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SYSTEMS SOLUTIONS

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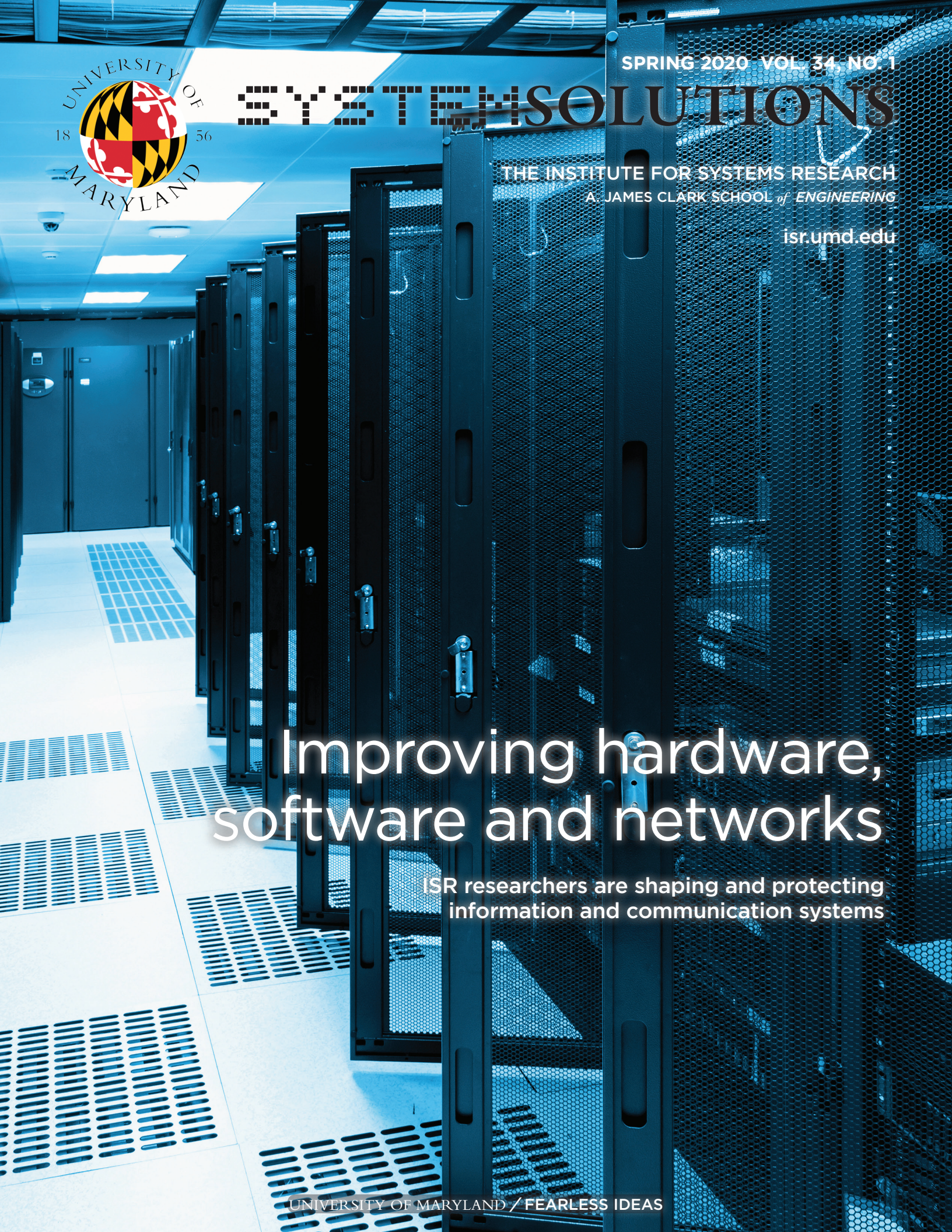


Improving hardware, software and networks

ISR researchers are shaping and protecting information and communication systems

Ankur Srivastava named seventh director of ISR

AL SANTOS

In July, A. James Clark School of Engineering Dean Darryll Pines named Professor **Ankur Srivastava** (ECE/ISR) the seventh director of the Institute for Systems Research. Srivastava will serve in this role for a five-year term. The dean wrote:

"It gives me great pleasure to announce that Dr. Ankur Srivastava has agreed to become the seventh director of the Institute for Systems Research.

Dr. Srivastava holds a joint appointment as professor in the Department of Electrical and Computer Engineering and ISR. He brings expertise in computer engineering with particular interest in hardware security. In addition to leading a highly successful research program, he also has substantial experience in various administrative roles. He served the Clark School as associate dean for graduate programs and also served ECE as associate chair for graduate affairs for five years.

Dr. Srivastava has made substantial contributions to the quality of our graduate programs. He organized the first "Ph.D. Open House" in October 2018 and led the strategic organization of the Clark Doctoral Fellows Program. Under his leadership, the Clark Doctoral Fellows program has seen substantial growth, leading to an increase in the number of fully funded domestic Ph.D. students. The Clark Doctoral Fellows Program also has contributed to improving the representation of women and minority students in our Ph.D. programs.

ISR offers a unique multidisciplinary environment that promotes and nurtures cross-cutting and transformative research. An increasingly connected world has created new opportunities for breakthroughs in systems thinking and research. I am excited to see that Dr. Srivastava hopes to lead ISR into a new realm of growth. Please join me in welcoming and supporting Ankur Srivastava in his new role.

I would also like to thank **Bill Regli** for his service as the ISR director. He is continuing his leadership role as the director of the Applied Research Laboratory for Intelligence and Security (ARLIS), the University of Maryland's University-Affiliated Research Center."

ISR faculty present eight talks at Northrop Grumman University Research Symposium

ISR faculty presented eight talks at the recent Northrop Grumman University Research Symposium, a national event with more than 50 technical presentations addressing Northrop Grumman research areas in mission and aerospace systems, machine learning and cybersecurity. It was organized by Keyla Contreras-Cottin, Northrop Grumman Mission Systems' University Relations Project Manager.

Cognitive processing and machine learning

"Understanding and Creating Robust Models of Actions from Observation," **Yiannis Aloimonos** (CS/UMIACS)

"Adversarial Machine Learning for Cognitive Sensors," **P. S. Krishnaprasad** (ECE/ISR)

"Neuromorphic Signal Processing: From Analytics for Deep Learning to Cortex-on-a-Chip," **John Baras** (ECE/ISR)

Science of test

"Non-destructive Test for Trojans via IR Imaging," **Ankur Srivastava** (ECE/ISR)

"Co-design of structure and intelligence for embedded system optimization," **Shuvra Bhattacharyya** (ECE/UMIACS) and ISR-affiliated **Cornelia Fermüller** (UMIACS)

"Learning to Collaborate," **Jeffrey Herrmann** (ME/ISR)

Cyber resilience and software safety

"Discovering and mitigating hardware-based cyber vulnerabilities (e.g. Spectre)," **Dana Dachman-Soled** (ECE) and **Ankur Srivastava** (ECE/ISR)

Quantum sensing and processing, systems resilience

"Emerging IoT technologies for distributed and collaborative sensing," **Nuno Martins** (ECE/ISR) and **Yasser Shoukry** (ECE)

IN THIS ISSUE:

Improving hardware, software and networks

ISR researchers are shaping and protecting information and communication systems

Research related to communications, networks and security have been central to ISR since its inception, and the need for improving and securing communication and data networks has intensified over the years. Here's what ISR is working on today in these critical areas.

Networks

In recent years, sensor and wireless communication advances have led to the emergence of new applications for monitoring, tracking, and even controlling operations in the physical world. More than 25 billion Internet of Things (IoT) devices are forecasted to be installed by the end of 2020, mainly through wireless networks. Sensors can be interconnected to report environmental conditions or provide crucial data, such as velocity and position in networks of vehicles. These applications heavily rely on the timely delivery of data to perform at their best.

A relatively new concept, the Age of Information (AoI), quantifies this notion of timeliness. AoI measures information time-lag at the monitor side; its minimization is regarded as a way to achieve fresher information at the receiver side. Because so many applications require timely information, AoI is becoming an increasingly important research area.

Distinguished University Professor **Tony Ephremides** (ECE/ISR) was recently awarded the NSF grant, "On the Fundamental Nature of the Age of Updates." This project uses the AoI concept to discover the relationships between information theory and signal processing, two of the main pillars of information science.

The project explores how the transmission and the age of received updates relate to the information structure of a signal, and shows how information ages over time. Ephremides is using an innovative approach to the traditional problems of signal processing by relating Nyquist's theory to causal signal reconstruction. The project uses AoI as a tool in handling the problem of caching and network control in volatile environments (e.g., Internet of Things and sensor networks).

Professor **Sennur Ulukus** (ECE/ISR) and her Ph.D. student **Melih Bastopcu** have designed a system that strikes a desired balance between information quality and freshness by solving for the optimum update scheme subject to a desired distortion level. They modeled the quality of an update as an increasing function of the transmitter's processing time spent while generating the update, using distortion as a proxy for quality, and model distortion as a decreasing function of processing time.

In addition, Ulukus and **Baturalp Buyukates** investigated age performance of uncoded and coded computation distribution algorithms, showing that a minimum data set-coded task distribution scheme asymptotically outperforms uncoded and repetition coded schemes.

In 2019 Ulukus and six international colleagues won the IEEE Communications Society Best Tutorial Paper Award for "Energy Harvesting Wireless Communications: A Review of Recent Advances," published in the *IEEE Journal on Selected Areas in Communications*. The paper summarized contributions in energy harvesting wireless communications, providing the current state of the art for wireless networks composed of energy harvesting nodes, starting from the information-theoretic performance limits to transmission scheduling policies and resource allocation, medium access, and networking issues.

