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Welcome to the Electrical and Computer Engineering Department. While last year had no shortage of challenges as we adapted to remote learning and other changes due to COVID, this year we are excited to return to in person classes and labs, and meet our colleagues and students face to face again.

We are extremely proud of our faculty who have been recognized with more than 20 major awards. These include significant awards from IEEE societies as well as others, NSF career awards, awards for distinguished teaching and mentoring, and many others.

This year has seen many new initiatives including energy efficient data center networks, autonomous exploration and metric semantic mapping using mobile robots, as well as new advances in wearable electronics and artificial neuron devices for efficient neural network accelerators. We are also beginning a new initiative in artificial intelligence called “The Institute for Learning-enabled Optimization at Scale” (TILOS) with the help of a recently awarded $20M grant from NSF.

Many of our faculty are exploring new pedagogical innovations including employing flipped classrooms, where students study course material in advance, and then lecture time involves interactive exercises to improve understanding. Some courses have even replaced traditional written tests with one-on-one oral exams. We also now offer many hands-on project-based classes on topics such as advanced digital circuit design, system-on-chip design, and systems engineering for the “Internet-of-Things”.

We are engaging our alumni to further enhance our students’ experience through efforts such as the alumni mentorship program, where students are paired with alumni having similar interests for individual and group meetings, career discussions, and social events. This program has been extremely popular for both the students and the alumni.

This report gives a brief overview of some of these activities that we are most proud of and some insight into our vision for the future.
## ECE by the numbers

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TARA JAVIDI

University of Michigan
ECE Distinguished Educator Award

This award from University of Michigan is the highest recognition granted by its ECE Department to its alumni in academia and recognizes those who have made a significant and lasting impact in education. Javidi’s award is in recognition of her excellence in information and system theory education, her research in communication and information processing systems and networks, and her contributions to diversity and inclusion, spanning from her doctoral studies at University of Michigan through her career at UC San Diego.

2021 IEEE Communications & Information Theory Societies Joint Paper Award

The paper addresses the important timely topic of millimeter wave (mmWave) communication with large antenna arrays, particularly the problem of adaptive and sequential optimization of the beamforming vectors during the initial access phase of communication. This joint paper award by the two IEEE societies is a very prestigious award that recognizes outstanding papers published in any publication of the IEEE Communications Society or the Information Theory Society within the previous three calendar years. The award recognizes the quality, originality, utility, and timeliness of works that span the interests of both societies.

HANH-PHUC LE

NSF CAREER Award
Next-Generation Integrated Hybrid DC-DC Converters for Future More-DC World

The proposed integrated research and education career development effort aims to facilitate faster developments and increase adoption of DC micro-Nano-grids for more efficient DC distribution in residential and commercial use in a More-DC world by realizing a next-generation integrated hybrid DC-DC power converter family with demonstrations for multiple important applications. In addition to developing advanced technologies in DC-DC converters with novel converter topologies, control, and loss analysis, the research also plans to demonstrate and evaluate the feasibility of a DC nano-grid using a single AC/DC converter to supply multiple DC loads through the integrated converter prototypes developed in this project.

PATRICK MERCIER

QIF 2020 North America (Qualcomm Institute)

ECE students Casey Hardy and Abdullah Abdulslam are the only ECE team to win the Qualcomm Innovation Fellowship award this year for their project “Vertical Hybrid Power Delivery for High-Performance Processors and Digital Systems.” This Fellowship promotes Qualcomm’s core values of innovation, execution and teamwork.

XINYU ZHANG

Best Paper Award in the ACM MobiCom 2020

Best conference paper “M-Cube: A Millimeter-Wave Massive MIMO Software Radio” This is one of the most competitive conferences with only about a 10% acceptance rate, and some really great papers this year, so winning the Best Paper Award among a program of stellar papers is particularly impressive.

This is a prestigious award from the IEEE Signal Processing Society, given to an individual who, over a period of years in his/her early career, has made significant technical contributions to theory and/or practice in technical areas within the scope of the Society, as demonstrated by publications, patents, or recognized impact on the field.

**TZU-CHIEN HSUEH**

**NSF Career Award**  
**Silicon-Photonics High-Resolution Real-Time Probability Apparatus for Quantum Applications**

The proposed silicon-photonics real-time probability measurement apparatus can provide high-accuracy time-correlated single-photon characterizations for the optical Qubit preparations and detections on a chip-scale to effectively accelerate the scalability and reliability of room-temperature quantum computing, imaging and communication systems for future civil quantum applications. The integrated-circuit innovation of this research is mainly based on the high-resolution asynchronous randomly-sampled averaging process along with a low-power variance-reduction technique implemented in a low-cost and almost fully digital circuit architecture to simultaneously achieve high-dynamic-range and high-accuracy real-time probability measurements.

**NIKOLAY ATANASOV**

**NSF Career Award**  
**Active Bayesian Inference for Collaborative Robot Mapping**

The proposed integrated research and education career development effort aims to design motion planning algorithms that enable robots to actively reduce uncertainty about their environment. Theoretically, this is an active Bayesian inference problem, aiming to achieve optimal control of a robot’s measurement and probabilistic estimation process. Practically, this is the goal of reproducing the curiosity that humans and animals exhibit when exploring an unknown environment on a robot system. The project also considers collaboration among multiple robots to collaboratively explore and build a map of their environment. Practical applications include environmental monitoring, disaster response, and security and surveillance.

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**TSE NGA (TINA) NG**

**NSF Mid Career Advancement Award**

Proposal entitled “MCA: Fabrication of Organic Structural Supercapacitors.” The overall goal of Ng’s project is to provide breakthrough research on energy storage technologies based on structural supercapacitors, which will potentially provide high peak power for rapid charging and extend device lifetime to minimize maintenance costs.
faculty honors

MICHAEL YIP

NSF Career Award
Contextually Informed Autonomous Robotic Surgery

The overall goal of this proposal is to imbue surgical robotics with situational awareness and clinically informed decision-making through anatomical context. Anatomical context — knowledge of the human anatomy and its various physiological attributes — is something that doctors learn over thousands of hours of study and training and is constantly used in surgical practice to inform them of what they are looking at, what they need to do, and how delicately they should proceed. This proposal focuses on mathematically defining anatomical context in terms of dynamical and semantic models of anatomy using reduced-order and neural network methods, establishing an “anatomical roadmap” that treats the human body as a semantic localization and navigation problem, and a trajectory optimization framework to enable safety-aware autonomous robotic procedures inside the body.

