SUMMER 2022 VOL. 36, NO. 1

SYSTEMSOLUTIONS

THE INSTITUTE FOR SYSTEMS RESEARCH
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AI, ML and autonomy

ISR's revolutionary research for vehicles, health care, robots

Plus: ISR innovations aboard the Webb Space Telescope

ISR research advances in artificial intelligence, machine learning and autonomy

In 1985, ISR was one of the original six National Science Foundation Engineering Research Centers. We have always focused on interdisciplinary advances for creating complex systems involving communication, control and computation.

Today, advances in these three areas have exploded, and ISR's leadership in building the complex systems of tomorrow continues. In this issue of *System Solutions*, we focus on the research of ISR faculty and students at the forefront of the integration of machine learning (ML), autonomy, and artificial intelligence (AI).

First, we look at a $68M ARL cooperative agreement headed by ISR faculty. Next, we feature systems powering technology in three different domains: autonomous vehicles and their networks; the changing face of medicine; and the increasing capabilities of robotics.

Prepare to be amazed!

IN THIS ISSUE:

ArtIAMAS

$68M ARL cooperative agreement for AI, ML and autonomy research

ISR faculty and their students are playing key roles in the University of Maryland and University of Maryland Baltimore County's (UMBC) new "ArtIAMAS" cooperative agreement with the U.S. Army Research Laboratory (ARL). Professor **Derek Paley** (AE/ISR), the director of the Maryland Robotics Center, is the lead researcher.

The five-year agreement, announced in May 2021, is worth up to $68 million and builds on a quarter-century research partnership between UMD and ARL in AI, ML, autonomy, modeling, and simulation.

The research focuses on safe, effective, and resilient technologies that work intelligently and cooperatively with humans and each other. It spans engineering, robotics, computer science, operations research, modeling and simulation, and cybersecurity.

In January 2022, UMD and the Clark School of Engineering received second-year ArtIAMAS funding of $10.375 million, one of the largest single-year sponsored research awards in the college's history.

To date, the project has involved 109 ARL researchers, 64 UMD and UMBC researchers, and 117 students. The major research areas and projects are listed here.

Collaborative Autonomy Research, Development, Test and Evaluation (RDT&E) Infrastructure

Professor **Jeffrey Herrmann** (ME/ISR) is the principal investigator for this area that addresses a lack of standard shared infrastructure, baseline scenarios, tools and common models for collaborative autonomous systems.

He is joined by **Derek Paley**; ISR Visiting Research Scientist **Craig Lawrence**; ISR-affiliated Professors **Adam Porter** (CS/UMIACS) and **Dinesh Manocha** (CS/UMIACS/ECE); Professor **Ming Lin** (CS/UMIACS); Assistant Professor **Michael Otte** (AE); and **Matt Scassero**, the Clark School's director for research, innovation and outreach.

The researchers are enabling collaborative RDT&E through shared infrastructure, digital twin development, robot navigation of complex terrain, simulation-based verification for autonomous systems, and long-distance collaborative autonomy.

"Currently, research teams have to build their own simulation testbeds to evaluate their algorithms and systems," says Herrmann. "This increases costs and delays the development of significant innovations. With ARL researchers we are planning and developing a modeling and simulation infrastructure with libraries of simulation models and tools for building and running them. This will save time and effort in evaluating how well new algorithms perform and in testing autonomous systems, an important challenge in robotics and autonomy."

Harnessing the data revolution

This research involves networking and sensing, a battlefield Internet of Things (IoT) testbed, adaptive cybersecurity for battlefield IoT, OpenML cross-domain learning, integrated mission planning for urban environments, and predictive maintenance for Army assets.

It is led by faculty from UMBC and also includes Research Engineer and Director of the Center for Advanced Transportation Technology Laboratory **Michael Pack** (CEE) and Professor **Peter Sandborn** (ME).

Closer human-machine teaming

This research explores how AI/ML sensor and computing systems can augment human performance for situational awareness, behavioral and physiological health assessment, battlefield uses, forensics, and metareasoning.

Dinesh Manocha, the principal investigator, is joined by ISR Director and Professor **Ankur Srivastava** (ECE/ISR), Assistant Professor **Huan Xu** (AE/ISR), ISR-affiliated Professor **Nikhil Chopra** (ME), Professor **Ramani Duraiswami** (CS/UMIACS), Principal of Campbell Code Consulting and FPE Adjunct Lecturer **Chris Campbell, Ming Lin, Craig Lawrence, Adam Porter, Jeffrey Herrmann,** and faculty from UMBC.

Autonomous systems use metareasoning to control how they make decisions. This project is generating knowledge about the performance of metareasoning approaches in human-autonomy teams that operate at different levels of human interaction, including supervising, advising, directing, and collaborating. Ultimately, successful metareasoning approaches will improve the performance of human-autonomy teams while maintaining the transparency needed for trustworthiness.

Research includes AI/ML on edge for situational awareness, individual and collective behavioral and physiological health assessment, explainable AI for the battlefield, perception-based interaction, forensics for human-machine teaming, metareasoning to improve team performance, and human-machine teaming and effective aggregation of information in complex systems.

Autonomous vehicles, their networks and security

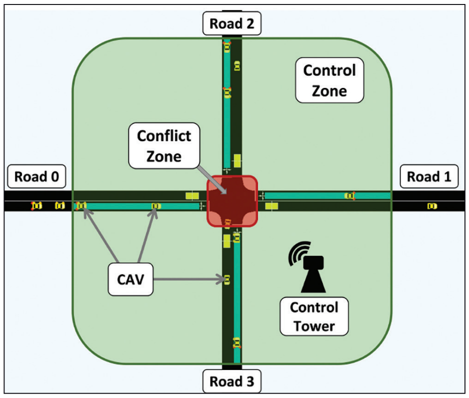
The advent of autonomous vehicles holds great promise but presents significant challenges. ISR experts in networks, cybersecurity and game theory are addressing both the potentials and the pitfalls.

Navigating unsignaled intersections

Intersections without traffic signals are the sites of 40% of all crashes, 50% of serious collisions, and 20% of fatalities. Motorists must make choices when they approach these intersections, which often have four-way stop signs and unprotected left turns. Safety is an issue if two vehicles approach at approximately the same time, or a driver decides not to stop or to wait their turn. Adding autonomous vehicles (AVs) into the mix could make these situations worse—but ISR faculty and students are developing new algorithms for AVs that actually could *improve* things significantly.

Professor **John Baras** (ECE/ISR) and his Ph.D. student **Nilesh Suriyarachchi**, and ISR-affiliated Professor **Dinesh Manocha** (ECE/UMIACS/ CS) and his Ph.D. student **Rohan Chandra** have developed GAMEOPT: Optimal Real-Time Multi-Agent Planning and Control for Dynamic Intersections.

GAMEOPT algorithms are designed for AVs equipped with vehicle-to-infrastructure (V2I) communication—known as connected autonomous vehicles (CAVs). CAVs are able to cooperate with each other to provide multiple sensing and actuation points in the traffic flow. Through GAMEOPT, CAVs can achieve safe, fair, and efficient intersection control.



USING GAMEOPT, VEHICLES COMMUNICATE WITH THE CONTROL TOWER IN THE CONTROL ZONE AND CROSS OVER TO THEIR DESIRED TARGET ROAD IN THE CONFLICT ZONE.

GAMEOPT's solutions come from many fields, including game theory, auctions, optimization, and deep learning. The hybrid approach first uses an auction mechanism to generate a priority entrance sequence for every vehicle. Next, GAMEOPT's optimization-based trajectory planner computes velocity controls that satisfy the priority sequence.

The algorithm improves throughput by at least 25%, time taken to reach the goal by 75%, and fuel consumption by 33% compared to both auction-based approaches and signaled approaches that rely on traffic lights and stop signs. Its implications can extend beyond intersection control to more general multi-agent systems.

Learn more. *go.umd.edu/gameopt522*

Calming traffic 'shock waves'

Baras and **Suriyarachchi** also believe CAVs hold the key to alleviating traffic shock waves on roadways. We have all experienced the sudden slowing, speeding up, and renewed slowing of traffic. These "shock waves" naturally occur when drivers hesitate or make sudden decisions. They are easily generated by even the simplest of triggers, such as a few cars slowing down to look at a distraction on the side of the road, busy merger junctions, minor collisions and road construction. They are a control problem that contributes to traffic congestion, higher fuel consumption, and diminished efficiency of highway networks.

Many new vehicles are equipped with radar sensors, vision-based sensors and even lidar ranging sensors that allow automated observation of surroundings. Control algorithms can leverage this information to make better driving decisions than humans. CAVs will go a step further, using their advanced sensing, actuation and communication capabilities to connect with each other and with roadside infrastructure.

At the IEEE 94th Vehicular Technology Conference (Fall 2021), Baras and Suriyarachchi presented research showing how CAVs could help solve the shock wave problem.

Traffic shock waves persist because of difficulties drivers have in sensing highway conditions and knowing how to drive in ways that could help dissipate them. The ISR researchers believe that interspersing even a small number of CAVs with conventional human-driven vehicles on a road could help. The CAVs could act as both "Lagrangian sensors," collecting local traffic information and sharing it to obtain a global state of traffic, and "Lagrangian actuators," allowing themselves and their surrounding vehicles to be controlled via inter-vehicle interactions. Slowing down and speeding up conventional vehicles could be achieved by the actions of CAVs dispersed among them.