Professor **Gang Qu** (ECE/ISR) has delivered tutorials on "Hardware-based Lightweight Authentication for IoT Applications" multiple times in international conferences. He systematically covers his group's recent research on how hardware and physical characteristics of IoT devices can help to build lightweight security primitives such as authentication protocols for data, user, and device. Qu and his students use traditional CMOS, emerging nonvolatile memory technologies, and voltage over scaling technique for user and device authentication as well as GPS spoofing detection. These practical approaches are promising alternatives for the classical crypto-based authentication protocols for the embedded and IoT devices in the smart world.

Cybersecurity

Professor **Prakash Narayan** (ECE/ISR) is working on data privacy issues and secret key generation. In "Data Privacy for a rho-recoverable function," Narayan and his student **Ajaykrishnan Nageswaran** represent a legitimate user's data by a finite-valued random variable and, given a function of the data, a querier is required to recover with at least a prescribed probability the value of the function based on a query response provided by the user. The user devises the query response, subject to the recoverability requirement, so as to maximize privacy of the data from the querier. Privacy is measured by the probability of error incurred by the querier in estimating

the data from the query response. The authors analyze single and multiple independent query responses, with each response satisfying the recoverability requirement, that provide maximum privacy to the user. In the former, they also consider privacy for a predicate of the user's data. Implementable schemes with explicit randomization mechanisms for query responses are given and their privacy compared with fundamental upper bounds. The work appeared in *IEEE Transactions on Information Theory*.

In the published monograph, *Multiterminal Secrecy by Public Discussion,* Narayan and alum **Himanshu Tyagi** (EE Ph.D. 2013, assistant professor, Indian Institute of Science, Bangalore) describe principles of information theoretic secrecy generation by legitimate parties with public discussion in an eavesdropper's presence. The parties are guaranteed secrecy through independence from the eavesdropper's observation of the communication. They develop basic technical tools for secrecy generation and compare information theoretic and cryptographic notions of secrecy. They then apply these methods of secrecy generation in two settings: a multiterminal source model and a multiterminal channel model. They also include new formulations with associated new proofs.

Professor **Sennur Ulukus** (ECE/ISR) is researching private information retrieval. She was one of five plenary speakers at the 16th Canadian Workshop on Information Theory in 2019, speaking on "Private Information Retrieval Capacity," the problem of retrieving a file (a message) out of M messages from N distributed databases so that no individual database can tell which message has been retrieved.

The Private Set Intersection (PSI) problem, a major cryptographic research topic, refers to the problem of determining the common elements in two sets (lists) without leaking additional information about the remaining elements in either of them. Ulukus, her former student **Karim Banawan** (Ph.D. EE 2018), and current student **Zhusheng Wang** took an information theoretic approach in a recent paper, showing that the PSI problem can be successfully recast as a multi-message symmetric private information retrieval (MM-SPIR) problem with message size 1.

In a paper published in *Entropy*, Ulukus and Banawan explored the secure degrees of freedom of three new channel models: broadcast channel with combating helper, interference channel with selfish users, and multiple-access wiretap channel with deviating users. They investigate various malicious interactions, including active adversaries, and prove that a deviating user can drive the secure degrees of freedom to zero.

Professor **Gang Qu** (ECE/ISR) and his students have studied security and privacy issues for both in-vehicle communications and vehicular ad hoc networks (VANET). They published "A Blockchain-based Privacy-Preserving Authentication Scheme for VANETs" in *IEEE Transactions on Very Large Scale Integration Systems*, "Pass and Run: A Privacy Preserving Delay Tolerant Network Communication Protocol for CyberVehicles" in *IEEE Design and Test,* "A Survey on Recent Advances in Vehicular Network Security, Trust, and Privacy" in *IEEE Transactions on Intelligent Transportation Systems,* and several conference papers.

Futuristic, secure hardware

ISR Director **Ankur Srivastava** (ECE/ISR) and his group work on designing fast, efficient and secure computer systems for a future in which Moore's law has slowed, Dennard scaling makes it difficult to continue making computers both faster and more energy efficient, and applications explode in diversity.

Future computers will use a mix of CMOS and non-CMOS devices, rely on radical non von-Neumann architectures and be subject to many security and reliability issues. They will need to be introspective, adaptive and self-healing. Srivastava works on side channel-based attacks, hardware trojan detection and mitigation, design obfuscation, microfluidically cooled 3D ICs, 3D IC co-design methodology, physically unclonable functions, and approximate computing.

Recently, Srivastava and his student **Abhishek Chakraborty** presented a paper at the IEEE Annual Symposium on VLSI that proposed a hardware-software co-design based obfuscation approach to render an unactivated accelerator chip functionally useless.

5G research at ISR

5G, the fifth generation standard for cellular communications promises advances in new directions, from extremely high-rate data transfers, to broad deployment of low-power Internet-of-Things (IoT) devices, to low-latency communications. These capabilities leverage technologies such as directional radios at higher frequencies and cloud-computing inspired software-defined networking (SDN).

In collaboration with the university's Applied Research Lab for Intelligence and Security (ARLIS), ISR Visiting Research Engineer **Wayne Phoel** is investigating 5G's reliability and security through a systems view. He is assessing future 5G network architecture and component technologies for control of autonomous vehicles, offloading artificial intelligence processing from power-constrained sensors, and real-time control of infrastructure like the power grid. The work uses model-based system engineering techniques to model the novel 5G use of SDN, enabling thorough understanding and composition of resilient 5G networks. A radio frequency (RF) shielded enclosure is being installed in the A.V. Williams Building to enable over-the-air testing of 5G devices and small-cell base stations. Both of these efforts involve collaboration with ISR faculty and students, as well as students in the Master's in Telecommunications program.

Distinguished University Professor **John Baras** (ECE/ISR) is working on SDN and Network Function Virtualization (NFV) as key 5G enablers. He is also conducting network slicing research with applications to autonomous vehicles, healthcare, factory automation, smart grids, environmental monitoring, and agriculture. In addition, his 5G work includes networks supporting collaborating robots and human-robot teams; hybrid networks (including drones and satellites) to extend 5G to rural and underdeveloped areas; network modeling and simulation; machine learning; network management; and resource allocation in 5G networks and associated virtual networks (networks as a service).

Baras and former ISR Postdoctoral Researcher **Chrysa Papagianni** have created a testbed for SDN/NFV for 5G and associated heterogeneous networks (LTE, mm, optical, satellite). Baras is currently working to link it to the Juniper Lab and to advanced network simulation and emulation. He is collaborating with Nokia Bell Labs, Verizon, Booz Allen Hamilton, Leidos, Comcast, NRL, ARL, APL, KTH and TUM on these projects.

Heard of Meltdown and Spectre? How about VoltJockey?

Professor **Gang Qu** (ECE/ISR) and his visiting student **Pengfei Qiu**, as well as his colleagues **Dongsheng Wang** and **Yongqiang Lyu** (both professors at Tsinghua University) recently discovered VoltJockey, a critical vulnerability in modern processors caused by hardware features that can break a trusted execution environment.

They have successfully broken ARM's Trustzone (in April 2018 and published in 2019 ACM SIGSAC Conference on Computer and Communications Security) and Intel's SGX (in March 2019 and won the **best paper award** in 2019 IEEE Asian Hardware Oriented Security and Trust Symposium).

Intel has given Qu and his colleagues its **Bug Bounty Award** and acknowledged VoltJocky as a high risk vulnerability with CVSS base score 7.9. As a comparison, the Meltdown and Spectre attacks that made headlines worldwide in 2017–2018 are medium risk with CVSS base score 5.6.

In a paper published in the *ACM Journal on Emerging Technologies in Computing Systems,* Srivastava and his student **Ankit Mondal** proposed the use of magnetic tunnel junctions as stochastic number generators in an SC-based hardware implementation of neural networks.

Srivastava and eight colleagues published "Keynote: A Disquisition on Logic Locking" in *IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems*. The survey of the evolution of logic locking is a primer for researchers interested in developing novel techniques in new domains. The authors introduce various "cat and mouse" games involved in logic locking along with its novel applications, including processor pipelines, graphics-processing units and analog circuits.

Information theory

Signal processing

Professor **Prakash Narayan** (ECE/ISR) specializes in multiuser information theory and coding, particularly probabilistic models for compression of multiple signals, reliable transmission among several users and secure communication. He characterizes the fundamental limits of performance, and analysis of coding, modulation and signal processing techniques for attaining this performance in a variety of communication networks.

In "Sampling Rate Distortion" and "Universal Sampling Rate Distortion," Narayan and **Vinay Praneeth Boda** (EE Ph.D. 2018) examine the coordinated and universal rate-efficient sampling of a subset of correlated discrete memoryless sources followed by lossy compression of the sampled sources. They reconstruct a predesignated subset of sources within a specified level of distortion. These papers appeared in *IEEE Transactions on Information Theory.*

Boda also had a single-author paper accepted by the journal. "Reconstructing Gaussian Sources by Spatial Sampling" was based on his dissertation. This article considers a Gaussian memoryless multiple source with m components with joint probability distribution known only to lie in a given class of distributions. A subset of $k \leq m$ components are sampled and compressed with the objective of reconstructing all the m components within a specified level of distortion under a mean-squared error criterion. Boda's achievability proofs highlight the following structural property: it is optimal to compress and reconstruct first the sampled components alone, and then form estimates for the unsampled components based on the former.