Saharnaz Baghdachi

UC San Diego Integrity Awards
Integrity is a core principle of the University of California, San Diego — it is essential to our excellence.

Baghdachi is being recognized in part for developing the pedagogy of oral exams in large undergraduate courses as well as authentic assessment methods to promote integrity and reinforce conceptual learning. She has volunteered considerable time in helping other faculty with their courses with respect to remote learning and academic integrity issues and received a CDIP grant from UC San Diego for her efforts. These approaches were developed in part to enhance academic integrity in large courses as we switched to remote learning this past year.

Eric Fullerton

2021 Achievement Award of Magnetics Society

This Is The highest award bestowed by the Magnetics Society, given in recognition of exceptional technical accomplishments in the field of magnetics. The citation for Prof. Fullerton’s award reads: “For groundbreaking and sustained contributions to the invention and development of modern exchange-coupled magnetic recording media and devices.” Prof. Fullerton has been a leading researcher in magnetism and magnetic recording for more than 25 years.

He is probably best known for the first implementation of antiferromagnetically exchange coupled (AFC) longitudinal recording media, where the bit is stored in two magnetic layers whose magnetizations are antiparallel. This technology allowed further scaling to magnetically thinner recording media that remains thermally stable and achieved improved resolution. The media directly addressed the problem posed by the superparamagnetic limit and the demagnetization created by the longitudinal configuration.

Curt Schurgers

UC San Diego Integrity Awards
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Schurgers is being recognized in part for developing the pedagogy of oral exams in large undergraduate courses as well as authentic assessment methods to promote integrity and reinforce conceptual learning. He has volunteered considerable time in helping other faculty with their courses with respect to remote learning and academic integrity issues and received an NSF grant for his efforts. These approaches were developed in part to enhance academic integrity in large courses as we switched to remote learning this past year.


[8] ELECTRICAL AND COMPUTER ENGINEERING
VITALIY LOMAKIN
IEEE Fellow
IEEE acknowledges those individuals who have contributed to the advancement of engineering science and technology. The grade of Fellow is bestowed on the recipient who has had an extraordinary record of accomplishments. Lomakin was awarded for his contributions to theoretical and computational electromagnetics.

ALEX VARDY
Jack Keil Wolf ISIT Student Paper Award
Vardy and his student Hanwen Yao were awarded the Jack Keil Wolf ISIT Student Paper Award entitled "A Deterministic Algorithm for Computing the Weight Distribution of Polar Codes" at this year’s IEEE International Symposium on Information Theory.

SIAVASH MIRARAB
Marye Anne Fox Endowed Fellowship
Mirarab advises CSE Department Ph.D. student Uyen Mai, who received the UC San Diego Marye Anne Fox endowed fellowship. Named for the campus late former chancellor, the fellowship is awarded to students with highly distinguished academic records. Mai works in the lab of electrical engineering professor Siavash Mirarab, and she develops computational methods that are scalable to large biological datasets.

GABRIEL REBEIZ
2021 International Microwave Symposium Student Paper Competition
Rebeiz and his student, Siwei Li were awarded 2nd place in the 2021 International Microwave Symposium Student Paper Competition for their paper entitled “An Eight-Element 140GHz Wafer-Scale Phased-Array Transmitter with 32dBm Peak EIRP and >16Gbps 16QAM and 64QAM Operation.” This is a significant achievement as the selection process was highly competitive from among around 300 papers submitted to the competition.

Paul Siegal
2021 Online Undergraduate Research Symposium (OURS) Outstanding Faculty Mentor Award in STEM
Paul was nominated by his mentees, who roundly praised the positive influence that Paul has had upon their academic pathways. Paul has won just about everything, from his research, to his teaching, and now his mentorship of students! This recognition is particularly notable given this unprecedented past year of the pandemic and ensuing rapid shifts towards remote learning and research.

FARINAZ KOUSHANFAR
Multidisciplinary University Research Initiative (MURI)

**Topic Name:** Cyber Autonomy through Robust Learning and Effective Human/Bot Teaming

**Project Name:** AutoCoMBOT: Autonomy in Cyberspace through robot learning and Man-BOT Teaming

The Department of Defense (DoD) awarded one of four highly competitive Multidisciplinary University Research Initiative (MURI). Farinaz is the Principal Investigator of this prestigious award, where she led the university multidisciplinary team with Co-PIs from UC San Diego, Northeastern University, UC Santa Barbara, and University of Michigan to win this award for their proposal entitled “AutoCoMBOT: Autonomy in Cyberspace through robot learning and Man-BOT Teaming.” Winning this highly competitive award requires tireless work from the Principal Investigator in putting together an excellent team and leading on every aspect of proposal preparation and writing (including putting together a series of mini workshops and internal talks).
Energy-Efficient Datacenter Networks

Professor George Papen’s current research is developing high-performance energy-efficient lightwave networks for datacenters. Along with colleagues within ECE, the Jacobs School of Engineering, two start-up companies founded by UC San Diego graduates and Sandia National Laboratories, they are developing advanced lightwave devices and networks that can connect thousands of computer servers within a data center using energy-efficient optical switches instead of power-hungry electrical switches. A prototype optical switch used in our network is shown below.

Using advanced optical networks, their goal is to double the number of useful operations per unit energy within a data center. The key insight to achieve our goal is that unlike electronic switches, optical switches aren’t bound by the limitations of electronics to transmit data. Instead, optical switches make direct “light path” connections from input ports to output ports. Since no conversion between optical and electrical data is required at every switch, optical switches don’t have the latency or electronic logjam or queueing delay issues that existing network switches have, and require much less power to route data irrespective of the data rate. This “rate agonistic” feature of optical switches means that the energy per switched bit decreases as the rate increases.

Over the past decade, their research team has assembled and tested multiple generations of optical networks. Our existing prototype optical network can run native (Linux) applications on a nine-node optical network testbed without modification. Working with collaborators at Sandia National Laboratories, our next generation system will be a 32-node system using four network connections per node and a 128 port optical switch being developed by one of the start-up companies within the team. Each node will have a high-performance Field Programmable Gate Array (FGPA) network interface card (NIC) running custom hardware-based protocols for the optical network. The development of the hardware protocols and optical switch is part of a $10.5M Lightwave Energy Efficient Datacenter (LEED) research program funded by the Advanced Projects Research Agency — Energy (ARPAE), the California Energy Commission, and UC San Diego.

