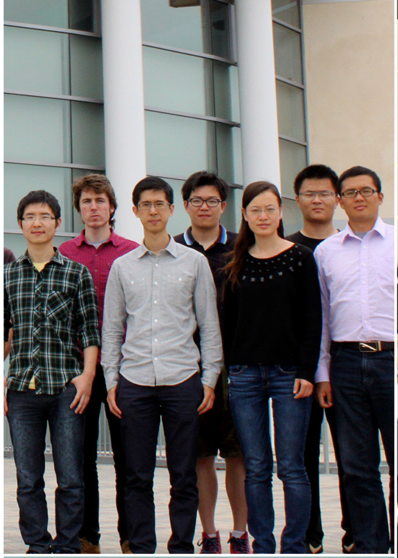
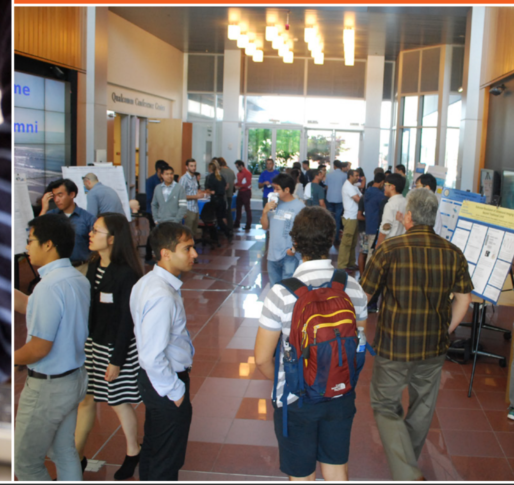
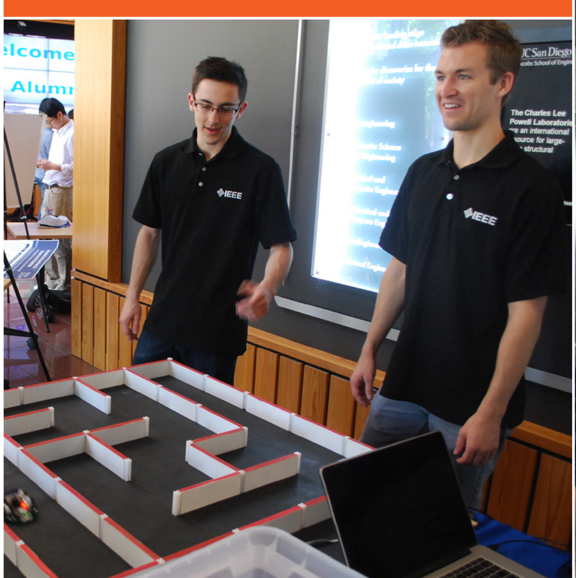


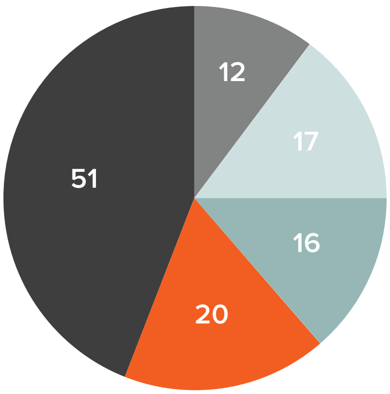


UC San Diego

Electrical and Computer Engineering



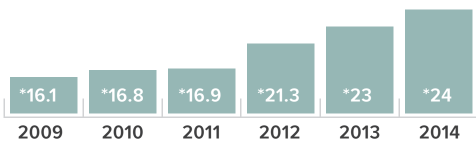
ECE AT A GLANCE



FACULTY

EXTERNAL FUNDING

*in $ millions per fiscal year



DEGREES OFFERED

B.S., M.S., Ph.D. - Electrical Engineering

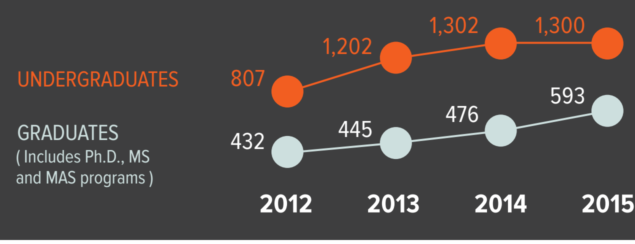
B.S., M.S., Ph.D. - Computer Engineering
(B.S. degree joint with Computer Science and Engineering)

B.S. - Engineering Physics

B.A. - Engineering and Society

MAS - Wireless Embedded Systems

STUDENT ENROLLMENT

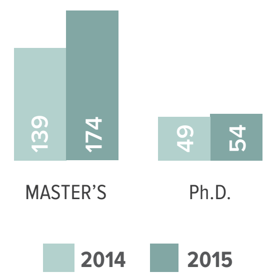


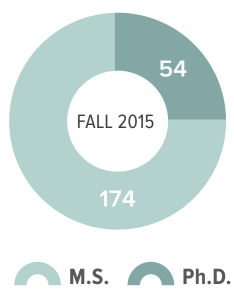
ANNUAL RESEARCH EXPENDITURES

2014 - 2015
$24,000,000

+35%
FROM
2010-2011

INCOMING GRADUATE STUDENTS





FACULTY LEADERSHIP

ECE faculty members play leadership roles in many of the interdisciplinary research units on the UC San Diego campus (listed below) that offer opportunities for collaborations across departments, divisions and schools.

RESEARCH UNIT	ECE FACULTY	TITLE
Calit2's Qualcomm Institute	Ramesh Rao	Director
Center for Wearable Sensors	Patrick Mercier	Co-Director
Center for Wireless Communications	Sujit Dey	Director
Center for Memory and Recording Research	Eric Fullerton	Director
Center for Information Theory and Applications	Alon Orlitsky	Director
DARPA Center for RF MEMS Reliability and Design Fundamentals	Gabriel Rebeiz	Director/PI
DARPA Soldier Centric Imaging via Computational Cameras	Joseph Ford	Director/PI
NSF Center for Integrated Access Networks	Shaya Fainman	Deputy Director

ENDOWED CHAIRS

Peter Asbeck, Skyworks in High Performance Communications Devices and Circuits

Shaya Fainman, Cymer in Advanced Optical Technologies

Eric Fullerton, Center for Magnetic Recording Research Professor

Andrew Kahng, High Performance Computing

Laurence Milstein, Ericsson in Wireless Communications Access Techniques

Alon Orlitsky, Qualcomm in Information Theory and its Applications

Bhaskar Rao, Ericsson in Wireless Access Networks

Ramesh Rao, Qualcomm in Telecommunications and Information Technologies

Gabriel Rebeiz, Wireless Communications Industry Endowed Chair

Paul Siegel, Center for Magnetic Recording Research Professor

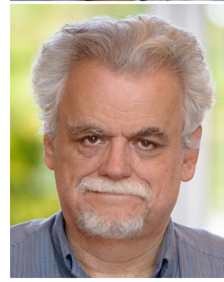
Stojan Radic, Charles Lee Powell in Wireless Communication

Alex Vardy, Jack Keil Wolf Chair

Paul Yu, William S.C. Chang in Electrical and Computer Engineering

CONTENTS

LETTER FROM THE CHAIRS



The Electrical and Computer Engineering (ECE) Department at the Jacobs School of Engineering traces its history back to 1965, with the creation of the department of Applied Electrophysics, which became Applied Physics & Information Science, then Electrical Engineering and Computer Science, and finally ECE as we know it today. Throughout those formative years, our vision focused on information and communication theory and systems, radio physics, and quantum electronics. ECE is among the leading departments of its kind in the nation, built on fundamentals of applied mathematics and engineering physics, providing multidisciplinary, systems-oriented education and research in seven core areas: Communication Theory and Systems, Computer Engineering, Electronic Devices and Materials, Electronic Circuits and Systems, Photonics and Optoelectronics, Intelligent Systems/Control/Robotics as well as Signal and Image Processing.

As we celebrate our 50th anniversary this year, we reflect on the contributions of our faculty and students. Throughout this period, faculty members have pioneered information technologies based on our strengths in information theory and coding, digital communication, high-speed electronic devices and circuits, photonics, and signal processing. Our department had an enormous impact on the establishment of new companies in wireless communications, networking, medical devices and systems, high-speed electronics, and the high-resolution lithography that continues to drive the miniaturization of future information systems. In the past decade, we made significant investments in a comprehensive and versatile nanotechnology program, including collaboration on the development and operation of the state-of-the-art Nano3 cleanroom facility in Calit2's Qualcomm Institute to support our faculty's research in nanoelectronics, nanophotonics, and nanomagnetics, as well as the three areas referenced in the name of Nano3: nanoengineering, nanoscience, and nanomedicine. With $24 million in external funding annually, our research activity ranks us among the largest of any ECE department in the country. This underscores the strength of our faculty and programs, from basic research at the nano level to advanced development at the system level.

The last few years, our department made a critical decision to invest in a new research thrust – Medical Devices and Systems (MDS) – including the establishment of a graduate program in ECE on MDS. We've been fortunate in recent years to recruit talented and passionate faculty in this exciting research direction. As of Fall 2015, the department has funded 14 MDS projects involving 22 ECE faculty members (see page 9), largely in partnership with collaborators from various departments in the UC San Diego School of Medicine. Given our strength in nanotechnology, information theory, electronics, photonics, signal/image processing and controls/robotics, we are confident that we can leverage ECE's prior success in wireless communication and networking to engineer new heathcare applications and technologies.

We recently had a banner recruiting year with five new faculty members (see page 4) in the areas of embedded and cyber-physical systems, nanoelectronic devices, flexible electronics, medical robotics, computational biology, and big data. Our faculty experts in photonics and optics are integral players in the newly-established American Institute for Manufacturing Integrated Photonics (AIM Photonics) – an effort to push the United States as a worldwide leader in photonics manufacturing. In education, we established a sequence of courses on power engineering and systems to meet industry demand for power systems engineers. We also started a workshop series to teach practical technical skills such as Python, Matlab and OpenCV; the workshops are taught by ECE alumni and graduate students.

We encourage you to browse through information in this brochure and please feel free to contact us if you have any questions or comments. Come visit us, and as you get to know ECE, you will find that the high rankings of our programs are well deserved – putting ECE among the best and most forward-thinking departments of electrical and computer engineering in the nation, even the world.

Truong Nguyen, PhD,
Chair

Kevin Quest, PhD,
Vice Chair

CELEBRATING ECE'S 50TH ANNIVERSARY

FALL 2015 - The Past: Recounting Accomplishments

Founders Day – November 13, 2015 ECE's year-long celebration kicks off with Founders Day. For the event, the department will bring back prominent and highly-visible alumni, past chairs, and others to reflect on ECE's first 50 years.

FALL 2015 & WINTER/SPRING 2016 - The Present: Showcasing Research Strengths

ECE will use the occasions of half a dozen conferences to be organized by the department or its faculty to underscore research strengths that characterize today's ECE. Among others, events currently planned include:

Power Amplifier Symposium - September 21-22, 2015
Circuits/RF Symposium – February 3-6, 2016
Information Theory and Applications Workshop – January 31 - February 5, 2016
Non-Volatile Memories Workshop – March 2016
Jacobs School of Engineering Research Expo – April 14, 2016
CWC 5G Forum – May 2016

SPRING 2016 - The Future: Exploring Tomorrow's Research and Education

Alumni Day – June 2016

The 50th anniversary festivities will close out the 2015-'16 academic year at Alumni Day. In sessions that we hope will attract current students, faculty as well as a large cohort of alumni and emeritus professors, the department will organize several sessions to explore future directions in research and engineering education.

http://ece50.ucsd.edu

FARINAZ KOUSHANFAR *Professor*

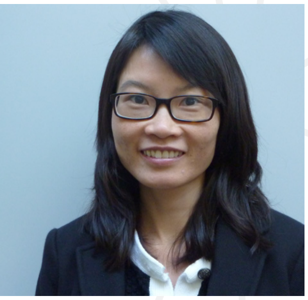
Farinaz Koushanfar will be joining the ECE faculty in January 2016 from Rice University, where she is currently an Associate Professor in Electrical and Computer Engineering. At UC San Diego, she will be directing the Adaptive Computing and Embedded Systems (ACES) Lab. Professor Koushanfar received her Ph.D. in electrical engineering and computer science and M.A. in statistics, both from UC Berkeley in 2005. Her M.S. degree is from UCLA and her B.S. from Sharif University of Technology, both in Electrical Engineering. Koushanfar's research interests include embedded and cyber-physical systems security, adaptive and low-power embedded systems design, design automation (DA), and in particular DA of domain-specific computing and learning applications. Professor Koushanfar serves as an associate partner of the Intel Collaborative Research Institute for Secure Computing to aid developing solutions for the next generation of embedded secure devices. Dr. Koushanfar is the founder of Women ExCEl at Rice and a co-founder of the Trust-Hub. She has received a number of awards and honors for her research, mentorship and teaching, including the Presidential Early Career Award for Scientists and Engineers from President Obama, the ACM SIGDA Outstanding New Faculty Award, and Young Faculty/CAREER Awards from NSF, DARPA, ONR and ARO.

DUYGU KUZUM *Assistant Professor*

Duygu Kuzum joined the ECE department in 2015, from a postdoctoral researcher position in the Bioengineering department at the University of Pennsylvania. She received her Ph.D in Electrical Engineering from Stanford University in 2010. Prof. Kuzum's research focuses on applying innovations in nanoelectronics to develop new technologies to better understand circuit-level computation in the brain. She developed nanoelectronic synaptic devices emulating the synaptic computation and plasticity in the human brain. This technology could lead to portable and energy-efficient computers that can learn and process information in real time similar to the human brain. Recently, Prof. Kuzum has been working on developing novel tools to probe brain circuits with high spatial and temporal precision. She is the author or coauthor of over 40 journal and conference papers. Her work on nanoelectronic devices was featured on the cover of Nano Letters, highlighted in Nature and covered by media outlets including the New Scientist, Nanowerk, and EE Times. In 2014 Dr. Kuzum was featured as one of the Innovators under 35 (TR35) profiled by MIT Technology Review. The same year, she was the recipient of a Penn Neuroscience Pilot Innovative Research Award and a Turkish-American Scientists and Scholars (TASSA) Young Investigator Award. In 2013 Dr. Kuzum also received a Texas Instruments Fellowship and an Intel Foundation Fellowship, as well as a PopTech Science and Public Leaders Fellowship.

SIAVASH MIRARAB *Assistant Professor*

Siavash Mirarab joined ECE in 2015. His research interests focus on accurate and scalable analysis of large-scale biological datasets. Dr. Mirarab's work particularly focuses on evolutionary biology and computational methods that use genomic data to reconstruct the evolutionary past. He is interested in algorithmic developments that enable us to analyze very large datasets with high accuracy and with reasonable computational demands. These algorithms find application in various areas of computational biology, including multiple sequence alignment, metagenomics, and phylogenetic reconstruction from whole genomes. Prof. Mirarab received his Ph.D. in Computer Science from the University of Texas at Austin in 2015. His Ph.D. research was supported by a Howard Hughes Medical Institute international graduate student fellowship and by Canadian NSERG PGSD awards. Prior to receiving his MS in Electrical and Computer Engineering from the University of Waterloo, Ontario, Canada in 2008, Mirarab received his BS in the same field from Tehran University, Iran, in 2000. In between his studies, he worked for various companies, including IBM and Cisco.



TSE NGA (TINA) NG *Associate Professor*

Tina Ng joined ECE in 2015. Her research focuses on the development of flexible electronics, aiming to push the boundary of how electronics are made and used, to potentially incorporate electronic control and power sources onto any surface. Her research method is based on additive printing, because this approach allows low-temperature patterning that is compatible with a wide range of materials, reduces wastes from mask steps, and enables rapid design changes and complex geometric or materials permutation. Flexible electronics are expected to have tremendous impact on fields from energy sustainability to bio-electronics, and they are on a research frontier in thin-film technologies involving the transformation of conventional fabrication processes to meet the demands of soft, pliant and easily damaged surfaces. Dr. Ng previously worked at the Palo Alto Research Center (PARC), a Xerox company, which she joined in 2006 immediately after receiving her M.S. and Ph.D. in Physical Chemistry from Cornell University. At PARC, first as a postdoctoral researcher and eventually as a senior research scientist, Dr. Ng's projects involved engineering solution materials and inventing new devices and systems for ink-jet and other types of digital fabrication. Some example prototypes include conformal organic photosensors for x-ray imaging, tactile sensors for electronic skin, and printed circuits for sensing in smart-packaging application. Her prototyping studies have advanced the design rules for printing flexible electronics in order to establish additive manufacturing as a new capability for industries in the long term. Her work on printed systems received the 2012 Innovation Award from Flextech Alliance and was named Runner-up for the Wall Street Journal Technology Innovation Award. During her graduate studies at Cornell University, Dr. Ng investigated force measurement techniques, such as cantilever magnetometry and electric force microscopy, to study nanoscale phenomena in thin-film semiconductors.

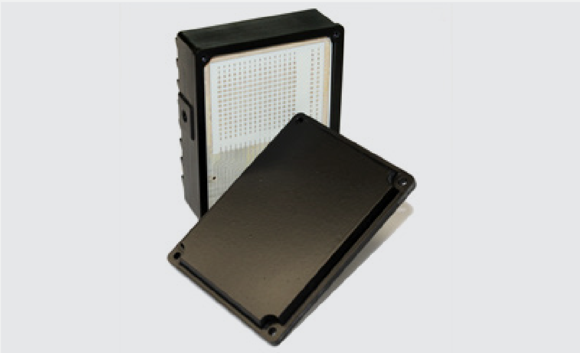
MICHAEL YIP, PH.D. *Assistant Professor*

Robotics, medical imaging, computer vision, medical devices, engineering design and instrumentation

Michael Yip will be joining ECE in January 2016 after completing his Ph.D. in Bioengineering at Stanford University in 2015. Prof. Yip's research focus is on developing new dexterous and agile robots that have a significant role in the future of medical robotics, where robot-assisted surgery has become the de-facto standard for a growing number of minimally-invasive treatments. Surgical robots have allowed clinicians to perform treatments with miniaturized robotic tools that make the surgical treatment more accurate, with significantly reduced trauma to the patient, and with better patient outcomes. His research involves the design of: (i) flexible and highly-articulated and dexterous robots for surgery, (ii) novel sensors and actuators for biomedical devices, and (iii) computer vision and augmented reality for image-guided surgery. These robots have been applied to motion-compensated beating-heart surgery, cardiac catheterization, ultrasound-guided robotic laparoscopy, and endoscopy. Dr. Yip's previous research included assistive devices and human augmentation; low-cost artificial muscles for high-performance robot prostheses, exoskeletons, and Disney animatronics; sensors for real-time monitoring of sports injury; teleoperation and open-source haptic devices and electronics for the new DIY "maker" movement. Dr. Yip earned his M.Sc. in Electrical Engineering at the University of British Columbia in 2011, and his B.Sc. in Mechatronics Engineering from the University of Waterloo in Ontario, Canada, in 2009.

CARS OF THE FUTURE

ECE faculty from very different research areas are converging in an unlikely place: the automobile. The automobile is fast becoming another 'thing' on the Internet of Things, as automakers build more computing, wireless communications, sensors and digital displays into new models. As cars get smarter, the race is on to build better technologies to make roadways safer and more responsive to the needs of drivers. In less than three years, ECE faculty members took home three high-profile awards for research that spans driver assistance systems, automotive radars and networking:



Clockwise from left: Bhaskar Rao; Mohan Trivedi receiving Outstanding Research Award from ITS Society; automotive radar developed in lab of Gabriel Rebeiz

WHEN CARS ARE AUTONOMOUS, WILL PEDESTRIANS BE SAFE?

Gabriel Rebeiz received one of the R&D Magazine R&D 100 awards in 2014 for a project with Toyota to create advanced automotive radars that can identify people more effectively than do other radar solutions. Specifically, he developed a new class of high-resolution, millimeter-wave radars for autonomous driving called Automotive Phased Array Radar (APAR). Several types of radar-enabled early warning and pedestrian sensing systems have been developed by automotive manufacturers, but Toyota is the first to manufacture an APAR that satisfies the requirements for widespread use in vehicle safety systems while also providing a wide 100-degree sensing arc capable of effectively detecting pedestrians. Developed by Rebeiz's lab in collaboration with Toyota Technical Center, Fujitsu-Ten and the Michigan Technological Research Institute, the APAR technology features a single, silicon germanium package optimized for high-frequency 77-GHz signals and high-temperature operation. The RFIC has 16 phase shifters, which control the beam shape and direction of the radar, but the total chip package size is just 5.5 x 5.5 mm2. The APAR can identify people more easily because the beam-forming components are implemented in the RFIC.

INTELLIGENT VEHICLES

Mohan Trivedi accepted the IEEE Intelligent Transportation Systems Society Outstanding Research Award. He was honored for his "contributions to machine vision and learning for intelligent vehicles, and driver assistance and transportation systems." Trivedi accepted the award at the 16th International IEEE Conference on Intelligent Transport Systems in the Netherlands in November 2013. For more than a decade, researchers in Trivedi's Laboratory for Intelligent and Safe Automobiles (LISA) have developed technologies that capture and integrate visual and other information about the driver, the vehicle, and the area surrounding the vehicle. He calls the approach LiLo (short for 'looking in' and 'looking out'). In accepting the award, Trivedi observed that cars are getting smarter, but he does not expect autonomous vehicles to take over roadways anytime soon. Trivedi has focused instead on what he calls a driver-centered, holistic approach to tomorrow's intelligent vehicles. "Understanding human behavior may be essential for robotic systems," said Trivedi. "So we may want to think about these two systems not as ones that will fight with each other, but as a distributed, cognitive, intelligent system, where they share what they perceive and control in a very harmonious manner."

LISA researchers have demonstrated the ability to predict that a driver will change lanes a full two seconds before the driver does so. Similarly, predictive systems can tell in advance whether a driver plans to turn left or right. In his latest, three-year project with Audi – part of the Audi Intelligent Urban Assist program – Trivedi's team developed systems to assist drivers in large metropolitan areas, including a technique to recommend the best speed at which to merge into a designated lane, based on the distances and speeds of cars in surrounding lanes. Another technology developed with Audi makes it possible for the car to brake automatically if the car's computer detects that the driver is not alert to an impending danger.

SCHEDULING AUTOMOTIVE COMMUNICATIONS

In Fall 2013, **Bhaskar Rao** and ECE alumnus Yichao (Harvey) Huang (MS '10, PhD '12) received the IEEE Vehicular Technology Conference Best Paper Award. Their topic: "Multicell Random Beamforming with CDF-based Scheduling: Exact Rate and Scaling Laws." In a multicell multiuser MIMO downlink employing random beamforming as the transmission scheme, the heterogeneous, large-scale channel effects of intercell and intracell interference complicate analysis of distributed scheduling based systems. In their paper, Huang and Rao extended the analysis from two earlier articles they co-authored in 2013: "An analytical framework for heterogeneous partial feedback design in heterogeneous multicell OFDMA networks," published in IEEE Transactions on Signal Processing; and "Random beamforming with heterogeneous users and selective feedback: individual sum rate and individual scaling laws" in IEEE Transactions on Wireless Communications. Both of those papers studied the challenging scenario. The cumulative distribution function (CDF)-based scheduling policy utilized in those two papers was then leveraged to maintain fairness among users and simultaneously obtain multiuser diversity gain. The closed-form expression of the individual sum rate for each user was derived under the CDF-based scheduling policy. More importantly, with this distributed scheduling policy, Huang and Rao conducted asymptotic (in users) analysis to determine the limiting distribution of the signal-to-interference-plus-noise ratio, and they established the individual scaling laws for each user. Dr. Huang worked at Qualcomm as a senior systems engineer until recently, when he became a consultant for the Boston Consulting Group in Shanghai as of May 2015.