The paper introduces a communication-based cooperative control method for CAVs

in multi-lane highways in a mixed traffic setting. The method allows for proactive control application and exhibits good shock wave dissipation performance even when only a few CAVs are present. The results were verified on a three-lane circular highway loop using realistic traffic simulation software.
Learn more. *go.umd.edu/swm522*

Deceiving an autonomous vehicle's traffic sign recognition system

Cybersecurity attacks against fully autonomous vehicles are a looming threat that could come in many different forms. Work by Professor **Gang Qu** (ECE/ISR) and five co-authors shows how deliberately deceptive traffic signs could interfere with the real-world object detectors autonomous vehicles rely upon, resulting in life-threatening situations for vehicle occupants.

While AI and deep neural networks (DNNs) have boosted the performance of a large variety of computer vision tasks such as face recognition, image classification, and object detection, their proliferation also has created incentives and opportunities for bad actors to attack.

Within traffic sign recognition (TSR) systems being developed for AVs, object detectors use DNNs to process streaming video in real time. The DNNs help the TSRs recognize when an object that appears to be changing size and shape is actually the same object viewed from different angles.

Cybersecurity threats called adversarial examples (AEs) are digital static patches that can deceive DNN image classifiers into misclassifying what they see. Qu and his colleagues reasoned that if AEs existed as physical objects in the environment, they could cause vehicular havoc by fooling TRS systems that rely on DNNs. To test this idea, the researchers developed a systematic pipeline that could generate robust physical AEs to use against real-world object detectors.

Using a brand-new 2021 model vehicle equipped with TSR, the researchers ran experiments under a variety of environmental conditions (sunny, cloudy and night), distances from 0m to 30m, and angles. The physical AEs generated by the researchers' pipeline were effective in attacking the YOLOv5-based object detection architecture TSR system and could also deceive other state-of-the-art object detectors. Because the TSR system was so effectively fooled, the authors concluded AE attacks could result in life-threatening situations for autonomous vehicles.

The authors also noted three defense mechanisms that could defend against real-world AEs, based on image preprocessing, AE detection, and model enhancing.
Learn more. *go.umd.edu/ae522*

Brief takes...

Highway merging. **Suriyarachchi, Baras, Faizan Tariq** and **Christos Mavridis** won the Best Student Paper Award at the 2021 IEEE International Conference on Intelligent Transportation Systems (ITSC) for an algorithm that optimally coordinates CAVs to improve highway merging efficiency and safety.
Learn more. *go.umd.edu/merge522*

Aggressive drivers. **Dinesh Manocha** and **Rohan Chandra's** GAMEPLAN is a robotics-based algorithmic auction framework for AVs that helps them make decisions in traffic merging, at unsignaled intersections, and in roundabouts. GAMEPLAN instructs the AV to follow an optimal turn-based ordering in which more aggressive or impatient drivers are allowed to move first. While counter-intuitive, this approach is game-theoretically optimal and successfully prevents collisions and deadlocks with human drivers in the real world.
Learn more. *go.umd.edu/gameplan522*

Improving health care with AI and ML

ISR faculty fluent in AI/ML, signal processing and neuroscience are connecting with colleagues in medicine and computer science to develop new technologies for better patient outcomes.

ML provides a new way to monitor depression

With $1.2 million in NSF funding, a team led by Professor **Carol Espy-Wilson** (ECE/ISR) is creating a computerized framework that uses machine learning (ML) to meld language, speech analysis, and clinical expertise. They are developing an app to help depression patients and their clinicians detect speech changes that occur when the condition worsens.

Espy-Wilson, an expert in signal processing and the mechanics of speech production, knows the complex, neurologically based act of speaking is also a good indicator of mental health issues. Speech coordination has a distinct signature when mental illness is present. People with depression exhibit "psychomotor slowing"—they think, speak, and move more slowly based on the severity of their condition.

"All the gestures of the body slow down," Espy-Wilson says. "The articulation coordination of speech is simpler, resulting in speech that is slower, less variable and has more and longer pauses."

When these changes can be reliably detected, clinicians will be better able to make timely and accurate interventions.

The framework's speech inversion system uses ML to convert acoustic signals into articulatory trajectories, capturing changes related to mental health. It can classify both depression and schizophrenia presenting with delusions and hallucinations with 89% accuracy.

The smart phone app will be offered to patients to use between doctor visits. The app will ask the person questions and use the articulatory markers in their spoken replies to alert their clinician to any worsening condition.

"We hope people will want to use the app regularly, starting when they are feeling fairly well and are most likely to comply," Espy-Wilson says.

The project started with a AI + Medicine for High Impact (AIM-HI) Challenge Award seed grant. These grants bring together UMD and University of Maryland School of Medicine researchers for research initiatives that link artificial intelligence and medicine. In the current project, Espy-Wilson is joined by Professor **Philip Resnik** (Linguistics/UMIACS), Assistant Professor **John Dickerson** (CS) and Professor **Deanna Kelly** (Psychiatry, UMSoM).

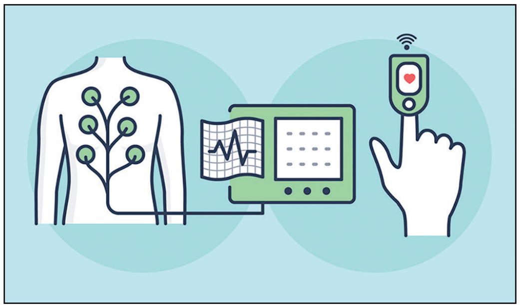
AI helps uncover biomarkers for chronic pain

People living with chronic pain know that far better management and treatment options are needed. One source of hope lies in the ability of AI to help medical researchers better navigate the complexities of how the body processes and modulates pain-causing stimuli.

Professor **Pamela Abshire** (ECE/ISR) and Professor **Robert Ernst** (School of Dentistry, University of Maryland Baltimore) have been awarded a 2022 MPower seed grant to establish a scientific foundation for understanding and treating chronic pain in the gastrointestinal tract. They are using data science and AI techniques for pathway discovery and *in vivo* sensing of biomarker correlates of nociception and pain. Abshire and Ernst have been collaborating since 2020, when they won an AIM-HI Challenge Award together.

MPower seed grants are awarded by the Joint Steering Council of the University of Maryland Strategic Partnership: MPowering the State. This is a formal collaboration between the University of Maryland's Baltimore and College Park campuses.

AI-driven home device could produce ECG-quality results



The gold standard for detecting early heart problems is the electrocardiogram (ECG), the test where electrodes are placed on the patient's chest in doctor's offices and hospitals. Outside of these settings, there is no convenient and inexpensive way to monitor heart conditions.

A home heart monitor that can produce ECG-quality results may one day become available, thanks to ISR-affiliated Professor **Min Wu** (ECE/UMIACS), an expert in digital forensics and signal processing who has received $1.2 million in NSF funding. Wu is collaborating with Assistant Professor **Sushant Ranadive** (School of Public Health), an expert in cardiovascular physiology and kinesiology.

They are using AI to uncover the relationship between ECG results and those from photoplethysmogram (PPG), a way to measure cardiac activity by monitoring changes in blood volume beneath the skin. While PPG is cheaper, more convenient and more accessible than ECG testing, it provides less direct information on cardiac activity and is not as well understood. Wu believes AI can be used to reconstruct ECG-quality results from PPG data—key to developing a user-friendly PPG finger sensor that can be used at home.

Learn more. This "Three-Minute Thesis" video by Min Wu's student Xin Tian explains the research in more detail: *youtu.be/F8fYKDbBZ5Q*.

AI/ML and computer vision for robotics

The AI field of computer vision involves training computers to capture and interpret information from images and videos. By applying ML models, computers can classify and respond to objects in visual data. ISR researchers are at the forefront of advancing computer vision and integrating it with robotics to develop new capabilities.

Using underwater robots to detect and count oysters

Oysters are filter feeders that clean water and create habitat for other species. They are essential to the Chesapeake Bay, but their beds have undergone ecological stresses and shrunken in size. It's hard to tell how successful the projects to restore oysters habitats have been. One issue is that measuring the numbers of oysters and their physical dimensions has always been performed manually, on a small scale.

Advances in AI/ML, computer vision and robotics could improve the monitoring process. Remotely operated, maneuverable underwater vehicles are becoming affordable and can be fitted with sensors and cameras for sampling.

Professor **Miao Yu** (ME/ISR), postdoctoral researcher **Behzad Sadrfaridpour** (UMIACS), ISR-affiliated Professor **Yiannis Aloimonos** (CS/UMIACS), Professor **Yang Tao** (BIOE), and **Donald Webster** of the UMD Wye Research and Education Center, are advancing this idea as part of a $10M USDA National Institute of Food and Agriculture project to transform shellfish farming with smart technology and management practices for sustainable production.

The team is creating computer vision algorithms—convolutional neural networks (CNNs)—to detect, count, and calculate the dimensions of oysters. CNNs can track oysters in consecutive image frames so they are not identified multiple times.