This type of future-looking research using real hardware is essential to decarbonize future data centers and is an excellent example of the highly cross-disciplinary research being conducted within the ECE department.
Automated Cross-Layer Customization of Secure, Robust and Private AI

We are at the CUSP of the fourth industrial revolution empowered by machine learning and application automation: seamlessly connecting people, data, and computing machines. The vision of Farinaz Koushanfar’s Lab research is to make this future automatically and efficiently realizable on constrained devices in a safe, private, and reliable way using a unique automated holistic co-design of data subspaces, algorithm, hardware, and software. The research in the lab has invented several state-of-the-art techniques in the field, including the concept of logic locking and its usage to protect hardware, software, data, and algorithms; the first holistic IP protection framework for both white-box and black-box settings enabling systematic watermark insertion in deep learning networks before distribution; the first known methodologies to attest and bind a specific instance of a learning algorithm on trusted platforms; the fastest-ever reported results for cryptographically secure deep learning on private data; and the first set of tools for unsupervised defense and characterization to ensure robustness in face of both adversarial learning and data poisoning attacks.

The research in the lab is cross-disciplinary and brings together students and postdocs from a diverse set of backgrounds including machine learning, computer engineering, and security/privacy. The current research projects include collaborative and federated learning, robust learning in dynamical systems and causal time series data, private federated learning, and, design, characterization, customization, and acceleration of privacy-preserving methodologies including hybrid methodologies containing fully homomorphic encryption, secret sharing, and garbled circuits. These methodologies are at the heart of many modern applications such as intelligent healthcare, financial data analysis, security analysis, and scientific computing.

Artificial Neuron Device for Efficient Neural Network Accelerators

As the amount of data for computing exponentially increases, data transfer between memory and processor turns into a major bottleneck, so-called Von Neumann bottleneck, dominating the system-level energy consumption and causing excessive delays. That has been particularly problematic for machine learning applications involving data-intensive computations.

To circumvent this limitation, in-memory computing architectures have been proposed and demonstrated promising results. Although in-memory computing architectures provide a solution toward minimization of the data transfer between memory and processor, non-linear functions (e.g. rectified linear function (ReLU), sigmoid, and tanh), which play an essential role in learning algorithms, are still implemented with large-scale and energy-consuming complex circuits or using external general-purpose processors.

Neuroelectronics Group led by Prof. Duygu Kuzum have recently developed a nanoscale device that can replace the complex circuits for non-linear functions to provide substantial gains in area and energy efficiency for acceleration of machine learning algorithms.

The Neuroelectronics Group at the University of California, San Diego has developed a nanoscale device that can replace the complex circuits for non-linear functions to provide substantial gains in area and energy efficiency for acceleration of machine learning algorithms. The device, which they call the “Neuroelectronics Neuron,” is a nanowire heater that precisely controls the insulator-to-metal transition of vanadium oxide (VO2), a material that exhibits an interesting electrical switching phenomenon known as the Mott transition. By controlling the resistance of the VO2 gap, the device can emulate the input-output characteristics of a rectified linear function (ReLU), a widely used non-linear activation function in machine learning.

In collaboration with Schuller Nanoscience group (Prof. Ivan K. Schuller), Prof. Kuzum’s Neuroelectronics group came up with the idea of harnessing electronic switching characteristics of a novel material, vanadium oxide (VO2), for implementing one of the widely used non-linear activation functions, ReLU, in a nanoscale device form. VO2 exhibits an interesting electrical switching phenomenon, insulator-to-metal transition so-called Mott transition. They designed and fabricated a four-terminal nanodevice including a nanowire heater to precisely control insulator-to-metal transition of VO2. As a result, the resistance of the VO2 gap can be gradually controlled to emulate input-output characteristics of ReLU function. More importantly, this Mott ReLU device can directly generate output voltage to drive another synaptic array without additional drivers. It enables direct stacking of multiple network layers with minimal peripheral circuits, which is essential for scalable hardware implementations of large-scale neural networks.

Neuroelectronics group integrated Mott ReLU neurons with resistive memory crossbar (RRAM) arrays. They demonstrated that hardware implementation of convolutional neural networks based on Mott ReLU neurons and RRAM synapses occupies a ~1000× smaller area and consumes ~100× less energy in comparison to the CMOS implementations for complex image classification tasks. Dr. Kuzum’s group will continue to innovate new devices harnessing nonlinear switching characteristics of nanomaterials towards developing large-scale, highly parallel, and energy-efficient computing systems.
Enabling New Wearables through Ultra-Low-Power Wi-Fi

Next generation wearable devices, which include smart glasses, augmented/virtual reality headsets, or even advanced wireless earbuds, all require high-bandwidth communication into the 1-10 Mbps range. However, this cannot come at the cost of battery life. State-of-the-art wireless earbuds have battery lives of only a few hours — and this will only get worse as functionality and data rates go up in future generations. Similar problems arise for other wearable device applications, including brain-machine interfaces, smart watches, medical devices, and even beyond to all sorts of Internet-of-Things (IoT) applications.

The main cause of poor battery life in many of these applications is the high power consumption needed by the radios responsible for wireless communication. Unfortunately, conventional wireless techniques are severely challenged at improving their energy efficiency, especially when compatibility with existing smartphone hardware is needed. Completely new design approaches are desperately needed to help enable many of the exciting applications envisioned in this space.

Research in ECE, led by Patrick Mercier and Dinesh Bharadia and their team of graduate students and postdocs, are developing new classes of wireless communication systems that are compatible with existing wireless hardware such as Wi-Fi and Bluetooth, but at power levels that are ~1,000x lower than conventional approaches. The extremely low power approach is enabled by a technique called backscattering. Essentially, it takes incoming Wi-Fi signals from a nearby device (like a smartphone) or Wi-Fi access point, modifies the signals and encodes its own data onto them, and then reflects the new signals onto a different Wi-Fi channel to another device or access point. By eliminating the need to generate the Wi-Fi signal directly on the device, many circuit blocks can be completely eliminated, leading to extremely low power consumption.