PAPER TRAIL

OPTICAL INFORMATION PROCESSING

The Optical Society of America (OSA) awarded its 2015 Emmet N. Leith Medal to Shaya Fainman, ECE's Professor of Advanced Optical Technologies. OSA uses the medal to recognize significant contributions to the field of optical information processing, including sensing and analog signal processing as well as computing (classical and quantum) and optical storage. Fainman was cited for his work on the "extension of Fourier optics methods to the femtosecond and nanometer regimes." In related news, OSA members elected Shayan Mookherjea a Fellow in 2013.

ANTENNAS FOR SATELLITE RECEIVERS

After winning four major awards in 2014, **Gabriel Rebeiz** continued his streak in 2015. He received the IEEE Antenna and Propagation Harold A. Wheeler Applications Prize Paper Award. Rebeiz was honored for his paper on "A Circularly Polarized Multiple Radiating Mode Microstrip Antenna for Satellite Receive Applications." The research underlying the prize-winning paper is part of a larger effort to "understand the potential benefits of antenna apertures supporting multiple simultaneous radiating modes." The paper also presented a novel pattern reconfigurable antenna designed for satellite receive applications in L-band as well as demonstrated full hemispherical steering of a single beam null and conical steering of a single beam peak. Each year the award goes to the authors of the best paper on applications in the IEEE Transactions on Antennas and Propagation from the prior year. Looking back at the 2014 honors bestowed on Rebeiz, they included the 2014 Kuwait Prize in Applied Sciences, the IEEE Microwave Prize, and the IEEE Daniel E. Noble Award for Emerging Technologies.

HAIL FELLOWS

The ECE department boasts 35 IEEE Fellows among its active faculty members. The most recent professor elected to the organization's highest body was **Young-Han Kim**, effective January 2015, who was honored for his contributions to feedback communication and "network information theory". Kim's research has addressed new challenges that have arisen in the evolution of communication networks. Through an investigation of new paradigms of interactive feedback communication over networks, as well as the development of a common set of conceptual, mathematical, and algorithmic tools for the emerging convergence of computation, control, and communication over networks, Kim has provided the scientific and engineering community with a deeper understanding and capability in these areas. Kim has become a leading academic in his field, including as co-author of a comprehensive textbook on "Network Information Theory." He has received an array of awards and honors for his research, including the 2012 IEEE Information Theory Paper Award.

The IEEE Information Theory Society created the James Massey Research and Teaching Award for Young Scholars to honor outstanding achievement in research and teaching by young scholars in the information theory community. Young-Han Kim was selected for the notable impact he has had on the field through his publications, patents, product development, and research awards. The society also cited Kim's new and innovative teaching methods, curriculum development with inclusion of current research, and innovative short courses and tutorials in fields of interest to the information theory community. Kim's research contributions have been both deep (bringing new techniques to solve previously elusive problems) and broad (spanning many aspects of information theory, communication, and signal processing). In addition, the pioneering textbook he co-authored has revolutionized the way information theory is taught throughout the world. The 700-plus-page volume "Network Information Theory" co-authored with Stanford's Abbas El Gamal summarized, unified, explained and extended the state of knowledge about multi-user information theory.

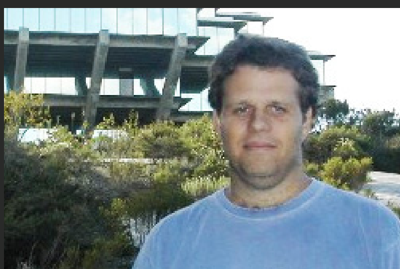
ECE has averaged the addition of roughly one new IEEE Fellow annually. Other inductees over the past five years included **Sujit Dey** (for 2014), **Kenneth Kreutz-Delgado** (2013), **Eric Fullerton** (2012) and **Ian Galton** (2011).

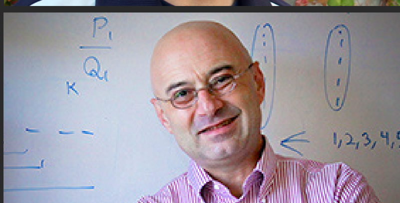
Top down: ECE professors Shaya Fainman, Gabriel Rebeiz and Young-Han Kim

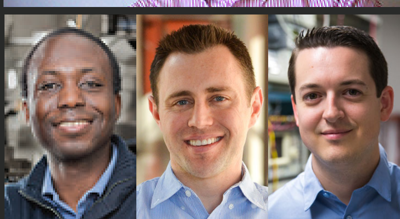
CAREER AWARDS

Drew Hall received an NSF CAREER Award in 2015 to study ultrasensitive magnetic sensing technology (similar to what is found in modern hard disk drives) to enable new medical applications such as point-of-care disease diagnoses and wearable medical sensors. “More generally, my research investigates ways of fusing circuits with biology, a new area known as biosensors and bioelectronics,” said Hall. Applications of Hall’s research will empower individuals to quantitatively diagnose diseases both earlier and at the point-of-care, which will ultimately lead to better treatment outcomes and reduced costs.

In 2014 an NSF CAREER Award went to Shadi Dayeh. The award will allow Prof. Dayeh to pursue his research into "High Density Bio-Compatible Electro-Fluidic Neural Interfaces for Mapping the Brain." Previous CAREER award winners among young ECE faculty have included Truong Nguyen, Nuno Vasconcelos, Massimo Franceschetti, and Gert Lanckriet, whose five-year award ends in 2016.







YAHOO! AWARDS

For two years in a row, **Nuno Vasconcelos** was awarded Faculty Research and Engagement Program awards by Yahoo! Labs. The program provides support for faculty members collaborating with Yahoo! scientists on cutting-edge research to promote major advancements in Web science. The awards go as high as $50,000. Both Vasconcelos and **Gert Lanckriet** were honored with the award in 2013, and Vasconcelos was among very few repeats tapped for another award in 2014. That year, the competition placed particular emphasis on proposals involving research on mobile, personalization and advertising marketplaces, and Vasconcelos ended up as the only University of California faculty member selected for the Yahoo! award – making him one of 25 recipients, roughly half of them outside the U.S. In 2015 the Yahoo! honor went to computer engineering professor Steven Swanson from the CSE department.

STANDING THE TEST OF TIME

Sometimes called ‘test-of-time’ awards, many conferences look back to discern how prescient or influential a paper was in the 20/20 hindsight of history. In the case of the International Conference on Machine Learning (ICML), the so-called ’10-year’ award selects the most impactful paper from a decade earlier. At the 2014 conference, **Gert Lanckriet** was honored for his joint paper with F. Bach and Michael I. Jordan, when Lanckriet was still finishing his Ph.D. studies at UC Berkeley. The paper, “Multiple Kernel Learning, Conic Duality and the SMO Algorithm,” published in 2004, was honored at ICML 2014 for having the most impact of any paper published 10 years earlier. SMO stands for Sequential Minimal Optimization. The original paper presented experimental results showing that the authors’ SMO-based algorithm was significantly more efficient than the general-purpose interior point methods available in optimization toolboxes at that time.

RADIO FREQUENCY ID

The IEEE Radio Frequency ID conference took place in San Diego in April 2015, attracting experts from both industry and academia to share technical research and savvy. At its conclusion, organizers announced the Best Paper award, which went to a paper written by **Alexander Vardy** and alumnus Hessam Mahdavifar (PhD ’14). In their paper, “Coding for Tag Collision Recovery,” Vardy and Mahdavifar introduced the new notion of singulation code. Vardy’s research in ECE is broadening understanding of the uses as well as limitations of error-correcting codes in encoding data for transmission and storage.

YOUNG FACULTY SUPPORT

Boubacar Kante was awarded a Hellman Fellowship for the 2015-‘16 academic year. The Hellman Fellowship is designed to provide financial support and encouragement to young faculty in core disciplines who show capacity for great distinction in their research and creative activities. Kante’s research aims to unravel and exploit the possibilities of using electromagnetic waves to achieve novel functions and devices for use in a wide range of fields, including global energy, defense, and medicine.

Drew Hall received an inaugural seed grant from Cal-BRAIN, a UC San Diego-led consortium channeling state funds into research on brain activity mapping. The $120,000 grant allows Hall’s group to pursue his research in “Magnetic Monitoring of Neural Activity Using Magnetoresistive Nanosensors.” Hall is using his lab’s expertise in integrated circuits for bioelectronics, biosensors, lab-on-chip devices and other biomedical systems to develop more efficient, long-term brain-monitoring devices.

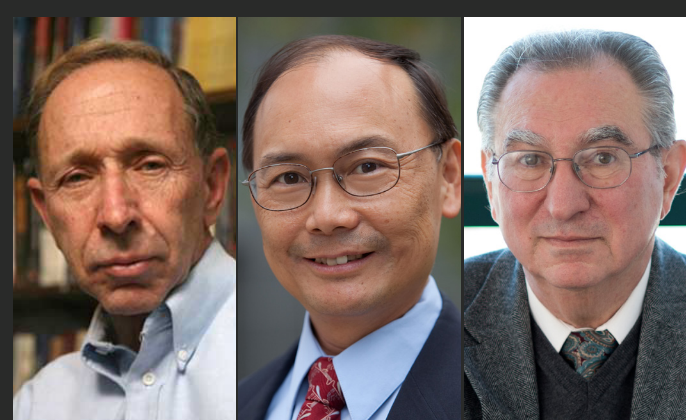
Patrick Mercier is the first-ever ECE recipient of an Arnold O. Beckman Young Investigator Award. The 2015 Beckman Award will support Mercier’s work on cellular-scale bioelectronics and “exploring new frontiers in biology.” The award usually singles out promising young faculty in chemistry or life sciences, but it also fosters “the invention of methods, instruments and materials that will open up new avenues of research in science.”

HONORING ENGINEERING EDUCATORS

In Spring 2015, the UC San Diego Chancellor’s Associates honored ECE Prof. **Laurence Milstein** with a Faculty Excellence Award. He was cited for his scholarship and overall contribution to the campus and community. Milstein accepted the award for Excellence in Graduate Teaching. He was the only Jacobs School of Engineering faculty member among the 2014-15 awardees. Milstein is also the first ECE professor honored in the annual awards since the Chancellor’s Associates began handing them out in 1991.

In 2014, Distinguished ECE Prof. **Charles Tu** received an IEEE Region 6 Outstanding Educator Award. Region 6 covers the western U.S., including Alaska and Hawaii. Tu was cited "for exceptional leadership in engineering education and dedication to the IEEE student branches of the San Diego Section." He is no stranger to education awards: As far back as 2006, Tu was named Engineering Educator of the Year by the San Diego County Engineering Council.

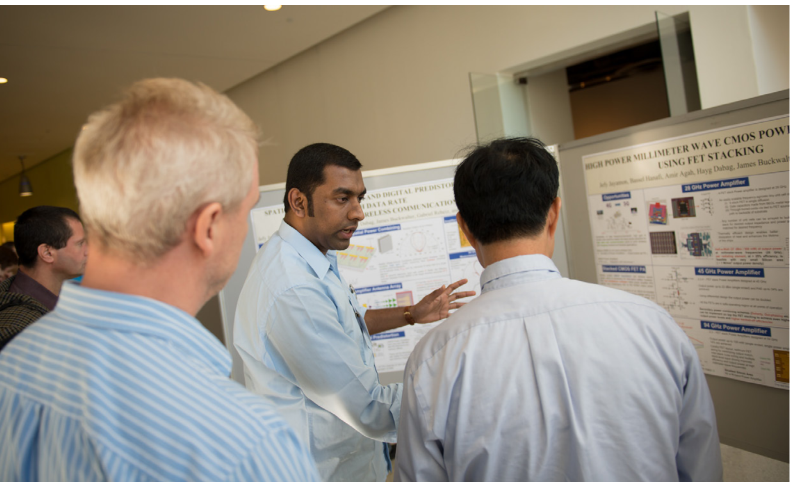
ECE Adjunct Professor **John Proakis** received the IEEE James H. Mulligan, Jr., Education Medal in 2014. Known as a digital communications expert, inspiring educator, and prolific writer, Proakis has helped shape electrical engineering and digital communications programs and composed textbooks that have influenced graduate students worldwide. He also developed an outstanding reputation of providing inspired teaching and supervision of students with an academic career that began in 1969. In announcing the Mulligan medal, IEEE cited Proakis for “contributions to electrical engineering education through influential textbooks and inspiring leadership in integrating research and education.” He is also widely known for his 10 textbooks, including “Digital Communications” (McGraw Hill), now in its fifth edition.



5G WIRELESS AND THE INTERNET OF THINGS

The Center for Wireless Communications (CWC) staged its second 5G Forum on Next-Generation Wireless Systems and Applications in mid-May 2015. ECE faculty played a key role not only in organizing the forum, but also as the primary source of speakers, including professors Peter Asbeck, Sujit Dey, Ian Galton, Gert Lanckriet, Patrick Mercier, Truong Nguyen, Al Pisano, Bhaskar Rao, Ramesh Rao and Gabriel Rebeiz. “First- and second-generation wireless was all about voice technology, and 3G and 4G were all about data,” said CWC Director Dey. “Different people working in wireless technologies have different views about the direction 5G is headed, and we in academia are working with our partner companies to define it. We expect, for example, that 5G networks will have 1,000 times more capacity and other such quantitative parameters, but I believe it will be much more than that.”

Many companies are developing infrastructure to support some of the most talked-about features of 5G wireless: always-on and on-demand connectivity both indoors and outdoors, with very low and predictable time delays, all in a device that’s cheaper, lighter, more secure and more energy-efficient than current smartphones. More than 100 representatives from companies, including Yahoo!, Intel, Ericsson, Samsung, Mitsubishi Electric, Nokia, Keysight Technologies, Symantec Research Labs, and Kaiser Permanente, attended the two-day forum.



The key takeaway? In the words of keynote speaker and Ericsson Chief Technology Officer Erik Ekudden, “5G technology will go way beyond the smartphones, TVs, tablets and other devices that we’re using today.” Although advances in wireless technology will soon make it possible to download gigabytes of data in a second from our phones (allowing us to watch 3D video or work and play in the cloud from our devices), 5G will also lead to improvements in augmented reality, industry automation, wearable devices, mission critical apps (such as e-health applications) and self-driving cars.

The so-called Internet of Things (IoT) — which wirelessly connects common objects like home-lighting systems and appliances — is shaping up to be another major focus for 5G developers.

Some speakers at the 5G Forum talked about device-to-device communication, an enhancement of today’s 4G LTE technology that could minimize reliance on cell towers. If so, it could be a major step in the direction of energy efficiency. For his part, the CWC director is leading an effort to save power consumed by base stations by switching off the antennas from time to time and sometimes leaving them idle. This strategy can also be applied to batteries, which can draw power from them in various bursts (rather than continuously draining them), and leave them idle periodically to give them time to rest.

“A challenge with renewable energy like solar and wind is its intermittent nature, with power generation inconsistent throughout the day,” said CWC’s Dey. “By matching the energy consumption of the base station with the solar/wind energy generation we can reduce grid power usage.”

“As soon as you move above a few gigahertz (on the wireless spectrum), power becomes extremely expensive,” noted Keysight’s Pierpoint. “That’s going to be one of the key things with 5G, especially with higher millimeter wave frequency, all of which I can tell you we’re not well set up to deal with. We believe going forward you’re going to need some key performance indicators, so these are definitely research topics.”

Optimizing data rate, reliability and security is crucial for many of the technologies that are emerging from the tail-end of LTE and the early stages of 5G. These range from mobile health applications to the avalanche of big data produced by medical devices and other Internet-connected devices on the so-called “Internet of Things”. To keep pace with emerging ideas for dealing with the wireless Internet of Things, CWC’s Dey pledged to broaden the dialogue at future forums by involving more companies from application domains to help guide 5G requirements and the scope of CWC’s 5G research. http://5g.ucsd.edu

POWER ENGINEERING

ECE has developed a new series of courses in Power Engineering to address the anticipated need for engineering professionals in the energy field. Fields of renewable energy including solar and wind, electric and hybrid electric vehicles, power supplies and UPS systems, pulsed power, and power systems, have commanded increasing interest from students as well as relevancy in the research community. There is strong demand for power electronic and power system engineers, and this demand is expected to grow very quickly in the near future. Graduates with a desire to work in these fields must have a comprehensive understanding of power converters and electric machines, as well as strategies suitable for controlling them. Following is a quick look at the five initial courses in Power Engineering to be offered by ECE, and the types of jobs that are available and require this expertise against the backdrop of high demand for power electronic and power systems engineers that is expected to grow in future.

POWER SYSTEM ANALYSIS AND FUNDAMENTALS

This course introduces concepts of large-scale power system analysis: balanced three-phase systems, single-phase and three-phase transformers, per unit system and single line diagram, transmission line modeling, and power flow study. It provides the fundamentals for advanced courses and engineering practice on electric power systems, power electronics, electric machinery, smart grid, and electricity economics. The course requires implementing some of the computational techniques in simulation software. Graduates taking this course would be better positioned to seek jobs in power system planning, distribution systems, transmission line design, and smart grid systems.

ENERGY CONVERSION

AC and DC machines are widely used in many modern energy conversion applications, including propulsion for hybrid-electric vehicles, power system grid, distribution system, industrial companies, electric vehicles, wind energy generation, and flywheel energy storage systems. Interest in electric machines is steadily increasing because of the flexibility of controls offered by modern power electronic circuits. Principles of electro-mechanical energy conversion, fundamental concepts of magnetic circuits, and the steady-state performance of direct current, induction, and synchronous machines will be discussed in this course. This course provides fundamentals of energy conversion in electromechanical systems and understanding of three-phase system operation.

INTRODUCTION TO POWER ELECTRONICS

This course aims to teach you how to become an electrical engineer who is able to get something to work. Power electronic circuits provide the means for efficient control and conversion of electric power through the use of solid-state switches. Applications of power electronics include switch-mode power supplies, DC/DC and DC/AC converters, electric and hybrid electric drives, high-voltage DC networks (HVDC), and renewable and hybrid generating systems, among many others. This course provides a conceptual foundation for the analysis and design of power electronic circuits, covering principles of operation of AC/DC and DC/DC converters. Also, thermal design and protection of the power converters will be covered. Graduates with a desire to work in renewable energy including solar and wind, electric and hybrid electric vehicles, power supplies and UPS systems, pulsed power, and power systems, need to have a good understanding of power converters as well as strategies suitable for controlling them.

POWER ELECTRONICS II

This course provides an education for seniors and graduate students on high-frequency power converters. Design and control of DC/DC converters, PWM rectifiers, single-phase and three-phase inverters, power management, and power electronics applications in renewable energy systems, motion control, and lighting will be presented. Synthesis and analysis techniques will be developed, while applications and advances of the high-frequency switching power converter in renewable energy and electric vehicles will be presented. Graduates hoping to work in renewable energy of all kinds should have a good understanding of power converters as well as strategies suitable for controlling them. Students will design and simulate a power conversion system for a real project.

POWER SYSTEMS OPERATION AND CONTROL

This course introduces the basic concepts as well as analysis and optimization methodologies underlying reliable and economical operation and control of power systems. The topics include economic dispatch, linear programming, unit commitment, dynamic programming, fuel scheduling, hydrothermal coordination, optimal power flow, state estimation, and control of generation. Economic and reliable operation of any power system requires tradeoff between economics and reliability. Many different practical power system operation problems, corresponding optimization formulations and solution techniques are discussed in the course. It provides the fundamentals for advanced courses and engineering practices in electric power systems, smart grid, and electricity economics.

MEDICAL DEVICES AND SYSTEMS

In July 2015 ECE selected eight new projects and awarded fellowships in the second round of the Medical Devices and Systems (MDS) Initiative – an effort to encourage collaboration between ECE and the UCSD medical community. Teams of ECE faculty members, in partnership with physicians from the UC San Diego Medical Center or VA Hospital, competed to apply electrical and computer engineering core competencies to needs in the medical field. Following are the eight projects selected by MDS for the 2015-'16 academic year (with ECE faculty in *italics*):

CONTEXT RECOGNITION WITH SMARTPHONES AND WEARABLE SENSORS

Amelia Eastman, *Gert Lanckriet*, Kevin Patrick, *Nuno Vasconcelos*

PI Gert Lanckriet designs and develops intelligent systems that automatically recognize a person's context (such as "running at the beach and listening to music" or "sitting in a bar and smoking") using smartphones or smartwatches and naturally-worn mobile sensors (e.g., accelerometer, GPS, magnetometer, and heart-rate monitor). The system enables effortless logging of daily behavior – contributing to the treatment and research of chronic medical conditions. This project will collect first-of-its-kind data from many participants in free-living conditions, using a mobile app (for iPhone and Android) that enables collection of sensor data and context labels with minimal effort on the part of subjects. The resulting data set, using machine learning, will allow the researchers to train context-recognition systems and to evaluate their predictions. The data will later be anonymized and published. The lab will recruit over 50 test subjects for data collection. If you are interested, please contact Yonatan Vaizman (yvaizman@ucsd.edu) or Kat Ellis (kellis@ucsd.edu).

AN EEG ANALYSIS PIPELINE FOR FM-BASED AMBULATORY EEG SYSTEM

Harinath Garudadri, *Patrick Mercier*, *Vikash Gilja*, Naznin Virji-Babul

Over 1.7 million Americans suffer from mild traumatic brain injury (mTBI) annually, and there is no objective gold standard for measuring the extent of such injuries. Guidelines for athletes are purely subjective, so athletes may return to play before full recovery – leaving them vulnerable to devastating outcomes such as second-impact syndrome. This MDS project aims to develop a low-power, clinical grade, ambulatory electroencephalography (EEG) system embedded in a football helmet that is linked to a wireless stadium network for real-time monitoring of all players (on the field and off). PI and Qualcomm Institute research scientist Harinath Garudadri and colleagues are also developing an automated, real-time EEG data analysis pipeline to monitor the degree and severity of impacts along with changes in the brain's electrical activity continuously during game play. The goal is to demonstrate the acquisition of artifact-free, high dynamic range EEG data with wearable form factors and prepare for clinical studies.

CLINICAL TRANSLATION OF LOW-IMPEDANCE HIGH-DENSITY CONFORMABLE PEDOT

***Vikash Gilja*, *Shadi Dayeh*, Eric Halgren, David Barba**

Today mapping of brain tumors and epilepsy relies on electrical stimulation of implanted, metal-based electrodes spaced several millimeters apart, yet recording neural activity from finer-scale, poly(3,4-ethylenedioxythiophene) polystyrene sulfonate (PEDOT:PSS) electrode arrays would increase spatial scale and signal fidelity by orders of magnitude – providing additional information to inform decisions about tumor resection boundaries, etc. Today's macroelectrodes are over 100 times larger than the organic PEDOT:PSS array contacts, and they can pass more electrical current safely for stimulation. The contacts are deployed on a parylene substrate that is under 4 microns thick, allowing it to be highly conformable to the contours of a brain. The team has received IRB approval for testing on humans. Under PI Vikash Gilja, the investigators from ECE, Radiology and Neurosurgery will test the conformable array in geometries compatible with current surgical approaches. They also plan to customize microelectrode configurations for the clinical setting.

A MAGNETIC FLOW CYTOMETER FOR B-CELL MALIGNANCY DIAGNOSIS AND FOLLOW-UP

***Drew A. Hall*, *Eric Fullerton*, Frank Zhao**

The most common symptom of B-cell lymphomas – swelling of lymph nodes – is a common side effect of many infections and diseases. There is no easy way to diagnose the swelling as a lymphoma (much less differentiating among the 20 different types of lymphoma), so to be proactive about diagnosis, many patients are subjected to invasive biopsies unnecessarily. Under PI Drew Hall, researchers from ECE, UC San Diego Medical Center and the VA hospital are developing a highly sensitive and specific portable device to diagnose B-cell lymphomas in peripheral blood. The device would enable "liquid biopsies" that maintain the diagnostic rigor of traditional biopsies, but require only a simple blood draw. The device would use magnetic-based sensing technology (like in hard disk drives) but in the form of magnetic nanosensors and magnetic nanotags to detect fragments of lymphoglandular bodies that carry the CD20 receptor from the cell surface. Sample preparation could be done in a doctor's office, and the test would return results within 20 minutes.