In 2019 Narayan was awarded a three-year, $475K NSF grant for "Reconstructing Multiple Sources by Spatial Sampling and Compression." This project takes an information theoretic approach to develop fundamental principles that govern sampling of a small subset of a much larger set of correlated signals and processing them efficiently in order to reconstruct accurately a desired larger group of signals. These principles will be useful in applications such as smart homes with multiple networked smart sensor devices operating under transmitter power and channel bandwidth limitations.

Data storage and recovery

Professor **Alexander Barg** (ECE/ISR) works in information and coding theory as well as geometric problems motivated by signal processing applications. His current research has been focused on algebraic constructions of codes for distributed storage and private distribution estimation.

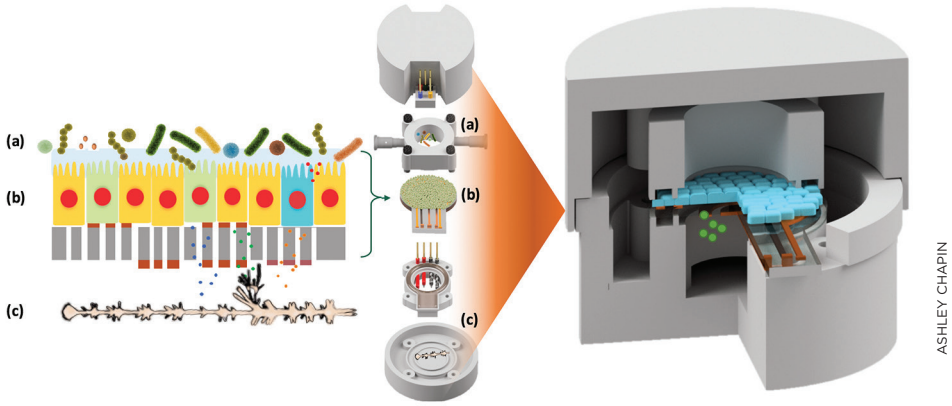
Barg currently is the principal investigator for the NSF award, "Information Recovery Under Connectivity and Communication Constraints." The project addresses data storage issues connected with modern, large-scale distributed storage systems, which store data on thousands of storage nodes. Failure of individual nodes is an everyday operational reality. This project investigates methods of data recovery in systems with limited connectivity where the cost of data repair is governed by the length of the path between the nodes, and therefore depends on the topology of the network. Barg is establishing fundamental limits of communication complexity for data recovery that account for connectivity properties of the underlying network and constructing coding methods that ensure data integrity against node failures, incorrect information, or adversarial action that approach the bounds on the minimum possible amount of communication.

Barg and his former student **Min Ye** (EE Ph.D., 2017) recently won the IEEE Communications Society's Data Storage Technical Committee's Data Storage Best Paper Award for their paper, "Explicit Constructions of High-Rate MDS Array Codes With Optimal Repair Bandwidth." The paper was published in *IEEE Transactions on Information Theory* in 2017 and also formed a chapter in Min Ye's Ph.D. thesis.

Barg recently concluded an NSF grant, "Coding and Information: Theoretic Aspects of Local Data Recovery," which addressed fundamental problems in data coding that can improve the efficiency of distributed storage systems by increasing data reliability and availability while reducing storage overhead compared to existing industry standards. The main results of this project are related to new constructions of erasure codes with various locality properties, and are related to classic code constructions such as Reed-Solomon codes and codes on algebraic varieties (curves and surfaces). A 2019 paper by **Itzhak Tamo** (ISR postdoc 2012–14, now an assistant professor at Tel Aviv University), Min Ye, and Barg gave a construction of Reed-Solomon codes that support repair of failed storage nodes under the constraint of minimum communication between the nodes in the system. Barg and Ye's award-winning research mentioned above also was conducted in the framework of this project.

The research performed for this project contributed toward increasing reliability and efficiency of general systems of cloud storage and cloud computing platforms.

Developing a platform to investigate the effects of intestinal serotonin on gut and brain health



ASHLEY CHAPIN

THE *IN VITRO* DISCOVERY PLATFORM FOR DIRECT, REAL-TIME MONITORING OF SEROTONIN SIGNALING INCLUDES (A) GUT MICROBIOME BACTERIA, (B) A CULTURED GI GUT EPITHELIUM, AND (C) NERVOUS TISSUE.

Professor **Reza Ghodssi** (ECE/ISR) is the principal investigator for a $1 million National Science Foundation to develop a platform that can investigate the complex effects of intestinal serotonin on both gut and brain health. The project, "Developing engineering solutions to investigate microbiome-to-neuron communication," aims to provide a more realistic picture of the complex gut-microbiome-brain axis system (GMBA).

The award leverages expertise in electrical and computer engineering, bioengineering, molecular biology, neuroscience, physics, and data science. Joining Ghodssi are three co-PIs: Professor **William Bentley** (BioE/Fischell Institute/IBBR), Associate Professor **Jens Herberholz** (Psychology/NACS), and Professor **Wolfgang Losert** (Physics/IPST/IREAP).

Neuroscientists recently have become interested in the connection between the gut and the brain as a way to comprehend the molecular causes of neural activation and behavior. Intuitively, this connection makes sense: think, for example, about how difficult it can be to focus when you are experiencing gut pain, or, alternatively, how you might have a knot in your stomach when you feel anxious. Facilitating this connection are neurotransmitters, the molecules that spur the nervous system to action.

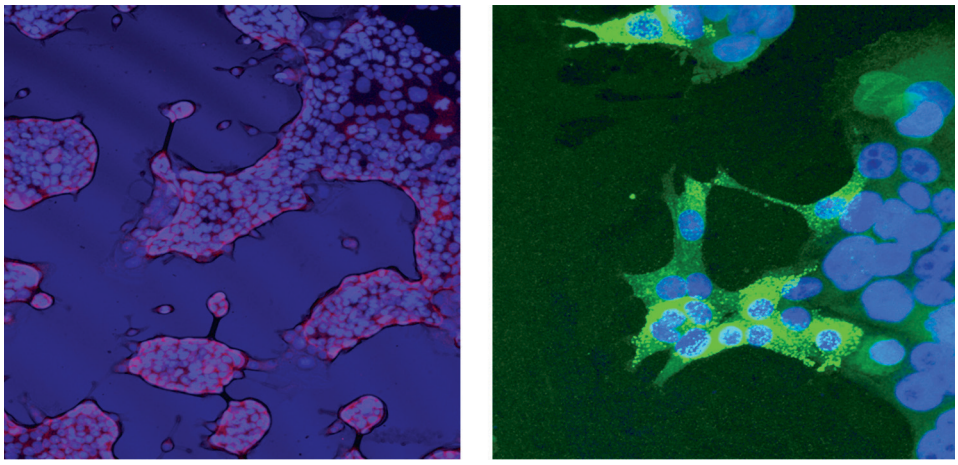
The neurotransmitter serotonin, produced by the gut lining, regulates the link between gut and brain, affecting everything from bowel function to one's mood. The gut microbiome, the community of microorganisms that live in the human digestive tract, influences serotonin production.

Neuroscientists know generally that the gut microbiome stimulates the generation of gastrointestinal serotonin, but it is less well understood how specific bacterial species influence serotonin's production and, subsequently, by what pathways this serotonin affects neural processes. Current technology is unable to effectively study gut microbiome-triggered cellular and molecular signaling up close and in real time, but the researchers are working to fill this knowledge gap to monitor and model the real-time processing of gut microbiome serotonin activity.

The new *in vitro* discovery platform packages simplicity, novelty, and customizability to provide a fuller picture of the GMBA. The researchers will first culture a model of the gut lining using bioengineering techniques to monitor the gut's creation of serotonin through multimodal integrated electrodes. Then, they will colonize the gut lining with different combinations of gut bacteria. To measure the neurophysiological effects of different serotonin productions of these colonies, the platform will integrate the nervous system and innervated hindgut of a crayfish model system; this will provide data about the relationship between the central and enteric nervous systems as well as about corresponding hindgut motility. Finally, the project will use machine learning to process the results through a computer model that simulates the outcomes of different combinations of gut bacteria. This will provide the clearest picture yet of how a system as complex and individually unique as the gut microbiome impacts both gut and brain health.

Past studies of the gut microbiome have often relied upon germ-free mice, by which the effects of gut bacteria are observed through the colonization of these animals' sterile intestines.

Ghodssi notes, "Our new discovery platform provides an alternative approach for this exciting arena of GMBA research. We are developing microsensors to extract and measure real-time data on how cells and molecules communicate and by connecting these to a proxy for the human nervous system. With its many applications for the study of brain and behavior, we believe that this collaborative effort can significantly advance the field of neuroscience."



ASHLEY CHAPIN

A MODEL GUT EPITHELIUM SHOWING TIGHT CELL JUNCTIONS (RED) AT LEFT AND THE EXPRESSION OF SEROTONIN (GREEN) AT RIGHT.

Neuroscience/Brain

Researchers part of $5.3M BRAIN Initiative grant

IMAGE COURTESY NIH

Assistant Professor **Behtash Babadi** (ECE/ISR), ISR-affiliated Professor **Patrick Kanold** (Biology) and Professor **Wolfgang Losert** (Physics/IPST/IREAP) are working on one of nine BRAIN Initiative U19 center grants awarded by the National Institutes of Health (NIH) in 2019. "Readout and control of spatiotemporal neuronal codes for behavior" is a $20M, five-year project led by John Maunsell, a professor of neurobiology at the University of Chicago.

Seed funding from the University of Maryland's Brain and Behavior Initiative (BBI) allowed Losert and Kanold to obtain preliminary data for the project. ISR was instrumental in BBI's formation and a number of its faculty are involved in the initiative.