So far, ECE researchers have shown that a data stream of 2Mbps can be transmitted across a 10m link while consuming only 28uW of power — all while being fully compatible with existing Wi-Fi hardware. In more recent work, they have demonstrated inclusion of multiple antennas, towards MIMO-based communication that consumes about the same amount of power, but can now operate at a distance of 23m.

Future work involves incorporating more wireless standards into the mix, increasing the communication distance, and further reducing the power consumption. Successfully doing so will enable all sorts of new and exciting applications in the wearables and IoT spaces, and beyond.
Five ECE faculty are part of a UC San Diego-led team that received a $20M dollar grant from the National Science Foundation. The Institute for Learning-enabled Optimization at Scale, or TILOS, is part of NSF's National AI Research Institutes 2021 funding, a five-year, $20M investment to create 11 multidisciplinary, multi-institution research institutes that advance AI research and workforce development. The institute will be housed at the Halıcıoğlu Data Science Institute (HDSI), UC San Diego's campus hub for data science and artificial intelligence, and is partially funded by Intel.

The TILOS mission is to "make impossible optimizations possible — at scale and in practice". Optimization is a fundamental component of machine learning, an important area of modern AI. Conversely, learning can help solve difficult optimization problems. Foundational research in TILOS will explore this interplay to develop optimization methods that can change the leading edge of real-world practice. In close collaboration with industry partners, institute researchers will develop learning-enabled optimization tools for application domains of strategic importance to the United States. The institute has dedicated teams that focus on three areas in particular: chip design, robotics, and communication networks.

Professor Andrew B. Kahng will serve as principal investigator and director of TILOS. He is a well-known expert in chip design automation methods and will co-lead the Chips team in TILOS.

Professor Tara Javidi will serve as co-PI of the project, and co-lead the Networks team. Energy efficiency is one of the areas where breakthrough in AI and optimization are urgently sought. "Sustainable scalability of our modern information infrastructure is at stake," Javidi said. "Optimizing the design and operation of networks will enable new capabilities in autonomous driving, augmented and virtual reality for telemedicine, and robotics, while also achieving tremendous energy savings to help combat climate change," she added.

Professor Farinaz Koushanfar will work with both Kahng and Javidi. Her research will pursue more intelligent embedded computer systems that can ensure low-overhead security and trust, reduce energy usage, and improve performance within resource constraints. Her work has applications in Internet of Things (IoT), antipiracy systems, medical devices, automotive systems, deep learning networks and secure bioinformatics.

Professors Nikolay Atanasov and Xiaolong Wang will be part of the Robotics faculty team in TILOS. Atanasov will initially pursue distributed inference algorithms for multi-robot simultaneous localization and mapping, while Wang will pursue new ways in which human demonstrations can guide reinforcement learning in large state and action spaces.

TILOS is a partnership of UC San Diego with the Massachusetts Institute of Technology; San Diego-based National University; the University of Pennsylvania; the University of Texas at Austin; and Yale University. Learn more at tilos.ai
$12.25 Million Grant to Improve Epilepsy Treatment

UC San Diego electrical engineering professor Shadi Dayeh leads a new $12.5M grant from the National Institutes of Health to improve treatment of drug-resistant epilepsy. The grant funds a series of interrelated efforts to develop and enhance brain-sensing and brain-stimulating platform technologies. The project brings together expertise from all across UC San Diego and includes Massachusetts General Hospital and Oregon Health & Sciences University.

Today, people with drug-resistant epilepsy rely on sensor technologies to identify the specific regions in the brain that most likely trigger epileptic seizures. The sensors are embedded in a thin flat material that is placed directly on the surface of the brain in order to record brain activity. Each sensor in the grid records the brain waves being produced by the area of the brain near each sensor. Surgeons then target this area for surgical removal, or for implantation of an electrical pulse generator that modifies seizure generation. These current technologies are still somewhat imprecise, and improved mapping of target brain regions would allow better surgical planning.

To improve technologies for drug-resistant epilepsy treatment, Dayeh and his interdisciplinary team leverage their advances in materials science, device, and integration techniques to develop grids of sensors that offer surgeons with a much clearer picture of the spots in the brain likely initiating the seizures.

One of the improvements that has emerged from efforts led by Dayeh is a 100-fold increase in the density of sensors embedded within the grids. The new NIH grant will allow the team to expand technical refinement of these higher-density grids and their testing in pigs to the point where they are ready for full-scale clinical trials in people. More generally, this work is poised to enhance our understanding of brain physiology.

"Materials science and advanced technology integrations are leading to big advances in less invasive sensor technologies which rest on the surface of the brain cortex," said Dayeh, who leads the Integrated Electronics and Biointerfaces Laboratory. "There is so much potential for materials science to advance clinical medicine, but it needs to be done extremely carefully and the work must engage clinicians and patients as soon as possible. That’s what we’ve been doing, and this grant will allow us to continue this important work."

The team will also be testing related probes that are inserted down into the cortex, rather than resting on the surface. In some cases, information available from these kinds of “depth probes” is necessary to identify the areas triggering seizures.

Electrical engineers at the UC San Diego Jacobs School of Engineering are leaders and key players in multiple efforts funded by this grant to make the device wireless and to make it clinically viable. This includes the wireless transfer of data and the energy necessary to power the implanted components of the device, and the software display of the high channel count recording. Funding for sustained conversation and dialog that includes researchers from multiple fields, patients, patient advocates, and bioethicists.
Spintronics at the Speed of Light

The interplay of light and magnetism is at the forefront of modern ultrafast sciences and engineering of new memory and spintronic devices. This area has expanded with the development of femtosecond laser sources which can generate sub-100 fs laser pulses, and is able to switch magnetic devices on the picosecond to femtosecond timescales. The optical control of magnetism is known as all optical switching (AOS) and is an example of the magnetic domains written by an ultrashort laser as shown in the figure. AOS is currently the least-dissipative and fastest method for magnetic writing. The low-power manipulation of magnetization, preferably at ultra-short time scales, has become a fundamental challenge with implications for future magnetic information storage and memory technologies.

Research by the Fullerton and Fainman groups in the Center for Memory and Recording Research (CMRR) and ECE at UC San Diego in collaborations with groups in France, Germany, Japan, the Netherlands, and Sweden are pushing the limits of optical control of magnetism. We have demonstrated that AOS can be observed in a broad range of material and not limited to selected alloy films as had been previously observed. This includes optical control in ferromagnetic films and granular magnetic recording media that potentially enable breakthroughs for numerous applications since they include materials that are currently used in magnetic data storage, memories and logic technologies.