A MULTI-MODAL INTEGRATED PROBE FOR REAL-TIME CLOSED-LOOP CONTROL OF EPILEPSY

***Duygu Kuzum*, *Patrick Mercier*, Anna Devor**

Thirty percent of epilepsy cases worldwide remain drug resistant and untreatable. Epilepsy drugs commonly fail because of their toxicity, side effects, or failure to reach seizure onset zone by crossing the blood-brain barrier. The most effective solution to treat or control epilepsy without the side effects could be determining the microcircuits responsible for epileptic activity and developing targeted local and on-demand interventions acting only on the affected regions of the brain. The researchers are developing an integrated probe for real-time, closed-loop control of epileptic seizures with optical stimulation. The probe will consist of transparent graphene electrodes for electrophysiological sensing, and optical waveguides delivering light for optogenetic stimulation (waveguides later to be replaced with integrated LEDs). The stimulation offers immediate control of specific cell populations using light-sensitive opsins for on-demand, real-time control of epileptic seizures. An interface circuit will be developed to sense specific epileptic waveforms and trigger optical stimulation to stop seizures.

ELECTRIC-FIELD IMAGER AND STIMULATOR TO ACCELERATE WOUND HEALING

***Tina Ng*, *Ian Galton*, *Yuhwa Lo*, Todd Costantini**

Experts in electrical systems and tissue regeneration are collaborating on a better treatment for wounds. Wounded epithelia tissues generate a significant lateral electric field (25-150mV/mm) that is actively regulated by intact cells to transport ions – and direct cell migration to the wound. Applying external electric stimulation near injured tissue has been shown to accelerate wound healing, but using contact electrodes on a wound is not recommended because of the risk of infection. The team is developing a non-invasive device to monitor and manipulate the wound's local electric field, which they hope will provide local feedback to improve significantly the effectiveness of electrical stimulation therapy. The solid-state sensor and stimulator sheet will be implemented in thin-film transistor technology and tested on mouse wound models and surfaces simulating human wounds. The next step will be to integrate sensors and stimulation microelectrodes to offer precise control of electric stimulation to speed up wound healing.

SMART NOISE MANAGEMENT SYSTEM FOR HEARING AIDS

***Bhaskar Rao*, Harinath Garudadri, Carol Mackersie, Arthur Boothroyd**

In a prior study funded by NIH/NIDCD, PI Bhaskar Rao and colleagues from UC San Diego and SDSU implemented a fully functional hearing-aid simulation (demonstrated at ECE Alumni Day 2015), and it is now being used to investigate self-fitting protocols. The simulation runs on a laptop and includes sub-band amplification, wide dynamic-range compression, and adaptive feedback cancellation. Industry partner Starkey has supplied the team with prototypes of its own hearing aids for use in self-fitting R&D. The goal is to develop a novel, smart noise management (SNM) system for improving intelligibility in multiple noisy environments. The system would use data-driven sparse dictionaries, which are learned using a suitable machine-learning algorithm. The SNM system will implicitly and adaptively discriminate and classify sound components to improve intelligibility in noise.

Smart noise management for hearing aids

DESIGN OF A HIGHLY-ARTICULATED, LOW-PROFILE FLEXIBLE ROBOT FOR COLORECTAL ENDOSCOPY

***Michael Yip*, *Joseph Ford*, Bard Cosman, Samuel Ho**

PI Michael Yip and colleagues from ECE, Surgery and Gastroenterology are designing and building a highly-articulated, flexible and endoscopic robot to be used for colorectal endoscopy. Currently, this procedure is performed using handheld endoscopes, with a simple bending articulation of the tip of the device. Without direct control of the full shape of the endoscope, the device tends to push and scrape against the walls of the colon. This can lead to loops forming on the endoscope, resulting in distension and visceral pain. The proposed robot will have embedded, full-length shape control using micromotors with twisted-thread actuators to control shape, and by distributing the actuators along the endoscope's body, they will provide local control of bending with the dexterity to match the complex shape of the colon anatomy. Robotic shape control will minimize contact with tissues, avoid looping effects and reduce pain to the patient, and improve control and navigation of the endoscope.

UNDERSTANDING INFORMATION: HOW WE GET IT, HOW WE USE IT, HOW TO BENEFIT FROM IT

For most computer users, information is only valuable when it serves a context-specific purpose, such as providing the GPS coordinates for a new restaurant or a list of search results for a query on airline flights to Fiji.

But for ECE Prof. Tara Javidi, understanding how people acquire and use information in various engineering applications is just as valuable. She has won a succession of NSF grants dealing with questions of information acquisition in four contexts: cognitive networking, enhanced spectrum access, computer vision and social networking, and how to best control information flow in large cyber-physical systems such as datacenters or smart energy grids.

ECE Prof. Tara Javidi (right) explains an information algorithm

The main thrust of all Javidi's projects has been to combine tools from control theory, information theory and statistics to jointly optimize data collection, analysis and processing. "In most inference and learning applications, often the existence of a set of collected samples/data is assumed and the designers focus on how information can be mined and inferred from this data," said Javidi. She notes, however, that with the abundance of sensing technologies and the massive scale of many cyber-physical systems, "a decoupled process of data collection introduces a large degree of inefficiency. In particular, the problem of information collection cannot be ignored or taken for granted without introducing inherent loss of performance."

Javidi and her collaborators are taking a novel approach — trying to predict which sensing and data collection resources are best utilized, where, and when. "We want to take that a step forward," explained Javidi. "Say I want to look at the data from a large electricity grid to predict failures (small or cascading) or even typical aspects of the network operation such as what time of day is best for doing certain energy-rich tasks. To do so, I need to predict which piece of data is most informative, where and when, but also which piece of information can add reliability to such a prediction.

"Practically speaking, this means that an efficient design must address how, when and where certain sensors in certain areas of the grid need to be turned on and which piece of information needs to be moved around in the network."

The problem, says Javidi, is that these types of large, cyber-physical systems are so ever-changing, and have so many sensors, that collecting all possible data typically results in a glut of information. This may be inefficient and overwhelming in terms of processing, and it also makes the data collection excessively expensive and resource-intensive.

"There are two sets of problems at the core of the proposed work: one is that of scale and decentralization of control, and the other is the trade-off between cost, accuracy, and dimension of data," continued Javidi. "In modern, large-scale, cyber-physical systems, it is not feasible for a central 'decision-maker' to regulate the information from the sensors. So what we need to do is control the information in a fairly localized fashion, so it's more efficient and scalable, and at the same time be careful about the nature of information exchange to ensure reasonably accurate global knowledge."

To address scalability and decentralized design, Javidi and her team can extrapolate from results of a now-ending project on "Inference by Social Sampling." The motivation behind the research was to see what information about the world could be derived from a social network by asking certain questions or by looking for certain clues, such as how frequently a topic appears in online conversations.

"You look at the way your friends are interacting, and from that you try to determine what types of global behavior the network might see," she explained. "Here the critical issue is that in a social network, any individual user only has access to decentralized information held in their local social circle. However, the users' fairly rich social connectivity allows for the information to be disseminated across the network globally, albeit at a slower time scale. In the design of cyber-physical systems we extend this line of work and reasoning to find out how we can design a mechanism through which global information sharing is achieved through local interactions."

In addition to studying these problems of network scale and decentralized control of information, Javidi is studying a second class of problems: the tradeoffs that arise when acquiring information. These tradeoffs chiefly include the effects on the speed of information acquisition, accuracy of the acquired information, and the cost of collecting the data.

Javidi notes that many problems in data acquisition today involve scenarios where an entity needs to collect information but also to control how much and what type of information it collects. "In fact, when gathering a limited amount of information, there is often an inherent tradeoff between how fast information is acquired and how accurate the information is," she noted. "You want to be smart about the measurements you're taking because the value of the information varies over time."

Javidi and her former student, Mohammad Naghshvar (PhD '13), who is now at Qualcomm Research, first carefully examined the challenges of active hypothesis testing and the difficulty of controlling uncertainty sequentially. Javidi says that initially these challenges "felt like a control problem, a resource allocation, sensor scheduling problem. But then we noted that this really is an information theory/statistics problem."

They approached the problem by applying what they knew about how radios transmit knowledge over a channel (by coding and decoding the information) and applying it to the understanding of sensor scheduling, for example. They eventually cracked the problem by combining analytical tools from statistics, information theory and control theory, specifically stochastic control theory. (The conclusions formed the basis of Naghshvar's PhD dissertation, "Active Learning and Hypothesis Testing".)

"We showed that while variants of the same problem have appeared in the literature for each of these fields, a combination of tools and viewpoints are necessary to fully understand the fundamental trade-offs in the problem of information acquisition," said Javidi. "We showed that an optimized process of information collection faces a fundamental tradeoff between speed and accuracy, which becomes further complicated by the cost and feasibility of data collection and sensor management." The results of this study appeared in the prestigious Annals of Statistics*.

In more recent projects, Javidi and her collaborators are tackling specific applications of her theoretical work to the context of cognitive networking, wireless frequency spectrum management, as well as sequential rendering and processing of images and video, and decision problems in computer vision and cognition. But Javidi argues that "this is only the tip of the iceberg."

"There has already been research into how to make accurate decisions with the data you have," Javidi concluded. "That's not new. What's new with this research is now we're advocating that in a cyber-physical system – instead of mindlessly collecting all possible information and centralized processing of this information – we must, in a manner similar to what an experienced clinician often does, prioritize which information is most valuable over time and space, and how it can be collected and processed in a scalable and cost-effective manner."

*M. Naghshvar, T. Javidi, "Active Sequential Hypothesis Testing," The Annals of Statistics, Vol. 41, No. 6, December 2013.

NEW NETWORKS, NEW RESEARCH QUESTIONS

As networks change, so do the ways in which they can be studied. Engineers at UC San Diego are beginning to apply rigorous scientific methods to a range of new and emerging networks – including the networks of people who use the Internet. Case in point: the headline-grabbing, UC San Diego-led study, "Detecting Emotional Contagion in Massive Social Networks." In March 2014, ECE Prof. Massimo Franceschetti and Ph.D. candidate Lorenzo Coviello were part of the team that provided a roadmap to a new engineering subfield called "network science" that has also attracted collaborators from the social sciences.

In the 2014 study, researchers analyzed over a billion anonymized status updates among more than 100 million users of Facebook in the United States for signs of "social contagion." Positive posts beget positive posts, the study found, and negative posts beget negative ones, with the positive posts being more influential, or more contagious. To identify possible causal relationships in the massive data set, the researchers needed to find a mathematical model capable of representing the data. "Our goal was to provide a model to capture causative effects using observational data. This was the main problem we were facing at the beginning of the project," says Coviello, first author on the paper, who developed a model based on an external variable that influences the emotions of people—rain. "We cannot control weather," added Coviello, "but if it's a rainy day, it's like we are running an experiment."

Using this model, the researchers analyzed a billion Facebook updates from people in the 100 most populous U.S. metropolitan areas. In doing so, they discovered that rainy weather reliably changed the tenor of posts, increasing the number of negative posts by 1.16 percent and depressing the number of positive posts by 1.19 percent. The researchers used the rain-induced change on the emotional content to estimate the spill-over effect on friends who live in different cities and are not experiencing the same weather. "Our study suggests that people are not just choosing other people like themselves to associate with but actually causing their friends' emotional expressions to change," said UC San Diego political scientist James Fowler. "We have enough power in this data set to show that emotional expressions spread online and also that positive expressions spread more than negative."

As the emerging discipline of network science develops, researchers will have the tools to study more kinds of new networks in increasingly rigorous ways, which should open up new possibilities for research collaboration between engineers and social scientists.

*I. Coviello, Y. Sohn, A.D.I. Kramer, C. Marlow, M. Franceschetti, N.A. Christakis and J.H. Fowler, "Detecting Emotional Contagion in Massive Social Networks," PLOS One, March 2014.

CROSS-LAYER OPTIMIZATION AND SPOOFING COGNITIVE RADIO

Wireless communication systems involve many layers, such as the medium access control (MAC), application (APP), and physical (PHY) layers. Most researchers focus on one layer, e.g., video compression, or error correction coding. Cross-layer optimization approaches take a broader view, trying to design the layers of the system so they are jointly optimized*. ECE professors Pamela Cosman and Laurence Milstein have been working on PHY-APP and MAC-APP cross-layer optimization problems. In compressed video, some bits are more important than other bits to the reconstructed visual quality, so they can, for example, be given more physical-layer resources. Bits which are more important can be given greater reliability through more forward error corrections, through hierarchical modulation, or through spatial diversity in a MIMO system. These techniques can substantially increase the capacity of a video transmission system.

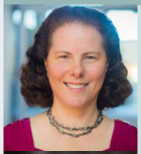
In a separate collaboration, professors Cosman and Milstein are collaborating on another challenge in wireless communication – cognitive radio. Users are divided into primary users, who can access the communication channel at any time, and secondary users, who must sense whether a channel is being used before they access it. One mechanism involves a sensing interval during which primary users transmit and secondary users sense the channel. Alternatively, in a data transmission interval, both types of users can transmit. In a military context, an adversary of the cognitive radio system with a fixed power budget could use power either to jam the communications during the data transmission interval, or to put out energy during the sensing interval, in order to make the secondary users believe that the channels are already in use by primaries. This is referred to as spoofing. ECE's Cosman and Milstein studied the optimal division of the power budget between jamming and spoofing under different system loads, power budgets, and channel models.

*D. Wang, L. Toni, P.C. Cosman, and L.B. Milstein, "Resource Allocation and Performance Analysis for Multiuser Video Transmission over Doubly Selective Channels," IEEE Transactions on Wireless Communications, Vol. 14, Issue 4, pp. 1954-1966, April 2015.

PACKET LOSS VISIBILITY

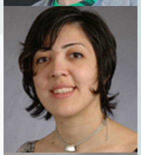
When packets of compressed video are transmitted over an error-prone network, some packets may be lost, delayed, or corrupted. Some of these losses may be visually annoying to the end viewer of the video, whereas other losses will be invisible. ECE Prof. Pamela Cosman and her students have studied the visibility of packet losses in compressed videos for many years. Many factors affect visibility, including location of the lost slice in a given frame, frame type, and the amount and complexity of motion. Now, based on extensive human observer experiments, they have developed models for predicting the visibility of video packet losses, and have designed strategies for giving extra error protection to the more important packets.

FACULTY



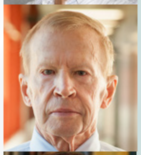
PAMELA COSMAN
Image and video compression for transmission over wireless, Internet or other telecommunications networks, image and video processing, computer vision, video quality evaluation.

MASSIMO FRANCESCHETTI
Information science of complex networks and systems: random networks, wave propagation in random media, wireless communication, control systems with information loss, algorithms and protocols.



TARA JAVIDI
Wireless systems: stochastic and optimal resource allocation, network design and control, multi-access control, and topology design in ad-hoc systems.

YOUNG-HAN KIM
Statistical signal processing and information theory, with applications in communication, networking, data compression, and information processing.



ROBERT LUGANNANI
Processes with an impact on communications, particularly those which are stochastic (random) in nature.

LAURENCE MILSTEIN
Digital communications theory and wireless communications, specializing in spread-spectrum systems; signal transmission; bandwidth considerations; and broadband wireless.

ALON ORLITSKY
Communications and information theory, with particular interests in signal processing, data compression, speech recognition and learning theory.

BHASKAR RAO
Digital signal processing, estimation theory and optimization theory, with applications to digital communications, speech signal processing, human-computer interactions.

RAMESH RAO
Architectures, protocols and performance analysis of wireless, wireline and photonic networks for integrated multimedia services.

PAUL SIEGEL
Information theory, coding theory, and communication theory, with applications to digital data storage and transmission.

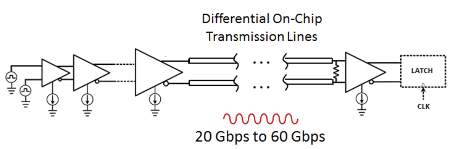
ALEXANDER VARDY
Information theory, specializing in error-correcting codes for data transmission and storage.

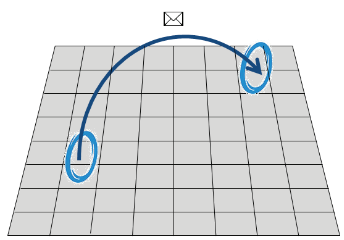
KENNETH ZEGER
Information coding and data compression, information theory, and signal processing, including image and speech processing.

ULTRA-LOW LATENCY ON-CHIP NETWORKS

Moore's Law continues to enable the doubling of cores in each successive process generation, making it possible to integrate many more processors in future. Current technology has already enabled chip-multiprocessors and multiprocessor systems-on-chip with hundreds of cores. These many-core processors are becoming vital in all aspects of computing, from emerging cloud computing services to mobile Internet applications. A central architecture choice in the design of many-core processors is the choice of the on-chip network architecture. The on-chip network fabric enables distributed applications to communicate and interoperate in an orchestrated and efficient manner. The performance of distributed applications is often limited by the performance of the on-chip network fabric. For example, threads are often dependent on data produced by other threads, and they often have to wait for such data to arrive before they can proceed. Delays in data delivery can dramatically reduce the available parallelism in very harmful ways. Therefore, high throughput and low latency are two very important goals in the design of on-chip network fabrics, as is low power consumption. Unfortunately, as the number of integrated cores and the size of on-chip networks continue to grow, major challenges must be confronted and overcome in order to reach each of these design goals.

To tackle these challenges, ECE Prof. Bill Lin, his team and collaborators have been developing fundamentally new classes of on-chip network architectures based on high-speed transmission lines. Unlike current hop-by-hop, on-chip networks that can suffer from very long delays when communicating from one side of the chip to the other, well-designed transmission lines can deliver packets across the chip in as little as two nanoseconds, which is potentially more than one-to-two orders of magnitude faster than conventional on-chip networks that require many hops and long queuing delays between hops. Further, for the same throughput, well-designed transmission lines can deliver up to 60 Gigabits per second of throughput over just a pair of wires at substantially lower energy consumption than conventional on-chip network technologies for the same throughput.





GETTING AROUND INFORMATION OVERLOAD

The tremendous growth of enterprise data exposes enterprise users, especially knowledge workers, to too much information, creating a problem commonly known as Information Overload. One way around the problem is to have a personal assistant who can inform you if he or she feels something deserves your attention. Now imagine that you could get that same personalized attention and service -- from the smartphone in your hand.

It could happen sooner than you think, thanks to research under way in ECE's Mobile Systems Design Laboratory. To help knowledge workers access useful content more efficiently, Ph.D. candidate Chetan Verma and ECE Prof. Sujit Dey are developing an enterprise file recommendation system in collaboration with Symantec Research Labs. The goal is to model user access patterns and automatically determine if a created file or folder in a repository is relevant for the knowledge worker. As a result, knowledge workers do not need to search through numerous remote repositories or even be aware of the generation of relevant data. The system can serve personalized recommendations, while complying with access controls and privacy settings set by the enterprise. The overall approach is divided into two phases: offline training, activity of enterprise users is monitored to capture recurring patterns or interests in models; and online classification of models applied to new content to determine if it should be recommended to the user or not.

According to the researchers, current evaluations based on real-world data show that it is highly feasible that enterprise employees will be able to use file metadata to build a low-footprint system that can correctly predict useful files with high accuracy.

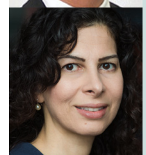
STOCHASTIC COMPUTING

Stochastic computing (SC) acts on data encoded by bit-streams, and is an attractive, low-cost and error-tolerant alternative to conventional binary circuits in key applications such as image processing and communications (and particularly for future Internet of Things devices). In work slated to appear at the International Conference on Computer-Aided Design in November 2015, ECE Prof. Andrew Kahng and his group have explored the use of energy reduction techniques such as voltage or frequency scaling in SC circuits. In their work to date, the researchers have shown that, due to inherent error-tolerance, SC circuits operate satisfactorily without significant accuracy loss even with aggressive scaling that improves their energy efficiency by orders of magnitude. To find the minimum-energy operating point of an SC circuit, the Kahng group proposes a Markov chain model that allows users to quickly explore the space of operating points. They are also investigating opportunities to optimize SC circuits under such aggressive scaling. Prof. Kahng found that logical and physical design techniques can be used to expand significantly the already powerful accuracy-energy tradeoff possibilities in stochastic computing circuits. The project's simulation results, published in 2015, show that the optimized SC circuits can tolerate aggressive voltage scaling with no significant degradation in the signal-to-noise ratio after a 40 percent supply-voltage reduction (1V to 0.6V), leading to a 66 percent energy saving.

FACULTY

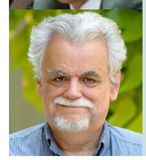
SUJIT DEY
Mobile cloud computing, wireless multimedia, adaptive networks and applications, green computing and communications, and embedded systems-on-chip.

ANDREW KAHNG
Physical design of Very Large Scale Integrated (VLSI) circuits, and the International Technology Roadmap for Semiconductors.



FARINAZ KOUSHANFAR
Embedded and cyber-physical systems security, adaptive and low-power embedded systems design, and design automation, in particular of domain-specific computing and learning applications.

BILL LIN
Novel embedded system and VLSI architectures for communications and networking applications.

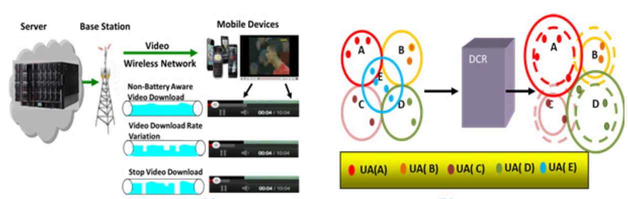


KEVIN QUEST
Collisionless shock structure, magnetic reconnection, as well as plasma waves and instabilities.

GREEN WIRELESS NETWORKS

In order to increase the energy efficiency of base stations and battery lifetime of mobile devices, PhD candidate Ranjini Guruprasad and ECE Prof. Sujit Dey in the Mobile Systems Design Lab, together with collaborators from San Diego State and T-Mobile, are exploring the design of "green" wireless networks.

Two key frameworks are guiding development of green wireless networks. The first aims at increasing the battery life of mobile devices during video download, while ensuring Quality of Service (QoS) to users. Figure A depicts a typical video download scenario from the video server through the base station to the mobile device over the wireless network (represented by the pipes, and the blue portion indicates the amount and flow of data). As opposed to conventional non-battery aware video download techniques, the proposed battery efficient video download techniques utilize device buffer characteristics to vary video bit rate and video download rate (shown as rise and fall in second pipe), including stopping download at times (shown as gaps in the third pipe). The RF and baseband components of the base station and mobile device are reconsidered in a way that reduces the battery load imposed by the RF and baseband processing on the mobile device. Initial results have shown that it is possible to increase the battery lifetime by up to 60 percent with nominal loss in user experience by using battery-efficient video download techniques compared to conventional non-battery-aware video download techniques.



The second framework is called Dynamic Cell Reconfiguration (DCR). It aims to reduce the power consumption of base stations while satisfying the QoS user requirements. DCR is motivated by the observation that the cellular networks are over-provisioned in terms of coverage and capacity. As depicted in Figure B (right), DCR adapts cell (base station) size and capacity as well as adapting transmit power while maintaining user QoS requirements. Initial simulation studies showed that, compared to the conventional practice of keeping all base stations on and transmitting at maximum transmit power using all the RF chains, initial simulation studies showed that using DCR techniques can achieve more than 70 percent savings in total wireless network power consumption, and up to 40 percent savings in individual base station power consumption.

ELECTRONIC CIRCUITS & SYSTEMS

MAGNETIC SENSORS FOR MOBILE HEALTH

Infrastructure already exists to integrate medical diagnostic tools with mobile technology (a trend known as mobile health, or mHealth). Taking advantage of this opportunity, the Biosensors and Bioelectronics research group, run by ECE Prof. Drew Hall, is working on developing low-cost, point-of-care biosensor devices that allow individuals to test biological samples, analyze data, and aggregate the results for study by medical professionals – all without the need for a centralized laboratory or bulky and expensive equipment – and he believes that ultrasensitive and magnetic sensing technology may hold the key.