The researchers recently produced videos of oysters in the Chesapeake Bay with the help of a local waterman. Afterwards, they annotated the visual data captured from the bay bottom and created an oyster data set. They used a state-of-the-art CNN called Mask R-CNN for target tracking and instance segmentation, and employed detectron2 for training and evaluating the oyster data set.

Their trained networks' prediction results showed an Average Precision (AP50) of 81.8. They also combined the detection CNN with an object tracker that could count the number of oysters.

Learn more. *go.umd.edu/MCoysters921*

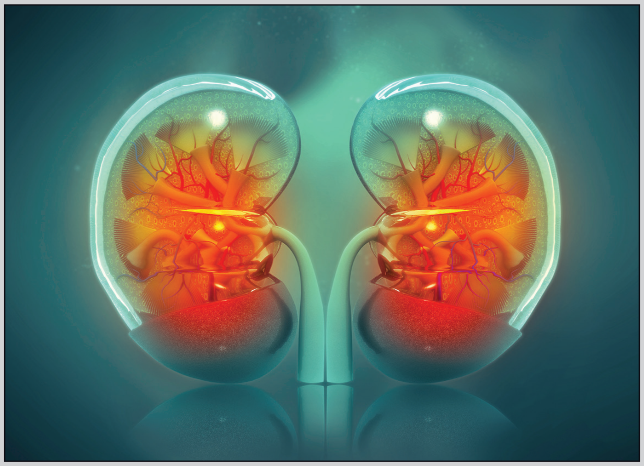
Brief takes...

Spotting drones. When used maliciously, drones are security and confidentiality risks. Better ways to detect their presence are needed. A team led by ISR-affiliated Professor **Yiannis Aloimonos** (CS/UMIACS) uses the most ubiquitous part of a drone—the propeller—as the basis for a new detection scheme that is 92% accurate.

Learn more. *prg.cs.umd.edu/EVPropNet.*

EPIC Kitchens. Improving computer vision will lead to automating manufacturing inspections and identifications, and better event detection for autonomous vehicles. Worldwide competitions using huge datasets are held to advance computer vision. **Learn more** about an ISR team's experience in an "EPIC Kitchens" challenge: *go.umd.edu/epic522.*

New funding for ISR faculty



Improving the kidney transplant process

Kidney transplants are the gold standard treatment for end-stage renal disease patients. However, there are many constraints. For example, there may be a blood type or human leukocyte antigen tissue type incompatibility between transplant candidates and their kidney donors. Or there may be a significant access problem, especially for renal patients in low socioeconomic communities.

Professor **Michael Fu** (BMGT/ISR) is helping improve patient access to and options for kidney transplants. He is part of a $1 million NSF project to enhance the transplant system. It will combine a personalized antibody removal regimen known as "desensitization" with a kidney paired donation system (KPD), improving both access and decision-making.

The five-institution project is led by Naoru Koizumi at George Mason University and includes participation by researchers at the George Washington University Transplant Institute, the Virginia Commonwealth University Health Hume-Lee Transplant Center and the University of Louisville.

Fu's contribution is to develop a decision-support tool that will help patients decide whether to accept an offered kidney or wait for a better offer. The offered kidney might be compatible but of relatively poor quality. Or it could require the patient to undergo the desensitization regimen. Fu's tool would help the patient weigh their options and make a good decision.

The researchers are working together to develop stochastic simulation and optimization-based algorithms for matching donors and recipients in the new combined system. Algorithms will be tailored for the GWU and VCU transplant centers, which are interested in developing a joint local KPD exchange.

"We believe our model will help match kidney donors and transplant candidates in a KPD system where desensitization is a viable option," Fu says. "We really hope to improve the quality of life of end-stage renal disease patients, and to reach chronically underserved low socioeconomic communities."

Shamma, alum Elhilali in new MURI soundscape project

Professor **Shihab Shamma** (ECE/ISR) is a co-principal investigator on a 2022 Department of Defense Multidisciplinary University Research Initiative (MURI), "Learning to Mine a Soundscape." His former student and postdoctoral researcher, **Mounya Elhilali** (ECE Ph.D. 2004), a professor in the Electrical and Computer Engineering department at Johns Hopkins University, is the principal investigator for the overall project. This MURI is sponsored by the Office of Naval Research.

As humans, animals and machines navigate and interact with their environments, they make inferences from the acoustic signals they receive, which provide information about the context and physical structure of the environment. This helps them make sense of their surroundings so they can adapt their behaviors. Inferring from sounds is informed by learned representations. This project will identify the nature and role of representations in guiding perception and behavior in humans, animals, and models.

Professor **Ramani Duraiswami** (CS/UMIACS) also is a co-PI. The research includes colleagues from Carnegie Mellon University.

Natural neuronal network 'rules of life'

Scientists wanting to develop better algorithms and engineering models that will increase computer speeds and abilities would benefit from advances in understanding how the brain works. The brain's networks of neurons are remarkably fast and efficient at solving pattern recognition and classification problems—far better than the most sophisticated computers.

Researchers have made only limited progress in understanding what underlies the brain's capabilities. For example, they do not yet understand the physical mechanisms inside a living neuron and its networked neighbors.

Professor **Pamela Abshire** (ECE/ISR) is the principal investigator for a $2.9 million NSF grant to explore the "rules of life" of neuronal networks. She is joined by ISR-affiliated Associate Professor **Timothy Horiuchi** (ECE) and Professor **Ricardo Araneda** (Biology).

The project brings together recent technological advances in patterning, electrical recording, optical stimulation, and the genetic manipulation of neurons. The team is studying how to nurture a healthy culture of neurons while continuously observing and stimulating them at fine scale. They hope to uncover how the individual parts of a single neuron contribute to the overall learning and computation of the neural network.

Earlier researchers experienced technical limitations that left them working on too large a scale. "The interface was not fine enough," Abshire says. "Now with new tools we can program a single neuron to respond selectively to one pattern out of many."

While understanding how sophisticated networks of neurons work is a future goal, working with simple neurons and sparse networks must come first. Abshire's team is developing a proof-of-concept demonstration of a programmable computation by neurons in an engineered microenvironment. The research will have significant implications for the scientific understanding of natural neuronal computation and will affect work in artificial intelligence, robotics, and neural prosthetics.

Learn more. Watch Pamela Abshire's Distinguished Scholar-Teacher lecture on this work: *go.umd.edu/nnn422.*

Planning for collaborative autonomy testing

Robotics research increasingly is focusing on teams of autonomous ground robots and unmanned vehicles for search and rescue, mining, material handling, and secure facilities protection. Researchers are inventing algorithms to help these autonomous systems better collaborate with each other. However, setting up and running simulation models to test, evaluate, validate and verify the algorithms is time- and resource-consuming.

A new NSF project led by Professor **Jeffrey Herrmann** (ME/ISR) is laying the foundation for a better autonomous systems modeling and simulation infrastructure with lower barriers and better collaboration. Co-PIs are Professor **Derek Paley** (AE/ISR), ISR-affiliated Professors **Adam Porter** (CS/UMIACS) and **Dinesh Manocha** (ECE/CS/UMIACS), and Assistant Professor **Pratap Tokekar** (CS/UMIACS).

The researchers represent robotics systems, modeling and simulation, test and evaluation, and software engineering. They are developing use cases, designing infrastructure architecture and identifying key partners. These will lead to recommendations for hardware, software, APIs, user interfaces, libraries of models, a development and testing environment, and documentation.

'Third lung' respiratory assistance technology

The COVID-19 crisis has underscored the need for better respiratory assistive technology. Doctors observed that COVID patients placed on ventilators were prone to ventilator-induced lung injuries, and that those with potentially reversible lung failure often died before their lungs had the chance to recover.

Supplemental extrapulmonary gas exchange is a promising technology for these circumstances. With $3.6 million in NSF funding, Professor **Miao Yu** (ME/ISR), Professor **Hosam Fathy** (ME/MEII), Associate Professor **Jin-Oh Hahn** (ME); and Professor **Joseph S. Friedberg,** M.D. (UMSoM Surgery) are working to perfect a version of this treatment called "third lung."

"To the best of our knowledge, our third lung technology is one of the first attempts to establish and demonstrate the potential of peritoneal perfluorocarbon (PFC) circulation to supplement gas exchange in the lungs," says Hahn.

PFC is a dense, colorless, nontoxic, and inert fluorine-based liquid equipped with extraordinary gas dissolving properties. When this oxygen-rich liquid is pumped into the body cavity, the oxygen diffuses into the blood vessels while carbon dioxide diffuses out.

Friedberg originally invented and successfully demonstrated the concept; the engineers are improving it in ways that make it more medically feasible and cost-effective.

ISR's Miao Yu is developing sensors that can accurately measure dissolved concentrations of gases. Fathy and Hahn are working on algorithms to more precisely control pressures, temperatures, and flow rates. The team also is creating a sophisticated data acquisition system to track the process.

While spurred by the need to help save lives during the pandemic, the research has much broader applicability and may be appropriate for a very large population of patients.

Friedberg notes, "Long term, we believe this technology could find a standard role in the treatment of any patient who has recoverable lung injury from any cause."

Better post-stroke recovery

People who have had minor strokes have a tremendous potential to return to their prior level of function. But despite "good recoveries," more than 40 percent of patients continue to experience problems with concentration, attention, executive function, processing speed, and mood. These problems appear regardless of stroke size, location, or co-existing depression.

