with the same diagnosis, say a thoracic-4 injury, may have very different functionalities, not to mention body dimensions."

Exoskeletons of the future, he says, will come with degrees of personalization with respect to weight, height and gait patterns. Using AI, designers will be able to customize their trajectories to optimize the robots' performance.

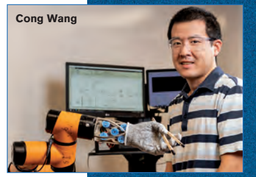
For Evely, the test alone was worth the effort.

"Just to stand, to have an eye-level conversation, makes it worthwhile," he says of the trial, adding, "It's not going to cure my paralysis, but I'll do anything for science and research that moves us forward. I'm all for it. I'm looking forward to the day when I can stand and hug my sons."

Watching him, Pal shares, was a peak moment in his career.

"For someone who is paralyzed to get up and walk around, more or less independently, in just one session, was the coolest."

Teaching C-3PO Everyday Life Skills


Cong Wang

C-3PO walked upright and spoke six million languages, but never did much with his hands besides flapping them in alarm.

Such is the state of modern robotics and cyberintelligence, where droids do backflips and conduct natural-language conversations, but precision manipulation of physical objects remains elusive, says CONG WANG, an associate professor of electrical and computer engineering. Backed by a National Science Foundation CAREER grant, his plan to advance these skills involves a two-fingered robot, crowdsourcing and artificial intelligence.

"It's what I call robot physical intelligence. To handle a lot of everyday work, you don't need to be an expert of all the truth in the universe. But instead you need to be able to move your body and use your hands in a specific manner," explains Wang, who is building a "chopstick robot." Two electromechanical fingers are enough to do many jobs — one finger to serve as a brace and platform, the other to slide forward and backward and move sideways or vertically.

Wang will connect his chopbot to the Amazon Mechanical Turk crowdsourced task system, which lets remote volunteers perform minor tasks. He will ask them to manipulate the robotic hand against simple games and object pickups.

Each finger on the hand will have sensors to record movement data such as depth, direction, pressure and speed. When the research is done, all movements will be fed into an artificial intelligence processor, in an attempt to teach the robot which manipulations worked and which didn't. Potentially, the robot will learn from these actions and even develop its own manipulations that the human volunteers hadn't tried. In that case, a robot will teach us new tricks.

"It's going to take a nontrivial evolution, a process for robots to gradually develop a physical intelligence," he acknowledges. "That process, I think, can be accelerated by mentoring from humans."

ARTIFICIAL INTELLIGENCE

Q&A

Photo: Courtesy of Microsoft

The Utility of AI Rests on Ever-Improving Data

Iksha Herr M.S. '03
Managing Director, Data and Artificial Intelligence, Microsoft's Health and Life Sciences Division

Q: WHAT DOES YOUR JOB ENTAIL?

A: My role at Microsoft's Health and Life Sciences business unit is divided into two aspects. One is leading the Data and Artificial Intelligence (AI) organization that consists of data scientists, engineers, data governance experts, computer scientists, data architects and others to support a portfolio of clients from the Life Sciences, such as the pharmaceutical, biotech and medtech sectors, payers and providers, to solve a variety of problems across the drug and device development, therapeutic and health insurance value chain. The other is in providing subject matter expertise related to data science and AI for the generation of insights and evidence using data from the health care continuum.

Q: HOW CAN MACHINE LEARNING AND AI IMPROVE PATIENT CARE?

A: The areas in which AI/ML-based modeling can be applied to improve patient care are ever expanding. Collaboration between stakeholders across the health care continuum will help to speed up this process by sharing data, insights, methods, resources and technology, etc.

Q: IN WHAT AREAS OF HEALTH CARE ARE ADVANCED DATA ANALYTICS MOST BENEFICIAL?

A: I don't think there are any specific health care problems that are uniquely suited to advanced analytics, in general. The lack of availability of data and usable data for certain types of diseases and health care problems plays a significant role in determining whether advanced analytics can be applied or not.

Q: WHAT CHALLENGES DO WE FACE WITH RESPECT TO DATA INTEGRITY AND RELIABILITY?

A: In general, data is collected for specific purposes in the health care space. For example, data is collected into an Electronic Medical Record (EMR) during the delivery of health care when a patient-clinician interaction takes place in a health care setting. This data can subsequently be used for clinical research. However, since the EMR data was collected for a specific purpose, when it is used for secondary purposes like clinical research, all the data elements needed may not be available. In order to create data that can be used for many different applications, we will need to approach data collection, regardless of the primary purpose of the collection, in a more holistic way.

Q: HOW CAN WE ADDRESS BIASES OR MISREPRESENTATIONS IN DATA IN AI-BASED ANALYTICS?

A: In my opinion, bias in data needs to be addressed by understanding the data better, rather than trying to address bias via analytic methods. As an example, understanding the primary purpose a data set was collected for, the collection method, the representativeness of the data set, etc., will help to understand bias and then design ways to address the bias.

Q: WHAT FUTURE ROLE DO YOU SEE FOR ADVANCED DATA ANALYTICS AND AI-BASED METHODS IN PATIENT CARE AND CLINICAL MANAGEMENT?

A: I think the use of advanced analytics and AI will mature in the future to a point where AI-based insights will be readily available not just in the health care space but in many more parts of everyday life, for humans to consider and make decisions based on these insights.

Tracking AI's Rise, From Neural Networks to Edge Computing

Stavros Zervoudakis '91, M.S. '92
Vice President of Artificial Intelligence at Mutual of America Financial Group
Adjunct Assistant Professor at New York University

Photo: Janet Zheng

Q: HOW DID A PROCESS ENGINEER BECOME AN EXPERT IN DATA ANALYTICS AND ARTIFICIAL INTELLIGENCE (AI)?

A: As an intern for ADP during my master's program at NJIT, I led a team that created tools to automate time-consuming quality assurance processes. This allowed us to minimize the ineffective use of resources on repetitive tasks. My graduate research focused on neural networks, the underlying technology of deep learning, a subset of AI. Process (re)engineering, automation and AI, where applicable, share a goal: making it simpler and easier to get things done. Over the past 10+ years, I've led data and AI-related initiatives aimed at improving processes related to company restructuring, financial services, process reengineering, fraud detection and natural language processing for startups and large organizations. Currently, I'm building the AI practice for a financial services firm.

Q: WHY ARE BUSINESSES TURNING TO AI?

A: AI is used extensively for predictive and prescriptive analytics. With the proliferation of no-cost, open-source software, developers are able to rapidly develop and deploy new applications. There are, for example, over 355,000 free Python language packages. Scikit-Learn, TensorFlow, PyTorch and spaCy are used extensively for AI applications. Such resources are used to build custom solutions and integrate them into their environments. For example, we can extract useful information from conversations with clients, and then use those insights with data from historical interactions and social media to create deep learning graph models that give a 360-view of customers, while improving personalization and service satisfaction.

Q: WHAT'S NEW IN AI IN 2022? WHAT ARE THE PITFALLS?

A: I expect business processes to be more data-driven and AI-enabled decision-making to be more prevalent in 2022. In the health care industry, for example, advances in image understanding, the science of identifying diseases and the ability to predict the outcomes of experimental drugs will take off. However, per Gartner, (the technology research company), 85% of AI projects fail. Why? Project leaders have little management experience, fail to include experts with domain knowledge and rush delivery of models. Data, the fuel of AI, is often limited, incomplete and invalid. A focus on coding that fails to appreciate problem-solving and soft skills drives good resources away.

Q: WHAT DO YOUR STUDENTS AT NYU LEARN ABOUT AI IN YOUR DATA ANALYTICS COURSE?

A: My two-semester course starts with basic statistics, probability and visualizations, and moves to advanced concepts in big data, machine learning, deep learning, graph computing and autoML, which automates data science and model deployments. We also touch on the ethical aspects of AI, such as how to deal with ethical bias which may be hidden in the data used to train a model.

Q: HOW DO YOU THINK THE AI LANDSCAPE WILL CHANGE OVER THE NEXT FEW YEARS?

A: Operationalization of AI platforms through consolidation of tools and automation of techniques, as well as cloud-based AI services, will enable further reach for smaller businesses. Improvements in augmented reality using AI will improve personalization for consumers and efficiency in research and business applications. Edge AI, used on devices and smart homes, will transform society in ways unimaginable just five years ago, adding to the battle of privacy versus convenience and enriching the conversation on ethical AI.

**This interview represents the views of Stavros Zervoudakis and not his employers.*

Injecting Complexity and Creativity Into the STEM Curriculum

Top: West Deptford High School seniors Daniel Varela (left) and Jacob Cobb built light-trackers mounted on a rotating servo motor that transmit real-time data on the light intensity measured by sensors to a Chromebook computer.

Bottom: Engineer Pramod Abichandani developed an experimental Internet of Things-based curriculum to teach computer science and software engineering to high school students.

During a period of remote learning, the students in Michael Pustie's engineering class at West Deptford High School in New Jersey received kits containing the components for an experimental curriculum designed to whet their appetite for sensor-based engineering ventures.

Their initial task was to build a simple Internet of Things (IoT) device: a light-tracker mounted on a rotating servo motor that transmits real-time data on the light intensity measured by sensors to a Chromebook computer. Senior Daniel Varela recounts writing 100 lines of code just to program the device to position the light source — a moving telephone flashlight in a darkened room — precisely between its two sensors.

"It's good to test things in the real world, through trial and error, to see what works," says Varela, who adds that the project also got him thinking about potential applications. "I was studying chemistry at the time and looking at renewable energy sources, such as motorized solar panels that follow the Sun. I wondered about the possibility of angling crops in such a way that maximized or minimized sunlight to optimize growth."

Pustie's students were the first participants in a National Science Foundation-funded project led by NJIT to develop an IoT-based curriculum to teach computer science and software engineering to high school students. The course uses inexpensive microcomputers that run code to collect, analyze and share data with other devices or users. Their kits contain several types of sensors, Arduinos, motors, display boards and other electronic parts.