“This technology can empower individuals and trained professionals with the necessary equipment to quantitatively diagnose diseases at the point of care,” said Hall. “It also allows diseases to be diagnosed earlier due to the ultrasensitive nature of the device, which will ultimately lead to better treatment outcomes and reduced costs. The technology also provides a means for preventative healthcare with increased portability and wireless infrastructure, as well as the ability to track therapy and disease progression, as well as low-cost diagnostic platforms for resource-limited settings such as developing countries. They will help to democratize health care.”

Several different types of magnetic sensors have been used to detect biomarkers (proteins, nucleic acids, and cells) labeled with magnetic tags. The most sensitive are the same as the sensors used in nearly every hard-disk drive: magnetic tunnel junction (MTJ) sensors. While MTJ sensors surpassed giant magnetoresistive (GMR) sensors in hard-disk drive read heads nearly a decade ago, they have yet to make a substantial impact in biosensing due to manufacturing challenges and substantially higher noise (despite the increased transduction efficiency that is 10-50 times higher than GMR sensors).

According to Hall, his research addresses these issues and makes progress towards mobile health point-of-care medical diagnostic and monitoring platforms* by addressing the underlying research challenges. Those challenges include: integration of MTJ biosensors with the associated electromagnet on the same chip; transduction based on temporal magnetic signatures afforded by the tight integration of the magnetic biosensor and electromagnet; and development of a novel scheme to remove flicker noise and temperature dependence. “The results of this research will provide a pathway toward ubiquitous, wearable and point-of-care biomolecular sensors,” said Hall. To demonstrate those advances, Hall is building two mHealth platforms: one for point-of-care diagnosis of cardiac biomarkers for acute myocardial infarctions in an ambulatory setting; the other, a wearable biosensor for continuous, long-term monitoring of wounds.

FACULTY

PETER ASBECK
Design and development of high-speed transistors and integrated circuits, power amplifiers and optoelectronic devices using compound semiconductor materials and heterostructures.

IAN GALTON
Data converters, frequency synthesizers, clock-recovery systems, DSP techniques to mitigate the effects of non-ideal analog circuit behavior in mixed-signal ICs implemented in CMOS silicon chips.

DREW HALL
CMOS integrated circuits for bioelectronics, biosensors, lab-on-a-chip devices, and other biomedical devices and systems.

PATRICK MERCIER
Energy-efficient circuit and system design, including miniaturized devices for biomedical applications that employ novel RF, analog, digital, power management, and energy harvesting architectures.

GABRIEL REBEIZ
Design of silicon RFICs for microwave and millimeter-wave systems, including phased arrays and low-power circuits, active and passive imaging system, THz CMOS and SiGe electronics, RF MEMS, cognitive radios, antennas, radars.

DANIEL SIEVENPIPER
Novel electromagnetic structures for antennas and other applications.

BANG-SUP SONG
CMOS integrated circuits for communications, design of integrated filters, frequency synthesizers, RF circuits, analog-digital data converters, and other devices critical to wireless communications.

ULTRA-MINIATURIZED ENERGY MANAGERS

Power management integrated circuits (PMICs) are critical for just about all mobile electronic systems, especially those powered by lithium-ion batteries (to step down the 2.8-4.2V battery voltage). Shrinking their size while maintaining performance is critical for the unobtrusive, low-power wearable sensor systems for health monitoring and more that researchers are developing in UC San Diego’s new Center for Wearable Sensors.

Case in point: the ultra-miniaturized energy management chips developed in the lab of ECE Prof. Patrick Mercier, who is co-director of the Center. Some such systems may even scavenge energy from the environment, including sweat on the skin. Data would be wirelessly sent to your phone or perhaps to your doctor.

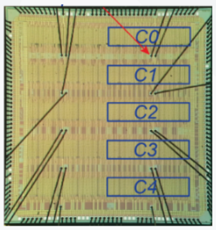
“Whether you are powering a device from a battery or an energy harvester, the voltage of the battery or energy harvester is never the same voltage that you need for your sensor or your wireless transceiver,” explained Mercier. “So we need intermediate chips to efficiently process and manage that energy.”

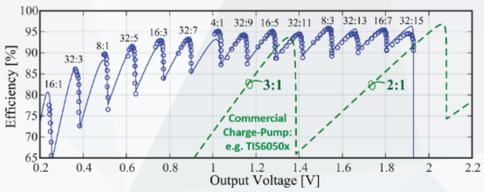
Anywhere there are electronics, these types of chips are needed. “Our smartphones have dozens of them,” added Mercier. “Unfortunately, current energy management circuits are either too large to support the needs of next-generation mobile phone or wearable applications, or are too inefficient and eat into a device’s battery life. Our goal with this research is to design PMICs that are both small and energy-efficient.”

Ultra-miniaturized energy management chips from the lab of ECE Prof. Patrick Mercier

CAPACITORS VS. INDUCTORS

Switched-inductor architectures are often the preferred choice for 'stepping down' battery voltages because they can easily regulate to arbitrary levels. However, conventional PMICs require relatively large inductors to regulate efficiently: fundamental physics limits the achievable power conversion efficiency when using smaller inductors. In fact, inductors are one of the main components that sets the thickness of modern smartphones, and are also the reason why laptop chargers (bricks) are so large. There is not much engineers can do to decrease their volume while also maintaining high efficiency. This is becoming an increasingly important challenge in mobile applications where space is at a premium (e.g., smartphones, smartwatches, and Internet of Things devices).



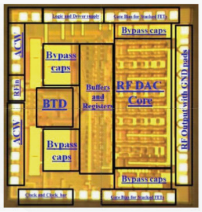


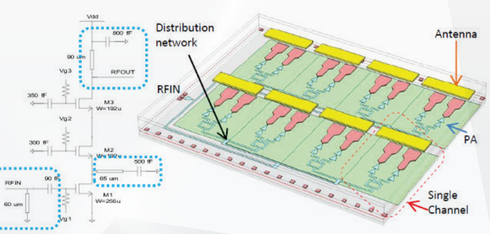
In contrast, Prof. Mercier and Loai Salem*, a PhD student in the ECE department, have developed a di erent kind of PMIC based on switched-capacitors (SC) rather than switched-inductors. The benefit of going to SC architectures are that discrete capacitors offer 7x the cost savings, while taking up 8x smaller footprint than today's standard inductor-based PMICs. Unfortunately, SC PMICs are only efficient at discrete ratios of input-to-output, limiting their regulation capability across the voltages that modern processors and radios require. To address this, Mercier and Salem have invented several new SC DC-DC converter topologies that increase the number of ratios to enable smooth voltage regulation, while doing so in a manner that keeps efficiency high and utilizes a minimum number of capacitors compared to any prior-art. Recent prototypes are now pushing beyond the performance capabilities of comparable switched-inductor research prototypes and commercial parts in both size and efficiency.

*L.G. Salem and P.P. Mercier, "A Battery-Connected 24-Ratio Switched Capacitor PMIC Achieving 95.5%-Efficiency," in Proc. IEEE Symposium on VLSI Circuits, June 2015.

HIGH-EFFICIENCY CMOS POWER AMPLIFIERS

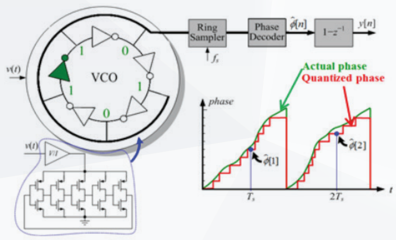
Complementary metal-oxide semiconductor (CMOS) technology plays a key role in most integrated circuits, but until recently was excluded from power amplifier applications because of its low voltage-handling capabilities. The situation is now changing because of the introduction of field-effect transistor (FET) stacking technology, in which a number of FETs are placed in series to share the overall voltage. Using this approach, ECE Prof. Peter Asbeck and colleagues have achieved new records for efficiency and power with CMOS power amplifiers at a range of frequencies. At 1-2 GHz, an amplifier with output power up to 1.4W achieves peak efficiency up to 65 percent, using digital inputs (so it operates as an amplitude digital-to-analog converter). At frequencies of 80-90 GHz, a single chip stacked CMOS amplifier array provides a record 250mW of radio-frequency output power. The chip has its outputs coupled directly to antennas located on a quartz superstrate placed on top of the CMOS (without direct connection), a technique pioneered by fellow ECE Prof. Gabriel Rebeiz.

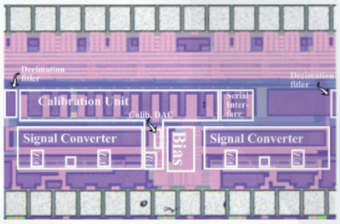




REVOLUTIONARY A-D CONVERTER ARCHITECTURE

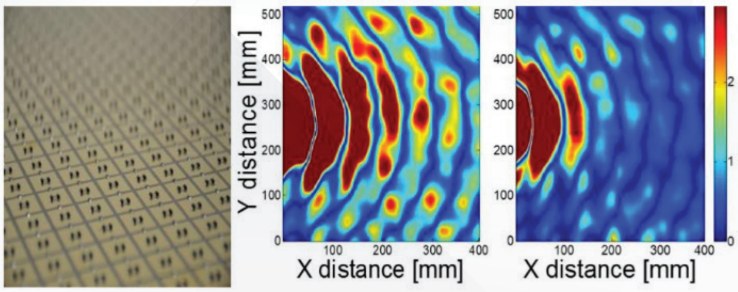
As Moore's Law leads to shrinking CMOS FET dimensions, the analog characteristics of the FETs are progressively worsening. The result: conventional methods for designing mixed-signal circuits can no longer achieve their customary accuracy. ECE Prof. Ian Galton has developed a radically new approach to analog-to-digital (A-D) conversion, in which the input analog voltage controls the frequency of a digital ring-oscillator, and purely digital techniques are used after that to provide an accurate measure of the voltage. The new approach was demonstrated in a 65nm converter that has 12 effective output bits, at an effective sampling rate of about 100 MS/s, and 38mW power dissipation. The same technique could be applied at scaled CMOS nodes, now down to 14nm.





NONLINEAR ABSORBERS

Nonlinear metasurfaces consist of periodic metallic structures which include nonlinear circuit components, and are designed to absorb high power microwaves. The nonlinearity allows the surface to reconfigure its topology, and thus its absorption properties depending on the input power level. ECE Prof. Daniel Sievenpiper and his team have built the first nonlinear absorbing surfaces to mitigate the effects of high-power microwave radiation on electronics. They demonstrated nonlinear absorption, and showed that they can provide better protection than conventional magnetic absorbing coatings. These nonlinear absorbing coatings can be used in future systems for preventing interference or damage to electronics from high power signals. The researchers have also developed the concept for a broadband self-tuning absorber, and are in the process of creating prototypes of this new structure which will allow them to exceed the current bandwidth limits for resonant absorbers.

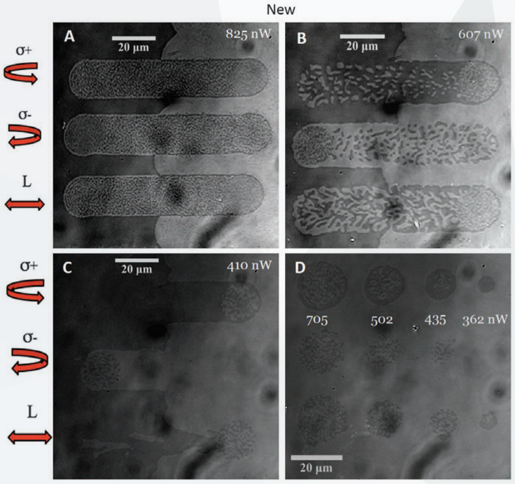


Pending more advances in nonlinear materials, to date researchers have been unable to realize the same type of nonlinear phenomenon at microwave frequencies as exist in the widely-studied self-focusing effect of optical beams. But according to a series of recent papers, including one in Applied Physics Letters*, Sievenpiper and his co-authors have demonstrated self-focused electromagnetic (EM) surface waves on a circuit-based, power-dependent impedance surface. The experiment was achieved on a nonlinear and power-dependent impedance surface. As the surface wave power increases, the self-focusing effect gradually becomes dominant over the natural diffraction effect of the beam, and a narrow, self-maintained beam profile was produced on the surface. As the power was boosted, the surface waves were highly focused to produce a hot spot. According to Sievenpiper and his colleagues, their latest findings may lead to a variety of other RF applications for nonlinear surfaces, such as power-dependent steerable antennas, or defocusing of high-power microwaves.

*Z. Luo, X. Chen, J. Long, R. Quarforth and D. Sievenpiper, "Self-Focusing of Electromagnetic Surface Waves on a Nonlinear Impedance Surface," Applied Physics Letters, Vol. 106, May 2015.

CONTROLLING MAGNETIZATION WITH POLARIZED LIGHT

For a wide range of ferromagnetic materials, researchers from UC San Diego and partner universities in Japan, France and Germany have discovered that the direction of magnetization can be completely controlled by polarized light without the need for magnetic fields. Their research, published in the journal Science* in September 2014, focused on materials currently being developed for high-density storage applications, and the study's findings on magnetization could significantly affect the data memory and storage industries that produce hard disks and magnetic random access memories. What's more, says ECE Prof. Eric Fullerton, a lead investigator on the study and director of UC San Diego's newly-renamed Center for Memory and Recording Research (see box), entirely new applications and types of memory devices could be on the horizon.



Magneto-optical response in zero applied magnetic field of multi-layer samples to various laser polarizations. (Source: Science)

"Our results showing that it is possible to switch magnetic bits using only the polarization of light could significantly simplify the design and improve the speed of magnetic recording," said Fullerton. "Magnetic storage is emerging in the memory market due to demands for higher-density, fast, and low-power, non-volatile memory. As industry trends toward silicon nanophotonics, miniaturization, and photonic-electronic integration, the ability to couple photonic, electronic and magnetic materials could enable completely new applications."

Ferromagnetism's most familiar form is the humble refrigerator magnet, but it is also a core component in many electrical devices, including magnetic storage used in commercial computing applications. In traditional magnetic storage devices, magnetic bits are switched using magnetic fields, a slow process that consumes considerable energy, and it is reaching density limits. Led by Fullerton, the international and interdisciplinary research team tested a rapid-pulse laser on a variety of ferromagnetic materials, including magnetic thin films, multilayers, and granular films. Previously, scientists had only been able to use all-optical control on a small set of ferromagnetic materials that did not lend themselves to data storage applications.

The next step is to scale the technology to write data on the nanoscale (versus the microscale as the team demonstrated) and time scales required for magnetic recording. "There is also a lot of work to understand the underlying mechanisms for optical switching of ferromagnets," added Fullerton. "We showed it works. Why it works and how to optimize it for applications still need to be addressed."

The research team consisted of visiting scholars at UC San Diego from the University of Lorraine in France (professor Stephane Mangin and Ph.D. student Charles-Henri Lambert), and other international partners from the National Institute for Materials Science in Japan, and the University of Kaiserslautern in Germany. Funding was provided by the Office of Naval Research through a Multidisciplinary University Research Award.

*C.-H. Lambert, S. Mangin, B.S.D.Ch.S. Varaprasad, Y.K. Takahashi, M. Hehn, M. Cinchetti, G. Malinowski, K. Hono, Y. Fainman, M. Aeschlimann, and E.E. Fullerton, "All-optical control of ferromagnetic thin films and nanostructures," Science, Vol. 345, Issue 6202, pp. 1337-1340, September 2014.

SAME ACRONYM, DIFFERENT NAME

Established in 1983, the Center for Magnetic Recording Research is changing its name. Henceforth, CMRR will keep the same acronym, but it now stands for Center for Memory and Recording Research. The center's mission remains three-fold: basic and applied research; education at the undergraduate, graduate and postgraduate levels; and technology transfer to the public and private sectors. The change of name to emphasize 'memory' is a natural move because of the expanded research thrust into memory technologies, including non-volatile memories and systems that are becoming an important component of modern computers. The new name will also be important for the future as CMRR pursues major research programs on the fundamental memory properties of materials and devices, as well as new computer paradigms (including quantum computing). ECE Prof. Eric Fullerton remains CMRR's director.

Right: Bust of information theory pioneer Claude Shannon in CMRR building

FACULTY

PETER ASBECK
Design and development of high-speed transistors and integrated circuits, power amplifiers and optoelectronic devices using compound semiconductor materials and heterostructures.

SHADI DAYEH
Overcoming coherency limits in heteroepitaxy of III-V compounds and Si/Ge semiconductor materials, hybrid hetero-integration science and technology, vertical junction photovoltaic devices, neural probes, in-situ microscopy of novel nanoscale phenomena.

ERIC FULLERTON
Magnetic recording and nano-technologies; thin film and superlattice growth, interfacial and thin-film magnetism, x-ray and neutron scattering.

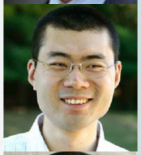
DUYGU KUZUM
Nanoelectronic devices, circuit-level computation in the brain, brain probes.

YUHWA LO
Biomedical devices and systems, bioelectronics, microfluidics, nanophotonics, and semiconductor nanoscaled devices.

TSE NGA (TINA) NG
Printed electronics, flexible sensing systems.

YUAN TAUR
Semiconductor device design, notably the structure and physics of transistors.

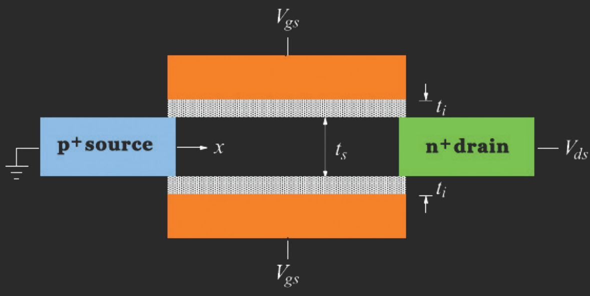
CHARLES TU
Compound semiconductor materials for electronic, optoelectronic, and photovoltaic devices.



JIE XIANG
Nanomaterial synthesis, advanced semiconductor physics, coupled nano- electro-mechanical systems (NEMS).

PAUL YU
Microwave photonics, electronic and opto-electronic devices and advanced materials for use in photonic devices.

TUNNELING TRANSISTORS

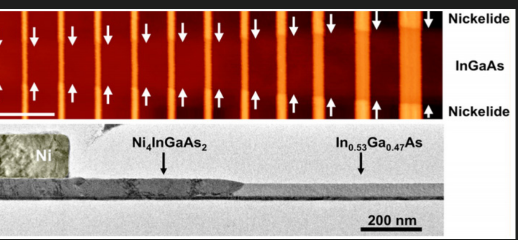


Schematic of the double-gate (DG) TFET.

In the race to succeed the omnipresent metal-oxide-semiconductor field-effect transistor (MOSFET) that has shrunk transistors a thousand-fold since they were introduced in the early 1970s, tunnel field effect transistors (TFETs) have stirred a lot of interest because they promise to deliver steep turn-off slopes, which would, in turn, enable a sharp reduction in supply voltage to below 0.5 V. This is particularly impressive in the world of mobile, always-on computing where power is a critical factor. Yet the downside is the flipside of their principal benefit, because TFETs boast relatively low on-currents as well. Staggered heterojunctions have been proposed to boost the on-current by lowering the barrier height for band-to-band tunneling at the source junction, but abrupt band offsets at the boundary would render inapplicable the conventional uniform field approximation for tunneling probability. In an article in IEEE Transactions on Electron Devices*, ECE Prof. Yuan Taur and ECE students Jianzhi Wu and Jie Min showed that the tunneling barrier in a nanowire TFET is of an exponential nature, with a decay length related to the cross-sectional film thickness or diameter. From that finding, they derived a model for the exponential barrier in closed form, which they then used to investigate the effect of source degeneracy on the on-current and turn-off slope. The researchers concluded from the model that source degeneracy helps the linear region I-V characteristics, but degrades the saturation current. Formulated for a double-gate TFET with an exponential potential barrier, the ECE-developed model generates continuous I-V characteristics with a single integral over the tunneling window, providing insights into the effect of source degeneracy on linear and saturation region currents. The model also showed that the debiasing of V by the channel inversion charge plays a key role in the saturation voltage and linearity of I-V curves.

*Y. Taur, J. Wu and J. Min, "An Analytic Model for Heterojunction Tunnel FETs with Exponential Barrier," IEEE Transactions on Electron Devices, Vol 62, No. 5, pp. 1399-1404, May 2015.

A NANOSCALE VIEW OF COMPOUND III-V SEMICONDUCTORS



First study of solid-state reaction between metal (Ni) and ternary III-V InGaAs nanochannels shows 33% (plus or minus 5%) uniaxial height expansion in formed nickelide segments.

The rapid development of ultra-scaled III-V compound semiconductor devices led to recognition that, at nanoscale, metal-semiconductor contacts and their performance show definite size effects. In a paper published in Nano Letters in 2015*, ECE Prof. Shadi Dayeh and Ph.D. student Renjie Chen reported the first study on the solid-state reaction between metal (in this case nickel) and ternary III-V semiconductor nanochannels (InGaAs) to reveal the reaction kinetics, formed crystal structure, and interfacial properties. The researchers observed a size-dependent nickel surface diffusion dominant kinetic process that gradually departed to a volume diffusion process as the Fin width increases. In turn, the crystalline interfacial relationship was responsible for introducing a uniaxial height expansion of somewhere around 33 percent, plus or minus 5 percent, in the formed nickelide segments, with negligible lateral expansion. The nickelide formation led to both in-plane and out-of-plane compressive strains on the Fin channels that opened up the InGaAs energy bandgap. According to the ECE researchers, the observations advanced understanding and development for self-aligned contacts to III-V nanochannels and for engineering new processes that can enhance their device performance.

In a related story, heterogeneous integration of III-V compound semiconductors to silicon (Si) substrates is seen as a precursor to high-speed electronics and hybrid optoelectronic systems for data processing and communication. Now Prof. Dayeh and colleagues have developed an innovative fab-compatible, hybrid integration process of III-V materials to Si, specifically, from InGaAs thin films to insulator-on-Si. Their findings** "pave the way for incorporating a variety of III-V electronic and optoelectronic devices on a Si CMOS platform," said Dayeh, thus enabling low-power electronic and fully integrated optoelectronic applications.

*R. Chen and S. Dayeh, "Size and Orientation Effects on the Kinetics and Structure of Nickelide Contacts to InGaAs Fin Structures," Nano Letters, Vol. 15, Issue 6, pp. 3770-3779, April 2015.

**X. Dai, B.-M. Nguyen, Y. Hwang, C. Soci and S. Dayeh, "Novel Heterogeneous Integration Technology of III-V Layers and InGaAs FinFETs to Silicon," Journal of Advanced Functional Materials, Vol. 24, Issue 28, pp. 4420-4426, July 2014.

NANOSHELLS AND TANDEM STRUCTURES FOR SOLAR CONVERSION

A multidisciplinary engineering team in the Jacobs School of Engineering developed a new nanoparticle-based material for concentrating solar power plants designed to absorb more than 90 percent of the sunlight it captures and to convert that sunlight to heat. By contrast, current solar absorber material functions at lower temperatures and needs to be overhauled almost every year for high-temperature operations.

Funded by the Department of Energy's SunShot program, ECE Prof. Zhaowei Liu and Mechanical and Aerospace Engineering professors Sungho Jin and Renkun Chen recently published in two separate articles about their work in the journal Nano Energy.

In addition to strength in converting light to heat, the silicon boride-coated nanoshell material* was also able to withstand temperatures greater than 700 degrees Celsius and survive many years outdoors in spite of exposure to air and humidity.

The novel material features a "multiscale" surface created by using particles of many sizes ranging from 10 nanometers to 10 micrometers. The multiscale structures can trap and absorb light (contributing to the material's high efficiency when operating at higher temperatures). The material's ability to absorb sunlight was measured in Prof. Liu's optics laboratory using a unique set of instruments that take spectral measurements from visible light to infrared.