Johns Hopkins University School of Medicine neurologist **Elisabeth Marsh,** Professor **Jonathan Simon** (ECE/Biology/ISR), and JHU's **Neda Gould** (Psychiatry), are using a $460K grant from the NIH National Institute on Aging to shed light on whether mindfulness training could help minor-stroke patients experience more complete recoveries.

The researchers are using magnetoencephalography (MEG) brain scans to evaluate patients' depression, cognition, perception of recovery, and degree of re-integration into prior environments. Between scanning sessions, half the patients in the study receive mindfulness training, while the other half participate in a more traditional Stroke Support Group. The MEG scans will help determine the neurophysiologic effects of mindfulness training on subacute post-stroke depression and cognition.

Marsh and Simon have been conducting post-stroke research for several years. In 2020 their groundbreaking MEG brain scan work for the first time provided measurable physiological evidence of diminished neural processing within the brain after a stroke, and suggested that post-stroke acute dysexecutive syndrome (PSADES) is the result of a global connectivity dysfunction. It was published in the *Proceedings of the National Academy of Sciences of the United States of America*.

Two NSF grants for Barg's data coding methods

Professor **Alexander Barg** (ECE/ISR) is the principal investigator for two $500K NSF grants on data coding methods.

Modern-day data centers store large volumes of information in distributed form, placing parts of the same data file on different servers in the system. But servers fail on a regular basis, and when they do, recovering the data depends on methods of encoding. Developing these methods is critical to designing large-scale storage systems.

In the first project, Barg is constructing methods of data encoding that account for low-cost data recovery based on connections between the servers, such as spatial proximity or the availability of communication links.

These advances in high-density storage systems apply new computer science and applied mathematics tools to the code design. Barg is establishing new statistical properties and limits on the volume of data that can be stored in the system while maintaining recovery functionality.

In the second project, Barg is investigating uniformly distributed codes and their construction, evaluating their properties, looking at a group of related geometric problems, and identifying their uses in applied problems of algorithm design, computer vision, and economical representation of data.

He is using ideas based on recent developments in computer science as well as classical methods in applied mathematics, aiming at new characterizations and applications of uniformly distributed sets of binary sequences.

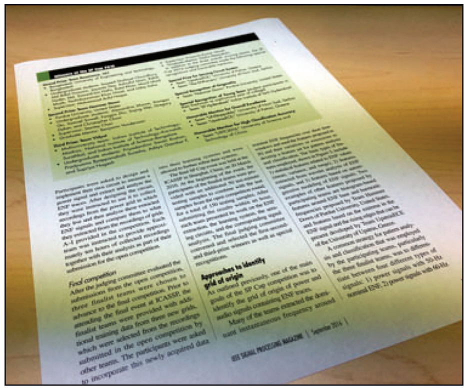
Electric power grid signatures may aid in image and video verification

As video and still images about Ukraine flood cable television, Internet news sources and social media channels, verifying their authenticity is of utmost importance. Responsible news organizations spend considerable time and resources on identifying dates, locations, and what actually is taking place in the images. But bad actors are still able to get old, faked, deliberately mislocated and misidentified graphics out to the world where viewers take them at face value. In the digital age, such verification issues are common in conflicts and political messaging around the world.

ISR-affiliated Professor **Min Wu** (ECE/UMIACS) is a specialist in digital media forensics, including new ways to verify the authenticity of these digital assets. For more than a decade, she has been exploring how an almost-unnoticeable, location-related environmental signature from electric power grids can capture useful time/location information. This signature, called the electric network frequency (ENF) signal, is part of a sensing stream at the time of recording and is inherently embedded in images and videos.

Researchers recently have worked out how to extract ENF traces from audio and video recordings. However, it is more challenging to extract an ENF trace from a single image, especially in scenarios that existing technologies cannot sufficiently address.

Wu is a co-author on "Invisible Geolocation Signature Extraction from a Single Image," new research that addresses this challenge.



AN ENF TRACE SIGNATURE CAN EASILY BE SEEN IN THIS DIGITAL IMAGE OF PRINTED PAPER. (COURTESY MIN WU)

Her former student **Chau-Wai Wong** (ECE Ph.D. 2017), now an assistant professor at North Carolina State University, is the lead for this work. His Ph.D. student **Jisoo Choi**; Wu's former student **Adi Hajj-Ahmad** (ECE Ph.D. 2016), now a data scientist with Amazon Alexa; and **Yanpin Ren**, Tsinghua University, China; are the other co-authors.

A ENF signal comes from the behavior of the power distribution network, which has a varying frequency that reflects the behavior of the power grid at the time of and location where the media recording was captured. This relationship enables researchers to estimate the time, location, and integrity of multimedia recordings.

To produce one frequency estimate, audio/video recordings typically need a signal that is several seconds long. Wu and her colleagues wondered whether there was a way for ENF traces to be captured in a single image taken at one moment in time, whether it would be possible to detect them, and whether the traces could be narrowed to 50 vs. 60 Hz.

They addressed an image's location by first mathematically examining the impact of ENF embedding steps such as electricity to light conversion, scene geometry dilution of radiation, and image sensing. They then incorporated verified parametric models of the physical embedding process into an entropy minimization method. The optimized results were used to create a two-level ENF presence–classification test that could identify whether a single image has an ENF trace. If the answer is "yes," the test is able to show whether it is at 50 or 60 Hz. The authors also quantitatively studied the relationship between the ENF strength and its detectability from a single image.

This is the first work to develop the forensic geotagging capability of environmental traces for individual images. The new capability will shed light on an image's location without requiring a visible landmark or GPS tag, and works as well on indoor images as is does with those taken outside.

Biofilm-fighting system for urinary catheters proves successful in simulated environment

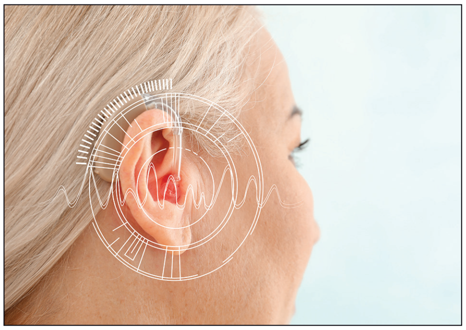
Bacterial biofilms are a major cause of infection in hospital settings and also are responsible for environmental biofouling. They can occur in an array of moist, inaccessible environments with complex curved geometries, such as urinary catheters, prosthetic implants, and water systems. In particular, catheter-associated urinary tract infections (CAUTIs), exacerbated by the emergence of antibiotic-resistant pathogens, are one of the most prevalent healthcare-acquired infections.

Work on an integrated bioelectric detection and treatment system for catheters by Professor **Reza Ghodssi's** (ECE/ISR) MEMS Sensors and Actuators Lab has now been successfully demonstrated in a commercial Foley catheter in a simulated environment. The research originally began in 2007.

"Integrated System for Bacterial Detection and Biofilm Treatment on Indwelling Urinary Catheters" was written by Ghodssi, alum **Ryan Huiszoon** (BioE Ph.D. 2020); former ISR postdoctoral researcher and alumnus **Sangwook Chu** (EE Ph.D. 2018); Electrical and Computer Engineering Ph.D. students **Jinjing Han** and **Justin Stine**; and UMD Research Associate **Luke Beardslee**, M.D., Ph.D. The paper was named a featured article by *IEEE Transactions on Biomedical Engineering* and the successful demonstration has led to a recent patent application.

This system represents a significant step forward for a device-based approach to CAUTI management and could be adapted for use with other medical devices prone to bacterial infections, such as prosthetic implants. It also would be a valuable tool for scientists working in biofilm research. **Learn more** about the dangers of biofilms and the promise this device holds for combatting them in urinary catheters: *go.umd.edu/mems522.*

How does the brain turn heard sounds into comprehensible language?



While hearing aids and other assistive devices have gotten better over the years, there is still a lot of room for improvement. Imagine if, in a crowded room with a lot of background noise, a device could help its wearer tune in to listen to just the person with whom she is having a conversation, and recede unwanted sounds into the background.

To get there, we need better understanding of the process by which the brain turns hearing into comprehensible language. Scientists know there is a neural pathway that connects our ears—which collect information about sounds—with our brains, which can distinguish among and interpret sounds, recognizing some of them as meaningful language. However, this physical path is only now beginning to be explored in detail.

Professor **Jonathan Simon** (ECE/ISR/Biology) is the principal investigator for a five-year, $2.88M grant from the National Institute on Deafness and other Communication Disorders at the National Institutes of Health that will bring researchers another step closer to fully understanding the system.

His co-PIs are Associate Professor **Behtash Babadi** (ECE/ISR), Associate Professor **Samira Anderson** (HESP), and **Stefanie Kuchinsky** (HESP affiliate).

The researchers will use sophisticated and accurate electroencephalography (EEG) and magnetoencephalography (MEG) scan studies of young normal hearing listeners to focus on what is going on inside the brain from the midbrain up to the language areas.

"Using EEG and MEG to simultaneously measure both midbrain and cortical speech processing puts us at the cutting edge," Simon notes. "No one else is doing that yet."