"The first layer of this technology is sensors, which are everywhere, including accelerometers, gyroscopes, chemical, biometric and environmental sensors. Students should know how embedded they are in the environment, in devices that make sense of the world around them and affect everyday life," says **Pramod Abichandani**, an assistant professor of electrical and computer engineering technology at NJIT and the project's principal investigator (PI). "They also need to learn how to make sense of the often-messy data that surrounds them — to filter out the noise — and to turn it into something useful through real-time sensor analytics."

Pustie, chair of the high school's science department, calls IoT devices "the perfect pull-in" as students already possess internet-connected appliances, such as Alexa, home security systems and smartphones.

"Students are capable of doing engineering, and I want as many as possible to try it and have a positive experience," he notes. "As tasks become more relevant, I find they do a better job."

The IoT curriculum is being tested in urban schools as well, in Philadelphia and New York City. Going forward, the plan is for students to come up with their own projects and, working in pairs, to build an app.

"Students have been doing robotics for 20 years now, but they are still largely confined to a fixed form factor such as a drone or a car while exploring robot building and programming. The IoT curriculum is designed to free them to build whatever they want, to allow their creativity to flow," Abichandani says.

Prateek Shekhar, an assistant professor of engineering education at NJIT and the project's co-PI, will further study the factors that affect student motivation in STEM education.

Sara Zapico develops DNA-based techniques to help investigators name unidentified remains, in some instances from a single tooth, decades after death occurred.

Cracking the Coldest Cases

Advances in DNA forensics have sparked an explosion in once-unsolvable criminal cold cases being cracked after a generation, but for the missing and unidentified, it is another story — known as the "nation's silent mass disaster."

Forensic anthropologist and biochemist **Sara Zapico** is at the forefront of research establishing new DNA-based techniques that may help investigators name the unidentified, in some instances from a single tooth, decades after death.

These methods would be key for identifying partial remains in the wake of mass disasters — an area where Zapico is an expert as a member of both Interpol's Disaster Victim Identification Forensic Genetic Subgroup and the American Academy of Forensic Science Standards Board, Disaster Victim Identification Consensus Body.

"When facing human remains, forensic anthropologists must create a biological profile, or a determination of a person's sex, ancestry, height and age," explains Zapico. "However, age estimation in adults is particularly difficult, because it is based on degenerative changes in bones and teeth that occur with age, and this can be affected by environmental factors, pathological conditions and fragmentary remains.

"Our current anthropological assessments can give us age estimates in adults with a window of plus or minus 10 years, but that isn't accurate enough comparing remains with missing persons database profiles. If we can reduce this window, we reduce the search pool to make an ID."

Zapico is homing in on certain chemical molecules that attach to DNA which modify and turn genes on or off throughout life. She says studying this process, or epigenetic DNA methylation, can offer a more precise timestamp in terms of how old a person is at death, because the patterns of DNA methylation change with age.

"One of the so-called letters of our DNA's code, cytosine, sometimes has a label, or methyl group, that can signal to the cell to stop the conversion into RNA and production of proteins," she says. "We've found that as a person has aged, some genes have more labels and other genes have less, and the combination of these patterns gives us a person's age estimate."

The initial breakthrough for Zapico came in 2015 when she was a visiting scientist at Catholic University Leuven, Belgium, as a research collaborator with the Smithsonian Institution. She and colleagues became the first to demonstrate a link between DNA methylation and age in tooth dentin tissue. Recently, she followed with new findings — identifying three gene markers in DNA extracted from pulp tissue of adult molars, offering age estimates within 1.5-2.13 years of a person's age.

"It is a great improvement compared to current anthropological methodologies," says Zapico. "Teeth are the hardest structures in our bodies and can withstand temperatures of more than 400°C, so even if the skeletal remains are too damaged, teeth remain, and DNA is preserved. The methylation patterns in pulp and dentin DNA may give us answers for cases where there is a single tooth to identify a person after a disaster.

"The next step in my research is to confirm the same age-related methylation patterns we've already demonstrated, but in tooth remains exposed to fire. … My hope is it helps identify people and increases public awareness of this issue worldwide."

Mixed-Reality Headsets for Nurses, Art Therapy for Alzheimer's Patients and the Hunt for Neutrinos


Pedro Regalado

New Powers for Nurses

The ongoing nursing shortage in the U.S. should not be measured in missing bodies only, but in partially hijacked ones as well. Consider these numbers: Nurses spend at least half their shift searching for patients' records and transcribing written notes from pad to computer. If computers are scarce, heading off to find one may require a time-consuming gown change.

Backed by a $50,000 National Science Foundation I-Corps grant, Ph.D. student **Pedro Regalado** is designing a wearable mixed-reality device aimed at giving nurses back this lost time, so they can concentrate on caring for patients.

"Certainly, we need more nurses, but we also have to make their jobs doable. They have to record the most minute clinical details throughout the day, such as every time a patient goes to the bathroom," he observes, noting that the COVID-19 pandemic brought their problems into sharp focus. "A nurse described for me the process of admitting people into an emergency room. The line was around the block and she signed them up on the street on sheets of paper. All of that would have to be transcribed accurately later."

His initial headset prototype would give nurses patient-recognition capability — putting names on the screen of their glasses — via a machine learning model capable of discerning faces in a variety of settings based on just a photo or two. The system would also include software that translates patients' non-English speech in real time, while converting the nurses' responses into the appropriate language. Their conversation would be converted into text.

Regalado's parallel mobile computing architecture would enable several tasks to take place simultaneously, such as recognizing patients and validating the QR code on their medications.

"Burnout is real — and so are human errors, such as misidentifying medications, with potentially lethal consequences," he notes.

While currently working with Microsoft's HoloLens headset, "eventually the device would look like glasses." To ensure privacy, it would include iris and voice recognition to prevent others from wearing it.

Regalado interviewed more than 150 nurses, doctors, product developers, staff trainers and hospital CEOs to distinguish "urgent needs from mere wants" and assess existing capabilities. Nurses, for example, admitted that notes occasionally got lost or were never entered over the course of an overloaded schedule.

"The biggest challenge for us will be doing all of this in real time," Regalado says. "If the headset takes more than 10 seconds to recognize a patient, for example, you might as well go to a desktop computer and look them up."


Annmary Ibrahim (left) and Faith Ramos

Sculpting Memories

Losing the ability to form memories and express ideas are two of the cruelest blows inflicted by Alzheimer's disease. Could therapy that targeted both simultaneously improve either — or both? A pair of digital designers has designed a mixed-media experiment to test the hypothesis.

Backed by a student seed grant from NJIT's Undergraduate Research and Innovation program, they plan to enroll 10 volunteers in early stages of the disease to sculpt in clay and then reflect on their creations in a virtual space constructed by the designers from images of a well-loved former environment, such as a room or garden.

"We plan to test whether patients recognize their own work while interacting with it in the VR (virtual reality) world, if they recall the process of creating it and how their memory retention is affected when they are placed into a past environment with their creations," says **Annmary Ibrahim**, a junior who was initially interested in exploring connections between memory and color.

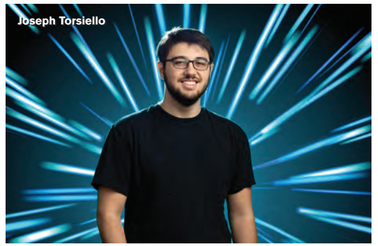
While they are sculpting, patients will be asked how they are feeling, as well as what they currently remember and struggle to recall about a topic they are discussing, such as where they grew up. After each session, their clay objects will be 3D-scanned, modeled and placed into both a basic default gray VR environment and their personalized environment.

In subsequent sessions, they will interact with their sculptures in the default and personalized VR environments, viewing them from different angles as they walk about the room. The students will ask them the same questions from their sculpting session.

While their study aims for the most part to explore the impact of art therapy and virtual reality on memory retention, they hope the exercises will bring joy and build confidence in the process. Their goal is to create a program that uses the many functions that remain intact and enjoyable for Alzheimer's patients, while also identifying and working on areas of decline.

"Patients in the early stage of the disease often maintain primary motor functions, including dexterity, muscle control and strength, as well as their basic senses, which allow them to derive pleasure from what they touch, see and hear," notes **Faith Ramos**, a sophomore who has watched her grandfather struggle with the disease.

"Creating artwork will allow them to express and communicate their thoughts and emotions that they are otherwise unable to verbalize. We hope that combining that with an interactive VR experience will allow them to connect with their art in a new way, with a deeper and richer multisensory experience."


Joseph Torsiello

On the Trail of Neutrinos

Perched in front of a computer screen, senior **Joseph Torsiello** spent the summer developing technologies aimed at detecting neutrinos, while pondering emerging theories about the composition of the universe.

Backed by a Fulbright Canada-MITACS Globalink scholarship, the physics and math major joined a research team at McGill University searching for a rare phenomenon that is so far only posited: a radioactive nuclear decay in which an atom of xenon disintegrates into a positively charged barium isotope, in the process emitting two electrons as in normal double beta decays, but, unusually, no antineutrinos.

In particle physics, the observation of a tiny signal may alter our understanding of the universe. Indeed, the scientists leading the project say that the reaction they seek "cannot occur according to the laws of physics as we know them, thus an observation would automatically demonstrate so far undiscovered laws of physics."

The McGill team is part of the global collaboration nEXO, which seeks to better understand the chargeless, nearly massless neutrino and determine whether it may, unlike all other known fundamental particles, be its own antiparticle. This demonstration could potentially shed some light on an unsolved mystery: why we observe more matter in the universe than antimatter.

Torsiello's job was to analyze images of expanding ion clouds generated when a laser struck a metal surface, such as copper. In these experiments, the McGill team is developing a device that will ultimately be used to create a source of barium ions necessary to study methods for tagging particles produced in the double beta decays.

"I'm analyzing the trajectories of particles, their length and angle, emanating from the source's surface and helping develop new ways of tagging decay products in future xenon-based double beta decay experiments," he says. "The electrons in such an experiment can be detected, and we can therefore see where the decay occurred and also characterize them. Depending on whether neutrinos are released or not, the electrons would have very different energy.

"Neutrinos are the most common particles in the universe that have mass. These experiments could lead to a whole new understanding of their physics," he adds. "If the neutrinoless double beta decay is observed, it would break lepton number conservation, because only electrons are created. In our current understanding of particle physics, the same number of particles and antiparticles must be created in an interaction. The violation of lepton number conservation in double beta decays requires that neutrinos are their own antiparticles."