Concentrating solar power (CSP) is an emerging alternative clean energy market that produces approximately 3.5 gigawatts worth of power at plants around the globe — enough to power more than two million homes, with additional construction in progress to provide as much as 20 gigawatts of power in coming years. One of the technology's attractions is that it can be used to retrofit existing power plants that use coal or fossil fuels because it uses the same process to generate electricity from steam.

Current CSP plants are shut down about once a year to chip off the degraded, sunlight-absorbing material and reapply a new coating, which means no power generation while a replacement coating is applied and cured. That is why the SunShot program challenged the UC San Diego team to come up with a material with a substantially longer life cycle that would be able to convert solar energy more efficiently and at much higher operating temperatures. The team is aiming for many years of usage life, a feat they believe they are close to achieving. In their most recent paper**, the researchers reported on successful tests of novel tandem structure combining two different materials with complementary optical properties and microstructure: copper oxide nanowires, and cobalt oxide nanoparticles. Their results demonstrated the efficacy of using novel tandem structures for enhanced light absorption of solar spectrum, with broad applications in solar energy conversion.

Microstructural images of as-made Si-Si boride core-shell nanoparticles: (a) TEM image showing 10-20nm thick Si boride shell, and (b) lower mag SEM image of overall core-shell nanoparticles

*T.K. Kim, J. Moon, B. VanSaders, D. Chun, C.J. Gardner, J.-Y. Jung, G. Wang, R. Chen, Z. Liu, Y. Qiao, S. Jin, "Si Boride-Coated Si Nanoparticles with Improved Thermal Oxidation Resistance," Nano Energy, Vol. 9, pp. 32-40, October 2014.

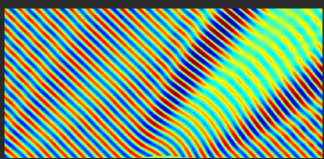
**T.K. Kim, B. VanSaders, J. Moon, T. Kim, C.-H. Liu, J. Khamwannah, D. Chun, D. Choi, A. Kargar, R. Chen, Z. Liu, S. Jin, "Tandem Structured Spectrally Selective Coating Layer of Copper Oxide Nanowires Combined with Cobalt Oxide Nanoparticles," Nano Energy, Vol. 11, pp. 247-259, January 2015.

A CLOAKING DEVICE FOR INVISIBILITY

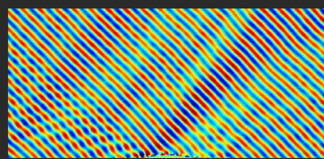
Researchers have developed a new design for a cloaking device that overcomes some of the limitations of existing "invisibility cloaks". In a new study, ECE researchers` have designed a cloaking device that is both thin and does not alter the brightness of light around a hidden object. The technology behind this cloak will have more applications than invisibility, such as concentrating solar energy and increasing signal speed in optical communications.

"Invisibility may seem like magic at first, but its underlying concepts are familiar to everyone. All it requires is a clever manipulation of our perception," said Boubacar Kanté, a professor in the Department of Electrical and Computer Engineering at the UC San Diego Jacobs School of Engineering and the senior author of the study. "Full invisibility still seems beyond reach today, but it might become a reality in the near future thanks to recent progress in cloaking devices."

As their name implies, cloaks are devices that cover objects to make them appear invisible. The idea behind cloaking is to change the scattering of electromagnetic waves — such as light and radar — off an object to make it less detectable to these wave frequencies.



UNCLOAKED



CLOAKED

Schematic of entire metasurface and coordinate system; (inset) unit cell of metasurface

One of the drawbacks of cloaking devices is that they are typically bulky. "Previous cloaking studies needed many layers of materials to hide an object, the cloak ended up being much thicker than the size of the object being covered," said Li-Yi Hsu, electrical engineering Ph.D. student at UC San Diego and the first author of the study, which was recently published in the journal Progress In Electromagnetics Research*. "In this study, we show that we can use a thin single-layer sheet for cloaking."

The researchers say that their cloak also overcomes another fundamental drawback of existing cloaking devices: being "lossy." Cloaks that are lossy reflect light at a lower intensity than what hits their surface.

"Imagine if you saw a sharp drop in brightness around the hidden object, it would be an obvious telltale. This is what happens when you use a lossy cloaking device," said Kanté. "What we have achieved in this study is a 'lossless' cloak. It won't lose any intensity of the light that it reflects."

Many cloaks are lossy because they are made with metal particles, which absorb light. The researchers report that one of the keys to their cloak's design is the use of non-conductive materials called dielectrics, which unlike metals do not absorb light. This cloak includes two dielectrics, a proprietary ceramic and Teflon, which are structurally tailored on a very fine scale to change the way light waves reflect off of the cloak.

In their experiments, the researchers specifically designed a "carpet" cloak, which works by cloaking an object sitting on top of a flat surface. The cloak makes the whole system — object and surface — appear flat by mimicking the reflection of light off the flat surface. Any object reflects light differently from a flat surface, but when the object is covered by the cloak, light from different points is reflected out of sync, effectively cancelling the overall distortion of light caused by the object's shape.

"This cloaking device basically fools the observer into thinking that there's a flat surface," said Kanté. The researchers used Computer-Aided Design software with electromagnetic simulation to design and optimize the cloak. The cloak was modeled as a thin matrix of Teflon in which many small cylindrical ceramic particles were embedded, each with a different height depending on its position on the cloak.

"By changing the height of each dielectric particle, we were able to control the reflection of light at each point on the cloak," explained Hsu. "Our computer simulations show how our cloaking device would behave in reality. We were able to demonstrate that a thin cloak designed with cylinder-shaped dielectric particles can help us significantly reduce the object's shadow."

"Doing whatever we want with light waves is really exciting," said Kanté. "Using this technology, we can do more than make things invisible. We can change the way light waves are being reflected at will and ultimately focus a large area of sunlight onto a solar power tower, like what a solar concentrator does. We also expect this technology to have applications in optics, interior design and art."

This work was supported by a grant from the Calit2 Strategic Research Opportunities (CSRO) program at the Qualcomm Institute at UC San Diego.

*L.-Y. Hsu, T. Lepetit, B. Kanté, "Extremely Thin Dielectric Metasurface for Carpet Cloaking," Progress In Electromagnetics Research, June 25, 2015.

FACULTY

SADIK ESENER
Photonics and opto-interconnects, optical data storage, biophotonics and cancer nanotechnology.

SHAYA FAINMAN
Applied optics and photonics, including 3D imaging, biomedical optics, optical signal processing and nano-photonics.

JOSEPH FORD
Physical optics system design and integration for applications in imaging, communications, and energy.

BOUBACAR KANTÉ
Wave meta-matter interaction, and nano-optics, as well as optical metamaterials, plasmonics, nanoscale-photon management and bio-physics.

ZHAOWEI LIU
Novel nanofabrication techniques and bio-photonics, high-speed and high-spatial resolution bioimaging and sensing, and light control at nanoscale using plasmonic structures.

YUHWA LO
Biomedical devices and systems, bioelectronics, microfluidics, nanophotonics, and semiconductor nanoscaled devices.

VITALIY LOMAKIN
Theoretical and computational electromagnetics, including analytical and numerical models and their application to the analysis and design of electromagnetic devices and systems.

SHAYAN MOOKHERJEA
Photonics, nonlinear optics, quantum photonics, nanotechnology.

GEORGE PAPEN
Advanced photonic systems, including optical communication systems, optical networking, environmental and atmospheric remote sensing.

STOJAN RADIC
Optical communications, information network infrastructure, optics and photonics.

AIM PHOTONICS

ECE faculty are core partners in a massive new photonics manufacturing and research center to be based in Rochester, New York. Vice President Joseph Biden and NY Governor Andrew Cuomo announced the American Institute for Manufacturing Integrated Photonics (AIM Photonics) in July 2015, an effort to push the United States as a worldwide leader in photonics manufacturing. ECE professors Shaya Fainman, Shayan Mookherjea and Albert P. Pisano (who is also Dean of the Jacobs School of Engineering) participated in the winning consortium of 124 companies, non-profit organizations and universities led by SUNY Polytechnic Institute. Other California partners include Caltech and Stanford, as well as three other UC campuses in Santa Barbara, Davis and Berkeley. The UC San Diego researchers have worked extensively in integrated silicon photonics for data communication systems. They aim to develop integrated silicon photonics to lower the energy-per-bit costs of next-generation, high-bandwidth networks. A goal is to build integrated photonics that are scalable and compatible with multiple platforms. The team will also explore technologies leading to smaller, less expensive, ultra-sensitive biochemical and medical sensing devices. Current sensing technologies utilize bulky equipment, which limit their sensitivity and specificity. Existing systems are also expensive. To overcome these limitations, the UC San Diego team will create new chip-scale integrated photonic sensor systems that can be easily integrated with future mobile platforms. Much of the work will be carried out in labs of the Qualcomm Institute on the UC San Diego campus, including its Nano3 nanofabrication cleanroom facility, and Prof. Fainman's Chip-Scale Photonics Testing Facility, which provides accurate, high-speed testing capabilities that are essential for developing new integrated photonic systems.

BREAKING POWER AND DISTANCE BARRIERS FOR FIBER OPTIC COMMUNICATION

Electrical engineers from ECE and the Qualcomm Institute have broken key barriers that limit the distance information can travel in fiber optic cables and still be accurately deciphered by a receiver. Photonics researchers at UC San Diego have increased the maximum power — and therefore distance — at which optical signals can be sent through optical fibers. This advance has the potential to increase the data transmission rates for the fiber optic cables that serve as the backbone of the internet, cable, wireless and landline networks. The research was published in the journal Science. The new study presents a solution to a long-standing roadblock to increasing data transmission rates in optical fiber: beyond a threshold power level, additional power increases irreparably distort the information travelling in the fiber optic cable.

(l-r) Co-authors PhD student Eduardo Temprana and Qualcomm Institute research scientist Nikola Alic in Photonics Systems Laboratory

"Today's fiber optic systems are a little like quicksand. With quicksand, the more you struggle, the faster you sink. With fiber optics, after a certain point, the more power you add to the signal, the more distortion you get, in effect preventing a longer reach. Our approach removes this power limit, which in turn extends how far signals can travel in optical fiber without needing a repeater," said Nikola Alic, a research scientist from the Qualcomm Institute, the corresponding author on the Science paper and a principal of the experimental effort.

In lab experiments, the researchers at UC San Diego successfully deciphered information after it travelled a record-breaking 12,000 kilometers through fiber optic cables with standard amplifiers and no repeaters, which are electronic regenerators. The photonics experiments were performed at UC San Diego's Qualcomm Institute by researchers from ECE's Photonics Systems Group, led by ECE Prof. Stojan Radic.

The new findings effectively eliminate the need for electronic regenerators placed periodically along the fiber link. These regenerators are effectively supercomputers and must be applied to each channel in the transmission. The electronic regeneration in modern lightwave transmission that carries between 80 to 200 channels also dictates the cost and, more importantly, prevents the construction of a transparent optical network. As a result, eliminating periodic electronic regeneration will drastically change the economy of the network infrastructure, ultimately leading to cheaper and more efficient transmission of information.

The breakthrough in this study relies on wideband "frequency combs" that the researchers developed. The frequency comb described in this paper ensures that the signal distortions — called the "crosstalk" — that arises between bundled streams of information travelling long distances through the optical fiber are predictable, and therefore, reversible at the receiving end of the fiber. "Crosstalk between communication channels within a fiber optic cable obeys fixed physical laws. It's not random. We now have a better understanding of the physics of the crosstalk. In this study, we present a method for leveraging the crosstalk to remove the power barrier for optical fiber," explained ECE's Radic, senior author on the Science paper. "Our approach conditions the information before it is even sent, so the receiver is free of crosstalk caused by the Kerr effect."

*E. Temprana, E. Myslivets, B.P.-P. Kuo, L. Liu, V. Ataie, N. Alic and S. Radic, "Overcoming Kerr-induced capacity limit in optical fiber transmission," Science, Vol. 348, No. 6242, pp. 1445-1448, June 2015.

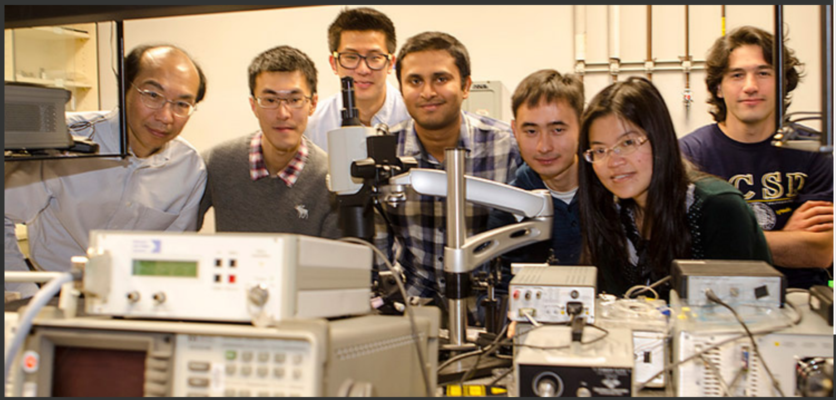
SIGNAL AMPLIFICATION IN OPTOELECTRONICS

A new signal amplification process developed by research team led by ECE Prof. Yuhwa Lo is poised to "fuel new generations of electrical and photonic devices – transforming communications, imaging, and computing." The researchers discovered a mechanism to amplify signals in optoelectronic systems that is far more efficient than the process long used by the semiconductor industry based on impact ionization.

"For many years, the semiconductor industry has relied on photodetectors for optoelectrical conversion, followed by low-noise electronic amplifiers to convert optical signals into electronic signals with amplification to enable information detection and processing," said Lo, who also oversees the Qualcomm Institute's Nano3 nanofabrication facility, where the new technique was tested. "Avalanche photodetectors that use impact ionization became the devices of choice and have remained so for many decades," in spite of their high operating voltage – typically 30 to 200 volts – and rapidly worsening noise with amplification.

Writing in Applied Physics Letters*, Lo and his collaborators report on a far more efficient mechanism to amplify signals. They dubbed it the cycling excitation process, or CEP. Hoping to reduce voltage (power) and noise, the team looked at the complex interactions among electrons in localized and extended states and phonons (a unit of vibrational energy arising from oscillating atoms within a crystal).

Like with most semiconductors, the device demonstrated at UC San Diego has a p/n junction, a boundary between two semiconductor materials within a single crystal of semiconductor. The structure is called a 'heavily compensated p/n junction' because, said Lo, "the only unique feature is that both sides of the p/n junction contain a substantial amount of counter doping," i.e., a large number of donors exist in the p-region, with acceptors in the n-region.



Yuhwa Lo (far left) with team members (l-r) Yuchun Zhou, Alex Zhang, Iftikhar Niaz, Lujiang Yan, Yu-hsin Liu and Mahmut Kavrik

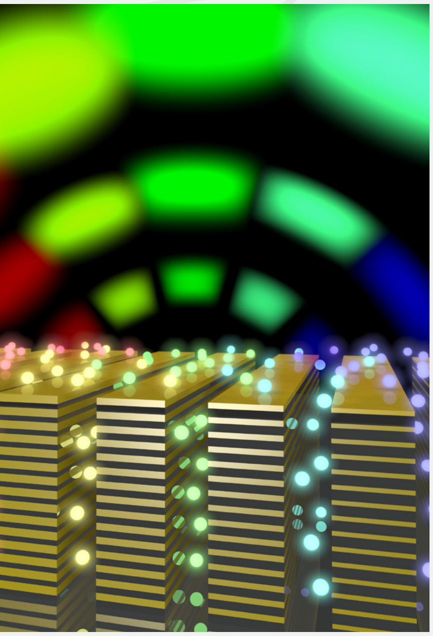
The key discovery and innovation for the amplification process was the use of compensating impurities as the intermediate steps for electron-hole pair generation. Explained Lo: "Impurity states are localized, so the conservation of momentum that limits the efficiency for conventional impact ionization can be greatly relaxed and leads to higher signal amplification efficiency and reduced operation voltage."

The team believes that the new signal amplification mechanism could be used in a wide array of devices and semiconductors, creating a new paradigm for the semiconductor industry.

"With an efficient gain mechanism at an operation voltage compatible with CMOS integrated circuits, it's possible to produce communication and imaging devices with superior sensitivity at a low cost," Lo pointed out. "By using other methods along with optical excitation to produce the seed carriers that initiate the cycling excitation process, we can conceive new types of transistors and circuits and extend the scope of applications beyond optical detection."

*Y. Zhou, Y.-H. Liu, S.N. Rahman, D. Hall, L.J. Sham and Y. Lo, "Discovery of a Photoresponse Amplification Mechanism in Compensated PN Junctions," Applied Physics Letters, Vol. 106, January 20, 2015.

FAST-BLINKING LEDS FOR COMMUNICATING UNDERWATER



Artificial metamaterial increases light density and blink speed of fluorescent light-emitting dye molecule. (Courtesy Liu Research Group)

ECE Prof. Zhaowei Liu's research bridges the areas of nanostructured materials, nanoscale photonics and plasmonics as well as their potential applications in optoelectronics and the biological sciences. In 2014 Liu and colleagues announced first steps in a project to develop fast-blinking LED systems for underwater optical communications.

Writing in the journal Nature Nanotechnology*, the researchers – including fellow ECE professors Paul Yu and Eric Fullerton – showed that an artificial metamaterial can increase the light intensity and "blink speed" of a fluorescent light-emitting dye molecule. The nanopatterned layers of silver and silicon in the new material sped up the molecule's blink rate to 76 times faster than normal, while producing an 80-fold increase in its brightness.

"The major purpose of this program is to develop a better light source for communication purposes," Liu said. "We have proved that this artificial, manmade material can be designed to enhance light emission and intensity, but the next step will be to apply this on conventional LEDs."

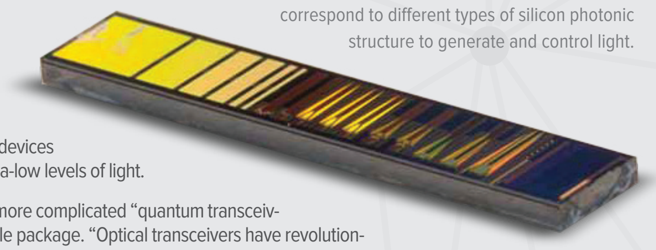
Extreme blinking speed – ultrafast modulation – in blue and green LEDs is a missing link that is necessary for increasing the rate at which information can be sent via optical channels through the open water, such as between ships and submarines, submarines and divers, underwater environmental sensors and unmanned underwater vehicles, or other combinations. If dramatically improved, optical wireless communications could eventually replace underwater acoustic communications systems for short-distance applications. Acoustic communications are limited by slow speed and low data rates and may possibly cause distress to whales, dolphins and other marine life. To do this, they must develop blue and green LED systems that blink one or two orders of magnitude faster than today's blue and green gallium nitride (GaN)-based LEDs. In underwater optical wireless communication systems, data is converted from an electrical signal to optical waves that travel through the water from a light source such as an LED to an optical receiver. Blinking blue and green LEDs are already used to transfer information through the water. (Blue and green LEDs are used because their light is less apt to be absorbed by the water than other colors.) The metamaterials developed by the researchers are synthetic, with properties not found in nature, and are specially designed to accelerate the light generation process. The materials are designed to have extremely strong interactions with the light emitters that are specific to the wavelength--or color--of the emissions. In the new report, the researchers used a dye molecule that gives off a yellow-green hue. So the next step will be to pair the materials with the blue and green LEDs.

"The design of the materials may not be the hardest thing," says recent graduate Dylan Lu (PhD '14), first author on the Nature Nanotechnology paper, who is now a postdoctoral scholar in Prof. Liu's group. "I think the major challenge, to apply it to LEDs, will be an integration issue." In 2015, Lu won ECE's Best Ph.D. Thesis Award for his dissertation on "Plasmonic Metamaterials for Active and Passive Light Control."

ECE's Liu has received $500,000 in funding from the Office of Naval Research to develop fast-blinking blue and green LED systems. "We started from advances in fundamental material research," said Liu, but now, "we want to transfer the knowledge to the LED business."

*D. Lu, J.J. Kan, E.E. Fullerton and Z. Liu, "Enhancing Spontaneous Emission Rates of Molecules Using Nanopatterned Multilayer Hyperbolic Metamaterials," Nature Nanotechnology, Vol. 9, pp. 48-53, January 2014.

EMITTING AND CONTROLLING QUANTUM LIGHT FROM SILICON



Silicon photonic chips are 3x15 millimeters; horizontal stripes correspond to different types of silicon photonic structure to generate and control light.

Electrical engineers from UC San Diego have demonstrated a way to emit and control quantum light generated using a chip made from silicon—one of the most widely used materials for modern electronics. The ECE researchers recently described their new device's performance online in the journal Nature Communications*.

Practical applications of quantum optics will seem more feasible if devices for generating and controlling these photons can be manufactured using conventional materials from the semiconductor industry such as silicon. These devices could have applications in secure communications, precise measurements of motion or shape, and sensing using ultra-low levels of light.

For example, the UC San Diego researchers suggest that their silicon pair-generation chip could be used as part of a more complicated "quantum transceiver" module, which would eventually integrate a controllable photon source with a sensitive photon detector in a single package. "Optical transceivers have revolutionized data communications, and tens of millions of these devices are used to send billions of bits of data all over the internet and inside data centers every second," said ECE Prof. Shayan Mookherjea. "But these transceivers contain lasers that are made using compound semiconductors, not silicon, which would be cheaper and easier to manufacture. The fact that silicon can be used to make a quantum photonic pair source, and that its spectral properties can be fine-tuned easily, is exciting from a technological point of view."

"Silicon is known to be a poor light-emitting material — there is no silicon diode laser, for example, despite many decades of research," added Mookherjea. "However, if you want to make a chip that emits quantum light such as pairs of single photons which are entangled in some quantum mechanical properties and you want to do it at room temperature so that the chip can be widely used, then it turns out that silicon is actually quite a good material for generating photons."

"A beam of light from a laser diode is shone into the chip, and for each pair of photons from the input beam that is absorbed by the material, a pair of photons is produced at two slightly different frequencies—one higher than the input and the other lower than it, such that the total energy is conserved," explained Marc Savanier, a postdoctoral researcher with the Micro-Nano-Photonics research group in ECE. "Our chip is compact — only millimeters in size — and it works at room temperature, and only requires a simple telecommunications-grade low-power laser diode as the input, and filters to separate the two daughter photons from their parent beam."

Spontaneous Optical Nonlinear Mixing (SONM), the process of photon creation exploited by the researchers in their device, has been shown in a number of different materials such as glass fibers, crystals, and semiconductors like silicon.

"One thing you have to do, though, is to pattern the silicon into waveguides and micro-resonators which enhance the optical intensity at specific wavelengths," noted Savanier. "These features are less than a micrometer in height and width—far less than the thickness of a human hair, for example. A piece of silicon by itself is not going to have a very high SONM coefficient and it won't generate a measurable number of entangled photon pairs."

In their work, the researchers show how the degree of entanglement is related to a measurement called the Joint Spectral Intensity (JSI), and describe a technique for measuring the JSI experimentally using single photon detectors.

"Previously, controlling the JSI of a photon pair source required a large assembly of optical components on an optical table, and painstaking alignment of spatial light modulators, cylindrical lenses and mirrors" said Savanier. "This made the photon-pair source apparatus bulky, vibration-sensitive, expensive, and not portable. The unique structure of our chip makes this process much simpler, more compact and lightweight."

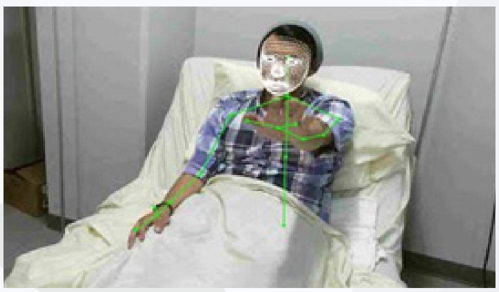
*R. Kumar, J.R. Ong, M. Savanier, S. Mookherjea, "Controlling the Spectrum of Photons Generated on a Silicon Nanophotonic Chip," Nature Communications, Vol. 5, No. 5489, November 2014.