These grants are among the largest awards given by NIH, dedicated to highly ambitious, multi-disciplinary, multi-university projects. Funding to Maryland researchers is worth approximately $5.3M. This connection with NIH strengthens neuroscience collaborations between NIH's Bethesda campus and the University of Maryland.

The project aims to revolutionize the understanding of brain function by providing a unifying account of how brain activity and behavior mutually inform each other in real time. Current research tends to examine the complex interaction of brain activity and behavior as separate problems. The U19 team examines how these two elements operate simultaneously: the external world shapes the patterns of brain activity, brain activity results in the manifestation of behavior, the elicited behavior reshapes the brain, and so on.

Neuroscience has mapped what happens in the brain given particular sensory inputs (neural code) and has studied how the different parts of the brain "read" the information contained in neural activity to form behaviors like decision-making (readout). The U19 team's research considers these two fields in tandem. They offer a unified explanation for the dynamic dialogue between neural code and readout—namely, how the brain simultaneously performs coding and readout to translate sensory input into behavior and adapt internal activity to the behavioral context.

To address this, the team of computational and systems neuroscientists, physicists and engineers is integrating theoretical and experimental approaches, particularly single-cell resolution imaging, to further control and guide behavior by manipulating brain activity. They are focusing on three senses—vision, audition and olfaction.

Losert is leading the "Data Science Core," which streamlines and centralizes data collection, analysis, and experimental design seamlessly across the scientific projects.

Kanold heads the project "Determining which Neurons Contribute to a Particular Behaviorally Distinguishable Percept," which is establishing causal links between neural activity and behavior.

Babadi is in charge of neural modeling, statistical data analysis, and model-based experimental design for the three science projects. He is also contributing data science tools to the Data Science Core.

The collaborative nature of this project is crucial to investigating the complex relationship between the brain and behavior. It requires a tight integration of state-of-the-art optical imaging and stimulation, cellular electrophysiology, theoretical modeling, and large-scale data analysis. The U19 team's unifying framework will allow the broader neuroscience community to resolve ongoing debates regarding neural coding previously stymied by considering only half of the problem.

Artificial intelligence

Game-playing AI development continues

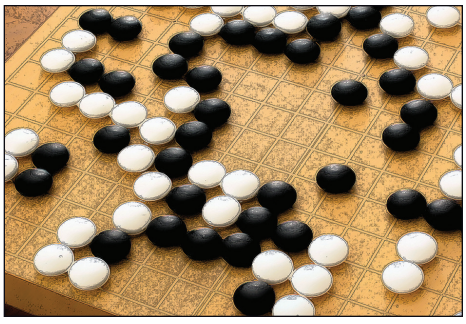
The Go-playing AI program AlphaGo and its successors AlphaGo Zero and AlphaZero have made international headlines with incredible successes in game playing. This line of AI systems was developed to beat humans at Go, checkers, chess, Scrabble and Jeopardy and are extending the boundaries of machine learning and its capabilities. They are evidence of the immense potential of artificial intelligence, and in particular, machine learning.

Adaptive multistage sampling (AMS) simulation-based algorithms for Markov decision processes (MDPs) are the core of these programs. Their deep neural networks are trained using a technique called Monte Carlo tree search (MCTS), with roots in an AMS simulation-based algorithm for MDPs.

These ideas were first explored in a 2005 *Operations Research* paper, "An adaptive sampling algorithm for solving Markov decision processes," written by then-ISR Postdoctoral Researcher **Hyeong Soo Chang**, Professor **Michael Fu** (BMGT/ISR), then-ECE Ph.D. student **Jiaqiao Hu** and Professor **Steven Marcus** (ECE/ISR).

Now, Fu has written a review of the original ideas and the ensuing developments in the *Asia-Pacific Journal of Operational Research*. He reviews the history and background of these programs, traces the origins of MCTS back to simulation-based algorithms for MDPs, and examines its role in training the neural networks that carry out the value/policy function approximation used in approximate dynamic programming, reinforcement learning, and neuro-dynamic programming.

Learn more. Read the paper at *www.worldscientific.com/doi/abs/10.1142/S0217595919400098*.

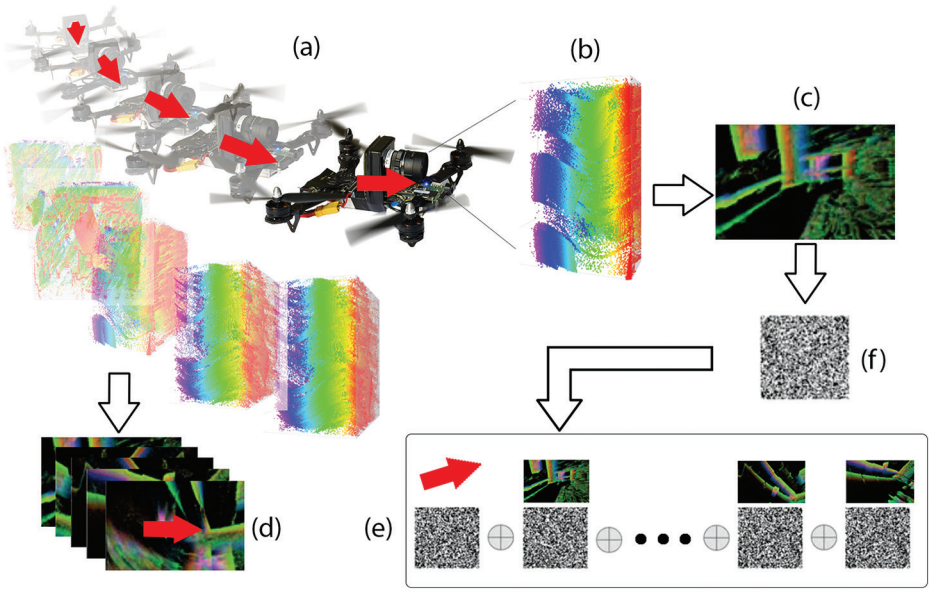


Helping robots remember

Hyperdimensional computing theory could change the way robotics AI works

What we humans see, hear and feel seamlessly combines with our brain and muscle memory to produce quick actions. Robots, on the other hand, act and react more slowly. They have no memory, and use a linkage system to coordinate sensor data with their motor capabilities.

A 2019 paper published in the journal *Science Robotics* introduced a new way of combining perception and motor commands using "hyperdimensional computing theory." It could fundamentally alter and improve the basic AI task of sensorimotor representation—how agents like robots translate what they sense into what they do.



PERCEPTION AND ROBOTICS GROUP

HYPERDIMENSIONAL PIPELINE. FROM THE EVENT DATA (B) RECORDED ON THE DVS DURING DRONE FLIGHT (A), "EVENT IMAGES" (C) AND 3D MOTION VECTORS (D) ARE COMPUTED, AND BOTH ARE ENCODED AS BINARY VECTORS AND COMBINED IN MEMORY VIA SPECIAL VECTOR OPERATIONS (E). GIVEN A NEW EVENT IMAGE (F), THE ASSOCIATED 3D MOTION CAN BE RECALLED FROM MEMORY.

"Learning Sensorimotor Control with Neuromorphic Sensors: Toward Hyperdimensional Active Perception" was written by Computer Science Ph.D. students **Anton Mitrokhin** and **Peter Sutor, Jr.**; their advisor, ISR-affiliated Professor **Yiannis Aloimonos** (CS/UMIACS); and ISR-affiliated Associate Research Scientist **Cornelia Fermüller** (UMIACS).

Integration is the most important challenge facing the robotics field. A robot's sensors and the actuators that move it are separate systems, linked together by a central learning mechanism that infers a needed action given sensor data, or vice versa.

The cumbersome three-part AI system—each speaking its own language—is a slow way to get robots to accomplish sensorimotor tasks. The next step in robotics is to integrate a robot's perceptions with its motor capabilities. This fusion, known as "active perception," would provide a more efficient and faster way for the robot to complete tasks.

In the authors' new computing theory, a robot's operating system would be based on hyperdimensional binary vectors (HBVs), which exist in a sparse and extremely high-dimensional space. HBVs can represent disparate discrete things—for example, a single image, a concept, a sound or an instruction; sequences made up of discrete things; and groupings of discrete things and sequences. They can account for all these types of information in a meaningfully constructed way, binding each modality together in long vectors of 1s and 0s with equal dimension. In this system, action possibilities, sensory input and other information occupy the same space, are in the same language, and are fused, creating a kind of memory for the robot.

The *Science Robotics* paper marks the first time that perception and action have been integrated.

A hyperdimensional framework can turn any sequence of "instants" into new HBVs, and group existing HBVs together, all in the same vector length. This is a natural way to create semantically significant and informed "memories." The encoding of more and more information in turn leads to "history" vectors and the ability to remember. Signals become vectors, indexing translates to memory, and learning happens through clustering.

The robot's memories of what it has sensed and done in the past could lead it to expect future perception and influence its future actions. This active perception would enable the robot to become more autonomous and better able to complete tasks.