The researchers hope to find the acoustic and neural conditions under which intelligible speech is perceived. They believe a grounded understanding of how speech processing progresses through a network path, and learning what compensating mechanisms the brain employs to perceive speech under degraded hearing conditions will result in foundational principles that can be used to develop "brain-aware" and automatically tuning hearing assistive devices for persons with hearing and related disorders.

Babadi says, "We hope new insights into how the brain's dynamic network excels in reliable speech perception under difficult listening conditions will pave the way for developing hearing-assistive devices that use brain activity as feedback in real time to enhance speech intelligibility."

Internal predictive model characterizes brain's neural activity during listening and imagining music

"Musical imagery"—the voluntary internal hearing of music in the mind without the need for physical action or external stimulation—is the subject of new papers on "the music of silence," by Professor **Shihab Shamma** (ECE/ISR) and his colleagues in the Laboratoire des Systèmes Perceptifs at the École normale supérieure, PSL University in Paris. The papers were published in the *Journal of Neuroscience*.

Neuroscientists know which parts of the brain are activated when we experience musical imagery. However, they do not yet know the extent to which imagined music responses preserve elements that occur during actual listening to music.

In the first paper, the researchers examined whether melodic expectations play a role in modulating responses to imagined music, as they prominently do during listening. Modulated responses reflect aspects of the human musical experience, such as its acquisition, engagement, and enjoyment. The study demonstrates for the first time that melodic expectation mechanisms are as faithfully encoded when one imagines music are they are during actual musical listening.

In the second paper, the researchers studied the brain's ability to learn and detect melodies by predicting upcoming music notes, a process that causes instantaneous neural responses as the music confronts our expectations. The study provides direct evidence that in both listening and auditory imagery the brain uses an internal predictive model to encode our conceptions and expectations of music, which we can then compare with the actual sensory stimulus, if it is present.

Learn more. *go.umd.edu/music1021.*

ISR modeling frameworks address a range of challenges

System theoretic approach to epidemic modeling

The evolution of the COVID-19 pandemic—its transmission, its always-changing nature, and the world's various responses to it—has led researchers towards better epidemic models for the future.

Professor **Nuno Martins** (ECE/ISR), Professor **Richard La** (ECE/ISR), and ECE Ph.D. student **Jair Certório** are proposing a system theoretic approach to select and stabilize the endemic equilibrium of a susceptible-infectious-recovered-susceptible (SIRS) epidemic model.

In this model, strategically interacting agents choose from a finite set of strategies that influence the transmission rate. They can repeatedly revise their choices after deducting intrinsic costs to benefit from incentive-based net rewards payoffs. An evolutionary dynamic model captures the agents' preferences by basing the influence of the payoff on the rate at which agents adopt or abandon strategies.

An epidemic population game is central to the paradigm. The main result is a dynamic payoff mechanism that—through incentives to the population—is guaranteed to steer epidemic variables to an endemic equilibrium characterized by the lowest prevalence of infections, subject to cost constraints. Using a Lyapunov function, the researchers establish an anytime upper bound for the peak size of the population's infectious portion.

Models for predicting NAS high flight delay days

The U.S. National Airspace System (NAS) is a highly complex and interrelated system that includes airlines, airports, system operators, and navigation facilities. "Bad days," when the NAS experiences a high number of flight delays, have been on the increase in recent years. The need to better understand, quantify, and improve operations of the NAS and reduce the number of "bad days" is one of the most urgent concerns of the Federal Aviation Administration's (FAA) Air Traffic Organization.

ISR researchers affiliated with the FAA Consortium in Aviation Operations Research (NEXTOR III) are using machine learning (ML) to model system delay and predict high-delay days.

Professor Emeritus **Michael Ball** (BMGT/ISR) and Professor **David Lovell** (CEE/ISR) joined Professor Mark Hansen and his Ph.D. student Lu Dai of the University of California, Berkeley in the research.

From data recorded in the 2010s, ML was used to model system delay and predict NAS high-delay days. Queueing delays, terminal conditions, convective weather (thunderstorms), surface and aloft winds, traffic volume, and special events such as holiday travel and rocket launches were examined. The researchers then trained models to relate system delay to these features.

They found the conventional wisdom is correct: queuing delays, thunderstorms, and wind are the most significant causes of system delays. They noticed "bad days" increased over the decade as storm activity worsened, especially after 2014.

Water market models for river users

With NSF funding, ISR-affiliated Professor **Steven Gabriel** (ME) and Associate Professor **Kaye Brubaker** (CEE), director of the Maryland Water Resources Research Center, are building game theory-based water market equilibrium models. These models will help improve water use in the watersheds of the Anacostia River in Maryland and D.C., and the Duck River in Tennessee.

The models include users such as water utilities, municipalities, residential consumers and dam operators. Cooperation is not naturally incentivized—actions beneficial to upstream users often negatively impact users downstream. New management approaches are needed to increase cooperation over water withdrawal rights, water quality responsibilities, and risks associated with flooding.

"We hope our models will lead to better water market designs that will incentivize better use of water resources," Gabriel says.

The team includes ME doctoral student Nathan Boyd and industrial advisors from the District of Columbia Water and Sewer Authority, the global engineering company Ramboll, and the Tennessee Duck River Development Agency.

The researchers anticipate the efficiency and equity gains will benefit municipal, industrial, and agricultural water users; treatment plant and network operators; and the natural environment.

Guiding building inspectors after earthquakes

It's critical to quickly and accurately assess infrastructure damage after a disaster. Inspections should be prioritized so damage assessments can benefit first-response relief efforts.

A $490K NSF grant is building a mathematical modeling framework that can guide inspection teams through post-seismic reconnaissance missions. Associate Professor **Ilya Ryzhov** (BMGT/ISR), along with Gi Ou and Nikola Markovic from the University of Utah, is developing a holistic approach that can prioritize buildings for inspection, and design inspection schedules to efficiently visit these buildings quickly with a small expert crew.

The researchers are integrating concepts from statistical and optimal learning with routing and scheduling models. The results will improve crisis management while also providing new insights into health and disease control after a disaster. They are expected to save lives, expedite regional hazard damage assessment, improve disaster management, and ensure ethical resource allocation.

Brief takes…

Electric scooters. The increase in dockless bicycles, electric scooters, and other personal mobility vehicles has raised safety concerns for both their users and the vehicles and pedestrians they encounter. Professor **Derek Paley** (AE/ISR) and a team of alumni and students have developed a modified social force model that can predict the interactions of a pedestrian crowd with an electric scooter. **Learn more.** *go.umd.edu/scooter522*

Air pollution. Combining real and synthetic data produces augmented reality, which opens up new statistical inference perspectives. Using a new AR computational framework, a team led by ISR-affiliated Professor **Benjamin Kedem** (Math) has modeled the drastic drop in 2020 air pollution levels in Washington, D.C., during the COVID-19 lockdown. **Learn more.** *go.umd.edu/kedem522*

ISR alum innovations on the Webb Space Telescope

After a successful launch on Dec. 25, 2021, the James Webb Space Telescope—the largest space observatory ever built—travelled flawlessly to its permanent "L2" parking spot 930,000 miles from Earth, where it has been undergoing testing and tune-ups before starting its scientific mission this summer. The product of decades of development and testing, Webb also carries the contributions of ISR alumni.

Webb is designed to collect infrared light from distant corners of the cosmos and enable scientists to probe the structures and origins of the universe. Its Near Infrared Spectrograph (NIRSpec), a breakthrough instrument developed at the NASA Goddard Space Flight Center, can observe 100 space objects simultaneously. Two ISR alumni—**Wen-Hsien Chuang** (ECE Ph.D. 2005) and **Dan Kelly** (ECE M.S. 2005)—played important roles in inventing and building the microelectromechanical systems (MEMS) microshutter array that controls how light enters NIRSpec.

Chuang helped pave the way for the microshutters in his Ph.D. thesis work on MEMS-based silicon nitride thin film materials and devices. He performed the first electromechanical characterization of MEMS actuators at cryogenic temperatures. Chuang was Professor **Reza Ghodssi's** (ECE/ISR) first Ph.D. student, and joined Intel after earning his doctorate. He has been with the company for more than 16 years.

"When we collaborated on this project with NASA Goddard, MEMS devices had not been used in space at cryogenic temperatures," Chuang says. "These microshutter arrays will be the first MEMS devices operating in space."

Chuang is looking forward to seeing his work from two decades ago go into use. "Webb will bring our understanding of the origins of galaxies, clusters, and large-scale structures in the universe to the next level," he says.

TOP: WEN-HSIEN CHUANG
BOTTOM: DAN KELLY

Dan Kelly, another Ghodssi student, has spent his career at NASA Goddard as an electronics systems engineer. Kelly's education in MEMS microelectronics and fabrication led to working on the NIRSpec microshutter array from 2004–2014. He's currently assigned to the next big project: the Nancy Grace Roman Space Telescope, scheduled for launch near the end of this decade.

"From 2004 to 2014, I was on the team that took the microshutter array from an early concept to a space flight-qualified component," Kelly says. "I can't wait to see the incredible scientific discoveries the mission will enable."

Learn more. Read a more detailed version of this story on the ISR website: *go.umd.edu/jwst122*.