FIBER-COUPLED MONOCENTRIC IMAGING

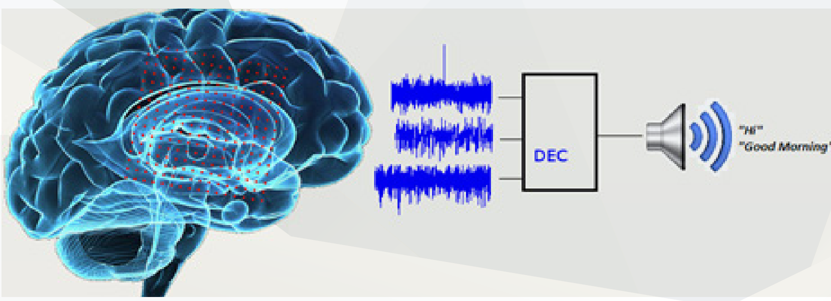
ECE Prof. Joseph Ford of the Photonic Systems Integration Laboratory leads the DARPA Soldier Centric Imaging via Computational Camera (SCENICC) research project on computational panoramic imaging systems, working with collaborators at Distant Focus Corp. The researchers use custom optics with hemispherical glass elements and 3D, high-index optical fiber bundles to achieve an unprecedented level of light collection and resolution for extreme wide-angle cameras. The current prototype is a video camera that captures 25 million pixels (megapixels) per frame of video. The camera's F/1.35 lens collects the image with a 126-degree field of view – in a fraction of the space required for conventional optics.

ENABLING A BIG DATA APPROACH TO HUMAN NEUROSCIENCE

Translating advances in neuroscience into effective treatments for neurological and psychological disorders relies on linking brain activity and behavior with high fidelity. Novel implantable neural interfaces are poised to scale clinical brain-mapping resolution by a factor of 10-100x within the next decade. Capitalizing on these advances requires a complementary scale-up in the duration and precision of clinical behavioral monitoring to enable a big data approach to human neuroscience. Toward this vision, ECE Prof. Vikash Gilja and colleagues aim to augment patient monitoring in the epilepsy monitoring unit, where patients are surgically implanted with cortical electrodes and monitored continuously for days to plan for brain-tissue resection. Neural activity is analyzed to localize probable seizure foci and to map brain areas necessary for language, motor and sensory function. To identify these areas, the clinical standard uses a manual and intensive procedure requiring sequential electrical stimulation of implanted electrodes. This technique has limited spatial resolution (~ 1 cm) and does not scale to higher channel counts. To overcome these limits, the team introduces a set of minimally-intrusive computer vision and physiological sensors to quantify and classify patient activity and sensory experience. These classifications, applied to free behavior and cued tasks, can passively map neural activity to potential function. This novel mapping technique and advances in neural interfaces enable higher-resolution brain mapping, while also increasing the precision of clinical decision-making and surgical planning. Furthermore, Gilja and his team intend to use data from the system to design novel brain-machine interface systems based on real-time decoding of motor movements, speech production, and behavioral context.



Mock patient room at ECE with sensor system output overlay (left) and illustration of a brain-machine interface estimating speech output from neural measurement in real time.



TOUCH, DEPTH AND EPIDERMAL ELECTRONICS

Combining bio-electronics, computer vision, computer gaming, high-dimensional machine learning, and human factors, ECE professors Pamela Cosman, Sujit Dey, and Truong Nguyen, together with collaborators in Bioengineering and Computer Engineering, are developing a home physical therapy assistance system that could replicate at home the physical therapy that a patient might currently have to receive in a therapist's office or other clinical setting. The long-term goal is to monitor patient kinematics and physiology during home exercises, with an avatar on a screen guiding the patient to move correctly with arrows and color coding (see figure). Using a Kinect color/depth camera and wireless epidermal electronics transferable to the skin with a temporary tattoo, the 3D movement trajectory and detailed pattern of muscle recruitment are derived and compared against the exercise done with an expert therapist. The project involves hand- and body-pose estimation and tracking algorithms that are robust to rapid motion and occlusions, and development of machine learning and avatar-rendering algorithms for multi-modal sensor fusion and expert-trained optimal control guidance logic, for both cloud and local usage. The system aims to provide real-time feedback to make home sessions as effective as office visits with a physical therapist, reducing the time and money required for full recovery.

Left: Snapshot of physical therapist and patient avatar rendering for shoulder extensor stretch, with guidance rendering

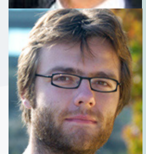
Right: (a) Hand joint tracking: input and results, (b) Classification of 45-degree arm swing motion by integrating skeleton (processed for spatial/temporal consistency) and spatio-temporal model (from body joint tracking)

FACULTY

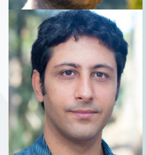
PAMELA COSMAN
Image and video compression for transmission over wireless, Internet or other telecom networks, image and video processing, computer vision, video quality evaluation.

KENNETH KREUTZ-DELGADO
Nonlinear dynamics and control, adaptive sensory-motor control, multibody systems theory, learning theory and pattern recognition, computational vision, and data compression.

VIKASH GILJA
Working with diverse set of electrophysiological and imaging methods in humans to advance engineering science of brain-machine interfaces (BMIs) through basic R&D of clinical applications.



GERT LANCKRIET
Machine learning, applied statistics, convex optimization, with applications to music information retrieval, computer audition, computational genomics, finance.



SIAVASH MIRARAB
Computational biology and bioinformatics, parallel computing, and big data analysis.

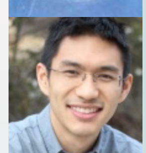
TRUONG NGUYEN
Image and video processing and communications, 3D video, complex wavelet transform and applications, motion-compensated frame rate conversion for interlaced and progressive video.

BHASKAR RAO
Digital signal processing, estimation theory and optimization theory, with applications to digital communications, speech signal processing, human-computer interactions.

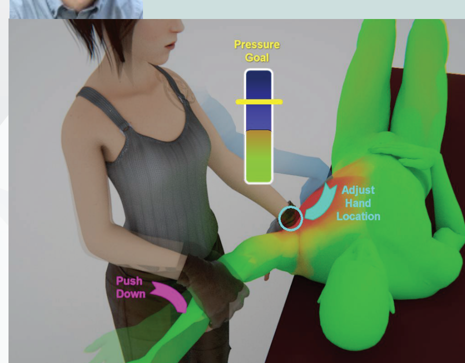
DAVID SWORDER
Guidance and control systems, signal processing of heterogeneous streams of data, including algorithms to filter, process and respond to simultaneously arriving streams of unlike data, estimation problems of hybrid systems.

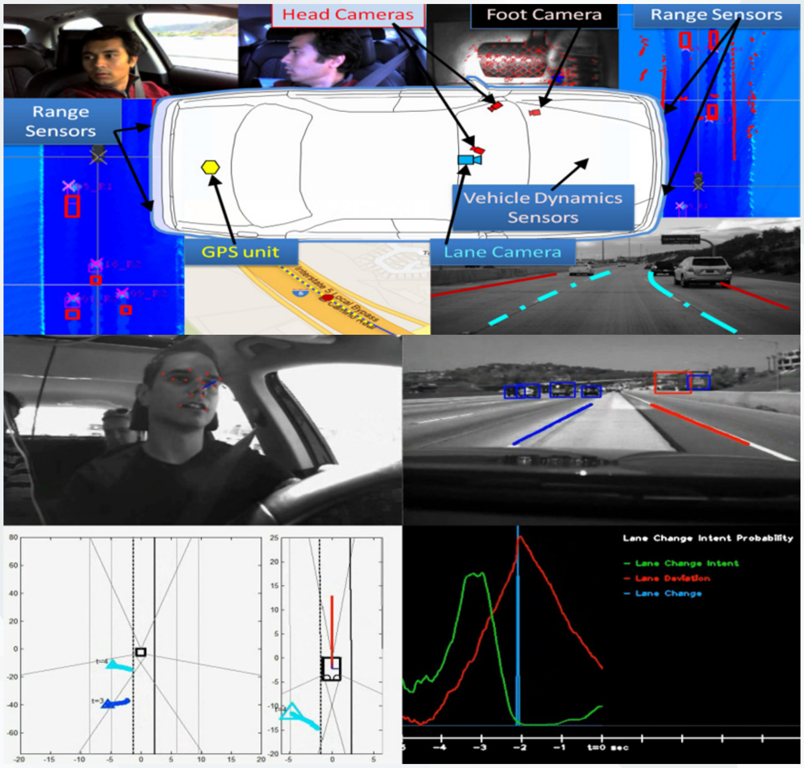
MOHAN TRIVEDI
Computer vision, robotics and sensors for intelligent transportation systems, intelligent environments, biometrics for facial recognition, and sensor-based intelligent systems.

NUNO VASCONCELOS
Computational modeling of biological vision systems, object recognition and tracking, action recognition, surveillance of crowded environments, multimedia search, classification, and retrieval, medical imaging, design of machine learning algorithms.



MICHAEL YIP
Robotics and controls, medical robotics, soft robotics, optimization, machine learning, sensors and actuators, control theory, computer vision, image guidance and augmented reality, teleoperation, and haptics.





Top: Multimodal, multi-sensory intelligent vehicle testbed
Bottom: Predicting driver intent to change lane

COMPUTER VISION FOR INTELLIGENT VEHICLES

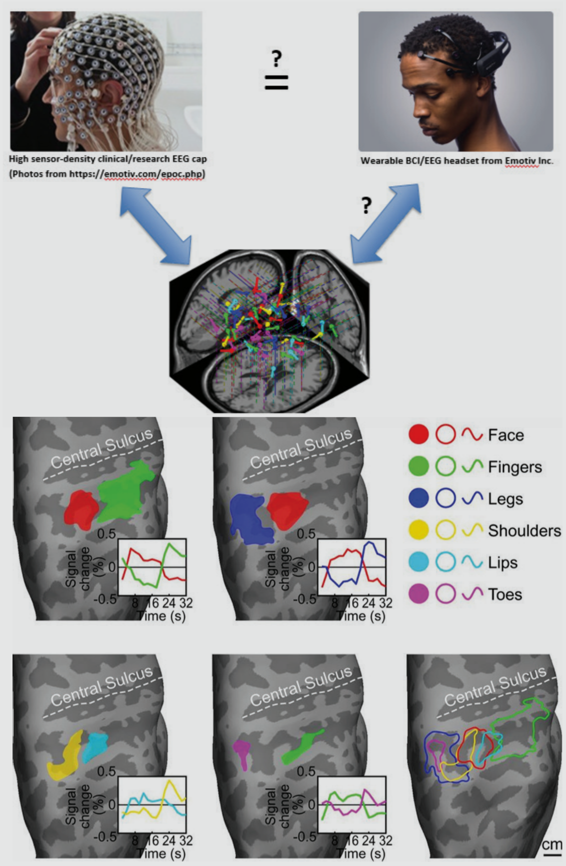
The Laboratory for Intelligent and Safe Automobiles (LISA) continues to pile up awards and new funding at the intersection of NSF and corporate R&D efforts such as the Audi Urban Intelligent Assist project. Under ECE Prof. Mohan Trivedi, the LISA team developed an important reputation as a leading provider of robust machine vision for so-called "active safety" (e.g., when a car automatically brakes if it perceives danger and the driver isn't paying attention.)

The lab's multiple automotive testbeds have allowed it to develop algorithms and techniques for monitoring driver attention inside the car, as well as everything that goes on outside the vehicle via the lab's multi-modal, multi-sensory intelligent vehicle testbeds. Each testbed has instrumented a commercial vehicle with internal and external cameras, range sensors, GPS units, vehicle dynamics sensors, and substantial computing and communications power to crunch the numbers in near-real time and feed the important information back to the driver. The ECE researchers focus on visual attention and target identification by monitoring the driver's head with a dedicated "head cam" and algorithms for analyzing the driver's eye movements. Similarly, a "foot cam" contributes importantly to the task of predicting whether the driver will make a turn, slow down or otherwise inadvertently anticipate an activity involving application of the foot to either the brakes or the accelerator. In addition to predicting the intent of a driver based on these and other human gestures, a major current focus of LISA research is on machine learning for efficient object detection – in hopes of preventing accidents automatically by alerting the driver sooner to a potential collision. ECE's Trivedi received the Outstanding Research Award (see Faculty Honors, page 5), in part, based on the lab's success in predicting the intention of a driver to make a lane change. To produce that intent, car sensors studied hand gestures and analyzed the interactivity. LISA researchers also used what they call "integrated synergies" to determine the efficient detection of lanes and vehicles surrounding the car.

PROCESSING (BRAIN) SIGNALS

ECE Prof. Ken Kreutz-Delgado and his colleagues use advanced statistical signal processing, time-series analysis, and machine learning algorithms to process EEG and fMRI signals for brain monitoring, cognitive state/alertness assessment, affective state assessment, and brain-computer interfacing (BCI). Working closely with Dr. Scott Makeig, director of the UCSD Swartz Center for Cognitive Neurosciences (SCCN), and ECE Prof. Bhaskar Rao, Kreutz-Delgado and his graduate students have created novel algorithms for cortical activity source localization from scalp-surface EEG recordings and the fitting of dynamic models to measured time series of brain activity patterns (dynamically changing constellations of brain cortical patch activities). These algorithms – which utilize novel approaches to source separation, sparse signal processing, compressive sensing, time-series analysis, estimation of Granger causal influence, feature extraction, and pattern recognition – have been incorporated into the widely available EEGLAB, the SCCN-developed, interactive Matlab toolbox for processing continuous and event-related EEG, MEG, and other electrophysiological data. The figure conceptually motivates some of Prof. Kreutz-Delgado's research in brain activity source localization. The left-hand photograph shows a high-density (> 64 sensor) EEG cap and the arrow pointing to the lower central figure demonstrates the need to develop algorithms that can localize the actual physical sources of dipolar cortical-patch activity on the brain cortex. Traditional EEG does not solve the source localization inverse problem needed to determine the exact centers of brain activity that produce the mixed signals sensed at the scalp sensor locations, while the algorithms developed by Kreutz-Delgado's team directly addresses the source localization issue. The brain is highly dynamic, with constantly changing activity patterns, which motivates additional research by Kreutz-Delgado's research group on the development of multivariate and non-stationary time-series algorithms to track changing brain activity patterns. Pictured at right in the figure is a wearable, low-density EEG cap that is now commercially available. The photo represents ongoing research in how and whether (hence the question mark) it is possible to determine high-density cortical activity from a constantly shifting, low-density array of wearable scalp electrodes, and whether it can be shown to the same degree of accuracy as offered by a high-density clinical EEG cap. The ability to obtain high-fidelity measurements of brain activity from comfortable, robust and affordable low-sensor-density EEG caps will greatly facilitate applications of EEG such as brain-computer interfaces, gaming, and monitoring of alertness and illness-related brain signatures (such as those associated with epilepsy, and even, perhaps, neurodegenerative diseases) in non-clinical, real-world settings. Prof. Kreutz-Delgado's research and students are, and have been, funded by a variety of funding sources including the Army Research Lab and the NSF.

Working with Ruey-Song Huang from the Institute for Neural Computation, Kreutz-Delgado is developing probabilistic approaches to detecting and validating brain activity from fMRI signals. It's part of an overall effort to construct human brain atlases, or "body maps" (see figure) based on fMRI data derived from experiments with different types of wearable stimulation devices. Creating body maps is a difficult challenge, because the data derived from different devices are not easily comparable, or even from one machine to the next. Kreutz-Delgado also labels brain regions by Bayesian classifiers as well as an expectation maximization (EM) algorithm.



Top: Cortical activity localization using low-sensor density EEG headsets
Bottom: Body maps are part of an effort to construct human brain atlases from fMRI data

HANDS-ON EXPERIENCES

The ECE department has embarked on an extensive effort to increase experiential learning, i.e., increasing the opportunities offered to undergraduates to engage in hands-on experiences that reinforce the basics of electrical and computer engineering by giving undergraduates more opportunities to connect engineering theory with practice. This is part of the Jacobs School-wide Experience Engineering Initiative. The department is doing so by launching a series of new undergraduate courses and workshops covering topics not previously part of the undergraduate curriculum (with the exception of some 'capstone' courses targeted at seniors and organized around quarter-long team projects).

Undergraduate Courses

Case in point: ECE 5 is a project-based course, but it is designed for new freshmen who might be attracted to its less-than-stuffy sub-title, "Making, Breaking and Hacking Stuff." The course introduces first-year students to various ECE depths, without requiring the many pre-requisites that might be required for courses targeted at juniors or seniors. Key concepts include circuit theory, assembly and testing; embedded systems programming and debugging; transducer mechanisms and interfacing transducers; signals and systems theory; digital signal processing; and modular design techniques.

As with capstone courses, ECE 5 engages students in the creation of technologies that vary in topic, for example:

- Manipulating sounds;
- Interfacing the physical world;
- Wireless communications and optics; and
- Robotics

To give students experience with the building process, they will be required to build devices as the lab component of each learning module. To "interface with the physical world," students will build circuits interface sensor modules including GPS, accelerometer, gyroscope, humidity and pressure gauges and audio. For manipulating sounds, they must build a 3 OpAmp microphone plus filter plus speaker driver circuit, and prior to analyzing communication links, they must build circuits to transmit and receive data over an optical link. The final lab involves building a robot that can follow a line (path finding), or do mapping or part handling. At the end of the quarter, the robots and their creators compete head-to-head in a robotics competition.

After 10 weeks in ECE 5, students should know how to use electrical test equipment, program Arduino embedded systems and interface sensors, modularize complex designs into manageable sub-components, debug circuits and embedded systems, work in a team environment, and to write and present technical information.

ECE 15 is an existing course in which students get hands-on experience with programming in C. But henceforth ECE 15 will be part of a series of undergraduate courses.

ECE 16, for instance, provides an Introduction to Embedded Systems. The course will introduce students to embedded systems concepts, but also with structured 'hands-on' development, focusing on concepts such as real-time, sampling, communication, and basic signal processing. Students taking ECE 16 also learn technical skills, including microcontroller programming (applying C from ECE 15) and Python programming.

Another new course, ECE 17, will expose students to Fast Prototyping. The course aims to teach undergrads how to prototype a mechatronic solution as quickly as possible, using:

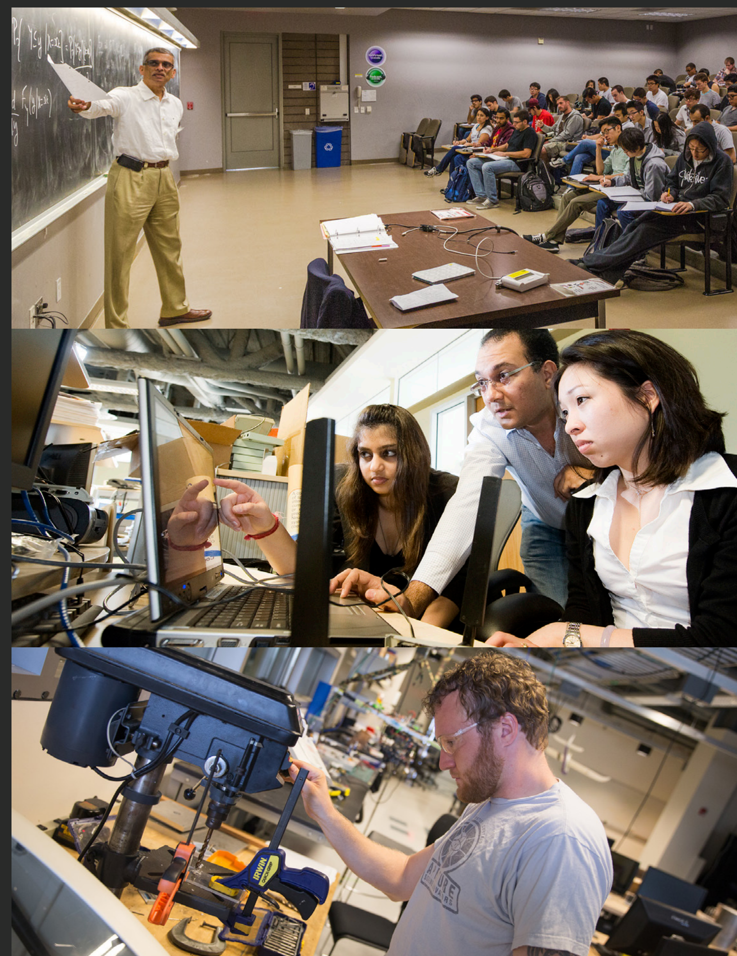
- Cheap/accessible materials, adhesives, fasteners, and suppliers;
- Fast prototyping techniques such as laser cutting and 3D printing; and
- Fast assembly and system integration shortcuts.

The lab-based course also introduces students to servo systems (including solenoids and other actuators, a variety of sensors, plus analog filtering, LEDs, phototransistors, Arduino and C++ and Solidworks for design. Indeed, the design-focused course will culminate in an open house demo day, when students will present their respective prototyped inventions.

Workshops

In addition to hands-on experiences integrated into new and existing courses, ECE decided to establish a series of workshops to empower interested students with practical technical skills as well as introducing students to design and entrepreneurship. Some of the workshops will take place in August, which will give students an opportunity to solidify basic skills that will become critically important in the undergraduate project-based courses.

What sets the workshop series apart, is that they will be led, primarily, by ECE alumni or friends of the department who can vouch for the value of these basic skills no matter what job students eventually take in electrical or computer engineering when they graduate. Instructors for inaugural Summer 2015 workshops included ECE alumni Karl Ni (PhD '08), now a research scientist at Lawrence Livermore National Laboratory, and two ECE-trained Qualcomm engineers, including staff engineer Natan Jacobson (PhD '11) and multimedia R&D staff member Chunchen Liu (PhD '07). Other instructors from Qualcomm included Liu Liu, who did her M.S. at UC Riverside, University of Wisconsin-Madison Ph.D. graduate Seyfullah Oguz and Jeff Ren who got his PhD at the University of Texas at Dallas. Kangli Hao works for Samsung and participated in the entire design and development of the first three generations of that company's smart watch.



(Top to bottom) ECE undergraduates in Prof. Ramesh Rao's probability class; undergraduate hands-on mentoring; then-ECE senior William Mutterspaugh building a robotic device in embedded systems course

The inaugural Summer 2015 workshops covered five topics:

- MATLAB Fundamentals is an introduction to the widely-used, high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numerical computation;
- Introduction to Python Programming taught students the easy-to-learn and flexible cross-platform high-level interpreted language, including practical examples for image processing and detecting an anagram;
- Smart Hardware Entrepreneurship and an Introduction to the Internet of Things (IoT), an ecosystem based on smart, networked devices that are far more complicated than Android/iPhone apps;
- OpenCV stands for Open Source Computer Vision, a library of programming functions mainly aimed at real-time computer vision. Applications include facial or gesture recognition, mobile robotics, stereo vision and augmented reality ; and
- Build Your First Artificial Intelligence System. This introduction to AI algorithms that power technologies such as the iPhone's Siri and "OK, Google". In this course, Lawrence Livermore's Karl Ni introduced students to tools, basic theory, and building blocks of deep learning, allowing them to build their own deep-learning neural networks that learned to image content.

Future workshops on the drawing board will likely include human-centric design, Arduino programming, Raspberry Pi 2, SPICE (a powerful circuit simulator), and an in-depth conversation with alumni entrepreneurs. For more information on the summer workshops, visit http://ecesummer2015workshops.weebly.com.

COMMUNICATING RESEARCH

In Spring 2015, ECE also debuted a series of Communicating Research workshops taught by Qualcomm Institute communications officer Tiffany Fox. The topic: “How to Speak Science and Be Understood.” The department stressed the need for value-added, hands-on training sessions on public speaking, improving visual aids and using social media to publicize research findings. Researchers are generally trained in how to write or present for academic audiences (specifically other researchers in their field), but “collaboration is becoming more and more interdisciplinary.”