While COVID kept him working remotely, Torsiello notes, "I'm happy to play a small role in a big collaboration."

TECHNOLOGIES OF 2021

PORTALS TO OUR PAST RESHAPERS OF THE PRESENT GATEWAYS TO THE FUTURE

Step back to late-19th century Istanbul and stroll through the sunlit courtyard of an Ottoman insane asylum. Jump forward to a graffitied alley in 21st-century Rome to explore the beloved Grottapinta street shrine before it was restored. Examine the intricate 3D-printed skull that helped a team of doctors in 2020 decide how to restructure a young girl's face. Practice home-based, remotely monitored virtual reality "games" created to restore hand functions to people recovering from strokes.

Play charades with a humanoid robot that may one day provide care to the disabled or seek missing persons at a rescue site.

Board a student-conceived, space-based refueling station designed to supply energy and water to Moon and Mars service missions.

TRAVELING THROUGH TIME TO A ROMAN SHRINE

Historian LOUIS HAMILTON first encountered the Grottapinta shrine, one of more than 650 sacred sites located at street corners and on byways in Rome, in 2012. In a covered alley that was once a corridor leading into the Theater of Pompey, its painted walls and frescoes decayed and graffitied, the shrine drew a steady stream of devotees who left flowers and notes on a shelf below the presiding Madonna. Five years later, the shrine was sanitized and repainted. Its followers largely drifted away.

Hamilton is now using virtual reality to explore their departure. Using the game engine Unity, he and a team of students and faculty created virtual models of the alleyway before and after the restoration, and enrolled 60 "visitors" to walk through them both. Using eye-tracking software, the team monitored what they looked at and for how long. Preliminary results suggest the viewers' gaze patterns correlate not only to their previous religious practice and identity, but also vary by their gender, income and age. More comparison data is being analyzed.

"More broadly, I'm interested in how changes in the urban fabric may have unintended effects on religious practice, and the implications for the restoration of heritage sites and community development going forward," he says.

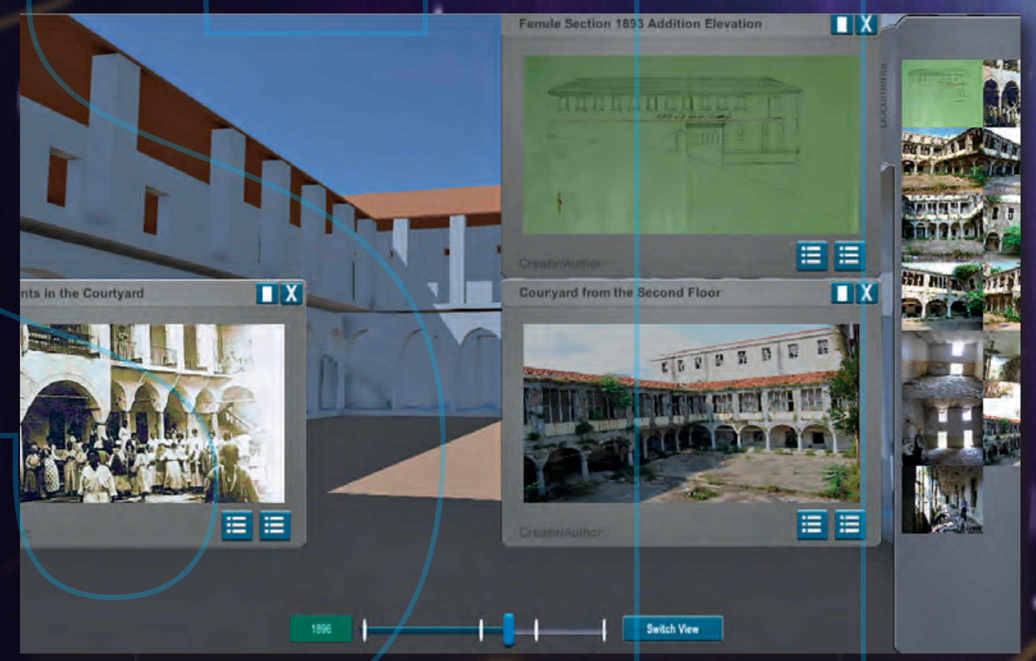
Hamilton's group has built the largest geographic database of Rome's shrines, or edicole sacre. They use Google Street View to catalog measurable devotion over the years at these shrines — the presence of offerings such as candles and notes — and the infrastructure around them to determine correlations between architecture and the use of religious spaces.

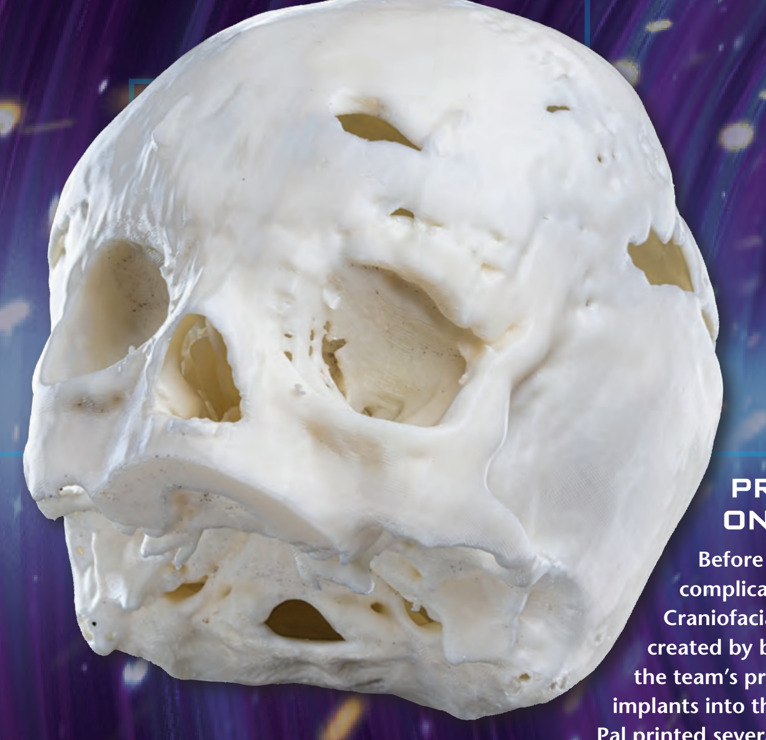
STROLLING VIRTUALLY IN A 19TH-CENTURY INSANE ASYLUM

Upon entering BURCAK OZLUDIL's virtual model of the women's ward of the Toptasi Insane Asylum in Istanbul, visitors walk through a vast open-air courtyard where patients mingled under the elements after meals, before climbing a staircase leading back to their rooms around a corridor secured by iron bars.

"To understand evolving treatments of madness in the late 19th-century Ottoman Empire, it's important to see how people moved inside the institution," notes Ozludil, an architectural historian. "How the space was constructed in the late 1890s was considered a crucial part of the healing process, designed to accommodate the increasingly 'medicalized' needs of mental patients — a regular schedule of activities, doctors' visits and the timely administration of drugs — in tandem with the emerging field of psychiatry."

The royal complex that housed the imperial hospital still stands, but the asylum is long gone. Working without blueprints, Ozludil constructed her model from government documents, medical publications, photographs and the accounts of physicians and visiting psychiatrists from around the world. One by one, she figured out how each part of the structure was used. "Without patients' accounts, this gives us a sense of what their daily life was like," she says. "By using SpatioScholar, a digital analysis platform I developed, I can simulate their daily routines." She adds, "I have visited this building and know it by heart. But experiencing it in its 19th-century form, walking around, entering rooms and documenting their size and how much sunlight they had, was a profound experience for me."





PRACTICING SURGERY ON A 3D-PRINTED SKULL

Before opening up a young girl's skull for a long and complicated surgery, a team of six doctors from the New Jersey Craniofacial Center practiced operating on a 3D-printed model created by biomedical engineering professor SAIKAT PAL. One of the team's primary concerns was how exactly to fit their synthetic implants into the large gaps in her cranium they were sealing.

Pal printed several models for the individual physicians and one for the family, so that the entire team could better understand — and see — possible surgical strategies and agree on the best one. He then printed dummy implants so the surgeons could simulate the operation and practice different approaches.

"The hardest part of making these models is the fine detail, including creating air pockets to simulate the spongy bone of the skull," notes Pal, who has worked on new methods to automate the precise extraction of 3D geometries from medical imaging "so you don't have to be an engineer to do it."

The doctors were also correcting the girl's orbital dystopia, in which movements in the plates of her skull, lacking the normal sutures, caused her eye sockets to shift onto different planes, among other asymmetries. Their goal was to give her back a more normal appearance, while reducing risk in the six-hour surgery. Pal's skull and implant models helped simplify some of the decisions.

"It's gratifying to see the results after a year's preparation by this brilliant team," he says.

COMING TO YOUR LIVING ROOM: STROKE THERAPY

The COVID-19 lockdown left many physical therapy patients stranded, and perhaps none more urgently than people recovering from strokes, for whom timely interventions can mean long-term motor progress. At the best of times, some lack access to these services altogether.

With these exigencies in mind, a team of biomedical engineers from NJIT and Rutgers University developed a home-based rehabilitation device for the upper extremities that provides dynamic motor recovery feedback and the means to connect remotely with a therapist. They are backed by National Science Foundation and National Institutes of Health grants to test the device and commercialize it.

The therapy consists of virtual reality-based video games designed to feel like recreation, thus encouraging longer, more frequent sessions. The program algorithms track patients' movements in real time and adjust game difficulty levels based on patients' progress. A secure wireless data connector collects detailed information on their movements, also in real time. While patients are playing a game, the secure communication channel allows remote supervision by clinicians, technical support and face-to-face interactions via video conferencing.

"The three-month period following a stroke is a good window for therapy, as the brain is forming new networks. These exercises promote neuroplasticity for motor recovery," says ASHLEY MONT, a Ph.D. candidate at NJIT and the chief innovation officer of NeuroTechR3, the NJIT spin-out company formed to commercialize the technology. "But not everyone can afford this therapy or travel to a clinic for it. People six months out, when they can still make improvements, may no longer have insurance coverage."