Alum Young Wook Kim's bioelectric effect toothbrush

ISR/ECE alum **Young Wook Kim** (ECE Ph.D. 2014), a former student of Professor **Reza Ghodssi** (ECE/ISR), has transferred his Ph.D. research on the bioelectric effect to a pioneering consumer product that improves mouth and gum health. Kim is the founder of ProxiHealthcare Inc., the manufacturer of the TROMATZ toothbrush. This toothbrush employs the bioelectric effect to effectively attack the mouth's plaque and tartar biofilms. It has received FDA and FCC approval in the United States and can be purchased on Amazon.

Bacterial biofilms form in a variety of moist, inaccessible environments—like the mouth—where bacteria adhere to the complex curved surfaces of teeth. Given time, bacteria encase themselves in an extracellular matrix, forming biofilm. This matrix offers the bacteria significant protection and makes it easy for them to spread.

Dental plaque, and its hardened state, tartar, are types of biofilm. Left unchecked, plaque and tartar contribute to bad breath, gum disease, and eventually the loss of teeth.

Kim's toothbrush propagates a small electric current and field approximately one inch from the edge of the device. The resulting electrostatic force (the bioelectric effect) induces relaxation of biofilm structure and helps detach plaque from teeth. This effect is enhanced with simultaneous mechanical brushing. In addition, this "electroceutical" effect can increase the effectiveness of toothpaste and medicines.

Kim notes that because the electric field and microcurrent are activated near gum tissue, they can improve gum health. "The microcurrent aids in the production of adenosine triphosphate (ATP), a resource for cell energy," he says. "ATP helps cells reduce inflammation and pain."

Kim's idea to produce a bioelectric effect toothbrush was born when he was completing his M.S. thesis on biofilm sensors. "I thought about how the bioelectric effect is focused on the electrical properties of the biofilms and works across bacterial species," Kim says. "That meant this technology could be applied to different kinds of bacterial biofilms—for instance, in the mouth."

Learn more. Read a more detailed version of this story on the ISR website: *go.umd.edu/MCtooth921*.

ISR faculty news

Academic society fellows, awards, positions

The Institute of Electrical and Electronics Engineers (IEEE) has elevated Professor **Carol Espy-Wilson** (ECE/ISR) to the rank of Fellow "for contributions to speech enhancement and recognition." Espy-Wilson is currently applying her expertise to a project developing a phone app that can help track symptoms of depression *(see story on page 4)*.

IEEE has elevated Professor **Rance Cleaveland** (CS/UMIACS/ISR) to Fellow "for contributions to verification tools for finite-state and cyber-physical systems." Since 2018, Cleaveland has been serving as director of the National Science Foundation's Division of Computing and Communication Foundations. He will return to the University of Maryland when his NSF appointment ends in July 2022.

ISR-affiliated Professor **Min Wu** (ECE/UMIACS) is the 2022–2023 president-elect of the IEEE Signal Processing Society. Wu is an international expert on multimedia signal processing, media forensics and information security, and has been an active member of the society for more than 25 years. She will begin serving as president on Jan. 1, 2024. Founded as IEEE's first society in 1948, the SPS is the world's premier association for signal processing engineers and industry professionals.

Assistant Professor **Huan Xu** (AE/ISR) and alum and Millennium Engineering and Integration UAS Program Lead **Lina Castano** (AE Ph.D. 2015) have received awards from the American Institute of Aeronautics and Astronautics (AIAA) for their work on a collision avoidance and hazard mitigation system for unmanned aircraft. Capabilities of this kind are crucial to enabling the integration of unmanned aircraft into the national airspace system. Xu won the AIAA National Capitol Section's Engineer of the Year Award, while Castano won the Hal Andrews Young Engineer/Scientist award.

Professor **Sennur Ulukus** (ECE/ISR) won the IEEE Communications Society's 2020 WICE Outstanding Achievement Award, "for outstanding technical work and for achieving a high degree of visibility in the field of communications engineering, through research and service."

The IEEE Computer Society and the Visualization and Graphics Technical Committee has awarded its IEEE VIS Test of Time Award to ISR-affiliated Professor Emeritus **Ben Shneiderman** (CS/UMIACS), Professor Emeritus **Benjamin Bederson** (CS/UMIACS), and **Martin Wattenberg** of SmartMoney. Shneiderman and Bederson are experts in visualization and visual analytics and were directors of the University of Maryland's Human-Computer Interaction Lab (HCIL).

The award is for seminal academic papers on Treemaps the three wrote 20 years ago. The papers are the foundational work that underlies modern treemap algorithms. The Test of Time Award recognizes articles published at previous conferences whose contents are still vibrant and useful today and that have had a major impact and influence within and beyond the visualization community.
Learn more. Watch a video of the three talking about their work and the award. *youtu.be/ApB1aBI7txs.*

Publications

Professor **Sennur Ulukus** (ECE/ISR) and alum **Eytan Modiano** (EE Ph.D. 1992), professor at the Massachusetts Institute of Technology and a former student of Professor Emeritus **Tony Ephremides** (ECE/ISR), were two of the guest editors of a May 2021 special issue on the Age of Information for the *IEEE Journal on Selected Areas in Communications*. The special issue includes 20 contributed papers that reflect the state of the art in Age of Information research, including one co-written by Ephremides.

Human-Centered AI, written by ISR-affiliated Professor Emeritus **Ben Shneiderman** (CS/UMIACS), has been published by Oxford University Press. Instead of focusing on the risks of AI, Shneiderman speaks to the opportunities it presents and how to capitalize on them. He explains how an expansion from an algorithm-focused view to a human-centered perspective can shape the future of technology to better serve human needs. He also provides human-centered AI design metaphors that show how to get beyond current limitations and see new design possibilities for empowering people. **Learn more.** *Follow Shneiderman on Twitter: @benbendc.*

Multimedia

ISR-affiliated Professor **Steven Gabriel** (ME) is in northern Europe, where he is serving in two competitive professorships and developing research collaborations with colleagues. Over the winter he sat down with Julius Wesche, a researcher at the Norwegian University of Science and Technology's Energy Transition Initiative, for an episode of Wesche's *Energy Transition* podcast. They talked about "Joe Biden's Infrastructure Bill and Its Influence on the Energy Transition." **Learn more.** Listen to the podcast: *go.umd.edu/sgpod122.*

Jennifer Hoeritz of the Robert H. Smith School of Business interviewed Professor **S. "Raghu" Raghavan** (BMGT/ISR) for the college's "course tour" video series. Raghavan talks about his experiences teaching in an online environment, and how it allows him to "flip the classroom"—very helpful in teaching quantitative material. **Learn more.** *youtu.be/p2NqFCxO4Ng.*

University of Maryland awards

The University of Maryland has named Professor **Pamela Abshire** (ECE/ISR) a Distinguished Scholar-Teacher. She is the 11th ISR faculty member to be honored with the designation, joining Derek Paley, Sennur Ulukus, Reza Ghodssi, Min Wu, Carol Espy-Wilson, Avis Cohen, K. J. Ray Liu, Michael Fu, Steve Marcus, and Thomas McAvoy.

Professor **Carol Espy-Wilson** (ECE/ISR) was recognized as a Campus Woman of Influence in 2021. Ellin K. Scholnick, the chair of the President's Commission on Women's Issues, said, "You have served as a pioneer, role model and mentor, especially for African-American women in the sciences through your distinguished record of professional accomplishments and advocacy for and mentorship of women in arenas such as the Advancing Faculty Diversity initiative."

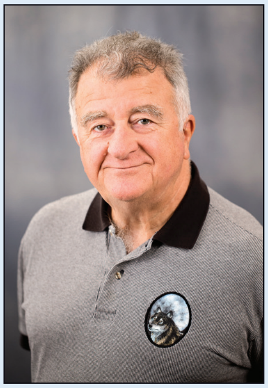
ISR-affiliated Professor **Min Wu** (ECE/UMIACS) received the Clark School's 2021 Senior Faculty Outstanding Research Award.

The award recognizes faculty with exceptionally influential research accomplishments.

Retirements

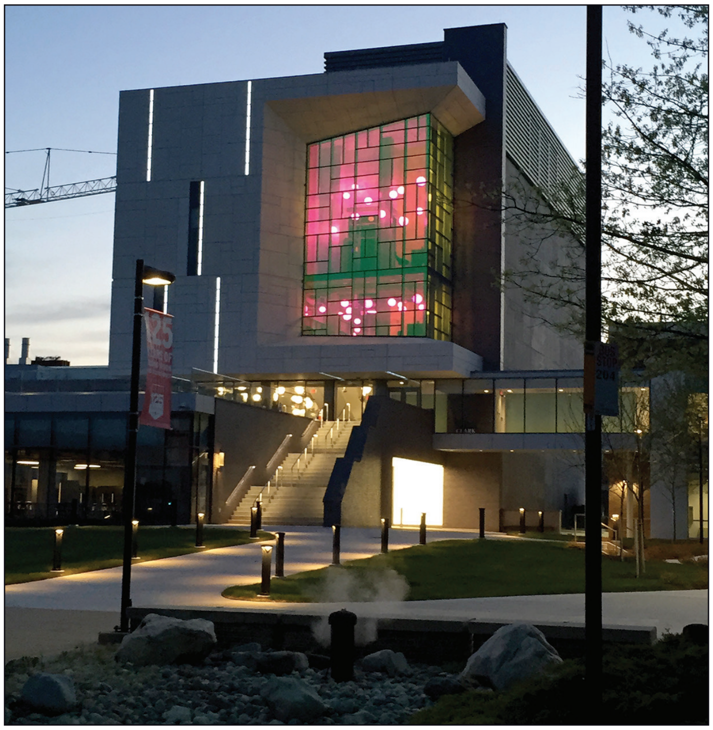
Three long-time ISR faculty members retired to emeritus status in the past year.