In addition to directly controlling magnetism, optical excitation of magnetic materials enables the emergent field of ultrafast or THz spintronics. Spintronics refers to the class of devices that exploit the spin of the electron instead of the charge. Femtosecond laser pulses of magnetic films trigger ultrafast spin and charge currents that flow from a magnetic layer into adjacent nonmagnetic layers. These ultrafast spin current can be exploited to encode magnetic information enabling multilevel optical magnetic recording or can be converted into ultrafast charge currents via spin-to-charge conversion mechanisms and then emits in THz radiation. The spintronic based THz emitters opens new directions in THz engineering by converting optical pulses to THz pulses using ultrafast spin currents.

Mobile robots need a precise understanding of their surroundings at geometric and semantic levels for successful assistance in transportation services, warehouse and home automation, and environmental monitoring. The Existential Robotics Lab, directed by Dr. Nikolay Atanasov, works on active simultaneous localization and mapping (SLAM), a problem where robots autonomously explore an unknown environment, keep track of their motion, and collaboratively build a 3D map. For indoor applications, Dr. Atanasov’s team develops probabilistic estimation techniques for reconstructing scene geometry and object categories from streaming RGB images and depth measurements. The likelihoods of different semantic categories at different spatial locations are organized in an adaptive-resolution (octree) map, which is updated incrementally as new information arrives. To enable autonomous exploration, the team has devised approximations of the Shannon mutual information between the map and the measurements, which may be evaluated rapidly along potential robot trajectories to select informative ones. This allows the robots to navigate intelligently in unknown environments and acquire critical information for their mission. For outdoor applications, Dr. Atanasov’s team develops machine learning techniques for terrain mapping using unmanned aerial vehicles (UAVs). Distance measurements cannot be easily obtained onboard UAVs, so the team has proposed graph neural network techniques to optimize a 3D terrain mesh model in agreement with photometric, semantic, or thermal observations. The mesh vertices are projected to the image space and associated with visual features, which are subsequently processed by a graph neural network to deform the vertex positions. This allows generation of accurate metric-semantic models of outdoor environments in real-time, which is important for environmental monitoring, such as detection of fire initiation, fuel classification, and hot-spot monitoring after a fire event.
AI-Powered Personalized Recommendation System Helps Lower Blood Pressure

Electrical engineers at UC San Diego have developed an artificial intelligence platform that fuses data from disparate health and lifestyle sensors, wearables and apps into one site, using this combined data stream to paint a broader picture of a user’s health, and make personalized recommendations for them to improve a specified health outcome. In a clinical trial with hypertensive patients, those using the P3.AI platform saw their systolic and diastolic blood pressure decrease by 3.8 and 2.3 points respectively, compared to 0.3 and 0.9 points for subjects in the control group who did not receive personalized recommendations.

Researchers detailed the early findings of the Proactive, Personalized and Precise Insights and Recommendations using AI project, or P3.AI, in July 2021 in the IEEE Journal of Translational Engineering in Health and Medicine.

In addition to the clinical trial with hypertensive patients, this P3.AI platform powered the eCOVID app used in a clinical trial of patients with moderate cases of COVID-19 in San Diego. The same methodology, though a slightly different platform, was used to predict depression, and recommend personalized mental health treatment, to participants in a UC San Diego School of Medicine study.

“Instead of telling you 10 different generic things to do, and encouraging you to totally change your life — which is often what hypertensive patients are currently told — this system will recommend one or two specific actions for you to take that would be most effective for you, and will show you with easy to interpret data how effective the changes are. We’ve seen again and again that general guidance leads to poor compliance; this system is capable of providing the personalized, explainable recommendations needed.”

Eventually, the goal is for patients and their doctors to be able to use this AI platform to improve any number of health conditions through personalized, data-driven recommendations. The platform can be integrated with electronic health records using APIs, enabling healthcare providers to get a more accurate and holistic picture of patients’ well-being.

This AI platform for personalized health is one of several projects at the Center for Wireless Communications focused on applying advances in wireless technologies to Connected Health challenges. Other projects include an on-demand virtual physical therapy system; developing an Image Processing Platform for MRI-based Rectal Cancer Diagnosis; and are working to reduce the power constraints and advance the communication capabilities of Internet of Medical Things devices.

![Average Speed vs. Blood Pressure](image)
The ECE Department Summer Research Internship Program (SRIP) offers undergraduate and master’s students a chance to gain paid, hands-on experience in a research lab. Over the course of ten weeks, participants engage with a research group and benefit from enrichment activities such as workshops on research communication, research writing, and other pertinent topics.

2021 SUMMER RESEARCH INTERNSHIP PROGRAM BY THE NUMBERS

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Consumers of today’s 5G cellphones may have experienced one of the following tradeoffs: impressive download speeds with extremely limited and spotty coverage, or widespread and reliable coverage with speeds that aren’t much faster than today’s 4G networks.

Today’s high band 5G systems communicate data by sending one laser-like millimeter wave beam between a base station and a receiver — for example, a user’s phone. The problem is if something or someone gets in the way of that beam’s path, then the connection gets blocked completely.

"Relying on a single beam creates a single point of failure," said Dinesh Bharadia, a professor of electrical and computer engineering at the UC San Diego Jacobs School of Engineering, who is the senior author on the ACM SIGCOMM paper.

The technology presents a solution to overcome a roadblock to making high band 5G practical for the everyday user: the speedy wireless signals, known as millimeter waves, cannot travel far and are easily blocked by walls, people, trees and other obstacles.

"Two Beams are Better Than One"

Bharadia and his team, who are part of the UC San Diego Center for Wireless Communications, came up with a clever solution: split the one laser-like millimeter wave beam into multiple laser-
like beams, and have each beam take a different path from the base station to the receiver. The idea is to improve the chances that at least one beam reaches the receiver when an obstacle is in the way.

The researchers created a system capable of doing this and tested it inside an office and outside a building on campus. The system provided a high throughput connection (up to 800 Mbps) with 100% reliability, which means that the signal didn’t drop or lose strength as the user moved around obstacles like desks, walls and outdoor sculptures. In outdoor tests, the system provided connectivity up to 80 meters (262 feet) away.