JOINING THE NEW COMMERCIAL SPACE RACE

The prospect of multiplanetary habitation has launched a new space race focused on business innovation that is quickly expanding beyond NASA, SpaceX rocket rides and enhanced satellite services. The Japanese lunar exploration company ispace, whose mission is to "incorporate the Moon into Earth's economic and living sphere," plans to notch a first commercial sale next year, for example, when its robotic vehicle collects a rock from the Moon and sells it to NASA.

In his "Moon, Mars and Beyond: Space Is Open for Business" course, entrepreneurship professor RAJA ROY teaches his students to apply business skills to starry ventures. He has drawn students from every school on campus — rising engineers, financiers, inventors, architects and policymakers.

Roy has first taught them about the different regions of space — from low Earth orbit, to the cislunar space, to the cis Martian space — and the emerging entrepreneurial opportunities for each of them. "Travelers to Mars will likely spend two to three years there," Roy says. "They'll need oxygen, water, transportation, dust mitigation, systems and subsystems that work together and employ reusable parts."

One group in the class, composed of an architect, a mechanical engineer and a business student, have proposed a refueling station at a Lagrange point (where the Earth and Moon's gravitational pulls are equal) that would supply fuel and water to service missions to the Moon and Mars.

Roy notes, "The group researched the complementary capabilities needed to set up the system, such as docking systems and software, before designing it."

PLAYING CHARADES WITH AN ENTHUSIASTIC ROBOT

TOCABI, a nearly 6-foot-tall, remotely operated humanoid robot, smiles and blows kisses, solves jigsaw puzzles and hams it up at charades, conveying that it's all good fun. With 33 degrees of freedom, the robot displays strikingly human movements, twisting its arms sinuously, clenching its fists and toasting companions with a water bottle.

Last fall, TOCABI (Torque Controlled compliAnt Biped) won a spot at the 2022 finals of the ANA Avatar XPRIZE competition, where robots from 15 teams will perform dexterous physical tasks, but also show "human presence" in their interactions. They are being developed as human avatars for remotely controlled roles, such as emergency responders, caregivers and repair workers.

NJIT's MATHEW SCHWARTZ, an industrial designer, began working on the robot in 2013 as a researcher at the Digital Human Research Center, part of the Advanced Institutes of Convergence Technology at Seoul National University, under the direction of Jaeheung Park.

TOCABI uses torque control. Unlike robotic arms in a manufacturing facility controlled by commanding a position, which can be dangerous for humans who don't anticipate its movement, torque control determines where it wants to go and then calculates and commands the energy needed to direct the motors for that movement.

Following the robot's debut at the XPRIZE semifinals, Schwartz notes, "Designing TOCABI has been an educational and inspiring long-term collaboration. Bringing a design perspective has been more than just sketching concepts — it's been a foundational role of balancing how to make a real-world robot that looks and moves in an understandable way to integrate with peoples' daily lives."

A Former Human Avatar Reflects on Collective Intelligence

Niccolo Pescetelli
Assistant Professor, Humanities and Social Sciences

Photo: Courtesy of Niccolo Pescetelli

One cold and lonely Halloween night at the MIT Media Lab, when I was a postdoctoral researcher, I let 2,000 strangers control my actions via an internet web platform. Their collective mission was to track and destroy a rogue AI called Zookd. I was their physical avatar. Called BeeMe, the live performance was the first large-scale demonstration of the power of real-time collective intelligence augmented by technology.

The platform I designed let online participants from around the world see and hear my surroundings through a camera on my chest that livestreamed the action on YouTube. They used a text chat to communicate with each other and a real-time voting mechanism to coordinate my successive movements through seven rooms, guided by a storyline containing clues. Actions that received the most votes were delivered to me through earphones by an assistant.

These actions — and my navigation — got increasingly complex: make a cup of coffee, locate Zookd's androids and meet up with another human avatar who is also on the move. Should the "team" play one of us against the other to win or coordinate our actions? It took them an hour to delete the rogue AI with a code I was instructed to enter on a keyboard. Success!

So what is collective intelligence? It's people interacting to share, integrate and exploit information to make smarter decisions than they could produce individually. This phenomenon is not special to humans, but is observed in swarms of insects, flocks of birds and schools of fish. Crisis management, which adapts in real time to new knowledge and events in the world, and the structuring of optimal online education offerings, are two obvious applications.

The BeeMe experiment, and the focus of my ongoing research, diverges from traditional studies in collective intelligence: forecasting, such as guessing the next presidential candidate or stock market fluctuations; perceptions, such as detecting which line is longer in a list; and estimations, such as calculating the number of jelly beans in a jar. If we're to truly harness these powers, they need to bolster our capacity to quickly adapt to changes in the environment and be resilient in the presence of uncertainty or noisy information.

The BeeMe results were encouraging. Although several users tried to troll me by upvoting irrelevant actions ("do 20 push-ups"), and despite conflicting preferences, knowledge and plans, the group managed to coordinate their suggestions in real time to complete the 10 steps they were given and defeat the villain. This type of real-time collective control has rarely been studied. Compared to Twitch Plays Pokémon, in which a crowd online coordinates the actions of a Pokémon game character, or Reddit's Place, where multiple participants draw on a white digital canvas, BeeMe uniquely mixed physical and online spaces.

I investigate technology-mediated human collective behavior and spend a lot of time thinking about the impact of artificial intelligence, search engines and recommendation algorithms in so many spheres of our lives. The benefits of using these algorithms are evident. Do I really want to search for that paper I read about machine learning — after forgetting the title, author and journal where it was published — without a search engine?

However, it is less clear — and little researched — how these algorithms affect our capacity to solve complex problems together. In a recently published paper in *Nature Communications*, I showed that common search engines diminish the diversity of information that groups can forage online. In my study, participants were asked to solve various geopolitical forecasting questions, such as guessing the outcome of elections in Hungary, with permission to search for relevant information online via Google. The results were surprising. Prior to conducting internet searches, people with similar demographic, political and personality traits came up with very different answers. However, after using search engines, people sharing these characteristics became highly correlated in their responses. Thus, by feeding us news that "they" think is appropriate for us, algorithms can skew the information that a group finds online and, in the end, influence our judgments.

For me, studying the side effects of seemingly innocuous algorithms such as search engines makes me think more deeply about how I interact with people online. How diverse are my friends and co-workers, or the news that I consume? What are the downstream effects of the algorithms operating online, for me and for the social networks I'm part of?

Being able to answer these questions is the first step toward designing algorithms that do not just optimize click-through rates, returns on investment and advertisement customization. What I'd like to do is design ones that are more ethical: algorithms that enhance our capacity as a society to cooperate and solve complex tasks together and augment our collective intelligence. The main tools I use are signal detection theory (which allows us to recognize signals within noise), agent-based modeling (models that simulate groups, networks and societies) and Bayesian theory and behavioral analysis.

If we're going to manage pandemics and climate change successfully, we need to take on internet silos that provide polarizing information. I propose an alternative: content that enriches, and for people on all sides of a debate, offers a window into something new.

Harnessing the Power of Tiny Bubbles

Like seltzer-swilling humans, plants are also partial to bubbly libations. Environmental engineer **Wen Zhang** hopes to exploit this predilection to design efficient irrigation systems.

"One of our goals is to reduce the amount of synthetic fertilizer needed to grow crop plants by applying it more precisely. We think nanobubbles may help us," says Zhang, director of NJIT's Sustainable Environmental Nanotechnology and Nanointerfaces Laboratory. "With their negative charge, they attract positively charged mineral nutrients in the soil such as calcium and potassium, mobilizing them and promoting their uptake. They also stimulate plant genes that control the production of growth hormones."

To meet growing food demand, global fertilizer use continues to expand. However, these methods have long proved inefficient: The absorption ratio of nitrogen fertilizer in a harvested crop can be as low as 40-50%, with the residual lost through surface runoff that pollutes streams and lakes. Despite this, plants become "addicted" to chemical fertilizers and can't grow without seasonal applications, says Zhang, whose research is supported by the U.S. Department of Agriculture.

In a recent laboratory test, he and another engineer, **Taha Marhaba**, soaked soil-planted fava seeds with successive batches of water containing ultrafine bubbles, between 200 and 500 nanometers in diameter, made with gases such as nitrogen, oxygen, carbon dioxide and hydrogen. The results were encouraging: Germination rates increased between 6% and 25% compared to controls. In another experiment, they increased the size of leaves and stems on different vegetable plants by 10-50% by watering them with nitrogen nanobubbles. In a field study with collaborators from Tongji and Fudan Universities in China, rice crops irrigated with air nanobubble water saw yields rise by 8% compared to the control, while reducing the amount of fertilizer used by about 25%.

Nanobubbles are naturally occurring. They exist inside biological systems such as bacteria and algae cells that produce or store gas to control buoyancy, for example.

Researchers have discovered that they have a host of other useful properties when suspended in liquids, including a high degree of stability against dissolution and collapse if they're not exposed to high temperatures or agitation. Because they have a surface charge and are water repellant, they resist agglomerating and expanding, so they don't rise to the surface and burst. Their persistence in water, their high surface area and their random movements allow them to move materials around, including nutrients for plant growth, ozone used in bacteria disinfection and oxygen needed to aerate hypoxic environments.

They are difficult to produce in a usable form, however. Zhang has been working on new engineering approaches to generate nanobubbles with tailored properties, including different compositions, sizes and masses to use in various applications. To date, he's delivering nanobubble gases singly, but he wants to figure out how to combine oxygen and hydrogen, for example, for possible fuel-cell applications.

"One of the challenges to utilizing nanobubbles in different engineering scenarios is to control their bubble size, their concentration and their durability," he says. "We're also still figuring out the best way to produce them."

He and his collaborators obtained a patent this year on a membrane bubbling process to generate variably sized nanobubble gases in water. Their device, composed of two ceramic membranes, can generate bulk nanobubble water of different bubble sizes and kinds by adjusting membrane pores, surface hydrophobicity (e.g., how water repellant the surface is) and the amount of air flow and pressure supplied in the process. To date, the device has repeatedly created nanobubbles between 200 nm and 400 nm in diameter that remain stable in size and concentration for as long as 48 hours.