“Technical terms and jargon -- which are often used and even encouraged in academic papers and presentations -- just won’t work when you’re communicating with diverse audiences,” said Fox. “With the advent of social media, students have even more opportunity to give a voice to the amazing work coming out of their labs and research groups. The sooner students learn how to communicate in an approachable, understandable way, the greater an impact they can have, not just in their chosen fields, but the larger world.”

The five workshops were open to ECE seniors and graduate students, including four taught by Fox on:

- Giving oral presentations: best practices for oral research presentations, including the challenges of presenting scientific topics; the differences between scientific audiences and the lay public; developing a “three act” structure for effective presentations; emotional contrast; eliminating jargon and buzzwords; use of metaphor and anecdote; and a one-hour practicum in which students are challenged to develop their own three-act presentation.
- Using social media to communicate research: the impact of social media on research and funding; students were given a breakdown of social media tools and the workshop dispelled myths about social media; the ‘civics’ of social media (guidelines for posting, following, privacy issues, etc.); and a practicum in which students were asked to put social media skills to use.
- Panel discussions and Q&A: learning how to speak without notes in extemporaneous settings like panels and during Q&A sessions; taming nerves; handling difficult questions; reading the audience’s body language; making elevator pitches; and the one-hour practicum on ‘table topics’ when students are invited to speak extemporaneously on assigned topics.
- Communicating with the lay public: In the final workshop of the five-part series, students learned tips and tricks for communicating with the lay public and general audiences, including the media and policymakers. Key pointers included how to become a “thought leader” and brand your research; how to reach out to the media and handle media interviews; reaching out to policy makers; handling bad publicity, threats and harassment, and the one-hour practicum in which students were asked to create a research ‘branding strategy,’ including messaging, visuals and tactics for dealing with controversy.

A fifth workshop on Entrepreneurship was taught by Rakesh Kumar, CEO of TCX Technology Connexions and author of “Fabless Semiconductor Implementation” (McGraw-Hill 2008). Kumar briefed students on trends in the semiconductor industry and the key elements for becoming a successful entrepreneur. The workshop addressed the importance of communication within the context of entrepreneurship, especially communication with customers and partners.

COURSES IN ENTREPRENEURSHIP

Capitalizing on the interest in entrepreneurship and startups, the ECE department is also launching new courses devoted to the challenge of turning engineering ideas into companies.

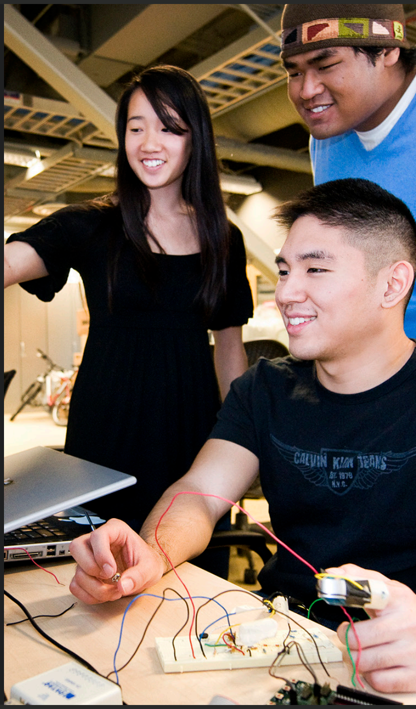
ECE 180 kicks off in Fall 2015 under the course title, “Successful Entrepreneurship for Embedded Microsystems.” Entrepreneur and IEEE Fellow Rakesh Kumar (see prior story) promises to prepare students to launch their own companies and to enter incubators that help startups get their footing. Kumar is also a past president of the IEEE Solid-State Circuits Society, and his course syllabus indicates that he will tell them why many microsystem startups fail, while exposing students to methodologies for success in countering the failure rate and getting their innovative microsystem ideas to the marketplace.

Slated to launch in Winter 2016 is another course, “Entrepreneurship for Software/Systems.” It aims to be primarily experiential, focusing on starting, growing, and financing a new technology-based venture. The sessions follow the natural order for starting a new business: choosing your idea and your team, validating the idea with customers, honing your pitch, dealing with the legal issues of starting a business, building a great product, deciding among financing strategies, developing a go-to-market and operating plan, and how to exit successfully. “We will spend part of nearly every class giving you feedback on your actual pitch, your product, and your business,” said instructor Jay Kunin. “We will invite guest speakers who are currently working in the venture ecosystem: entrepreneurs, investors, lawyers, marketers, and so on.”

Kunin’s course has three overall objectives. Students completing the course should:

- Understand the range, scope, and complexity of issues involved in starting a technology-based business;
- Learn to think entrepreneurially (i.e., focus on customers, not technology); and
- Gain experience in the tools (including pitching) and processes of creating a successful startup.

The course should benefit students who want to create their own company, or who want to work in a startup or existing entrepreneurial organization. Student teams interview customers to validate the need, build a business model around their findings, and develop a prototype, demo, wireframe, design or brochure that illustrates the value to, and use by, the customer. The students end the quarter presenting their respective business plans for a startup to a panel of guest judges from the campus and San Diego’s venture capital and entrepreneurship community.



FRONTIERS FOR UNDERGRADUATES

The new Frontiers of Innovation Scholars Program (FISP) launched by the campus in 2015 awarded scholarships to students working under three ECE faculty members. While undergraduate students were awarded $3,000 each, the funding was allocated to each project’s principal investigator. Three ECE professors received funding to employ undergraduates, yet only one of the undergrads is majoring in electrical or computer engineering.

- Computer Engineering senior Rafael Aguayo and CSE undergraduate Jennifer Lu both received FISP awards to work with ECE Prof. Gert Lanckriet on “Multimodal machine learning framework for activity and mood recognition using mobile and stationary sensors.” It was awarded in the “enriching human life and society” category. Aguayo had previously worked in Lanckriet’s Computer Audition Lab since January 2014.
- Quynhmy Nguyen, who is majoring in Chemistry and Biochemistry, is nevertheless working with ECE Prof. Daniel Sievenpiper. Their project focuses on "Electromagnetic Stimulation of Mouse Neuronal Cells Using a Dense Magnetic Coil Array." The category was “exploring the basis of human knowledge, learning and creativity.”
- Mechanical Engineering major Joshua Parzivand was funded to work with ECE Prof. Boubacar Kanté. The project involves “Controlling Radiative Heat Transfer with Metamaterials,” in the “understanding and protecting the planet” category from UC San Diego’s strategic plan.

Six ECE graduate students were selected to receive $25,000 each under the FISP program. For details, see page 24 Graduate Students.

FRONTIERS OF INNOVATION

In connection with the release of a strategic plan for the campus, UC San Diego launched a new, interdisciplinary scholarship program in March 2015. To make an investment in the future of interdisciplinary research, the campus awarded fellowships to 80 Frontiers of Innovation Scholars Program (FISP) recipients who are Ph.D. students, 20 postdoctoral researchers, and 100 undergraduates. The graduate students and postdocs were each obliged to work with faculty from at least two departments.

Postdoctoral scholars and Ph.D. students were awarded up to $25,000 each. Ph.D. students and postdocs who received funding in FY2015 will be allowed to re-apply for a one-year renewal of funding in FY2016, but preference in the latter round will be given to new applicants. Undergraduate funding is for one year only.

The Frontiers of Innovation awards highlight some of the exciting research going on in ECE labs. Here's a short digest of the inaugural winners from ECE. The majority of ECE Ph.D. students to receive FISPs were primarily selected to pursue grants in biomed-related areas, and are covered by the "enriching human life and society" category of UC San Diego's new strategic plan.

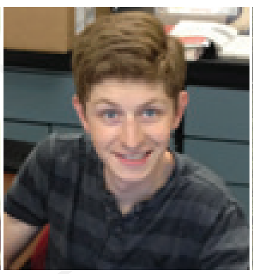
Enriching human life and society:

- **Lindsay Freeman**: Cartridge Lab on Chip for Mobile Health (CLOC) (working with Shaya Fainman and Victor Nizet from the School of Medicine)
- **Cooper Levy**: Low-Noise Mostly Digital Integrated Electronics for Ultra-Sensitive Room-Temperature Magnetometry to Explore Cardio-Biomagnetism in Humans (working with Patrick Mercier and Roland Lee from Radiology)
- **Byeong Keun Kang**: Development of Quantitative Analytics for Parkinson's Disease (with Truong Nguyen and Irene Litvan from Neurosciences)
- **John Hermiz**: Enabling High-Density Human Brain Mapping Experiments (with Vikash Gilja and Eric Halgren from Radiology and Neurosciences)
- **Marian Chuang**: Quantitative Analysis of Cytoskeletal Dynamics in Cell Repair in vivo (with Pamela Cosman and Andrew Chisholm from Biological Sciences)

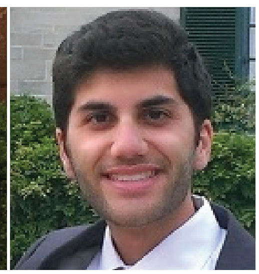
Exploring the basis of human knowledge, learning and creativity:

- **Luca Pion-Tonachini**: Human Brain/Body Interactions during Intentional Upper-Limb Actions (with Kenneth Kreutz-Delgado and Scott Makeig from the Institute for Neural Computation)

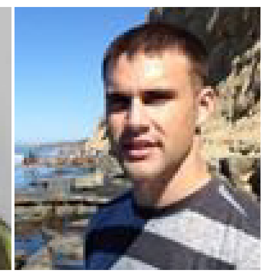

Lindsay Freeman


Cooper Levy


Byeong Keun Kang


John Hermiz


Marian Chuang


Luca Pion-Tonachini

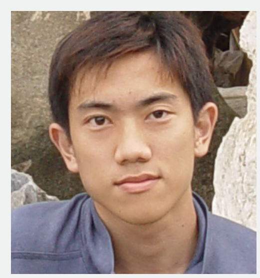
Two grad students from Biological Sciences were awarded FISPs to work on projects in which their co-mentor would be from the ECE department. Professor Sadik Esener co-mentored Justin Plaut with professor Dong-Er Zhang from Biological Sciences. Their topic: "Nanotechnology Mediated Reprogramming of Interferon Responses in the Tumor Microenvironment." Similarly, ECE Prof. Shadi Dayeh co-mentored John Thomas Scott on the project "Single Synapse Recording in Mammalian Systems Using Novel Nanoscale Arrays" with mentor Yimin Zou from Biological Sciences.

In addition to the above categories, the strategic plan identifies two other research themes: understanding and protecting the planet; and understanding cultures and addressing disparities in society.

PH.D. THESIS AWARDS

ECE established its Ph.D. Thesis Award for outstanding doctoral students submitting their dissertations in the 2014-'15 academic year. Selected by the graduate affairs committee based on overall quality of the research in their thesis, the inaugural award went to two students in its inaugural year:

- **Tuck-Boon Chan** (PhD '14) - Dissertation: *Mitigation of Variability and Reliability Margins in IC Implementation*


Tuck-Boon Chan

Nominated by the members of his thesis committee led by ECE Prof. Andrew Kahng, Dr. Tuck-Boon Chan graduated with a specialization in computer-aided design. He was praised for his 17 conference papers and 5 journal articles on such topics as device modeling, lithography simulation, circuit performance modeling, integrated circuit (IC) physical implementation, and design for manufacturing. Beyond the obvious breadth of his research, his committee noted that Dr. Chan's Ph.D. work consistently tackled and solved high-value problems facing the IC industry. According to Kahng, the former student's solutions were "creative and practical," leading to strong follow-on activity in industry while opening up new directions for academic researchers. Dr. Chan is now a Senior Engineer at Qualcomm.

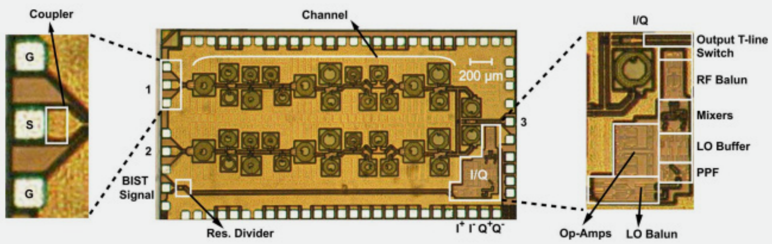
- **Danyong (Dylan) Lu** (PhD '15) - Dissertation: *Plasmonic Metamaterials for Active and Passive Light Control*


Danyong (Dylan) Lu

Dr. Dylan Lu is currently a postdoctoral scholar in the group of ECE Prof. Zhaowei Liu, his advisor prior to receiving his Ph.D. in 2015. He was nominated by Liu as well as other members of his thesis committee, including Shaya Fainman and MAE Prof. Sungho Jin. Dr. Lu was cited for his dissertation, which also led to a number of high-profile publications; see page 19. He was also lauded for his 22 journal articles and conference papers in publications such as Nature Nanotechology, Physics Review, Applied Physics Letters, Optics Express, and Nano Energy, with 11 of those publications occurring in 2014 alone. Dr. Lu also has one U.S. patent to his name. His work has also been reported by various media outlets ranging from the San Diego Union-Tribune to Laser Focus World.

2014 MICROWAVE PRIZE

Former ECE graduate students Ozgur Inac and Donghyup Shin received the 2014 Microwave Prize, the oldest award granted by the Microwave Theory and Techniques Society. The award aims to reward the most significant paper and underlying research in the calendar year prior to judging. In this case, the research was also central to the doctoral work completed by both Inac (PhD '14) and Shin (PhD '13). The award was based on their paper, "A Phased Array RFIC with Built-In Self-Test Capabilities," which appeared in the IEEE Transactions on Microwave Theory and Techniques, Vol. 60, No. 1, pp. 139-148, January 2012. Their co-author on the paper, ECE Prof. Gabriel Rebeiz, also won the same award 14 years earlier (the first repeat win in 40 years) even though the awards were in different areas – RF MEMS in 2000 and RFICs in 2014. Inac is now at Intel, while Shin is a staff scientist at Broadcom, working on IC designs.



Micrograph of 16-element receiver chip for phased array radar system

Ozgur Inac

Dongyup Shin

YONATAN VAIZMAN RECEIVES RITA L. ATKINSON GRADUATE FELLOWSHIP

In 2015 ECE graduate student Yonatan Vaizman was chosen to receive the Rita L. Atkinson Graduate Fellowship. The fellowship was made possible through a donation by Rita and former UC President Richard Atkinson to the "Invent the Future" student support campaign, which provides funds to support interdisciplinary science studies that cross traditional boundaries. Vaizman is a member of Prof. Gert Lanckriet's Computer Audition Laboratory, and his research interests include context recognition, multi-sensor analysis, music information retrieval, optimization and machine learning, and audio signal processing.

POSTER GIRLS (AND BOYS)

Forty-four ECE graduate students turned out for the 2015 Research Expo organized by the Jacobs School of Engineering to present their research in the expo's poster session. At its conclusion, a panel of experts weighed in with best-poster awards, and the poster deemed the best among all Electrical and Computer Engineering entries was the work of Ph.D. student Minu Mariam Jacob (pictured), who works under ECE Prof. Daniel Sievenpiper. Her poster on "W-Band Spatial Power Combiner" demonstrated how high-frequency, quasi-optical and spatial power combining techniques can overcome limitations of individual solid-state devices, while also maintaining a constant combining loss as the number of active devices and net output power increase. The prototype spelled out on the poster was designed to yield an output of 3 watts from 81-86 Gigaherz, but Jacob noted that higher output powers can be achieved by increasing the number of active devices.

Minu Mariam Jacob

Robert Tolley Alex Phan

Graduate students Robert Tolley and Alex Phan emerged the winners among students presenting their work during the Center for Memory and Recording Research (CMRR) Spring 2015 Research Review poster session in May. Tolley is a fourth-year Ph.D. student working under CMRR Director Eric Fullerton. He collaborated with research scientist Fred Spada on the winning poster, "Enhanced Kerr Microscopy Systems at the CMRR." Both Tolley and Phan are graduate students based in CMRR, where Phan works under Prof. Frank Talke. For his winning poster, Phan collaborated with undergraduate Phuong Truong on research titled, "Development of an Optical-Based Intraocular Pressure Sensor."

ECE alumna Nasim Eibagi (PhD '15) has focused on magnetic memory and thin films. She was singled out for a Best Poster award at the 58th International Conference on Magnetism and Magnetic Materials in November 2013. Working with a team from the CMRR, Eibagi and ECE Prof. Eric Fullerton received the award for their poster on "Exchange Coupled Composite Bit Patterned Media for Microwave Assisted Magnetic Recording."

Nasim Eibagi

ROBERT PERA (BS, MS '02)

As Chairman, co-founder and CEO of Ubiquiti Networks, Inc., Robert Pera did the unthinkable: he created from scratch a wireless hardware company that pushed his net worth over a billion dollars after taking Ubiquiti public on the Nasdaq over-the-counter stock market in 2011. However, while other entrepreneurs have reached that milestone and had to relinquish their company to new MBA-trained managers, Pera has remained Ubiquiti's chief executive officer and continued to put up scores on the company's profit statements that at time reminded investors of another hardware company, Apple Computer: Ubiquiti's 44 percent gross profit margin is even higher than Apple's 38 percent margin in 2014.

In 2015, at 37 years old, Pera ranked #1054 on Forbes magazine's list of the world's billionaires, with a net worth estimated at $2.2 billion. On the Forbes 400 list of U.S. billionaires, Pera ranks #219, and in 2014, the same magazine ranked him #9 among the ten youngest American billionaires.

Pera, however, is not just any billionaire. He is among the select few with the wherewithal to acquire and run a major-league sports franchise. In Pera's case, fresh from taking Ubiquiti public, the former high-school basketball player led a buyout of the Memphis Grizzlies NBA basketball team in 2012, and despite slashing the payroll early on, the Grizzlies racked up their best year in the history of the franchise in 2014-'15, with 55 wins versus 27 losses.

Returning to Apple, the comparison is particularly apt because Pera idolized Steve Jobs and cut his professional teeth as a hardware engineer at Apple. Pera worked there for two years after earning his Master's degree in electrical engineering from UC San Diego, where he also completed two undergraduate degrees Phi Beta Kappa in electrical engineering and Japanese language. During a junior year abroad in Tokyo in 1999, Pera was struck by the speed of cellphone adoption in Japan (far faster than in the U.S. market). He returned to UC San Diego ready to focus on wireless communications. After finishing his undergraduate work, Pera stayed on to earn an M.S. in electrical engineering with an emphasis on digital communications and circuit design – two areas that would prove critical to his future success.

At Apple, Pera became bored with testing the company's Airport Wi-Fi routers for compliance with FCC rules on electromagnetic emissions. In the process, he realized that the routers' power sources were under par, and he told Apple so. When the company failed to fix the problem, he began to develop a solution in his spare time – a power source capable of sending the Wi-Fi signal dozens of miles antenna-to-antenna.

Pera playing basketball in pro-am game with members of his Memphis Grizzlies NBA team

"Apple is a great company," explained Pera, "but I realized I wanted to have more success faster."

So he quit Apple and launched Ubiquiti Networks in 2005 to address the needs of billions of people around the world without access to traditional Internet service providers over cable or phone lines.

"Most of the world's population is not connected to the Internet so there is a substantial digital divide among those in remote and under-connected areas versus the rest of the world," Pera told an interviewer in 2014. "My vision with Ubiquiti was to create Internet connectivity that is available everywhere. So we're focused on bringing connectivity technology to the masses while changing the economics associated with such deployments."


Ubiquiti Networks founder and CEO Robert Pera

The initial products were electronic cards with revved-up power sources which he sold to router manufacturers to integrate into their devices, but Pera feared that it would be too easy for someone to copy the technology. So instead, he built his own routers around the improved power source. By 2008, Ubiquiti was selling the Nano Station, an all-in-one machine purchased by Internet service providers to get home customers online.

The following year, Ubiquiti went further to protect its intellectual property. As IEEE was updating Wi-Fi protocols to focus on shorter distances (mainly indoors), Ubiquiti focused the signals more narrowly to work over longer distances, and also implemented a change in scheduling via proprietary software so that the signals would alternate when they arrived at antenna sites. The new device, AirMAX, began selling in 2009, and allowed consumers to circumvent the large Internet service providers as long as there was a line of sight between the home and the main distribution antenna (usually owned by a 'mom-and-pop' service provider).

According to Bloomberg Businessweek, Pera upended the wireless Internet industry. "He and the company's few dozen engineers have found ways to relay signals faster, farther, and cheaper," noted the magazine, "enabling tens of thousands of small Internet service providers to do business in corners of the globe where cables and wires haven't reached."

By 2011 Ubiquiti was racking up a 30 percent operating margin on several hundred million dollars in annual revenue. Then suddenly, Ubiquiti hit a brick wall in the form of counterfeit AirMAX devices manufactured in China and sold through a disgruntled former Ubiquiti distributor. When word got out, business briefly dried up as Ubiquiti mounted an international legal battle to shut down the counterfeiter.

It took nearly a year, but Pera got a preliminary injunction to halt sales of the counterfeit products, and after tumbling over 50 percent in the first half of 2012, Ubiquiti's share price rebounded to finish 2013 at the price they ended ($21 a share) the first day of trading after the initial public offering, and as of July 2015, the stock was trading around $35 a share.

Today, Ubiquiti is a full-service provider of wireless connectivity equipment. Its product lines include wireless access points, enterprise Wi-Fi, Voice-over-IP telephony, as well as switches, routers and other traditional wireless networking equipment, notably the line of AirMAX fixed outdoor wireless systems. But Pera warns against calling Ubiquiti a "hardware company." "At heart, we're a software company," he explained. "Most of our R&D is software and most of the company is R&D, but we monetize through selling hardware."

Indeed, the company also sells software that leverages the connectivity to deliver applications and solutions including video surveillance, billing, home automation controls and sensors, and energy management tools.

Among his critical decisions at Ubiquiti, Pera decided to diversify away from Internet service providers and entered the enterprise market, notably with its Unifi line of routers and switches. Even though enterprise is still barely 28 percent of total revenues, Ubiquiti's enterprise revenues were growing by more than 50 percent year-on-year in 2015.

Pera remembers his days at UC San Diego fondly, and says that ECE equipped him not only to get the job at Apple, but to understand the technology enough to leave Apple and set up a wireless Internet equipment manufacturing company.

Giving back to the university, Pera gave students and faculty a dose of excitement at the start of the 2014-'15 NBA season, when he held the Grizzlies' training camp in RIMAC Arena on the UC San Diego campus.

JOSHUA WINDMILLER (BS '07, MS '09, CPHIL '11, PHD '12)

Joshua Windmiller

Electrozyme, a company founded by a team of engineering alumni from the Jacobs School of Engineering, won a Most Innovative New Product Award from CONNECT in 2014. Since then, Electrozyme has changed its name. As of June 2015, it is now called Biolinq to more closely align with its future line of products.

The company has roots in ECE through Joshua Windmiller (BS '07, MS '09, CPhil '11, PhD '12), who co-founded the company with Bioengineering alumnus Jared Tangney (PhD '14). Recently, the two co-founders swapped jobs: Windmiller is now Chief Technology Officer, and Tangney is the company's CEO.

The co-founders also worked closely in the company's formative stages with the von Liebig Entrepreneurism Center and the Gordon Engineering Leadership Center, which provided Windmiller and Tangney with mentorship and entrepreneurial education. The two centers allowed the company to secure $100,000 in proof-of-concept funding from a Department of Energy fellowship. The centers were also instrumental in getting Biolinq accepted into San Diego's EvoNexus incubator.

Said Rosibel Ochoa, Executive Director of the von Liebig Center: "It has been a privilege for me having the opportunity to support the team and to see how their dedication and passion is being recognized by our community."

The Most Innovative New Product Awards are CONNECT's annual tradition honoring San Diego innovation focused on groundbreaking new products launched within the last year. The company also recently won a Best Product Development Award from IDTechEX last year.