To create their system, the researchers developed a set of new algorithms. One algorithm first instructs the base station to split the beam into multiple paths. Some of these paths take a direct shot from the base station and the receiver; and some paths take an indirect route, where the beams bounce off what are called reflectors — surfaces in the environment that reflect millimeter waves like glass, metal, concrete or drywall — to get to the receiver. The algorithm then learns which are the best paths in the given environment. It then optimizes the angle, phase and power of each beam so that when they arrive at the receiver, they combine constructively to create a strong, high quality and high throughput signal. With this approach, more beams result in a stronger signal.

“You would think that splitting the beam would reduce the throughput or quality of the signal,” Bharadia said. “But with the way that we’ve designed our algorithms, it turns out mathematically that our multi-beam system gives you a higher throughput while transmitting the same amount of power overall as a single-beam system.”

The other algorithm maintains the connection when a user moves around and when another user steps in the way. When these happen, the beams get misaligned. The algorithm overcomes this issue by continuously tracking the user’s movement and realigning all the beam parameters.

The researchers implemented their algorithms on cutting-edge hardware that they developed in the lab. “You don’t need any new hardware to do this,” said Ish Jain, an electrical and computer engineering Ph.D. student in Bharadia’s lab and the first author of the paper. “Our algorithms are all compliant with current 5G protocols.”

The hardware consists of a small base station and receiver. The base station is equipped with a phased array that was developed in the lab of UC San Diego electrical and computer engineering professor Gabriel Rebeiz, who is an expert in phased arrays for 5G and 6G communications and is also a member of the university’s Center for Wireless Communications.

The team is now working on scaling their system to accommodate multiple users.

More information can be found on the project’s website: wcsng.ucsd.edu/mmreliable

Paper: “Two beams are better than one: Towards Reliable and High Throughput mmWave.” Co-authors include Raghav Subbaraman, UC San Diego.

This work is supported by the National Science Foundation (grant 1925767).
ECE Student Organizations Win Gold

“Faster, Higher, Stronger — Together” was introduced as the new motto of the recent Tokyo 2020 Olympic Games; one could argue that it also represents the character of ECE's Student Organizations. With a full remote year ahead, ECE Student Organization leaders had to, once again, think out of the box when it came to hosting their programs and events. They ventured into new (virtual) territories like Slack, Discord, and even new interactive platforms like Topia and Gather, in an effort to minimize Zoom burnout. Despite these obstacles, they successfully hosted educational, technical, and social programs that supported ECE’s mission of world class research and hands-on experience . . . all while being students themselves! With events like Machine Learning Workshops, Recruiter Speaker Series, Neural Data Competition, workshops on how to minimize stress, and even a skincare routine night, the entire ECE Community stayed engaged, interested, and supported all year long. Even annual events like HKN's Alumni Brunch, USC's ECE Town Halls, ACM's Bit/Byte Program, IEEE's RoboCup Soccer Tournament, and Project in a Box's Innovative Conference were still able to happen; ECE's annual Student Organization-wide collaboration event, ECE Day, was a success largely in part because ECE student leaders came together and planned for this event as one group. Hosting anywhere from 2 to 200 events, our Student Organizations pushed their limits, never gave up, and triumphed to win a well-deserved gold medal.

The ECE Student Organizations shared their biggest accomplishments from 2020-2021:

**Association for Computing Machinery (ACM)**
ACM has doubled its online member base on Discord this past year with over 200 events and over 1,500 members! Despite being in a remote environment, ACM has cultivated a community for everyone interested in the field of computing.

**Eta Kappa Nu (HKN)**
HKN's greatest accomplishment during the COVID era was hosting our annual Honors Career Fair virtually. Larger companies including Qualcomm, Intel, and Lockheed Martin still attended and we had the same turnout of students as in-person. It was a huge success, and we can’t wait to host it again next year.

**IEEE @ UC San Diego**
We hosted a virtual ECE Day in collaboration with ACM, HKN, PiB, and ECE USC. We recreated Warren Mall, Jacobs Lobby, Qualcomm Room, and Henry Booker Room on the gather.town platform and had over 50 people attend our workshops, tabling, and showcases. Everyone absolutely loved the platform and it gave people who had never been to campus the chance to actually look around the spaces we spend the most time in.

**Project in a Box (PiB)**
Project in a Box's greatest accomplishment last year was expanding our outreach programs and adapting to the online environment by shipping project kits and hosting workshops through Zoom. We partnered with the San Diego Public Library and Institute of Americas, reaching K-12 students in San Diego and Mexico.

**Undergraduate Student Council (ECE USC)**
In the face of the pandemic and at the height of isolation, our student organization still strived to create the best environment for undergraduates to still get connected to the ECE family. With RCF, ECE Day, mentorship program, and our numerous other events the council performed optimally as if there was no pandemic.

**Women in ECE (WeCe)**
WeCe’s greatest accomplishment last year was to introduce Dr. Hortense Gerardo and the Anthropology, Performance, and Technology Program to the ECE Department.

**Triton NeuroTech**
Over the past year, we completed a number of high-profile projects in the realm of neurotech. In the fall, we submitted MiMap, an EEG-based Google Earth applet. Since then, we have been working on an EEG-based keyboard(Speller) so people with motor disabilities can type with their minds! Come check us out to see what else we have cooking.

**Graduate Student Council (ECE GSC)**
This year, ECE GSC beheld a tremendous increase in community participation, connecting 400+ students and alumni under a single slack platform. The newly launched buddy program helped 300+ incoming students find a mentor from their major. Finally, the ECE 290 seminar was the most successful, with 20+ professors and 6+ industry talk over all three quarters.
In the spirit of Dr. Henry G. Booker’s educational philosophy, the department recognized the following students for their hard work, dedication and commitment to academics. Additionally, recipients maintained a GPA of 3.7 or above in all ECE courses.

HENRY G. BOOKER MEMORIAL AWARD RECIPIENTS

Maximilian Apodaca, Allan Ateek, Adan Cambero Morales, Xuyang Cao, Geeling Chau, Wesley Chen, Willie Chow, Brandon Cramer, Hassan Eid, Angela Emerick, Jon Frigillana, Gregory Furman, Yuting Han, Warren Hu, Nicholas Johnson, Mark Kragh, Jinmou Li, Yuxin Li, Lingxi Li, Yejun Li, Albert Liao, Christopher Light, Christie Lincoln, Arden Ma, Htet Oo, Pedro Orso, Nikhil Pathak, Dylan Perlson, Ilya Petrov, Anh Pham, Karolyna Ramirez, Eli Romo, Shihao Shen, Eric Siu, Haihao Sun, Weitao Sun, Justin Tahmassebpur, Hong Wang, Jin Wu, Anfeng Xu, Jinhua Xu, Yijia Yan, Nuoyi Yang, Frank Ye, Xinyang Yu, Jiawen Zeng, Xiangjian Zeng, Yiming Zhao, Minghui Zhao
ECE AWARDS
ECE students, instructors and alumni were recognized for their significant contributions to the department. A list of this year’s award winners follows.