"This is an important new capability, because macrobubbles generally remain in water for minutes or even seconds, as they rise to the surface and burst," he says. "If they're any smaller, they may become unstable and dissolve or collapse due to the high surface tension."

Next spring, his nanobubbles will debut on another stage. With funding from the New Jersey Department of Environmental Protection, he and his collaborators have designed a boat that will launch on two lakes in the state that are being suffocated by algae blooms, physically removing them with air jets that force them to the surface and dispensing oxygen nanobubble treatments to replenish the water with dissolved oxygen.

"We plan to broaden the applications for this technology," says Zhang, who received a National Science Foundation I-Corps grant to commercialize it. "To name a few, we'd like to test ozone nanobubbles as a possible replacement for chlorination or traditional ozonation in water treatment; use ozone or oxygen nanobubbles in dental rinsing to combat microbe-driven periodontal diseases and the overuse of antibiotic chemicals; and nanobubble water to increase the mobility of contaminants in soil remediation."

Wen Zhang aims to free plants "addicted" to chemical fertilizers by developing efficient irrigation systems that use nanobubbles (inset) to apply them more precisely.

Whetting the Appetite of Pollution-Feasting Microbes

In his Environmental Microbiology and Biotechnology Laboratory, chemist MENGYAN LI is matching hungry microbes with customized menus of industrial pollutants, from chemical solvents, to microplastics, to pharmaceuticals, to per- and polyfluoroalkyl substances, or PFAS. His goal is to create green, energy-efficient approaches toward remediating pervasive contaminants that resist both natural degradation and conventional cleanup techniques.

"We identify strains of bacteria that are able to consume them, develop methods to accelerate their digestive powers and build devices such as biofilters and bioreactors to deploy in different settings," says Li, who is assembling a collection of promising microbes harvested from wastewater treatment systems.

He recently patented the use of a microbial strain called DD4 (Azoarcus sp.), which degrades 1,4-dioxane, an organic chemical stabilizer in products such as shampoos, laundry detergents and paints that is found at unsafe levels in groundwater and drinking water sites across the U.S. One of DD4's enzymes, toluene monooxygenase, initiates decomposition of the compound's stable circular structure so that it can be more easily degraded by other enzymes. To elicit that action, the microbe is first fed with chemicals such as propane or 1-propanol that prompt the enzyme's expression.

What is especially encouraging about DD4 is that it also degrades another class of pollutants, chlorinated solvents, which often coincide with dioxane. Typically, they are treated separately, often using remedies such as oxidizing chemicals that can themselves be hazardous.

"The goal is to find microbes that degrade multiple contaminants, are active in diverse environments, including nutrient-limiting ones, and regenerate," Li notes, adding that his lab is developing new approaches to accelerate the performance of key enzymes.

"There are numerous environmental factors that affect a microbe's performance if it is directly injected into places of contamination. However, water treatment facilities may be able to use add-on devices, such as bioreactors or biologically active filters, where water passes through the system and the bacteria inside consume the 1,4-dioxane so that the discharge is clean water," says Li, a National Science Foundation CAREER award winner, who received another NSF grant to develop biofilters coated with contaminant-eating microbes.

Gabrielle Esperdy researches what she calls "the everyday, unextraordinary" buildings in cities such as Asbury Park, in search of broad cultural themes.

Digging for Historical Gold in Unlikely Terrain

In the mid-1930s, a dowdy jewelry storefront at 703 Cookman Ave. in Asbury Park, N.J., shed its buttoned-up brick façade for sinuous angles, plate glass windows and gleaming chrome trim. The glamorous new face, the store owner hoped, would entice Depression-era shoppers with cash to spend, but a reluctance to do so.

"By maximizing the display space, shoppers felt immersed in the exhibited wares, while the curved lines of the bulkhead pulled them into the store. Many of these businesses also added colorful structural glass, which had a Wizard of Oz-like effect," explains **Gabrielle Esperdy**, an architectural historian who researches what she calls "the everyday, unextraordinary" buildings that dominate the American built landscape, in search of broad cultural themes.

In studying the New Deal's Modernization Credit Plan to revive downtowns and stimulate the economy, she started with the basics: the financial incentives to upgrade buildings and provide relief from some of the more onerous regulations required of new construction.

But new data-gathering methods she developed to find, aggregate and organize architectural data led to some startling insights, such as the widespread use of elements from European Modernism to transform languishing Main Streets from Asbury Park to Zainsville, Ohio.

"The conventional narrative was that Modernism did not exist in the United States in a significant way until after World War II, when the masters, the big names such as Mies van der Rohe, brought us icons such as the Seagram Building. It was already happening on the ground here, even in small cities," she asserts.

"Shopkeepers saw corporations including these elements, but didn't have the means to do so until the Roosevelt administration told private lenders that if they loosened up, the government would back them. They began popularizing architecture and ideas and formal motifs that emerged in Europe as a way of rejecting traditional architecture, but in the U.S. was used for commercial purposes to attract the middle class."

Esperdy has come up with troves of new architectural data that she digitizes and organizes by hunting through the publications and archives kept by diverse corporations and industries, including movie-theater and grocery-store chains and oil and gas companies, among others. "They allow me to track large-scale changes by aggregating small details," she notes.

She has documented trends in the use of construction materials as building economics changed, for example. In the 1930s, designers and manufacturers found new applications for a traditional material, marble, and figured out new ways to incorporate it in their different contexts, such as applying thin slabs to make them more luxurious. Perusing *American Grocer* magazine and other trade periodicals revealed the array of colored glass, including purples and blues, introduced into chain and independent stores, such as A&P and Piggly Wiggly.

Esperdy is a project researcher working with the Getty Research Institute's Ed Ruscha's Streets of Los Angeles archive, a partly digitized collection of photographs of midcentury buildings the pop artist captured from a moving vehicle. She collaborates with a data scientist at Yale to comprehend stasis and change along noted commercial thoroughfares, including Sunset and Hollywood Boulevards.

"Observing this landscape over 50 years, you can see how commerce got pushed further and further back from the road to accommodate cars and the beginnings of a polycentric metropolis. The Bullocks Wilshire [department store] didn't need to be downtown," she recounts. "New shopping hubs such as the retail corridor of LA's Miracle Mile allowed shoppers to avoid the density and traffic of downtown, and cars began to be prioritized over pedestrians."

Her recent book, *American Autopia*, which focuses on the car's impact on urban and suburban development, from the earliest days of the auto industry to the aftermath of the 1970s oil crisis, considers how designers, planners, critics and theorists constructed "an automobile utopia" as a place and an idea. Just as she collected and aggregated images of Main Streets, she compiled critical discourse on how architectural thinkers were responding to ways the car was transforming our metropolitan landscapes.

"The moment Model T's rolled out of Henry Ford's factory, they motored on to the pages of American architecture and planning journals," she says. "We were rethinking metropolitan regions within this new context much earlier than people thought."

She describes New Jersey as an even denser version of Los Angeles, but also a laboratory and testing ground for ideas about urban change emanating from New York, especially in terms of managing density. "The Pulaski Skyway was an engineering marvel that allowed you to drive over meadowlands to connect with other metropolitan regions."

Esperdy is involved in other digital initiatives that benefit her profession more broadly. She is the founding editor of the Society of Architectural Historians (SAH) Archipedia, an open-access encyclopedia on the history of the built environment in the U.S., which to date contains histories, photographs and maps for more than 20,000 structures and places, including buildings, landscapes, infrastructure and monuments.

The foundation content for SAH Archipedia was collected from the book series, *Buildings of the United States*, which Esperdy and her team converted into a dynamic web-based resource, a task that entailed transforming 20 years of text-based historical interpretation and analysis into a dynamic data structure.

Examining QAnon and Electronic Narratives That Shape Worlds

Andrew Klobucar and Kate Tyrol

QAnon theories were esoteric property of uncensored online imageboards such as 4chan and 8kun when they emerged in 2017. In May 2021, a poll by Public Religion Research Institute found 15% of Americans agreed with the QAnon narrative that "government, media and financial worlds in the U.S. are controlled by a group of Satan-worshipping pedophiles who run a global child sex trafficking operation."

Humanities professors ANDREW KLOBUCAR and KATE TYROL are working on a book, *End Matter: Interactive Narrative Play and Digital Storytelling*, where the pair takes a new socio-literary approach to examine how potent electronic narratives such as QAnon's take form, simultaneously shaping online social communities they are born in through interactive storytelling.

"Social worlds produced by electronic narratives — like those of QAnon, video games or interactive fiction — are co-constitutive. The story makes the online social space, and the space makes the story," says Tyrol, professor of NJIT's Cyberpsychology and Science, Technology and Society programs. "We can't use traditional literary or social science lenses in isolation to understand the phenomena associated with such narratives. ... We must use them in conjunction with one another."

Q's rare messages to followers, or "Q-drops," involve cryptic predictions and codified language that cascades across social media. "However, there's a thin layer of content mediators between Q and the broader follower base, and their few interpretations of Q-drops are actually the creation of the story. ... We see a social process there to explore," notes Tyrol.

The team says their work, expected in 2022, will blend literary analysis and digital ethnographic research to study interactive narrative play in QAnon communities after Q-drops, for instance.

"From a lit-theory perspective, we still don't really know how to read experiments like QAnon, nor do we have a formal methodology to study synchronous live interaction as a digital work of art," says Klobucar, associate professor of English. "Examples like QAnon require a carefully crafted narrative theory as well as insight into social behavior to define what is actually being produced as a story."

Listening to Noise and Nature With Smart Ears

Filing a noise complaint is a bit of a gamble. By the time an inspector arrives, the stream of trucks thundering by the night before may be long gone or the construction tools bedeviling the dinner hour turned off. In a dense soundscape, even pinpointing the worst offender can be a challenge. Was it a jackhammer or a tamping machine making that repetitive racket?

Where logistics, human perceptual capabilities or simple manpower may fall short, however, smart acoustic sensors are being trained to succeed. Endowed with machine listening, the auditory sibling to computer vision, these cutting-edge computing devices can distinguish individual sounds, record how often they occur and measure how loud each one is in order to provide the evidence needed to help enforce the city's noise code.