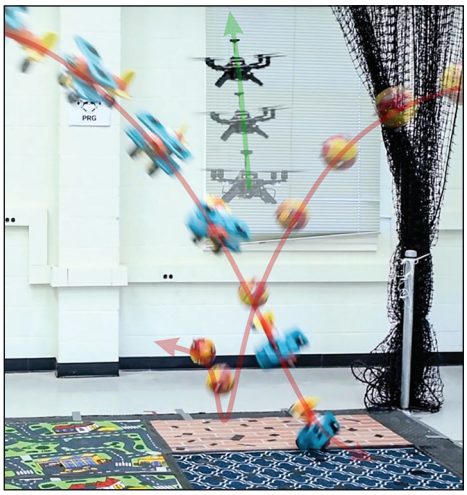
"An active perceiver knows why it wishes to sense, then chooses what to perceive, and determines how, when and where to achieve the perception," says Aloimonos. "It selects and fixates on scenes, moments in time, and episodes. Then it aligns its mechanisms, sensors, and other components to act on what it wants to see, and selects viewpoints from which to best capture what it intends. Our hyperdimensional framework can address each of these goals."

Applications of the Maryland research could extend far beyond robotics. The ultimate goal is to be able to do AI itself in a fundamentally different way: from concepts to signals to language. Hyperdimensional computing could provide a faster and more efficient alternative model to the iterative neural net and deep learning AI methods currently used in computing applications such as data mining, visual recognition and translating images to text.

"Neural network-based AI methods are big and slow, because they are not able to remember," says Mitrokhin. "Our hyperdimensional theory method can create memories, which will require a lot less computation, and should make such tasks much faster and more efficient."

Learn more. Watch a video at *youtu.be/UCAJi0ZFaZ8*. Read the *Science Robotics* paper at *robotics.sciencemag.org/content/4/30/eaaw6736*.

EVDodgeNet: a dynamic obstacle avoidance system for quadrotors



PERCEPTION AND ROBOTICS GROUP

The University of Maryland's Perception and Robotics Group (PRG) has developed EVDodgeNet, a dynamic obstacle avoidance system for quadrotor unmanned aerial vehicles using event cameras as sensors.

EVDodgeNet is a deep learning-based solution for dodging multiple dynamic obstacles that uses a series of shallow neural networks for estimating both the ego-motion and the motion of independently moving objects. The networks are trained in simulation and directly transfer to the real world without needing fine-tuning or retraining. The approach has been successfully evaluated and demonstrated with obstacles of different shapes and sizes.

The system requires a quadrotor with a single event camera and on-board computation. It was developed by **Nitin J. Sanket, Chethan M. Parameshwara, Chahat Deep Singh, Ashwin V. Kuruttukulam**, ISR-affiliated Associate Research Scientist **Cornelia Fermüller** (UMIACS), and ISR-affiliated Professor **Yiannis Aloimonos** (CS/UMIACS), along with Davide Scaramuzza, University of Zurich and ETH Zurich.

Learn more. Watch a video at *youtu.be/k1uzsiDI4hM*. Read a paper describing the system at *arxiv.org/pdf/1906.02919v1.pdf*.

Forecasting traffic for autonomous vehicles

New work by the Geometric Algorithms for Modeling, Motion and Animation (GAMMA) research team uses a combination of spectral graph analysis and deep learning to forecast urban traffic for future autonomous vehicles. The team includes **Rohan Chandra, Tianrui Guan, Srujan Panuganti, Trisha Mittal, Uttaran Bhattacharya, Aniket Bera**, and ISR-affiliated Professor **Dinesh Manocha** (CS/ECE/UMIACS).

In their paper, "Forecasting Trajectory and Behavior of Road agents Using Spectral Clustering in Graph-LSTMs," the researchers predict both low-level information (future trajectories) as well as high-level information (road agent behavior) from the extracted trajectory of each road agent. The formulation represents the proximity between road agents using a dynamic weighted traffic graph.

A two-stream graph convolutional LSTM network is used to perform traffic forecasting using these weighted traffic graphs. The first stream predicts the spatial coordinates of road agents, while the second stream predicts whether a road agent is going to exhibit aggressive, conservative, or normal behavior. The researchers introduce spectral cluster regularization to reduce error margin in long-term prediction (3–5 seconds) and improve the accuracy of predicted trajectories. They evaluated their approach on the Argoverse, Lyft, and Apolloscape datasets and highlighted the benefits over prior trajectory prediction methods.

In practice, the new approach reduces average prediction error by more than 54% over prior algorithms and achieves a weighted average accuracy of 91.2% for behavior prediction.

The researchers are looking to predict behavior through data-driven, rather than rule-based methods, and to optimize implementation using graphics processing unit (GPU) parallelization to improve the runtime.

Learn more. Read the paper at *arxiv.org/pdf/1912.01118.pdf*.

AI/Signal processing/Speech

Espy-Wilson, Sivaraman work to improve speech inversion

Professor **Carol Espy-Wilson** (ECE/ISR) and her former student **Ganesh Sivaraman** (EE Ph.D. 2017) are improving speech inversion, the process of mapping acoustic signals into articulatory parameters. "Unsupervised speaker adaptation for speaker independent acoustic to articulatory speech inversion" was recently published in the *Journal of the Acoustical Society of America*.

Speech inversion maps acoustic signals into articulatory parameters. An accurate robust speech inversion system could make a real impact on improving speech accent conversion, speech therapy, language learning, automatic speech recognition, and detection of depression from speech.

Differences among speakers makes speech inversion more difficult, and accurate speaker-independent systems are needed. Normalizing these differences is essential to effectively using multi-speaker articulatory data for training a speaker-independent speech inversion system.

Espy-Wilson and Sivaraman minimize speaker variability in the acoustic space attributed to vocal tract length differences between speakers for performing acoustic-to-articulatory inversion. Their goal is to normalize acoustic data from multiple speakers towards the acoustic space of a target speaker by exploring a vocal tract length normalization technique that transforms the acoustic features of different speakers to a target speaker acoustic space, minimizing speaker-specific details. The speaker-normalized features are used to train a deep, feed-forward, neural-network-based speech inversion system.

This approach can be extended to combine data from different articulatory datasets to create a single improved speech inversion system.

Learn more. Read the paper at *asa.scitation.org/doi/10.1121/1.5116130*.

‘Safety smart list’ can decrease time in ICU, lower hospital costs

A study in the *Journal of Critical Care* by ISR-affiliated Professor **Kenneth Wood** (University of Maryland School of Medicine) and his colleagues shows integrating a safety smart list into an intensive care unit (ICU) patient’s electronic health record (EHR) can decrease the length of stay in the ICU as well as its cost, without adversely affecting mortality.

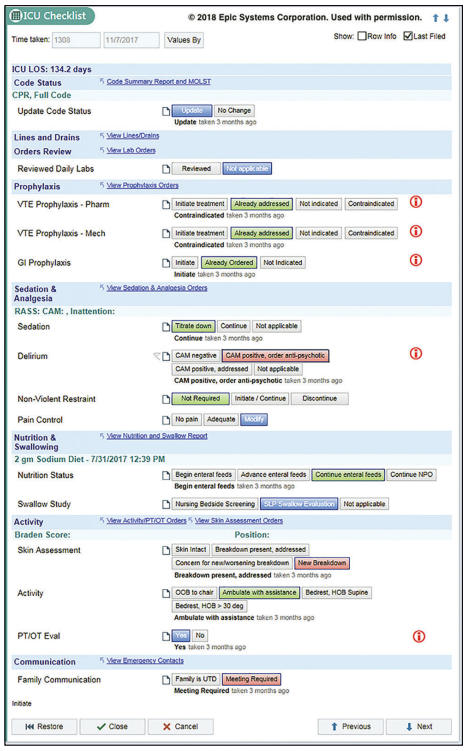
Checklists are an integral element of high-reliability industries such as aviation and nuclear power. In medicine, they are used to ensure that essential elements of care are addressed on a routine basis, facilitating standardization and adherence to essential guidelines. The EHR, with integrated nursing documentation, computerized physician order entry, and clinical decision support, has the potential to facilitate action at the point of care.

The researchers designed a comprehensive ICU patient safety/quality-of-care checklist, integrated it into the EHR, and subsequently tested its effect on patient outcomes. Their approach moved the idea of a checklist beyond a simple prompt, and transformed it into an informative “smart list” that translates documentation into orders and actions without additional effort.

The checklist covered common ICU conditions, which, when left unaddressed, have been associated with hospital-acquired infections, blood clots in the veins, and worse clinical outcomes. Checklist items include removing unnecessary catheters; verifying that deep venous thrombosis and gastrointestinal prophylaxis is addressed; assessing and managing sedation, analgesia, and delirium; advancing the patient’s enteral diet and mobility; and improving communication with family members and people with power of attorney.

The researchers developed a novel tool to usefully integrate the checklist with a patient’s EHR. The tool presented content only if it was relevant to the specific patient (for example, a prompt to remove a central venous catheter only if the patient had one). Supporting data was shown inline so that users could read it without leaving the smart list. The tool provided visual indicators that highlighted optimal patient conditions as well as those requiring attention and intervention (prompts turned green and remained checked on subsequent days when they were optimized). Each item was made actionable—selections automatically became orders that immediately affected patient care. The tool maintained existing operational and nursing workflows, which increased acceptance of the smart list and eliminated the need to train staff.

The team measured whether using the integrated smart list tool for critically ill



patients shortened ICU lengths of stay and lowered hospital charges without adversely affecting mortality rates. They found daily use more than 60% of the time decreased the ICU length of stay and was associated with lower hospital charges without changing the overall mortality rate.

Learn more. Read the paper at *www.sciencedirect.com/science/article/pii/S0883944119307841.*

EventAction interface improves recommender systems

People use online item recommender systems to improve their decisions. These systems not only help people find films to watch or books to read, but also are used in making medical treatment and career decisions. Despite their ubiquity, item recommender systems are far from perfect, and can be improved by giving users greater transparency and control.