**Best Undergrad Research Award**

- JUSTIN TAHMASSEBPUR
- EMILY NGUYEN
- ALBERT LIAO
- ALLAN ATEEK

**Best Lecturer Award**

- JOSE UNPINGCO
- HENRY WANG
- JUN LEE
- ARDEN MA

**Best Tutor Award**

- KEVIN KAO
- JONATHAN GUERRERO
- STANLEY DILLON HICKS
- CHRISTIE LINCOLN

**Undergraduate Student Service Awards**

- KEVIN KAO
- JUN LEE
- ARDEN MA
- CHRISTIE LINCOLN
Best Teaching Assistant Award

ADITI TYAGI  NILESH PANDEY  TYLER HACK  PHUONG TRUONG

Graduate Student Service Awards

XINYU CHEN  MADDIE WILSON  DHANANJAY JAGTAP  NEVO MAGNEZI

ISH KUMAR JAIN  JEFF PATZ  ROBERT DAVIS

Alumni Service Awards

AN CHEN  DAVID DING  KELLY LEVICK
To support students in their learning, instructors throughout the ECE department have continued to integrate innovative approaches into their classes, both at the graduate and undergraduate levels. A key component of these approaches to highlight is the idea of active learning, a topic that is well-studied in the Scholarship of Teaching and Learning (SoTL). It emphasizes that we learn more effectively by actively processing and applying new concepts, rather than being mere passive recipients of the information.

### Flipped Classroom

One approach to integrating the principles of active learning into traditional lecture-style classes is to take the focus away from the teacher and put it back on the student, in what is called “flipping the classroom.” At a basic level, the act of learning consists of two phases: the receiving of new information and the processing of that information, i.e., the sense-making. The latter part, the sense making, is the hardest, but in a traditional class format, students are asked to do this part on their own, away from the instructor or their peers. In a flipped classroom, on the other hand, students acquire the basic information in advance, for example through self-paced lecture videos. The instructor can now dedicate their lecture time to guiding students toward higher levels of understanding through interactive exercises, group discussions, or hands-on work.

Several key undergraduate courses have been transformed into this model. Core circuits classes such as ECE35 and ECE65 have built their lectures around the idea of peer instruction to great effect. In these classes, short conceptual problems are presented to students during lecture, and they are challenged to think about the questions individually first and then in a small group. The key element is that students are pushed to apply their knowledge, question their understanding, and explain their own reasoning, all while guided by the instructional team. Similar concepts are being used in ECE101, where students learn about digital signal processing through pre-recorded lecture videos and solve practice problems in class. ECE15, the ECE programming course, integrates peer instruction with conceptual code examples and short programming exercises in class.
Project-Based Learning

A second aspect of active learning is to learn-by-doing. Hands-on curriculum and project-based learning (PBL) have found a home in many ECE courses. Complementing our strong theoretically driven coursework, PBL provides opportunities for students to build larger, systems-level projects that additionally require technical skills, teamwork, and resiliency. Many of these courses are traditionally housed in the ECE Makerspace or in the Envision Arts and Engineering Maker Studio. At the undergraduate level, these project-based classes range from introductory courses to quarter-long design projects. ECE5 exposes freshmen to the basics of electrical engineering through a series of short projects, with the goal of providing them with confidence, motivation, and insight into what ECE has to offer.

Subsequent courses such as ECE16, ECE115, ECE140A/B, ECE144, and ECE148 take a project-based approach to topics such as embedded systems, rapid prototyping, product engineering, LabVIEW programming, and autonomous vehicles. ECE191 and ECE196 are group design courses where students focus on teamwork and hone their broader engineering skills. ECE111 on advanced digital design is another project-based course that prepares students for jobs in Systems-on-Chip designs and FPGA-based applications. More information can be found on the ECE hands-on courses page on the ECE website.

Recently, the idea of a flipped classroom has been combined with project-based learning in ECE16, where students learn the basics of systems engineering by combining hardware and software elements to create their own Internet-of-Things devices, while utilizing the flipped model for its theoretical components. Project-based classes are not restricted to the undergraduate level and are part of the graduate curriculum as well, such as ECE260C on advanced topics in VLSI design.

Pedagogical Innovations

In addition to introducing new pedagogical techniques into their courses, ECE faculty are also actively working on improving the assessment of students’ understanding. Oral exams have recently been integrated into several ECE courses such as ECE35, ECE65, and ECE144 to complement more traditional written exams. In these oral exams, students meet one-on-one with the instructional team, allowing them to verbally explain their thought processes. This helps instructors assess how students master the fundamental concepts underlying the solution strategies. In other classes, such as ECE101, students design exam questions themselves and grade other students’ submitted solutions. The idea is that they further deepen their learning by thinking about how their questions assess the learning outcomes for the course. The goal of exploring these new pedagogical techniques is to constantly improve the learning process for our students and prepare them for the challenges of an ever-changing workplace.
In an effort to keep students and alumni engaged and connected to campus resources during months of remote school and work, the Jacobs School’s Electrical and Computer Engineering (ECE) Department’s Alumni Advisory Board launched an ECE Alumni Mentorship Program (AMP) in October.

The six month program pairs a current ECE student with an alumnus who shares similar interests, not just in terms of academics and research, but broader hobbies or personal interests as well. In addition to two recommended mentor-mentee meetings a month, the whole group of participants meets for one or two additional group activities each month, including social events and discussion or guest speaker sessions. Participation has been sky-high.

“We’ve had an overwhelming response,” said Stefanie Battaglia, the program director. “We went into this thinking if we could get 50 students and 50 mentors that would be great. And out of the gates we’ve doubled that.”