"What we're doing is enabling machines to listen, extracting information from audio at a scale impossible for humans to hear and reporting it in real time. If you've deployed 60 sensors, for example, you can't have someone listening to them 24 hours a day," explains **Mark Cartwright**, an informatics professor and one of the lead machine listening researchers for an NYU-based project called Sounds of New York City (SONYC), which uses a smart acoustic sensor network to monitor, analyze and mitigate urban noise pollution.

Backed by the National Science Foundation, the team is building tools to measure the impact of different types of sounds on urban neighborhoods, so that city agencies can respond more effectively. Cartwright, a former research professor at NYU and a continuing collaborator, trained models to detect the presence of different sources, such as jackhammers, trucks and honking, developed methods to estimate their loudness and came up with the protocols for labeling data, while launching a campaign powered by citizen scientists to help do it. He worked on yet another feature that will be key to the sensors' success: compressing machine listening models to run on low-resources equipment, such as solar-powered devices or single-board machines.

Dashboards display the output of the SONYC sensors, which were placed in Manhattan, Brooklyn and Queens, enabling city noise inspectors to see when and where sounds are occurring. The team is currently testing a more need-driven approach, in which a new generation of sensors are sent for short-term deployment to locations to measure and document the patterns and impact of specific nuisance sounds.

"Let's say a warehouse moves into a community and the amount of trucking increases, much of it directed down a particular street. We'd want to quantify how disruptive it is and let regulators decide if the trucks should be routed differently," he says. "The aim is to provide evidence that can be used to push for accountability and changes in policy or plans. Should quieter electric jackhammers be used at a site, for example? Should backup beeper regulations change? Should emergency vehicles use different types of sirens?"

Installed in three boroughs of New York City, smart acoustic sensors identify individual sounds, while measuring their volume and how often they occur.

Mark Cartwright develops machine listening technologies for Sounds of New York City, a research initiative to monitor, analyze and mitigate urban noise pollution.

In another collaboration with NYU, called Spatial Sound Scene Description, he is working on new capabilities, including models to count particular sounds, such as vehicle noises, and to localize and track them in space, identifying their direction and distance from the sensor. Putting these sensors in place for a long time would allow urban ecologists, for example, to better understand migration patterns.

"There are important real-world tasks where the count and location of sources are important, especially when visibility is limited or sources are occluded. In addition to wildlife monitoring, these include perception for autonomous agents, such as self-driving cars; machine condition monitoring, such as sensing when and where factory equipment may fail; and sound awareness sensing for people who are deaf or hard of hearing," Cartwright says.

He adds, "Our ability to localize specific sound sources is still very rudimentary. We're also still having to teach the machine each different class we want it to detect or separate. In contrast, when we humans encounter a new sound, we may not know what it is, but we can still recognize it as a distinct sound. Machines can't do that well yet."

In his Sound Interaction and Computing Lab, Cartwright also develops tools for sound design and music production that align interfaces with users' goals and abilities, enabling novices to use complex audio tools for creative expression that typically require significant knowledge and experience to employ effectively.

Software synthesizers, for example, have scores of parameters. Like a pilot in training stepping into the cockpit of an airplane, it would take a long time to learn what all the gadgets are and how to use them. His tools would allow them to communicate their sound choices in descriptive language, the way they might describe them to a friend, or by making the sound with their own voice.

"In audio mixing, as with other problems, there is not one right solution but many possible ones that express a variety of artistic goals. People should not simply accept what's provided by the software," Cartwright says, adding, "In all my work, I strive to amplify human abilities rather than automate them away."

Cameras That Think

Even as they proliferate throughout the environment to enable a host of new "smart" applications, cameras remain mute witnesses. The images they capture are sent to the cloud for analysis, often well after the event they've recorded has occurred.

TAO HAN, director of NJIT's Ubiquitous Networking and Intelligent Computing System Lab, is proposing an alternative: a decentralized system of networked cameras, each with embedded hardware and software, that can be trained to recognize what they're seeing in real time and respond appropriately.

"A surveillance camera trained to detect gun crimes, for example, would know to send an alert to the police," Han notes. "In executing a lost dog query, the cameras would each run a machine vision algorithm that identifies specific breeds, colors and sizes, and then communicate with each other through a 5G wireless network to track its locations."

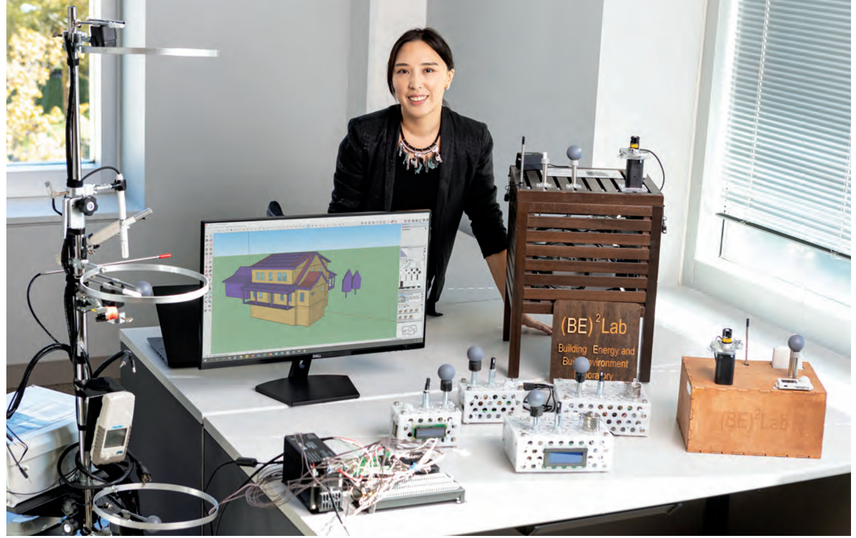
The network would include stationary surveillance cameras, as well as devices attached to bodies, cars and robots. Drones equipped with novel energy-efficient systems and machine vision algorithms, for instance, could automatically detect survivors at a disaster site without streaming video back to a central office for data analysis.

By eliminating the need to send voluminous visual data collected by cameras, much of it irrelevant, to the cloud for analysis, on-camera AI processing solves a big data problem, Han says, while also addressing related privacy concerns. The individual cameras can recognize a face without sending mugshots to the cloud, or describe the number of cars in a traffic jam without sending pictures of the vehicles and their drivers.

The major challenge, he adds, is designing machine vision algorithms that execute efficiently on small cameras with limited computing resources, including smartphones.

Ultimately, Han's goal is to create a platform that allows people throughout the world to share their smart cameras. He adds, "To preserve privacy and reduce traffic loads, the system would perform visual data analysis that allows its customers to only share information extracted from camera scenes, such as how many people are queuing outside an Apple store for a new iPhone."

Simulating Humans to Optimize Real-World Building Comfort



Hyojin Kim analyzes buildings' long-term energy performance, while also determining how occupant comfort is affected by energy efficiency improvements and building system changes.

In a gray cookie-cutter house with a neatly trimmed lawn, the toaster pops, the dishwasher hums and the lights flick on and off as the day progresses. There is nary a person in sight. The appliances are all automated, programmed to service a simulated family of four whose consumption of heat, electricity and water, as well as comfort, is measured by the minute.

Welcome to the NIST House, created by the National Institute of Standards and Technology in Gaithersburg, Md., as a net-zero energy residential test facility. Its primary occupants are more than 400 sensors attached and embedded in floors, walls and systems to measure the house's temperature, humidity and ventilation. The goal of the lab, which produces as much energy over the course of a year as it uses, is to test and demonstrate the feasibility of energy-efficient, high-performance buildings and technologies and to promote their adoption.

That's where building scientist **Hyojin Kim**, director of NJIT's Building Energy and Built Environment Laboratory, comes in. She began by analyzing the house's long-term energy performance, while also determining how occupant comfort was impacted by energy efficiency improvements and building system changes.

She determined, for example, how well the measured temperature and humidity matched the thermometer setting and whether heating and cooling distribution was consistent throughout the house and through the seasons. Based on that study, she developed a new method to rate whole-house performance, which integrates measured energy usage and comfort that can be applied to all residential buildings.

"We've all wondered why some of the rooms in our houses are always hot or freezing," she notes, adding that the NIST house tests the efficiency and effectiveness of various systems, such as new technology that circulates air more forcefully in smaller ducts, as compared with conventional systems.

To encourage wide deployment of these technologies, it is vital, however, to ensure that the emerging low-energy systems consume the amount of energy they purport to, while providing it reliably so that a real family would find the house's environment both comfortable and healthy.

Kim is currently conducting empirical validations of the U.S. Department of Energy's simulation software, Energy Plus, at the NIST house, in collaboration with Oak Ridge National Laboratory. Architects and engineers rely on these simulations to predict energy consumption in their proposals for new construction or major renovations. High-performance buildings aiming for LEED or Living Building Challenge certification, for example, use them to make informed design decisions based on predicted performance and also to prove their energy efficiency, she says.

"What if the tools are wrong? Homeowners would not realize the intended savings and it would diminish credibility across the board, considering the investment, the tax credits and utility incentives," she says. "Higher uncertainty in the modeling tool means higher risk for building owners and societal investments."

The stakes are real. Buildings consume 40% of the electricity produced and residential dwellings account for half of that.

Other sources of uncertainty in modeling include little knowledge about the impact on energy use of occupancy levels, the way occupants use spaces and real-time infiltration of outside air from windows and doors. To address this, Kim is developing a building energy model that takes into account, for example, the heat and humidity that people produce and how that varies with the number of occupants in the house at a given time and their activities.

Kim is also measuring indoor environmental quality (IEQ), which includes thermal comfort, air quality, lighting and acoustics. She is building a monitoring system to detect air velocity, temperature, humidity, carbon dioxide, illuminance, sound pressure levels and what is known as globe temperature — temperature measured within a globe to detect the combined effects of radiation. These include the amount of heat that radiates from different sources like computers or ovens, or from sunlight shining through a window, and air temperature.

"A building's energy efficiency is important, but we need to balance that with human comfort. We cool and heat a building for its occupants, who are there for a reason, and their productivity and well-being is related to the building's IEQ," she notes, adding, "There is research calculating changes in productivity related to temperature. We can attempt to measure the cost of bad IEQ."