A new interface developed by ISR-affiliated Distinguished University Professor Emeritus **Ben Shneiderman** (CS/UMIACS) and colleagues could help decisionmaking in student advising, treatment formulating, customer retention and sports coaching.

“EventAction: A Visual Analytics Approach to Explainable Recommendation for Event Sequences,” describing a new prescriptive analytics interface, appeared in the August 2019 *ACM Transactions on Interactive Intelligent Systems*. EventAction was developed in the Human Computer Interaction Laboratory; additional authors are Ph.D. student **Fan Du** (CS), Research Scientist **Catherine Plaisant** (UMIACS), Associate Professor **Neil Spring** (CS), and Ph.D. student **Kenyon Crowley** (iSchool).

EventAction uses both record attributes and temporal event information as features to identify similar records and provide appropriate recommendations.

While traditional item recommendations are based on choices by people with similar attributes, such as those who looked at this product or watched that movie, EventAction’s event sequence recommendation approach allows users to select records that share similar attribute values and start with a similar event sequence. Then users see how different choices of actions and the orders and times between them might lead to desired outcomes.

The paper applies a visual analytics approach to present and explain recommendations of event sequences. It presents a workflow for event sequence recommendation that is implemented in EventAction and reports on three case studies in two domains to illustrate the use of generating event sequence recommendations based on personal histories. It also offers design guidelines for the construction of user interfaces for event sequence recommendation and discusses ethical issues in dealing with personal histories.

Learn more. Read the paper at *dl.acm.org/doi/10.1145/3301402.*

Recent research funding to ISR faculty

Narayan: NSF information-theoretic signal processing sampling research grant

Professor **Prakash Narayan** (ECE/ISR) is the principal investigator for a three-year, $475K National Science Foundation (NSF) grant for "Reconstructing Multiple Sources by Spatial Sampling and Compression."

The mathematics of signal processing underlies much of the modern digital world today. Digital signal processing relies on a technique called sampling, that allows information to be gathered about the underlying signal using a subset of samples from the signal, and information theory is used to describe fundamental principles of sampling.

This project takes an information theoretic approach to develop fundamental principles that govern sampling of a small subset of a much larger set of correlated signals and processing them efficiently in order to reconstruct accurately a desired larger group of signals. These principles will be useful in myriad applications, for instance, in: potential smart homes with multiple networked smart sensor devices operating under transmitter power and channel bandwidth limitations; aerial surveillance systems for monitoring city traffic patterns or forest covers in which sources of information far outnumber the unmanned aerial vehicles or satellites that can be deployed; computer vision systems where data obtained from a limited camera scan and sensing must be interpolated to form a larger picture; and spotting trends in large social networks by polling small groups and gathering contextual data.

The larger goal of the project is to understand connections among universal spatial sampling, distribution learning and compression rate-distortion performance.

Regli is co-PI for ARM functional interoperable compiler project

The Advanced Robotics for Manufacturing collaborative (ARM) selected Siemens Corporate Technology and the University of Maryland to work on a technology project deemed critical to advancing robotic automation in manufacturing.

The project is one of 11 announced in 2019. ISR-affiliated Professor **William Regli** (CS) is a co-principal investigator for the research project, "Functional Interoperable Compiler."

The research is creating a high-level, standardized declarative language for robot programming. With this new language, workers of any skill level will be able to specify robot commands, using automated tools to translate functional specifications into procedural code that can execute tasks in various robotic platforms.

ARM is the nation's leading collaborative in robotics and workforce innovation. Structured as a public-private partnership, it accelerates the advancement of transformative robotic technologies and education to increase U.S. global manufacturing competitiveness.

Simon and Lau given 2019 BBI Seed Grant

Professor **Jonathan Simon** (ECE/Biology/ISR) and Professor **Ellen Lau** (Linguistics) were awarded a 2019 Brain and Behavior Initiative (BBI) Seed Grant for "Neural representations of continuous speech and linguistic context in native and non-native listeners."

Listeners and readers routinely generate context-based predictions that constrain perception and interpretation of language, but the form this top-down/bottom-up interaction takes is hotly debated. One critical question is how far down the processing hierarchy predictions are propagated—e.g. if 'I heard a dog...' predicts the word 'bark,' does this modulate neural responses in units that represent lower-level speech sounds and acoustic features, as well as higher-level semantic units?

The seed grant project aims to study this question for non-native speakers who are having difficulties in language comprehension. The researchers' method will provide more accurate estimates of top-down influences on neural responses because it tackles longstanding limitations of standard approaches with respect to the format of the input (controlled vs. naturalistic) and the ability to estimate spatiotemporal response functions for multiple stages of processing simultaneously.

This is the fourth time BBI has funded seed grant proposals. In total, across FY16, FY17, and FY18, the program awarded $1.3M to 21 projects; these have netted just under $11M in external awards.

"The BBI Seed Grant Program has facilitated our collaboration," Simon notes. "It accelerated my conversations with Ellen Lau from informal discussions of potential common interests to planning out the details of proposed experiments and deciding on the methodologies we will use to analyze the results."

NSF grant for research modeling animal dispersal

ISR-affiliated Professor **Bill Fagan** (Biology) is the principal investigator and Qualitative Ecologist **Eliezer Gurarie** (Biology) is the co-PI on a five year, $180,000 NSF collaborative research grant for "Modeling Animal Dispersal: Linking the Ideal to the Real."

Animal movement behaviors fundamentally influence the dynamics of populations and the interactions of species. Consequently, understanding animal movement is crucial to understanding ecological processes such as the growth and decline of wildlife populations and the spread of disease. Recent advances in remote sensing, GIS, and other technologies and in methods of analyzing data have greatly increased scientists' biological understanding of animal movement behavior. Similarly, recent advances in mathematical modeling and analysis have greatly increased theoretical insight about what movement strategies would optimize the fitness of ideal animals in variable landscapes. However, those two directions of research have developed independently.

The applied mathematics project will help build a bridge between mathematical and biological aspects of animal movement in dynamic landscapes. This bridge will strengthen understanding of how different types of animal movement behavior influence the performance and persistence of species and the outcomes of species interactions. The mathematical models will be informed by empirical data from animal tracking studies (especially those involving movement by deer, caribou, and similar animals).

Derek Paley named Maryland Robotics Center director

Clark School Dean Darryll Pines named Professor **Derek Paley** (AE/ISR) the sixth director of the Maryland Robotics Center in July. Paley is the Willis H. Young Jr. Professor of Aerospace Engineering Education with a joint appointment in the Department of Aerospace Engineering and ISR. He is the founding director of the Collective Dynamics and Control Laboratory.

Paley's honors include a National Science Foundation CAREER award in 2010 and a Presidential Early Career Award for Scientists and Engineers in 2012. He wrote the textbook *Engineering Dynamics: A Comprehensive Introduction*.

The Maryland Robotics Center within ISR advances robotic systems, underlying component technologies, and applications of robotics through interdisciplinary research and educational programs based on a systems approach. The center's research activities include all aspects of robotics including development of component technologies (e.g., sensors, actuators, structures, and communication), novel robotic platforms, and intelligence and autonomy for robotic systems.

Paley succeeds Professor **Miao Yu** (ME/ISR), who served as the center's director from July 2017 to July 2019.

ISR faculty news

Academic society fellows and awards

ISR-affiliated Professor **Min Wu** (ECE) and former ISR faculty member, Distinguished University Professor **K. J. Ray Liu** (ECE) were named 2019 Fellows by the National Academy of Inventors (NAI), joining the ranks of some of the nation's most prestigious and creative academic inventors. ISR faculty **John Baras** and **Ben Shneiderman** are also NAI members.

Professor **Alireza Khaligh** (ECE/ISR) has been elevated to Fellow by the Institution of Engineering and Technology. The worldwide professional society has more than 168,000 members in 150 countries and was formed by merging the Institution of Electrical Engineers and the Institution of Incorporated Engineers.

ISR-affiliated Distinguished University Professor **Ben Shneiderman** (CS/UMIACS) has been inducted into the IEEE Visualization Academy, the highest and most prestigious honor in the field of computer visualization. Joining him is Amitabh Varshney, dean of the College of Computer, Mathematical and Natural Sciences. The faculty were recognized for their work in human-computer interaction and high-performance computer graphics and visualization, respectively.

ISR-affiliated Professor **Dinesh Manocha** (ECE/CS) has been named to the Association for Computing Machinery SIGGRAPH Academy. He and Hanan Samet, a Distinguished University Professor of computer science, were in a select group of eight researchers chosen for membership in 2019. SIGGRAPH (special interest group in graphics) established the academy in 2018 to recognize individuals who have made substantial contributions to computer graphics and interactive techniques.

ISR-affiliated Professor **Min Wu** (ECE/UMIACS) is the 2019 recipient of the IEEE Education Society's Harriett B. Rigas Award. The annual award recognizes outstanding female faculty who have made significant contributions to undergraduate education and the global engineering community. Wu received the award for excellence and outstanding leadership in signal processing, education, and mentoring.

Plenary and invited speakers

Professor **Sennur Ulukus** (ECE/ISR) was one of five plenary speakers at the 16th Canadian Workshop on Information Theory (CWIT) in June. The prestigious workshop is an international conference on communications, information theory and signal processing. Ulukus spoke on "Private Information Retrieval Capacity."