117 students and 98 alumni are participating in this inaugural session of the program. Hamna Khan, an electrical engineering alumna who now works for Northrop Grumman developing solar array hardware for space vehicles, is president of the ECE Alumni Advisory Board. She said the idea for this mentorship program started last spring, when students, faculty, staff and alumni suddenly found themselves dealing with remote learning and work requirements.

“We knew the pandemic wasn’t going to end right away,” said Khan. “We had a feeling we had to figure out what it is we can do while we’re at home. We started talking to students, we talked to faculty, and we came up with this idea of why don’t we try this mentorship program? We’re helping students who feel even more lost and confused, and connecting with alumni who are eager to help.”

Khan spent days reading through every single participant’s answers to a long list of questions designed to ensure the mentors and mentees have enough interests in common to have meaningful conversations—from technical interests to hobbies, larger topics they care about such as climate change, social justice, intellectual property, or space for example, to areas where the students felt they needed help and areas the alumni felt they could offer advice.

The theme for fall quarter’s meetings is preparing for job interviews — how to polish LinkedIn profiles, resumes, conducting mock interviews and helping students develop the confidence to apply for roles they’re interested in.

Themes for winter and spring quarter will depend on feedback from alumni and students, but will include advice on being successful in the classroom, joining student organizations and getting involved in research opportunities on campus. Given the levels of participation for this first cohort of AMP, Khan said she anticipates this will be an ongoing annual program, starting each fall and running through spring quarter. Return mentors and mentees are welcome to reapply each year, and will be matched with a new partner. And new participants are always welcome.

“It’s been great to see how many alumni are participating in this that have never gotten involved before — so many new faces,” said Khan. “A couple were also interested in the Alumni Advisory Board and I love that we’re getting more people to understand that we’re here to help everyone and build a stronger ECE community.”

Learn more about ECE AMP and get involved: ece-amp.ucsd.edu
ECE AMP
Alumni Mentorship Program
Honoring the 2021 ECE Distinguished Alumni

The ECE Distinguished Alumni Award is presented to alumni with substantial accomplishments in the fields of systems, applied physics or applied mathematics. This year’s ECE Distinguished Alumni awardees are Anton Monk (Applied Mathematics), Gioia Messinger (Applied Physics) and Russell Byrne (Systems Engineering). The awardees were formally recognized at ECE Day.

Anton Monk
Anton Monk received B.S. and Ph.D. degrees in ECE at UC San Diego in 1989 and 1994, respectively. He is currently Vice President of Business Development & Strategy at Viasat. Before joining Viasat, Dr. Anton Monk was President of Virtex Strategies, a 5G technology strategy company. He was VP of technology strategy, business development and partnerships at XCOM Labs, which develops innovative wireless technologies in new 5G verticals such as industrial robotics & automation and multiuser AR/VR. Previously, he was VP of Strategic Alliances and Standards at Cohere Technologies, which developed a groundbreaking wireless modulation technique for next generation 5G cellular communications. He was a co-founder & held the roles of VP & CTO of Entropic Communications, a publicly traded semiconductor company that invented the MoCA home networking solution used by Pay TV service providers for multi-room DVR throughout the U.S. He holds more than 25 granted patents and has been an invited keynote speaker at global technology conferences. Prior to co-founding Entropic he was involved in the development of cable, satellite and wireless integrated circuits at Conexant and ComStream Corporation and was a researcher at the Jet Propulsion Laboratory. He is an active alum at UC San Diego, serving in the JSOE Dean’s Council of Advisors (2017-present), ECE Industry Advisory Board (2010-present), UC San Diego Gordon Leadership Center Board (2018-present).
Gioia Messinger
Gioia Messinger is a senior high tech executive, board member, serial entrepreneur and consultant that loves creating great products with great people. She is super-passionate about innovation and taking ideas from nothing to life-changing. For the last 15+ years she has started and managed businesses at the intersection of hardware, software, and subscription services (IoT). She was the founder & CEO of Avaak/Arlo (NYSE:ARLO) which defined the home video monitoring category and changed the way you watch your life from anywhere. Arlo, is the #1 DIY smart home security system in the market today with 48% US market share. She contributed to the development of the PillCam™ (NASDAQ:GIVN), a revolutionary wireless diagnostic product — and one of the first wireless ingestible health products ever conceived. Products that she have created have won numerous awards, including: CES Innovation Award, Popular Science 100 Best Innovation of the Year, IDEA and have appeared in numerous publications including: The New York Times, Time, Wall Street Journal and Business Week. She a member of the Council of Advisors for the Jacobs School of Engineering at UC San Diego and serves as a director on several private and public corporate boards.

Russell Byrne
After completing his BS degree in Electrical Engineering at UC San Diego in 1985, Russell Byrne spent five years at Fairchild Space Company and ST Systems (NASA contractors), where he worked in the areas of flight hardware Integration & Test, Attitude Control flight software, and robotics research. During that time, he completed his MS Degree in Electrical Engineering at the University of Maryland, College Park, as a part-time student. He then spent five years at the Jet Propulsion Laboratory (JPL) as a Senior Network Engineer, and three years at Cogent Software (a regional ISP) as a Senior Network Engineer. He left Cogent to join a fast-growing network consulting firm (Enterprise Networking Systems, which later became Netigy Corp.), where he spent three years as a network infrastructure performance consultant. Russell returned to JPL in 2002 to become the Ground Network System Engineer for the Deep Space Network’s flight network. In 2005, he left JPL for the second time to take his current position at Cisco Systems as a Systems Engineer. He has over twenty years of experience in technology. His thirteen years in networking include experience in LAN/WAN design, installation, management, administration, analysis and troubleshooting. Russell also has a strong background in software engineering and modeling, including experience with database system design, software design and implementation, and Unix system administration. His unique expertise lies in the areas of application profiling, network performance assessment, and capacity planning.

Robert “Bob” Lugannani Retires after 49 Years of Service!
After 49 years of incredible contributions to ECE as a faculty member, Bob officially retired in Spring 2021 after an enduring and impactful career.

Lugannani joined the UC San Diego faculty in 1972, after a two-year stint at Princeton. He had been on the technical staff at Bell Laboratories from 1964–1970. The major contributor IT Society Digital Library Project. He received his Ph.D. from Princeton University in 1964.

Bob has been a great colleague, from his contributions to the field of communications with works in stochastic processes to his love for teaching. Bob’s early work on independent random variables is still frequently cited today, and his excellent teaching has been praised by many students throughout his years in ECE.