Occupant comfort in real buildings is not well studied in the U.S., she says. Among other challenges, these measurements are expensive, requiring sensors and data loggers across a building. In light of rapidly evolving field instruments and communications systems, she developed a field toolkit to support comprehensive long-term IEQ data collection in the areas of thermal comfort, air quality, lighting and acoustics, at affordable prices based on IEQ sensors communicating with an open-source platform such as the Arduino and Raspberry Pi. The toolkit is compact, portable and easily installed and removed.

She is applying this technology not just to new construction, but to historic buildings as well, where modernizers focus on energy savings and preservation, but pay less attention to comfort.

"Compared to modern buildings that rely on mechanical systems, historic structures tend to have more dynamic indoor environments that are designed to maximize the use of natural resources," she says. "We need to monitor the post-rehabilitation dynamics."

Breathing Life Into Walls

How do you describe a wall? The words sturdy, motionless and opaque leap to mind. Architect VERA PARLAC, director of NJIT's Building Dynamics Laboratory, has spent her professional life rethinking their function in favor of surfaces that are not still, but responsive.

"Buildings are designed to be static and inactive, but they exist in a constantly changing context. We need them to respond to internal and external dynamics, such as the movement of the sun, to reduce energy consumption," she observes, noting some progress on that front with automatic shading systems.

But roadblocks remain, such as figuring out how to seamlessly incorporate kinetics into static building components, while improving the mechanics to facilitate their movement. Easing reliance on mechanical pieces that require maintenance, as in motor-operated louvre shades, which are also costly, noisy and vibrating, is a near-term goal.

Inspired by soft robotics, Parlac builds systems that integrate shape-changing materials, such as soft pneumatic, or inflatable, "muscles" made of silicone, to create movement in lightweight modular structures that function as pliable and programmable building skins. As conceived, embedded sensors would register changes, such as sunlight or human movement, that direct the wall's response, activating hydraulic pumps to inflate the pneumatic components.

She also incorporates shape memory alloy springs that instigate movement. An electrical current changes their molecular structure, causing them to shrink or expand and thus shift the direction of the lattices they are threaded through.

With further research into materials and mechanics, Parlac envisions new devices that will prompt walls to respond to human dynamics as well, shrinking or expanding to accommodate varying numbers of people and different room functions. These structures would likely be made without studs or sheet rock, out of inflatable or foldable materials rarely used in architecture.

"They needn't just be inside," she adds. "We could build external walls, perhaps heated in regions, that form themselves into shapes that can support a resting body by sensing a passerby's desire to stop, either through their stillness, metabolic rates or even a voice-activated application that asks: "Do you want to sit?"

Translating Data Into Technologies for Earth and Space

Four years after its founding, NJIT's Henry J. and Erna D. Leir Research Institute for Business, Technology, and Society is combining its core expertise in data analytics, business data science and technology translation to tackle emerging topics in sectors as diverse as health care delivery, unicorn ventures in space and public companies' communications with investors on Twitter.

The institute's broad mission is to foster sustainable economic development by taking on global challenges to corporate and business continuity and growth, says **Michael Ehrlich**, an associate professor of finance at NJIT's Martin Tuchman School of Management (MTSM) who became the director in 2020.

The study of how corporations use Twitter is a case in point. Tweets enable them to interact directly with investors and keep pace with the speed of information sharing on the web, but also present the potential for missteps that run afoul of the U.S. Securities and Exchange Commission. See Elon Musk and Tesla.

Researchers **Xinyuan Tao** and **Zhipeng (Alan) Yan** are particularly interested in correlations between what companies tweet — including their use of images and links — and how the equity market performs. Their goal is to create a new index for gauging manager sentiment.

First, however, they had to gather long-structured data, in this case millions of tweets from 1,500 companies between 2007 and 2020. They drew from both corporate and company leader accounts — a laborious process that even with supercomputers and two graduate students took more than a year. At the same time, Tao and Yan developed a spatial dictionary to analyze the sentiments of the tweets.

The potential for a new index is "really interesting because it's from the managers' perspective and very different from the investors' perspective, even though right now people don't know how important that is," says Tao, an assistant professor of finance at MTSM. "But, as time goes on, I do think that this will be an important market indicator."

Yan, an associate dean and professor of finance at MTSM, adds that "this can be a serious and impactful project around social media and its impact on the equity market and other secondary markets. So, rather than focus on the stock market, we can also look at the fixed-income market."

The study's initial findings are expected this spring.

The Leir Institute was also tasked with improving both practice and policy in arenas outside of business and industry that are central to economic and societal well-being, such as health care. Researchers at the institute, along with other colleagues at NJIT, take part, for example, in organizations such as the New Jersey Alliance for Clinical Translational Science (NJ ACTS), whose goal is to deliver more evidence-based treatments to more patients.

NJIT is partnering with Rutgers University and Princeton University on the multiyear effort, with NJIT applying its expertise in informatics, machine learning and artificial intelligence toward health care applications for improved outcomes, better accessibility and lower cost. NJIT researchers are developing AI technology, for example, that will improve patient interventions and engagement, particularly in underserved communities.

One of the researchers behind NJ ACTS, NJIT's **Yi Chen**, envisions the benefits of the project, which is funded by a $29 million grant from the National Institutes of Health and includes faculty from NJIT's Ying Wu College of Computing.

One of Chen's projects is to extract information from patient medical records, which typically exists in unstructured narratives written by health care providers, and reassemble it into a structured form that will be far more valuable and accessible, including for predictive modeling.

"You really have to analyze the data to find the knowledge and insight, and use that to provide assistance to physicians, engage patients and make health care more evidence-driven and more intelligent," says Chen, co-lead of the NJ ACTS informatics core and a professor of business data science and Leir Chair in Healthcare at MTSM.

To widen its scope and encourage outreach to corporations, nonprofits and government agencies to sound them out on unmet needs, the institute has begun funding early-stage projects with seed grants.

As Ehrlich puts it, "By soliciting ideas, we're trying to fund research that will solve real problems for businesses and people."

In terms of topics, the sky is not the limit. The recipients of a recent seed grant are exploring commercialization opportunities such as rocketry, satellites, materials science, health care, energy and tourism.

As business professor **Raja Roy** explained of his recent entrepreneurship class on the topic, "The basic issue here is how do you create value and how do you capture value? We are just shifting the context."

Michael Ehrlich directs NJIT's Henry J. and Erna D. Leir Research Institute for Business, Technology, and Society, the mission of which is to foster sustainable economic development by taking on global challenges to corporate and business continuity and growth.

Retooling the Real Estate Ecosystem

NJIT's newly launched Paul Profeta Real Estate Technology, Design, and Innovation Center, one of two centers created by the largest single donation in the university's history, will spur the use of disruptive technologies and other innovations as well as the development of new methods in design and construction and transformative business models in the real estate sector.

The center's goals include, among others, better integration of environmentally friendly and resilient design, the adaptation of transdisciplinary approaches in data analytics, virtual and augmented reality-based modeling and simulation, and the digital transformation of financial services in real estate. Funded by The Paul V. Profeta Foundation, Inc., the philanthropic arm of real estate investor and developer PAUL PROFETA, the center will also emphasize business development that enables future smart communities that are more equitable.

"Our interest is to look at real estate not as an investment option, but as a technology option. So, technology, innovation and design are all bundled," explains OYA TUKEL, dean of Martin Tuchman School of Management and acting director of the transdisciplinary center. "Paul is extremely interested in looking at real estate that way. He wants to make a mark."

Researchers will explore, for example, cost-effective alternatives to legacy processes related to the purchase, valuation, funding, management and rental of real estate property, as well as new technologies to both enhance the construction, operation and ongoing maintenance of facilities and support new developments such as electric vehicle charging and optimization. New financial mechanisms, such as automatic mortgage evaluation and approval systems, crowdfunded collateralized loans for property purchases and community-funded commercial real estate, are also viewed as key change drivers.

Architects and their collaborators will focus on topics such as office designs prioritizing physical distancing and flexibility, energy-efficient design and the creation of smart communities. The center will provide research, demonstrations and technical assistance in areas such as grid-interactive buildings, campus and portfolio-scale microgrids and advanced controls for building operation optimization.

As part of its education and training mission, the center is developing new courses, degree concentrations and certificate programs, while hosting workshops and guest speakers.

New Faculty

COLLEGE OF SCIENCE AND LIBERAL ARTS

Niccolo Pescetelli, assistant professor of humanities and social sciences, is a cognitive scientist who studies the interaction between artificial and collective intelligence, developing methods to facilitate adaptive collective behavior, such as reorganizing for remote work, social learning, group decisions and geopolitical forecasting. He has devised, for example, hybrid human-machine models to predict election outcomes.

Genoa Warner, assistant professor of chemistry and environmental science, investigates how chemicals in everyday consumer products impact human and environmental health. She has shown that components of plastics can disrupt functions of the female reproductive system. Using chemical biology, she studies the mechanisms through which environmental chemicals act, and works to develop safer alternatives.

Sara Zapico, assistant professor of chemistry and environmental science (forensic science), applies biochemical techniques to forensics, such as age-at-death and time-since-death estimations. She was the first to demonstrate the correlation between DNA methylation and age in dentin tissue in teeth, and a switch in cellular signaling pathways after death that determines more precisely how long ago it occurred.

Lijie Zhang, assistant professor of chemistry and environmental science, studies the impact of biogeochemical and mineralogical processes in the transformation of environmental pollutants, with the goal of sustainably remediating soil and water contamination. She demonstrated the role played by naturally occurring iron oxides, phyllosilicates and microbes, for example, in the cycling of mercury and phosphonates.

HILLIER COLLEGE OF ARCHITECTURE AND DESIGN

Kelly Hutzell, associate professor of design and director of the School of Architecture, focuses on urban transformations in disparate locations, from renewal in Pittsburgh to the fast-paced emergence of Doha. She created architectural guidebook apps for Doha and Boston. She also conducts mapping and design research addressing climate change, such as adaptations to sea level rise and carbon neutral development.

Won Hee Ko, assistant professor of design, examines resiliency and indoor environmental quality in architectural design, with the goal of balancing comfort, well-being and productivity with sustainability. She concentrates on the building envelope, and on mitigating dynamic aspects of the external environment, such as heat, light and air quality, to improve the indoor environment.