Professor **Jonathan Simon** (ECE/Biology/ISR) was an invited speaker at the Conference on Implantable Auditory Prostheses (CIAP) in July. During the session on enhancing the use of cochlear implants for perception of speech, voice and music, Simon spoke on "Towards Objective Measures of Speech Perception." In addition, Stefanie Kuchinsky of the Applied Research Laboratory for Intelligence and Security (ARLIS) and the Walter Reed National Military Medical Center, spoke on "Acoustic, linguistic, and cognitive factors impact effortful listening: Implications for cochlear implant users." Kuchinsky and Simon currently are co-PIs on an $8M National Institute on Aging grant to combat hearing loss in older Americans. Professor Sandra Gordon-Salant, Hearing and Speech Sciences, is the principal investigator. All three are part of the university's Brain and Behavior Initiative.

The University of Maryland was well represented at the second Auditory EEG Signal Processing Symposium in September. Invited speakers with Maryland ties included Assistant Professor **Behtash Babadi** (ECE/ISR), **Samira Anderson** (HESP), and **Nima Mesgarani** (EE Ph.D. 2008), an associate professor in the Department of Electrical Engineering at Columbia University and former student of Professor **Shihab Shamma** (ECE/ISR). Professor **Jonathan Simon** spoke at the conference and was member of the conference steering committee. Alumna **Mounya Elhilali** (EE Ph.D. 2004), Professor in the Department of Electrical and Computer Engineering at Johns Hopkins University and another former student of Shamma, also was a member of the steering committee.

ISR-affiliated Professor **Dinesh Manocha** (CS/ECE) was one of three keynote speakers at the 28th IEEE International Conference on Robot & Human Interactive Communication in October. Manocha's talk on "Autonomous

Driving: Simulation and Navigation" touched on the open challenges in this emerging field, including automated driving in dense and urban scenes. Also in October, Manocha was a keynote speaker at the Open Data Science Conference. Here his topic was "Autonomous Driving: Simulation and Navigation," a talk about the open challenges in the autonomous vehicles field.

Professor **Nuno Martins** (ECE/ISR), his former student **Shinku Park** (EE Ph.D. 2015) and Professor **Jeff Shamma** of King Abdullah University of Science and Technology (KAUST) led a tutorial session on "Payoff Dynamics and Higher-Order Learning in Population Games" at IEEE's 58th Conference on Decision and Control in December. The researchers discussed a theoretical framework and analytic methods to determine the time-evolution of strategy choices, out of a finite set with n elements, by the members of a large population in response to a payoff mechanism.

Best paper award

The IEEE Communications Society's Data Storage Technical Committee awarded the 2016-2017 IEEE Data Storage Best Paper Award to alumnus **Min Ye** (EE Ph.D. 2017) and Professor **Alexander Barg** (ECE/ISR) for their paper, "Explicit Constructions of High-Rate MDS Array Codes With Optimal Repair Bandwidth." The paper was published in *IEEE Transactions on Information Theory* in 2017 and originally was a chapter in Ye's Ph.D. thesis. Ye is currently a postdoctoral researcher in the Department of Electrical Engineering at Princeton University.

Patents

Professor **Michael Fu** (BMGT/ISR), Associate Professor **Ilya Ryzhov** (BMGT/ISR) and their former student Huashuai Qu (Ph.D. Mathematics 2014) are three of the inventors listed on U.S. Patent 10,417,699, issued Sept. 17, 2019. "Systems and methods for optimal bidding in a business-to-business environment" relates to systems and methods for optimally pricing high-volume commercial transactions between businesses, known as business-to-business (B2B) pricing. Eric Bergerson and Megan Kurka are also listed as inventors on the patent.

ISR-affiliated Professor **Neil Goldsman** (ECE) and his colleagues were issued U.S. Patent No. 10,446,592 on Oct. 15, 2019 for "silicon carbide integrated circuit active photodetector," a device that provides accurate, reliable measurement of ultraviolet (UV) radiation. Co-inventors on the patent are Akin Akturk, Zeynep Dilli, Brendan Cusack and Michael Gross. The patent is assigned to CoolCAD Electronics, LLC, a College Park company founded by Goldsman and Akturk for CAD and custom electronics design.

New ISR affiliate faculty

ISR welcomes Associate Research Scientist **Cornelia Fermüller** to our affiliate faculty. Fermüller is a research faculty member with UMIACS, the University of Maryland Institute for Advanced Computer Studies. Her research focuses on computer vision, robotics and human vision. She specializes in biological-inspired solutions for active vision systems.

Promotion

Alireza Khaligh (ECE/ISR) has been promoted to the rank of full professor. Khaligh directs the Maryland Power Electronics Laboratory (MPEL) where research focuses on power electronics, renewable energy systems, energy harvesting, plug-in hybrid electric vehicles, more electric aircraft, pyroelectric systems, solar PV converters and other smart grid technologies. With years of R&D experience in the modeling, simulation, design, and development of power electronics solutions, Khaligh's large team is highly experienced in a wide range of power electronic systems.

University of Maryland awards

Professor **Reza Ghodssi** (ECE/ISR) was the 2019 winner of the Clark School's Senior Faculty Outstanding Research Award, which recognizes exceptionally influential research accomplishments by Clark School faculty.

Assistant Professor **Behtash Babadi** (ECE/ISR) was the 2019 recipient of the Clark School's E. Robert Kent Teaching Award for Junior Faculty "in recognition of outstanding teaching evaluations, coursework development in ENEE 101 and senior and graduate level coursework supporting new specialization and graduate programs in machine learning."

The University System of Maryland's Board of Regents selected Professor **Miao Yu** (ME/ISR) as one of its 2019 USM Regents Faculty Awards for Excellence in Research/Scholarship/Creative Activities. The award is the highest honor the Board bestows to recognize exemplary faculty achievement.

ISR-affiliated Associate Professor **Timothy Horiuchi** (ECE) was a 2019 Elevate Fellow of the University of Maryland's Teaching and Learning Transformation Center. He participated in a program to redesign ENEE 303 to provide a more interactive classroom experience through design-oriented exploration of transistor circuits.

ISR-affiliated Professor **Elisabeth Smela** (ME) was one of five campus women recognized in 2019 as part of the University of Maryland's Celebration of Women. Smela has been a longtime advocate for women in general and academic women in the sciences in particular.

Professor **Carol Espy-Wilson** (ECE/ISR) was one of 14 UMD women faculty celebrated at the First to Advance celebration. The event was hosted by the university's ADVANCE Program for Inclusive Excellence. She also won a UMD Graduate School Faculty-Student Research Award to help fund her research into the automatic detection and monitoring of depression, based on changes in the articulatory coordination of speech gestures.

In ISR's annual awards ceremony, Professor **Alireza Khaligh** (ECE/ISR) received the ISR Outstanding Faculty Award and **Eliot Rudnick-Cohen** (ME Ph.D. 2019) won the George Harhalakis Outstanding Systems Engineering Graduate Student Award. He was nominated by his co-advisors in Mechanical Engineering, Professor **Jeffrey Herrmann** (ME/ISR) and **Shapour Azarm** (ME).

In memoriam

ISR notes the passing of one of its founding faculty members, **Carlos Alberto Berenstein** (Math/ISR), on Aug. 24, 2019. Berenstein participated in ISR from its inception as the Systems Research Center in 1985, becoming a permanent joint appointee within ISR in 1995. He retired in 2009. Distinguished University Professor **John Baras** (ECE/ISR), the first director of ISR, said, "Carlos was a brilliant mathematician who collaborated with many of us and many other people worldwide. His brilliance, positive attitude and open collaborative spirit will be missed by many."

Alumni news

Domenic Forte (ECE Ph.D. 2013) is a recipient of a Presidential Early Career Award for Science and Engineering (PECASE), the highest honor given to outstanding scientists and engineers beginning their independent careers. Forte's award, sponsored by the Army Research Office, will enable him to develop a "fingerprint" technology to secure electronic hardware systems. Forte recently received tenure and is an associate professor in the Department of Electrical and Computer Engineering at the University of Florida, where he is a member of the Florida Institute for Cybersecurity Research. As a doctoral student, he was advised by ISR Director **Ankur Srivastava** (ECE/ISR).

Amir Ali Ahmadi, (EE and Math B.S. 2006) also received a PECASE Award in 2019. Ahmadi was nominated for the award by the National Science Foundation. He is an assistant professor of operations research and financial engineering at Princeton University working in applied mathematics areas such as optimization, computational dynamics and control and computational complexity. As an undergraduate, Ahmadi worked with Professor **Nuno Martins** (ECE/ISR) and Professor **André Tits** (ECE/ISR). He earned a Ph.D. in electrical engineering and computer science at MIT in 2011.

Nima Ghalichechian (EE Ph.D. 2007) won an NSF CAREER Award for "Understanding and Exploiting Non-Linear Behavior of Phase-Change Materials for Millimeter-Wave Applications" for fundamental studies vital to future radio-frequency reconfigurable communication systems. Ghalichechian is an assistant professor in the Department of Electrical and Computer Engineering at Ohio State University and directs the RF Microsystems Laboratory. Ghalichechian was advised by Professor **Reza Ghodssi** (ECE/ISR).

The Institute of Electrical and Electronics Engineers has elevated alumnus **James Xiaojiang Du** (EE Ph.D. 2003) to the rank of Fellow for "contributions to wireless security." Du is a professor in Computer and Information Sciences at Temple University. At Maryland, Du was advised by then-ISR affiliated Professor **Mark Shayman** (ECE).

This past fall, alumnus **Hyun Jung** (EE Ph.D. 2016), a bioinformatics analyst at the Frederick National Laboratory for Cancer Research, took two first places, for liver cancer segmentation and viable tumor burden estimation, in a medical imaging grand challenge for pathology. The goal of the Pathology AI Platform challenge was to evaluate new and existing algorithms for automated detection of liver cancer in whole-slide images. At Maryland, Jung was advised by Professor **Reza Ghodssi** (ECE/ISR).