Professor Emeritus **Michael Ball** (BMGT/ISR) retired as the Orkand Corporation Professor of Management Science in the Robert H. Smith School of Business. A former chair of the Smith School's Decision and Information Technologies Department, Ball is an expert in operations research, supply chain infrastructure, modeling and analysis. Ball was a co-founder and co-director of NEXTOR, the National Center of Excellence for Aviation Operations Research, an eight-university consortium that received its first funding from the Federal Aviation Administration in 1996 and has been in continuous operation ever since. Within NEXTOR, Ball directed the Collaborative Decision Making research project.



Distinguished University Professor Emeritus **Tony Ephremides** (ECE/ISR) is one of the founding faculty members of ISR and a former co-director of the Maryland Hybrid Networks Center (HyNET). He retired as the Cynthia Kim Eminent Professorship Chair of Information Technology. He is an expert in communications systems (information theory, communication theory, multi-user systems, communication networks, satellite systems) with a focus on systems theory, stochastic systems, optimization, signal processing, wireless communications, and most recently, the age of information.

Professor Emeritus **Steve Marcus** (ECE/ISR) joined the University of Maryland as the ISR director in 1991, serving in this role until 1996. He later became the chair of the Electrical and Computer Engineering Department and served in key administrative roles in the Clark School and the university. Marcus specializes in control and systems engineering, analysis and control of stochastic systems, Markov decision processes, stochastic and adaptive control, learning, fault detection, and discrete event systems, with applications in manufacturing and communication networks.



THE IDEA FACTORY AT DUSK. IT IS LOCATED ACROSS PAINT BRANCH DRIVE FROM ISR'S HOME IN THE A. V. WILLIAMS BUILDING.

New UMD facilities for ISR research

The **E. A. Fernandez IDEA Factory,** dedicated in May 2022, fosters technology advances across engineering, the arts, business, and science. The Maryland Robotics Center's third-floor Robotics and Autonomy Laboratory is a shared research and education facility for faculty and students. It supports mobile robotics research, robotics prototyping and manufacturing, and optical inspection equipment. The first-floor ALEx Garage hosts student competition teams such as Robotics@Maryland, and is equipped with rapid prototyping 3D printers. The building also hosts the Alfred Gessow Rotorcraft Center, the Quantum Technology Center, Startup Shell, and spaces for students and faculty to meet, study, collaborate and relax. **Learn more** in this video tour: *youtu.be/OFCl_LCP8Q0.*

The **Southern Maryland Autonomous Research and Technology (SMART) Building**, which opened in Fall 2021 in St. Mary's County, includes underwater, air, and land testing facilities. It hosts the Maryland Autonomous Technology Research and Innovation Xploration (MATRIX) Lab, an open air-land lab with amphibious pool, a hydrology lab featuring a circulating water channel with an 80 cm by 130 cm cross-section, an AR/VR-capable research space, roof-top antenna farm, and outdoor ground and air vehicle testing.

Together with the UAS Test Site, the building forms "the southern node of an AI and autonomy network spanning the state of Maryland," according to Maryland Robotics Center Director **Derek Paley** (AE/ISR). Assistant Professor **Huan Xu** (AE/ISR) said the new labs go beyond standard bench testing, providing real-world scenarios in a controlled environmental setting. "I am beyond excited about having the new facilities and space available." **Learn more.** *go.umd.edu/smart522.*

Alumni news

Vikram Manikonda (ECE Ph.D. 1997), the former president and CEO of Intelligent Automation, Inc. (IAI) in Rockville, Md., has been named the chief technology officer of BlueHalo. Manikonda, a former advisee of Professor **P. S. Krishnaprasad** (ECE/ISR), joined IAI in 1999. He demonstrated a track record of delivering revenue growth and leading and managing IAI's innovative research and development. At BlueHalo, Manikonda is overseeing the development of defense and intelligence technology.

Timir Datta-Chaudhuri (ECE Ph.D. 2015) and 13 of his colleagues in the Institute of Bioelectronic Medicine at the Feinstein Institutes for Medical Research have developed a fully-implantable wireless bidirectional vagus nerve stimulation (VNS) and sensing device for mice. The invention has the potential to transform how bioelectronic medicine research is conducted in labs worldwide. Datta-Chaudhuri is an assistant professor at the Feinstein Institutes. At Maryland, he was co-advised by Professor **Pamela Abshire** (ECE/ISR) and Professor **Elisabeth Smela** (ME/ISR).

"Neuromodulation and bioelectronic medicine hold the potential to treat a variety of diseases without the use of traditional pharmaceuticals and their potential side effects," Datta-Chaudhuri said. "However, scaling devices to the size needed for studies in mice has been very challenging. This new device will finally enable the fundamental preclinical studies needed to inform future clinical trials that could lead to potentially revolutionary bioelectronic therapies for patients in need."

Domenic Forte (ECE Ph.D. 2013), an associate professor in the University of Florida's Herbert Wertheim College of Engineering, has been awarded its three-year Steven A. Yatauro Faculty Fellowship. The award honors faculty members who inspire students and are working on challenging societal problems. It will provide funding for Forte's SCAN Lab. Forte also recently won his college's Doctoral Dissertation Advisor/Mentoring Award. In January, Forte was a guest on the *EE Times Weekly Briefing* podcast, where he talked about why the problem of counterfeit integrated circuits recently has gotten worse. Listen to the episode at *www.eetimes.com/podcasts/wb-ep169/*. Forte was advised by ISR Director **Ankur Srivastava** (ECE/ISR).

Research by **Naomi Leonard** (EE Ph.D. 1994) and her colleagues that applies the principles of nonlinear feedback dynamics to the current state of the U.S. political system was featured in the Dec. 14 issue of the *Proceedings of the National Academy of Sciences of the United States of America* (PNAS) and in a *New York Times* essay by Thomas Edsall.

Leonard is the Edwin S. Wilsey Professor of Mechanical and Aerospace Engineering at Princeton University. She was advised by Professor **P. S. Krishnaprasad** (ECE/ISR).

Using a general model of opinion dynamics, Leonard's *PNAS* article helps illuminate what is driving political polarization in the U.S., as well as the factors that account for its asymmetric nature. By tying together elite and voter dynamics, the paper presents a unified theory of political polarization.

Nitin Sanket (CS Ph.D. 2021), a postdoctoral researcher in the Perception and Robotics Group (PRG), received two awards for his Ph.D. thesis involving autonomous aerial vehicles. He was advised by ISR-affiliated Professor **Yiannis Aloimonos** (CS/UMIACS).

Sanket earned the Computer Science Department's Larry S. Davis Doctoral Dissertation Award, which recognizes outstanding dissertations that convey excellence in technical depth, significance, potential impact and presentation quality. Sanket also was honored by the international open-access journal *Drones* with its 2021 Ph.D. Thesis Award.

His thesis, "Active Vision Based Embodied-AI Design for Nano-UAV Autonomy," introduces concepts used to develop a framework for algorithmic sensorimotor design of multirotor vehicles. Sanket showcases four methods that achieve activeness on an aerial robot. He also introduces the RoboBeeHive, a self-navigating aerial drone designed to pollinate flowers on a farm.

As a postdoc, Sanket continues to collaborate on projects involving computer vision and autonomous robotics. Sanket also is an assistant clinical professor in the First-Year Innovation and Research Experience (FIRE) course Autonomous Unmanned Systems.

Faheng Zang (ECE Ph.D. 2016), a former student of Professor **Reza Ghodssi** (ECE/ISR), has joined the Department of Micro-Nano Electronics at Shanghai Jiao Tong University as a tenure-track associate professor. He will continue his work in microsystems, microsensors and 3D micro- and nanostructures and explore opportunities to create new nanostructures and new fabrication methods for sensing and energy applications.

Chaitali Chakrabarti (EE Ph.D. 1990) has received the Joseph C. Palais Distinguished Faculty Scholar Award for excellence in research, teaching, and community service at Arizona State University. Chakrabarti is a world-renowned researcher on algorithm-architecture co-design of signal processing and communication systems, low-power embedded system design, reliable and energy-efficient in-memory computing and secure edge computing. Chakrabarti was advised by Professor **Joseph JáJá** (ECE).

David Bader (EE Ph.D. 1996) has received the 2021 Sidney Fernbach Award from the IEEE Computer Society for "the development of Linux-based massively parallel production computers and for pioneering contributions to scalable discrete parallel algorithms for real-world applications." Bader is a Distinguished Professor at the New Jersey Institute of Technology. He was advised by Professor **Joseph JáJá** (ECE).

Xiaojiang (James) Du (EE Ph.D. 2003) has been named the Anson Wood Burchard Endowed-Chair Professor in the ECE Department at Stevens Institute of Technology. Du was advised by Professor **Mark Shayman** (ECE). His research interests are in security, wireless networks, and systems.