NEWARK COLLEGE OF ENGINEERING

Farid Alisafaei, assistant professor of mechanical and industrial engineering, focuses on the mechanobiology of cells and tissues. He develops integrated computational and experimental tools to understand and harness mechanics in physiological processes, such as wound healing and stem cell migration, as well as in pathological processes, such as fibrosis, surgical adhesions, scar formation and cancer progression.

Shaahin Angizi, assistant professor of electrical and computer engineering, designs energy-efficient and high-performance processing-in-memory platforms to enhance functions, such as accelerating complex artificial intelligence and machine learning tasks, bioinformatics computation and graph processing. His hardware-friendly algorithm and platform processes big data in the memory unit without sending it to the processor, overcoming the memory wall challenge.

Rayan H. Assaad, assistant professor of civil and environmental engineering, uses computational methods, machine learning, modeling, simulation and optimization to improve the sustainability, resilience and performance of above and underground infrastructure systems. He also focuses on next-generation technologies and modern techniques for planning, designing, constructing, managing, maintaining, repairing and rehabilitating intelligent infrastructure facilities and smart construction projects.

Peter Balogh, assistant professor of mechanical and industrial engineering, models microscale biofluid dynamics associated with cancer progression, using high-performance computing to simulate cells flowing through 3D capillary networks in tumors and modeling the transport mechanisms underlying their spread to lymph nodes. He has developed a new method to simulate cellular-scale flows of cells through highly complex geometries.

Alexander Buffone Jr., assistant professor of biomedical engineering, focuses on understanding and directing blood cell migration, a key function in the body's immune response. He and his co-workers were the first to demonstrate the capability of various blood cells to "swim upstream" like salmon, and the first to show the critical signals controlling this phenomenon.

Kerri-lee Chintersingh, assistant professor of chemical and materials engineering, develops novel materials, coatings and reaction models, such as propellants, reactive inks and explosives, for various applications, including for defense against chemical and biological weapons. She also researches nanomaterials for use in chemical looping combustion to minimize the formation of atmospheric pollutants in industrial gas waste streams.

Tao Han, associate professor of electrical and computer engineering, develops next-generation mobile networking and computing systems that enable advanced applications, such as augmented/mixed reality for education, autonomous driving and telehealth. He is designing a global machine vision system that can efficiently extract, transfer and share useful information from ubiquitous cameras while preserving user privacy.

Amir K. Miri, assistant professor of biomedical engineering, researches and builds bioprinting platforms for use in the additive manufacturing of cell-laden biomaterials. He creates engineered models for health care-related uses, including new bioprinting techniques for regenerative medicine, such as laryngeal surgeries, and models for diseases, such as solid tumor and cardiovascular diseases.

MARTIN TUCHMAN SCHOOL OF MANAGEMENT

Joseph Micale, assistant professor of accounting, focuses on audit partner quality and the influence of regulation changes on auditing fees. He is investigating the impact of federal legislation that reduces mandatory disclosure and compliance on auditing costs during firms' IPOs, and auditors' perspectives on firms' uniqueness from peers as related to stock trades.

YING WU COLLEGE OF COMPUTING

Photo: Kazem Cheshmi

Kazem Cheshmi, assistant professor of computer science, builds new programming languages for developing fast programs involving mathematical operations, which are used in scientific computing, computer graphics and machine learning. He developed Sympiler, a domain-specific compiler program that automatically translates the source code from a programming language to a code that runs fast on the computer.

Yao Ma, assistant professor of computer science, works on network embedding and graph neural networks for extracting low-dimensional vector representations on graph-structured data, information that can then be fed into machine learning models to facilitate real-world applications in fields based on graph-structured data. These include online recommendations, social media, education and health care.

Shantanu Sharma, assistant professor of computer science, develops database management systems that preserve security and privacy. He has devised several methods for scaling cryptographic techniques for large data sets, which have been incorporated in a real-time, privacy-preserving, Wi-Fi-based system called TIPPERS. The system uses Wi-Fi connectivity data for localizing people both inside and outside buildings.

Hua Wei, assistant professor of informatics, studies reinforcement learning, a machine learning training method used in operations such as traffic flow optimization and data mining that deals with spatial and temporal data in urban systems and health care. Applications include traffic signal control, vehicle dispatching and a range of "smart city" functions.

AMERICAN ACADEMY OF OPTOMETRY DIPLOMATE

Tara Alvarez, professor of biomedical engineering, studies the links between visual disorders and the brain and develops novel devices to identify and treat them. She currently seeks to establish guidelines that will help clinicians diagnose and treat concussion-related convergence insufficiency, an eye coordination disorder that causes blurred and double vision, headaches and difficulties concentrating.

AMERICAN ASTRONOMICAL SOCIETY FELLOW

Photo: Philip Goode

Philip Goode, distinguished research professor of physics, was named for his work in helioseismology, advancing knowledge of the Sun's interior, thermonuclear reactions and radiation emissions, and leadership in university-based solar physics. He led the team that built and operated Big Bear Solar Observatory's 1.6-meter solar telescope, and later expanded its optical field threefold with multiconjugate adaptive optics.

AMERICAN PSYCHOLOGICAL ASSOCIATION FELLOW

Julie Ancis, professor and interim chair of informatics, focuses on the intersections of psychology, technology and diversity. She developed empirically supported clinical training models, culturally responsive psychological interventions, predictive models of educational achievement and best practices in the legal system. She now focuses on misinformation and its behavioral impacts and persuasive communicative visualizations.

AMERICAN SOCIETY OF ARCHITECTURAL HISTORIANS FELLOW

Photo: NJIT Media Office

Zeynep Çelik, distinguished professor emerita of architecture, researches urban history, colonialism, orientalism and modernism, focusing on the 19th and 20th centuries. Her scholarly works include *The Remaking of Istanbul*, winner of the Institute of Turkish Studies Book Award, and *Europe Knows Nothing about the Orient: A Critical Discourse From the East (1872–1932)*, among others.

FULBRIGHT FELLOW

Photo: Oscar Macciandaro

Joerg Kliewer, professor of electrical and computer engineering, advances the security, privacy and understanding of information analysis processing systems, distributed machine learning, emerging wireless communication systems and distributed storage. This includes strategies for future communication systems and for distributed computation to speed up machine learning while ensuring privacy.

IEEE COMPUTER SOCIETY SIDNEY FERNBACH AWARD

Photo: Oscar Macciandaro

David Bader, distinguished professor of computer science, works at the intersection of data science and high-performance computing, with applications in cybersecurity, massive-scale analytics and computational genomics. He played a key role in the development of Linux-based massively parallel production computers and is recognized for his pioneering contributions to scalable discrete parallel algorithms for real-world applications.

IEEE EMBS AWARD FOR EXCELLENCE IN BIOMEDICAL TECHNOLOGY

Photo: Oscar Macciandaro

Atam P. Dhawan, distinguished professor of electrical engineering and senior vice provost for research, created a low-angle transillumination imaging device that enables doctors to look beneath the outer layer of the skin to detect diseases such as early-stage skin cancers, isolate glucose from blood and illuminate spider veins, among other applications.

IEEE FELLOW

Photo: Oscar Macciandaro

Grace Guiling Wang, professor and associate dean for research of Ying Wu College of Computing, researches blockchain technologies, Internet of Things and mobile computing, and applications involving deep learning. She has designed distributed algorithms to facilitate the development of smart sensor networks and connected vehicles.

NATIONAL ACADEMY OF INVENTORS FELLOW

Photo: Oscar Macciandaro

Treena Arinzeh, distinguished professor of biomedical engineering, develops new materials and technologies for regenerative medicine applications. She pioneered, for example, the use of electrospinning to create fibrous scaffolds to stimulate tissue and nerve cell regeneration, and devised new methods for bone grafting, including bone graft scaffolds to substitute for bone grafts.

NATIONAL SCIENCE FOUNDATION CAREER GRANTS

Photo: Oscar Macciandaro

Murat Guvendiren, assistant professor of chemical and materials engineering, develops polymeric biomaterials with user-defined dynamic properties to make biomaterial scaffolds and medical devices for tissue engineering and regenerative medicine. He is currently focusing on bioprinting the interface between cartilage and bone to repair the damaged tissue that leads to osteoarthritis.

Tao Han, associate professor of electrical and computer engineering, develops domain-specific deep reinforcement learning methods and systems to automate the configuration, provisioning and orchestration of network resources and services in next-generation wireless edge computing networks. The goal is to expand affordable high-performance wireless connectivity, including in low-income and remote communities.

Photo: Satoshi Inoue

Satoshi Inoue, assistant professor of physics at the Center for Solar-Terrestrial Research, develops and conducts advanced simulations of solar coronal magnetic fields and plasma as they evolve in time, combining these with observed magnetic fields from solar instruments to reveal how solar flares are triggered.

SOCIETY FOR SIMULATION IN HEALTHCARE 2021 TECHNOLOGY INNOVATOR OF THE YEAR

Photo: Oscar Macciandaro

Salam Daher, assistant professor of informatics, uses computer graphics and virtual and augmented reality to improve training, especially in the health care domain. Her physical-virtual patients are life-size simulated patients with real-time physical tactile cues, such as temperature, pulse, speech and audible heart beats, as well as rich facial expressions.

Research at NJIT: By the Numbers

R1
Carnegie Classification® of Institutions of Higher Education research ranking

187
patents and intellectual property assets held by NJIT faculty

140
research institutes, centers and specialized labs

10
Fellows of the National Academy of Inventors

24
NJIT instruments in Antarctica

20
voice-controlled robotic hands 3D-printed in NJIT's Makerspace

1,100
number of steps taken by a paraplegic one day in Saikat Pal's laboratory

2,000
number of online strangers who collectively controlled Niccolo Pescetelli via an internet platform

$57.5 MILLION
amount raised in 2021 by companies in VentureLink

Since 2017:

72%
increase in external research funding

14
winners of National Science Foundation CAREER Awards

$4 MILLION
spent on undergraduate student research stipends

First-year students in a general engineering course last fall learned how to control the movement of individual fingers of a voice-activated robotic hand using Arduino coding and the Amazon Alexa application. Shown are three of 20 that were 3D-printed in NJIT's Makerspace for a variety of tasks.

NJIT

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