Samuel Gollob (ME B.S. 2019) entered graduate study at MIT last fall as an NSF Graduate Research Fellow. A student of former ISR faculty member **Sarah Bergbreiter,** Gollob won ISR's Outstanding Undergraduate Student Award in 2018.

Ketan Babaria (MSSE 2002) has been named the chief product officer at Roofstock, an online real estate investing marketplace based in Oakland, Calif. Roofstock is an online platform for investing in "shares" of fully-managed, single-family rental properties, allowing smaller investors to enter the real estate market without purchasing or managing an entire property. Roofstock is known as a "fintech," a company that uses technology to provide financial services to businesses or consumers in the financial and technology crossover space. At Maryland, Babaria was advised by Distinguished University Professor Emeritus **Ben Shneiderman** (CS/ISR).

Rick Stamper (ME Ph.D. 1997) was appointed provost and vice president for academic affairs at the Rose-Hulman Institute of Technology last summer. Stamper was advised by the late Professor **Lung-Wen Tsai** (ME/ISR faculty from 1986-2000) and conducted his graduate research in ISR's Intelligent Servosystems Laboratory. Stamper returned to his undergraduate alma mater, joining the faculty of mechanical engineering and engineering management. He has been on the Rose-Hulman faculty for more than 20 years in increasingly responsible positions.

Alumni academic hires

Ayan Mallik (EE Ph.D. 2019) joined the Arizona State University ECE faculty in the fall as an assistant professor. Mallik was advised by Professor **Alireza Khaligh** (ECE/ISR). Mallik, Khaligh and graduate student Jiangheng Lu invented the Integrated Power Electronics Interface for Enhanced Electric Vehicle Charging. This device won the University of Maryland's 2018 Invention of the Year Award in the Physical Sciences category, as well as the overall top prize. Mallik also won the Clark School's Doctoral Student Research Award in 2019.

Ahmed Arafa (EE Ph.D. 2017), became an assistant professor in the ECE Department at the University of North Carolina Charlotte last fall. At Maryland, Arafa was advised by Professor **Sennur Ulukus** (ECE/ISR). His research focuses on developing fundamental solutions for latency and security issues in current and emerging applications in communications and control.

Aisha Al-Obaid (ChBE Ph.D. 2019) has joined the Chemical and Biomolecular Engineering faculty of Kuwait University. At Maryland, Al-Obaid was advised by Professor **Raymond Adomaitis** (ChBE/ISR), working in his Thinfilm Research Group. Her Ph.D. thesis took both experimental and computational approaches to converting solar energy to storable hydrogen and oxygen using thin-film solar-active materials.

Alumnus **Marc Dandin** (EE B.S. 2004, M.S. 2007; BioE Ph.D. 2012) was appointed as an assistant professor in the Department of Electrical and Computer Engineering at Carnegie Mellon University this past fall. Dandin's recent work focuses on establishing new paradigms in technology integration for interfacing electronics with biological systems. At Maryland he was co-advised by Professor **Pamela Abshire** (ECE/ISR) and Professor **Elisabeth Smela** (ME/ISR).

Shinkyu Park (EE Ph.D. 2015) is an associate research scholar at Princeton University, working with ISR alumna **Naomi Leonard** (EE Ph.D. 1994). From 2016–2019, Park was a postdoc at MIT, where he worked on a fleet of reconfigurable robotic vessels and developed a distributed sensing/sampling platform for the urban epidemiology project, Underworlds. He was advised by Professor **Nuno Martins** (ECE/ISR).

Student news

Chapin, Bowen posters win at Bioscience Day

Two ISR Ph.D. students were winners at the university's Bioscience Day last fall. **Ashley Chapin** (BioE) won in the Bioengineering category for "Dynamic in vitro biosensing with flexible microporous multimodal cell-interfacial sensors." The poster presented an in vitro platform that can support growth of a model gut epithelium on a membrane-integrated cyclic voltammetry sensor with a carbon nanotube-modified working electrode for selective sensing of the neurotransmitter serotonin. Chapin is advised by Professor **Reza Ghodssi** (ECE/ISR).

Zachary Bowen (Biology) won the Neuroscience and Cognitive Science category for "Single cell and population encoding in input and associative layers of mouse auditory cortex among strains." The poster depicted research to characterize populations of neurons that were active both during tonal stimuli and in the absence of any stimulus. Bowen is advised by ISR-affiliated Professor **Patrick Kanold** (Biology). Bioscience Day is an annual event sponsored by the College of Computer, Mathematical and Natural Sciences for executives and professionals in industry and government.

Student autonomous drone racing team takes 2nd place at IROS

This past fall, an interdisciplinary team of undergraduate and graduate students affiliated with the Maryland Robotics Center took second place in the autonomous drone racing event at the 2019 IEEE International Conference on Intelligent Robots and Systems (IROS) in Macau. The challenge was to fly the drone autonomously through a set of gates, completing as many runs as possible in five minutes. The "TurboTerps" team completed 14 runs in 4:42, for second place. This is one place higher than in their 2018 debut at IROS in Madrid.

"We missed first place by only two gates," said team advisor and Assistant Professor **Huan "Mumu" Xu** (AE/ISR).

The team included **Swapneel Naphade**, an MSSE student specializing in robotics control; **Sharon Shallom**, an Aerospace Engineering undergraduate student; and Aerospace Engineering MS student **Derek Thompson**, a two-year competition veteran. Another team member, **Micah Moten**, a Mechanical Engineering undergraduate student, was not in attendance.

Competitive autonomous drone racing is an engineering and computer science challenge that requires an understanding of computer vision, the ability to develop algorithms that incorporate gate detection, and programming logic for the drone to understand when it has completed tasks. Team members do not fly the drones themselves; they must program them to navigate the course on their own.

Fiaz competes in Unix 50 challenge at Nokia Bell Labs

This past summer, ISR Ph.D. student **Usman Fiaz** completed a research internship at Nokia Bell Labs in Murray Hill, N. J., where he developed novel solutions for precise aerial grasping and investigated fast visual-SLAM algorithms for Nokia drones.

In the fall, Fiaz returned as a student coding competitor during Unix 50, a commemorative event marking Unix's 50th anniversary. The celebration featured many of the original team that built Unix and designed the C programming language, as well as luminaries in computing and robotics.

Fiaz and 11 other students vied to see who could program a robot to function autonomously in a simulated industrial environment. The students were judged on how well and how quickly they performed a series of tasks in these "industrial zones" within the UnixWorld Challenge arena.

Fiaz's team finished second and received an award for "Outstanding Achievement in Robotic Orchestration."

"It was a great experience," Fiaz says. "We received our award from Bell Labs President Marcus Weldon in front of the developers of Unix, and got lots of love from the folks at Bell Labs."

Fiaz is advised by Distinguished University Professor **John Baras** (ECE/ISR) and is affiliated with the Autonomy, Robotics and Cognition Lab. He won a University of Maryland Outstanding Graduate Assistant Award in 2018.

Five graduate assistants win Outstanding Award

Five ISR graduate students received the University of Maryland Graduate School's Outstanding Graduate Assistant Award; two in 2019 and three in 2020.

Zeyu Zhang (EE Ph.D. 2019) and **Debdipta Goswami** received the award in 2019. Zhang was advised by Professor **Alireza Khaligh** (ECE/ISR) and Goswami is advised by Professor **Derek Paley** (AE/ISR).

Abhishek Chakraborty, Nadee Seneviratne, and **Shenli Zou** are recipients in 2020. Chakraborty is advised by ISR Director **Ankur Srivastava** (ECE/ISR); Seneviratne is advised by Professor **Carol Espy-Wilson** (ECE/ISR), and Zou is advised by Professor **Alireza Khaligh** (ECE/ISR).

The award recognizes the important contributions that graduate assistants make to students, faculty, departments, administrative units, and the university as a whole. Recipients of the award are among the top 2 percent of graduate assistants on campus in a given year.

Yuntao Liu wins Wylie Fellowship

Yuntao Liu, an ECE Ph.D. student advised by ISR Director **Ankur Srivastava** (ECE/ISR), has won an Ann G. Wylie Semester Dissertation Fellowship. This full-time fellowship is part of the University of Maryland Graduate School's Semester Dissertation Fellowship program, providing support to University of Maryland doctoral candidates who are in the latter stages of writing their dissertations. Liu's research focus is hardware security, especially the security of deep learning hardware.

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ISR faculty on video

Professor **Raymond Adomaitis** (ChBE/ISR) gave an informative TEDxUMD talk on how he uses model-based design techniques to predict how systems will behave before they are even built. "Model-based design can predict the behavior of things that do not yet exist," Adomaitis says in his talk. Modeling represents the essential characteristics of a system, its environment and the interactions it has with other systems and operators. Physically based, predictive design models can extrapolate into the unknown and help engineers get away from empirical, ad-hoc and intuitive approaches that are still the basis of much design.

Learn more. Watch the video at *youtu.be/uS7wSX10exo*.

ISR-affiliated Professor **Yiannis Aloimonos** (CS/UMIACS) appeared in a Voice of America video in 2019, speaking about his work in hyperdimensional computing theory (see page 8). The theory has broad implications for improving the way robots perceive the world and act on what they see. Robots whose operating systems are based on hyperdimensional binary vectors (HBVs) could form "memories" that could fundamentally improve how they translate what they sense into what they do.

Learn more. Watch the video at *www.voanews.com/media/2282666/*.

You can watch many more ISR videos and seminars at our YouTube channel, *www.youtube.com/user/ISRUMD*.