Thomas Winkler (BIOE Ph.D. 2017) has joined the Technische Universität Braunschweig, Germany and is leading a junior research group, the µ4Life—Microsystems for Life Sciences. His research focuses on microphysiological models, easy-to-assemble non-PDMS microfluidics for low sorption, and impedimetric and electrochemical sensing modalities for biophysical and biochemical insight. Winkler is a member of the Institute for Microtechnology and Center of Pharmaceutical Engineering. He was advised by Professor **Reza Ghodssi** (ECE/ISR).

Nima Ghalichechian (ECE Ph.D. 2007) has joined the School of Electrical and Computer Engineering at the Georgia Institute of Technology as an assistant professor. He is the principal investigator of the mmWave Antennas and Arrays Laboratory. Ghalichechian worked as a research scientist, a research assistant professor and an assistant professor at Ohio State University from 2012 to 2021, where he established the RF Microsystems Laboratory in millimeter-wave antennas and arrays. He was advised by Professor **Reza Ghodssi** (ECE/ISR) and won the ISR Outstanding Systems Engineering Graduate Student Award in 2007.

Hesham El Gamal (EE Ph.D. 1999) has been appointed as engineering associate dean of academic affairs at the University of Sydney. His new position comes after 20 years at Ohio State University, where he was chair of the Electrical and Computer Engineering Department. His research interests are in information theory, proactive communications, space-time coding and decoding and graphical code design.

Himanshu Tyagi (EE Ph.D. 2013) has been promoted to associate professor by the Indian Institute of Science, where he is a faculty member in the Department of Electrical Communication Engineering. His research interests are in applying information theory to security, interactive communication and statistical learning. Tyagi was advised by Professor **Prakash Narayan** (ECE/ISR).

Victor De Oliveira (Math Ph.D. 1997) has been elected a Fellow of the American Statistical Association "for innovative and transformative methodological research in Bayesian spatial statistics and modeling non-Gaussian spatially dependent data, for significant contributions to environmental statistics, and for success in recruiting and supporting Hispanic STEM graduate students." De Oliveira is a professor in the Department of Management Science and Statistics at the University of Texas at San Antonio. He was advised by ISR-affiliated Professor **Benjamin Kedem** (Math).

Student news

Trisha Mittal, a Computer Science Ph.D. candidate advised by ISR-affiliated Professor **Dinesh Manocha** (ECE/CS/UMIACS), is a 2022 Adobe Research Fellow, one of only 10 students worldwide to receive the distinction. The funding will help her continue her affective computing work in improving deep learning algorithms that can interpret human emotions. "My work will help human-machine interaction feel more like human-human interaction," Mittal explains. **Uttaran Bhattacharya**, another Manocha Ph.D. student in computer science, won the award in 2021.

Rachel Suitor, an Aerospace Engineering Ph.D. student advised by Professor **Derek Paley** (AE/ISR), was part of the crew on a National Oceanic and Atmospheric Administration/National Geographic Society research expedition in the Gulf of Mexico. She worked with a swarm of "Driftcams," autonomous robotic sensing platforms that can move up and down in the water column and are configured with high-definition, low-light video capture systems that help scientists locate and identify various forms of aquatic life.

Sagnik Bhattacharya, a Ph.D. student of Professor **Prakash Narayan** (ECE/ISR), was named a 2022 Clark School Future Faculty Fellow. This program prepares Ph.D. students for careers in academia. Bhattacharya's doctoral research investigates fundamental problems of spatial sampling, learning, and compression in Markov random fields.

Ph.D. student **Fatemeh Alimardani** received one of 12 scholarships awarded in December 2021 by the Women's Transportation Seminar Washington, D.C. chapter. Alimardani is advised by Professor **John Baras** (ECE/ISR). She is developing traffic flow models and traffic management techniques based on artificial intelligence/machine learning and optimization methods. This work will improve the efficiency of existing highway systems without the need to change their infrastructure.

Ph.D. student **Joshua Levy** won an Outstanding Paper Award at the American Vacuum Society's 67th International Symposium. The MSE student is advised by Professor **Reza Ghodssi** (ECE/ISR) and is a member of the MEMS Sensors and Actuators Laboratory. He won the award for the best student presentation in the MEMS & NEMS Technical Group: "Thermally Released Spring-Loaded Platform for Capsule-Based Drug Delivery and Sensing." The paper describes a microneedle platform being developed for an ingestible capsule that can precisely deliver drugs inside the human gut system.

"Real-Time Priority-Based Cooperative Highway Merging for Heterogeneous Autonomous Traffic," a paper about connected autonomous vehicles written by **Nilesh Suriyarachchi, Faizan Tariq, Christos Mavridis** and their advisor, Professor **John Baras** (ECE/ISR), won the Best Student Paper Award at the 2021 IEEE International Conference on Intelligent Transportation Systems (ITSC). ITSC is the flagship IEEE conference in intelligent transportation.

"Age of Gossip in Networks with Community Structure" won the Best Student Paper Award at the 2021 IEEE International Workshop on Signal Processing Advances in Wireless Communications. It was written by 2021 ECE Ph.D. alums **Baturalp Buyukates**, now a postdoc at the University of Southern California; and **Melih Bastopcu**, now a postdoctoral researcher at the University of Illinois Urbana-Champaign; and their advisor, Professor **Sennur Ulukus** (ECE/ISR).

ISR Ph.D. and M.S. students won Dean's Research Awards in the past year. **Joshua Kulasingham** (ECE Ph.D. 2021) a former student of Professor **Jonathan Simon** (ECE/ISR/Biology), took a second place for "Time-Locked Cortical Processing of Speech in Complex Environments." Kulasingham also received an ECE Distinguished Dissertation Fellowship for this work. **Caitlyn Singam**, currently a Bioengineering Ph.D. student advised by Professor Emeritus **Anthony Ephremides** (ECE/ISR), won first place for her master's degree research, "Signal Routing Optimization for Disruption-Tolerant Networks." **Casey Beyers** (ECE M.S. 2021) received a master's research honorable mention for his thesis, "A Comparison of the Resonant and Non-resonant Dual Active Bridge Topologies for Single Phase Microinverters." He was advised by Professor **Alireza Khaligh** (ECE/ISR).

The UMD Autonomous Micro Air Vehicle Team directed by Professor **Derek Paley** (AE/

Student news continued on back cover...

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SYSTEM SOLUTIONS is a newsletter for colleagues, research partners, alumni and friends of the Institute for Systems Research, A. James Clark School of Engineering, University of Maryland.

ISR is a permanent state-supported institute of the University of Maryland within the A. James Clark School of Engineering, and one of the original National Science Foundation Engineering Research Centers.

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Student news

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ISR) took second place in the recent Vertical Flight Society's inaugural Design-Build-Vertical Flight (DBVF) Student Competition. The team includes undergraduate and graduate students who design, build, and fly quadrotor vehicles to compete in VFS student challenges. The team is a perennial powerhouse in the competition.

Three ISR graduate students won UMD Graduate School Ann G. Wylie Dissertation Fellowships, which provide a semester of full-time support to UMD doctoral candidates in the latter stages of writing their dissertations. **Ashley Chapin** (BIOE) is advised by Professor **Reza Ghodssi** (EE/ISR) and Professor **William Bentley** (BIOE/Fischell Institute). Her dissertation is titled "Serotonin Sensor Technology Integration into In Vitro and In Vivo Systems as Research and Clinical Tools to Address the Gut Brain Axis." **Christos Mavridis** graduated in December 2021, advised by **John Baras** (ECE/ISR). He continues working with Baras as a post-doctoral researcher. Mavridis's thesis topic was "Learning Latent Representations and Intrinsic Laws of Complex Systems." **Usman Fiaz** (ECE), currently advised by Baras, won for his dissertation, "Assured Autonomy in Multi-Agent Systems with Safe Learning." Fiaz also received a second UMD Graduate School award, the Michael J. Pelczar Award for Excellence in Graduate Study.

The Geometric Algorithms for Modeling, Motion and Animation (GAMMA) group led by ISR-affiliated Professor **Dinesh Manocha** (ECE/CS/UMIACS) won the best paper award at the IEEE Virtual Reality 2021 conference for work developing a transformer-based learning method that can simulate emotive human gestures from natural language text inputs. "Text2Gestures" focuses on improving the efficiency of agents used in virtual and augmented reality, online learning, and virtual social interactions. The goal is to create highly realistic agents endowed with social and emotional intelligence.

ECE Distinguished Dissertation Fellowships are awarded to outstanding students in the final stages of dissertation work. ISR Ph.D. students receiving the fellowships in 2022 are **Justin Stine**, advised by Professor **Reza Ghodssi** (ECE/ISR), for "Mesoscale Embedded Sensor-Integrated Systems for Localized Biomedical Monitoring," and **Nadee Seneviratne**, advised by Professor **Carol Espy-Wilson** (ECE/ISR), for "Generalizable Depression Detection and Severity Prediction Using Articulatory Representations of Speech." In 2021 the ISR winner was **Abhishek Chakraborty**, advised by ISR Director **Ankur Srivastava** (ECE/ISR), for "Design Techniques for Enhancing Hardware-Oriented Security Using Obfuscation."