Biolinq has developed a novel biosensor, applied as a transdermal patch on the skin, to analyze body fluids, mainly sweat, to "provide actionable health information that is normally only accessible using clinical-grade equipment and settings" said Windmiller. The company's first product is a non-invasive glucose sensing solution that provides real-time and continuous glucose measurement – without the need to extract blood.

Ironically, the glucose biosensor is not the application singled out by CONNECT for its award in 2014. At the time, the company was engaged in the development of a personalized hydration monitor. The biosensor could trigger personalized alerts on when to rehydrate, or a warning if the athlete is at risk of heat exhaustion.

"With this platform and our disposable biosensors, we can analyze the chemicals in your sweat in real time to give you feedback on your personal hydration needs," Windmiller told the San Diego Union-Tribune at the time of the CONNECT award. "So with our capability, what we can tell you is when it is time to rehydrate, what you should be rehydrating with — should you be ingesting water, or Gatorade, for example — and how much should you be ingesting."

The biosensor has gone through a series of iterations as Windmiller and his colleagues planned their first product launch. During Windmiller's PhD and postdoctoral research in Nanoengineering Prof. Joseph Wang's nanobioelectronics lab, the sensor was originally designed as a temporary tattoo to monitor battlefield injuries by deriving information from a soldier's sweat. The team then looked at using the platform to monitor top-notch athletes. But with the change in the company name and the decision to start selling the biosensor as a way to monitor blood-sugar levels without drawing any blood, it appears that Windmiller and his colleagues have come up with a high-value market that could set the company apart as it prepares to identify other potential application scenarios for the biosensors.

Biolinq has already received seed funding from strategic partners, including Dallas Mavericks owner Mark Cuban, and multiple SBIR grants from the National Institutes of Health.

Said Windmiller, "I am extremely fortunate to have graduated from such a respected program in the field, which has empowered me to become an authoritative figure in my field of expertise, thereby further serving to enhance the credibility of our endeavor to facilitate partnership, investment, and grant funding."

Shay Har-Noy

SHAY HAR-NOY (MS, PHD '09)

After graduation, Shay Har-Noy and fellow ECE alumni including Luke Barrington (PhD '08), Nate Ricklin (MS, PhD '07, '10) and Albert Lin (BS, MS '04, '05) started a company called Tomnod, which analyzed satellite images using a novel crowdsourcing approach. Less than two years later, the company was acquired by DigitalGlobe, the leading satellite imagery company with six earth-imaging satellites in orbit. Har-Noy and his colleagues brought their technology, intellectual property and customer base to DigitalGlobe, and most of the team relocated to the company's headquarters in Boulder, CO.

Working at DigitalGlobe, Har-Noy created a new initiative called Geospatial Big Data, which takes two million square miles of global satellite imagery each day – roughly 70 terabytes of data – and converts it into useful information. "One of the things that is most unique about UCSD is the interdisciplinary nature of a lot of students: how the departments work together," says Har-Noy. "Because it turns out that in business, in the real world, there's no such thing as an expert of just one topic. An expert of just one topic cannot actually get much done. I have to work with business people, with people who have other skills in computer science, electrical engineering, geography, database people and so on to actually build something worthwhile."

When he isn't working, Har-Noy enjoys rock climbing and mountaineering, and has been published by the American Alpine Journal several times. "There is no better metaphor for life than climbing mountains," he adds. "It's especially relevant for relationships, for entrepreneurship, for engineering tasks."

Reflecting on his professional life, he says it's not about money. "It's about doing something important and it's about challenging yourself," explains Har-Noy. "My impression of a successful career is consistently building bigger and more substantial things. Doing more and more and having a bigger and bigger impact. Which means your mountain is constantly getting bigger and bigger. So you stand on top of one peak, then you eye the next peak and find out how to get there."

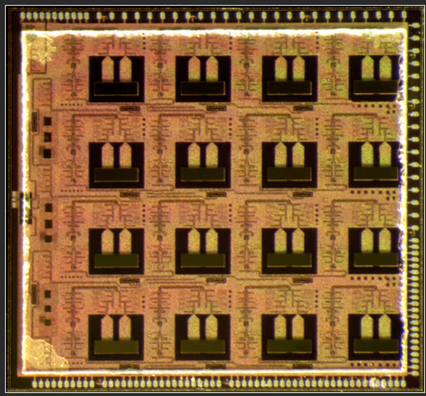
ALUMNI WEEKEND

On June 6, 2015, ECE alumni were among the thousands of former students who flocked to the UC San Diego campus during Alumni Weekend for activities ranging from symposia to the annual Triton 5K race. ECE students took over the entrance area of Jacobs Hall to showcase some of their posters and devices as well as student activities such as a maze used for the competition pitting micromouse robots against each other.

View photo album at http://bit.ly/ece-alumni-weekend-15

FIRST 5G, 256-ELEMENT 60 GHZ SILICON WAFER-SCALE PHASED ARRAY TRANSMITTER

ECE Prof. Gabriel Rebeiz calls it the largest radio-frequency (RF) chip ever built in the world. He is talking about a collaboration with the company TowerJazz to demonstrate the first 256-element (16x16) wafer-scale, phased array transmitter with integrated high-efficiency antennas operating at the 56-65 GHz frequency range. The first-time success was achieved for the wafer-scale RFIC using the global specialty foundry company's own proprietary models, kit and the mmWave capabilities of its 0.18-micron SiGe BiCMOS process.


4x4 Wafer-Scale Phased Array Transmitter at 110 GHz

The phased-array system-on-a-chip targets the emerging 5G high-performance wireless standard, which will aim for greater than 10 Gigabits per second (Gbps) peak data-rate communication. The array has beamforming capabilities that include independent amplitude and phase control for all 256 different antenna elements. By developing this wafer-scale chip, UC San Diego and TowerJazz have successfully demonstrated highly scalable RFIC transmitters for 5G phased-array applications. The collaboration was partially funded through collaboration with DARPA.

The work with TowerJazz demonstrates that the integration of the antennas and phased arrays on the same chip is important for high-performance wireless communications. Said Rebeiz: "Our vision that we've had for a long time is more integration."

Phased arrays allow the electronic steering of an antenna beam in any direction and with high antenna gain by controlling the phase at each antenna element. The radiation beam can be "moved in space" using entirely electronic means through control of the phase and amplitude at each antenna element used to generate the beam. This beam-steering technique is much more compact and much faster than mechanically steered arrays. Furthermore, phased arrays allow the creation of deep nulls in the radiation pattern to mitigate strong interference signals from several different directions. They have been in use since the 1950s in defense applications and have seen limited use in commercial systems due to their relatively high cost. The design produced by Rebeiz's lab and utilization of TowerJazz's wafer processes allowed them to reduce greatly the cost of phased arrays, especially at the millimeter-wave frequencies required for 5G communication systems.

"This is yet another leap forward in the area of phased arrays that we are proud to announce," said Rebeiz. "We have a track record of successful collaboration with TowerJazz and our ability to bring this innovative design from UC San Diego to market depends strongly on TowerJazz's SiGe BiCMOS foundry process, which enables lower-cost phased arrays through integration of multiple circuit functions and high efficiency antennas on the same silicon chip."

TowerJazz cited its interest in the $500 million emerging market for 5G 60 GHz base stations with beam-forming capabilities and Gbps data rate, and the company said its collaboration with Rebeiz's team brings attention to TowerJazz's "enabling role" in emerging 5G markets and standards. "We believe the results achieved by the UCSD 5G 60 GHz phased-array transmitter again demonstrates the remarkable teamwork between TowerJazz, UCSD and DARPA," said TowerJazz executive director David Howard. "Our collaboration will provide novel capabilities and technologies to both the aerospace and defense community as well as commercial markets."


Gabriel Rebeiz


Ian Galton

QUALCOMM FELLOWSHIP

Gabriel Rebeiz is also collaborating with another industry partner, Qualcomm. The company created its Fellow-Mentor-Advisor (FMA) Fellowship program to foster in-depth connections between Jacobs School of Engineering faculty and Qualcomm engineers, while enhancing the education of doctoral students working in faculty labs. Of the four awards given to Jacobs School faculty in 2015, two of the Qualcomm FMA Fellowships went to ECE faculty: Rebeiz, and Ian Galton. The award goes to faculty, and will benefit their Ph.D. students. For Rebeiz, the 12-month fellowship will provide $75,000 to support student tuition, fees and a stipend for a doctoral student working on Rebeiz's Advanced Phase Array Concepts project. Rebeiz's Student Fellow is Bhaskara Rupakula. Galton was awarded the fellowship to support his work on highly-digital VCO-based ADCs for LTE advanced and 5G receivers, with much of the work to be undertaken by his Student Fellow, Raghavendra Haresamudram.

CWC ATTRACTS CORPORATE SUPPORT

The Center for Wireless Communications (CWC), most of whose faculty members are based in ECE, has established relationships with two new member companies, bringing total membership to seven companies. Keysight Technologies (formerly Agilent) joined CWC in May 2015 and the company hosted a delegation of CWC professors who visited its headquarters in Santa Rosa, Calif. CWC Director (and ECE Prof.) Sujit Dey noted Keysight's "deep understanding and expertise in test and measurement technologies" for 5G circuits and systems. "The next-generation applications, networks and devices are going to be very heterogeneous with diverse requirements," said Dey, "The ability to measure and validate new solutions in partnership with Keysight is going to provide required credibility and new insights not otherwise possible."


CWC Director Sujit Dey (left) with attendees at a CWC research review

Keysight VP Mark Pierpoint became the company's representative on the CWC Board of Directors. "We look forward to partnering with other member companies to address the emerging needs of the wireless communications industry," said Pierpoint. "We look forward to working with CWC faculty and students on breakthrough research in areas such as wireless applications, networking, digital communication systems and high-speed integrated circuits enabling implementation of 5G and beyond."
To reach into more companies, CWC also has developed a Strategic Partnership program to enable collaboration with companies focused on domains of strategic importance to CWC. Those strategic domains include mobile health, the Internet of Things [IoT], data analytics, and security, among others. The latest company to sign up as a Strategic Partner is Symantec, the security and information protections company. Strategic domains are "important for the future growth of the mobile industry," said CWC's Dey. "Ensuring security, privacy and trust are becoming critical for several emerging mobile applications, in particular for mobile health and IoT applications. We look forward to partnering with Symantec to address these emerging concerns in our future projects in collaboration with other CWC member companies."

Added Darren Shou, a Senior Director at Symantec Research Labs: "Engaging with CWC better enables Symantec to innovate for the quickly changing world of broadband wireless and work towards a more secure future."

Keysight joined Mitsubishi, Nokia, Qualcomm, STMicroelectronics and ViaSat as full members in CWC, while Symantec joined as its first Strategic Partner.

ECE STARTUPS

ECE has had its fair share of entrepreneurial engineers who were not content to count on others to create new companies, going back to then-faculty member Irwin Jacobs, who co-founded Linkabit and, later, Qualcomm in 1985. Alumnus Ron Reedy (PhD '84) did the same in 1998 with Peregrine Semiconductor (where he is now CTO Emeritus). Also notable, however, is the wave of companies created by ECE faculty, students or alumni.

In December 2014, Intel Corp. acquired **Composyt Light Labs**. Composyt was barely six months old – the brainchild of ECE alumnus Eric Tremblay (PhD '08), who did his doctoral work under Prof. Joseph Ford in ECE's Photonic Systems Integration Laboratory. After finishing his PhD, Tremblay became a researcher at EPFL in Switzerland, and together with colleagues, they co-founded Composyt as an EPFL spinout. The company was developing a holographic head-mounted display in the form of smart glasses using see-through, augmented reality in lightweight, normal-looking eyewear that could supersede the current generation of virtual-reality goggles. After the acquisition, Tremblay and his colleagues remained in Lausanne, giving Intel an outpost in the Swiss city.

ECE Prof. Yuhwa Lo was an advisor to materials science and engineering alumnus Sung Hwan Cho (PhD '10), who became a Visiting Scholar in the ECE department while in the process of forming the startup, **NanoCellect Biomedical**, based in San Diego. The life-sciences startup develops lab-on-a-chip flow cytometers for researchers and clinicians to analyze cells and particles. The technology was co-invented by Cho, who is Chief Technology Officer of NanoCellect as well as a principal investigator on several of the nine SBIR grants awarded to the company by the National Institutes of Health (NIH). In November 2014 NanoCellect announced $2.8 million in new NIH funding, bringing the total since 2011 to $6 million. Next stop for the company: a Series A investment round and strategic partnerships to launch their microchip-based technology for sorting cells, micro-FACS (fluorescence activated cell sorter) for biomedical research and clinics.

A team of ECE students and alumni were behind the successful launch of **Tomnod**, a company with ambitious designs on supporting citizen science projects, including crowdsourcing, but geared to creating products that leverage satellite and aerial imagery of the earth. Qualcomm Institute research scientist Albert Lin (BS, MS '04, '06) did his undergraduate and master's work in ECE, and completed a Ph.D. in materials science, prior to founding Tomnod. His co-founders were early collaborators from other labs, including Luke Barrington (PhD '13), Shay Har-Noy (MS, PhD '09) and Nate Ricklin (MS, PhD '07,'10). Less than two years after launching the company, Tomnod agreed to be acquired by Digital Globe, the largest commercial company in the satellite earth imaging business. Tomnod still exists, as a division of Digital Globe at its Colorado headquarters. Har-Noy, Ricklin and Barrington all made the move. Albert Lin opted to stay at UC San Diego in the Qualcomm Institute, while co-founding another high-profile startup in earth sciences and exploration with a former president of the National Geographic Society.

In 2013, Emanuele Coviello (PhD '14) did a startup called **Keevio**, focusing on video, audio and music recommendation and monetization technology. He did his Ph.D. under Gert Lanckriet, who co-founded the company with him. Coviello's own background is in machine learning, deep learning and multi-media content analysis, and Keevio grew out of his work in Lanckriet's lab on music recommendation engines. Coviello designed, developed and refined algorithms to analyze, understand and organize audio-visual content. The company indexes multimedia content with descriptive tags and metadata. Those tags allow Keevio automatically to organize a video catalogue into browsable channels, to identify the most relevant content for advertisers, and to help users find new videos or songs that are in some way similar to existing music or video in their collection. Keevio has also developed MusicWalk, an online music player that recommends and streams music from YouTube based on the tags and metadata derived from each music video's audio waveform. The player can select videos based on acoustic similarities by genre, instrumentation, vocals, or mood descriptors. In 2014, Coviello and Lanckriet filed for a U.S. Patent for their "audio-based annotation of video."

Perhaps the most prolific mentor for electrical engineering students eager to create their own companies is ECE Prof. Sadik Esener. Two of his former students co-founded the company DevaCell (briefly dubbed DevaNano): Inanc Ortac (MS, PhD '08, '13) and ECE alumnus Ibrahim (Abe) Gokce Yayla (PhD '96). Ortac won first prize in the graduate student category at the 2012 Collegiate Inventors Competition. His research, which formed the basis of **DevaCell**, was on a targeted drug delivery system called "Nano-Wiffle-Balls for Cancer Therapy." It was a new approach to deliver cancer drugs just to the areas where the drugs are needed – promising to minimize collateral damage to non-cancerous cells. The "wiffle ball" technology is now called Synthetic Hollow Enzyme Loaded NanoShells (SHELS), presumably because the nanoparticles act like a shell carrying enzymatic drugs through the body without triggering an immune response (because the payload is hidden inside the shell). With the technology, "we expect that the lethal side effects to chemotherapy can be greatly reduced, the efficacy of the therapy can be increased, and the quality of life of patients can be improved," said Ortac. The approach makes the SHELS act as an extended-release drug system, and the technology took first place in the 2013 UC San Diego Entrepreneur Challenge. In June 2014, DevaNano was honored with a San Diego Business Journal Innovation Award in the medical research category.

ECE alumnus Michael Benchimol (MS, PhD '08, '12) did his dissertation on ultrasound-responsive particles for cancer therapeutics, and co-founded **Sonrgy** to commercialize the technology. At Sonrgy, the drug delivery involves using focused ultrasound for "exquisite 3D spatial selectivity" – in other words, to pinpoint where to release a therapy in order to localize the effects of pharmaceuticals for safer and more effective treatment. Benchimol remains the company's founder and chief technology officer. In 2014, the company secured an exclusive license from the University of California for the core SonRx technology that Benchimol had been working on under Prof. Esener. Sonrgy's tiny nanocarriers safely transport potent chemotherapy drugs to cancer tumors and release high doses on command in response to a focused beam of ultrasound. These carriers deposit drugs directly at the tumor cell sites, avoiding the many serious side effects of toxic chemotherapy circulating in the blood stream.

At one point, it seemed as if **Quanlight** was on its way to becoming the next big thing in LEDs. ECE alumnus Vladimir Odnoblyudov (PhD '06) launched the company immediately after graduation to commercialize his invention with his advisor, Prof. Charles Tu: novel yellow-amber-red chip LED technology. Later he moved to become an LED R&D manager at Micron Technology, which eventually spun off its LED group, and a team of semiconductor and LED experts including Odnoblyudov acquired the technology for their startup: Quora Semiconductor. Launched in March 2015, **Quora Semiconductor** is focusing on what it calls a "game changer" technology for LED lighting: gallium-nitride (GaN) on Engineered Substrate. Today, LEDs are fabricated on 2-inch or 4-inch substrates, because it's very difficult to go larger. But Quora claims that it has solved the problem of scaling to larger substrates through a proprietary engineered substrate on which GaN circuit structures are fabricated. The breakthrough could scale GaN substrates up to 12-inches or greater – dramatically reducing the cost of manufacturing. The process is also compatible with existing advanced silicon fabs, thereby eliminating the need for costly development. Quora is now working to bring the technology to foundries, based on more than 30 patents that Micron transferred to Quora.

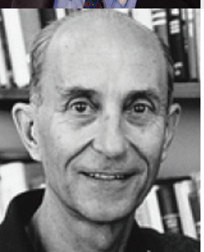
Another ECE alumnus, Jason May (MS, PhD '07, '09) is a member of the founding team at **Mission Microwave Technologies**, a company launched in 2014 and headquartered in Los Angeles. The company is developing the next generation of high-power, solid-state power amplifiers (SSPAs) that aim to be the industry's most efficient, lightweight, and compact SSPAs. To achieve that goal, Mission Microwave is using advanced GaN transistors, unique power combining technology, and novel full-system designs. May worked in the lab of Prof. Gabriel Rebeiz, where he developed the first ICs for millimeter-wave imaging in commercial semiconductor processes, and also co-developed the first 16-element, millimeter-wave phased array transmitter IC. After graduation he worked as an RF design consultant, and a research staff engineer at HRL Laboratories (designing millimeter-wave ICs and systems). The most immediate uses for the company's technology will be in ground-based, airborne and space-based applications such as Ku and Ka-band block upconverters (now in limited or pre-production), and high-power amplifiers.

MaxLinear, a semiconductor and integrated circuit design company, was founded by eight engineers, including ECE alumnus Sheng Ye (PhD '03). At UC San Diego, Ye worked in Prof. Ian Galton's Integrated Signal Processing Group, and he went on to hire several other students from the group, including Kok-Lim Chan (PhD '07). MaxLinear was incorporated in 2003 as a fabless IC design company based in Carlsbad, and today it has design centers in Irvine and Shanghai as well. The company specializes in designing low-cost, low-power and high-performance CMOS for cell phones, TV and cable set-top boxes, and other wireless consumer electronics. In 2015, MaxLinear acquired **Entropic**, the leader in semiconductor solutions for the connected home. Not coincidentally, Entropic was also co-founded by an ECE alumnus, Anton Monk (BS, PhD '89, '94).

A handful of eminent ECE faculty members will be long remembered for the seminal contributions in their respective fields, and the impact they had on hundreds, even thousands of students whom they taught. Herewith, a reminder of our late faculty members and the tremendous contributions they made to electrical and computer engineering at UC San Diego.

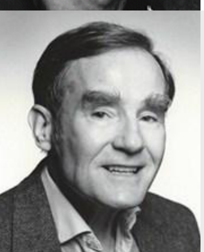
WILLIAM S.C. CHANG :: EMERITUS PROFESSOR (1931 – 2015)

William Chang, a pioneer in guided-wave optics and microelectronics, joined the faculty in 1979, and among his many accomplishments influencing the early formation of the department, Chang was credited with the establishment and nurturing of the microelectronic research and education program. He was Department Chair from 1993 to 1996. Prior to joining UC San Diego, Chang distinguished himself as an accomplished academic administrator as well as a renowned electrical engineer: he was at Stanford University from 1957 to 1959 and Ohio State University from 1959 to 1965. He became professor and chair of the electrical engineering department at Washington University in St. Louis in 1965, where he played an instrumental role in revitalizing that department. In 1976 he was named the Samuel C. Sachs Professor of Electrical Engineering. Chang's early research focused on masers and lasers but in 1971, he began working on optoelectronics and guided-wave research, which he continued at UC San Diego. He authored seven books in these fields, including Principles of Quantum Electronics (1969), RF Photonic Technology in Optical Fiber Links (2002), and Principles of Lasers and Optics (2005).



VICTOR RUMSEY :: EMERITUS PROFESSOR (1919 – 2015)

The English-born electrical engineer received his doctorate from Cambridge University. Prior to settling in San Diego to teach at the new campus in 1966, Professor Rumsey moved from government labs to university campuses. During World War II, he worked on radar research in England and the U.S., including the Naval Research Laboratory. In 1945 he joined the Canadian Atomic Research Laboratory, then transitioned to academia, initially as director of the Antenna Laboratory (now known as the ElectroScience Laboratory) at Ohio State University (1948-1954). Rumsey then taught at the University of Illinois for three years and UC Berkeley for nine (1957-1966). He became a member of the National Academy of Engineering in 1980, and Rumsey was elected an IEEE Fellow in 1980 for his "research in practical applications of electromagnetic theory, especially in design of radio antennas insensitive to frequency and polarization." He won awards, including the 2004 John Kraus Antenna Award, a Guggenheim Fellowship, and the IEEE Morris N. Liebmann Memorial Award in 1962 for "basic contributions to the development of frequency independent antennas."



CARL HELSTROM :: EMERITUS PROFESSOR (1925 – 2013)

Carl Helstrom, a former radio technician in the U.S. Navy, became a prominent expert on detection theory, and he was one of the earliest pioneers in the field of quantum detection theory. His work included the discovery of what is now known as the Helstrom measurement – the quantum measurement for distinguishing one quantum state from another with minimum probability of error. After his stint in the Navy, Helstrom earned his PhD from Caltech in 1951 and spent the next 15 years working in applied mathematics at Westinghouse Research Laboratories. He joined the new Applied Electrophysics department at UCSD in 1966 (one of eight new faculty that year), and for most of the 1970s Helstrom served – twice – as chair of the renamed Electrical Engineering and Computer Science department. In 1970, Helstrom was elected a Fellow of IEEE for his "contributions to communication and detection theory." He was also a Fellow of the Optical Society of America. Helstrom also served as Editor of the IEEE Transactions on Information Theory.

RENE CRUZ :: PROFESSOR (1959 – 2013)

The ECE professor and pioneer of network calculus passed away in June 2013 from complications of pancreatic cancer at age 54. Cruz established the field of network calculus as part of his doctoral work. Upending traditional, statistical heuristic approaches, he introduced deterministic models to describe information flow through a network of queues and was able to precisely calculate worst-case, end-to-end delays in a network. Network calculus remained at the heart of Cruz's work, and the mathematical models he and his collaborators developed are widely used today in the core of the Internet to ensure timely delivery of information. Cruz avidly researched constrained resource allocation problems, and he was able to apply his methods to a broad range of domains, including packet, circuit, wireless, photonic, video distribution, peer-to-peer and surface transportation systems. A named inventor on 39 patents, Cruz received the S.O. Rice Paper Award from the IEEE Communication Theory Society in 2008, and accepted an INFOCOM Achievement Award in 2009 for his "fundamental and pioneering contributions to network calculus." He was an IEEE Fellow (2003), Ericsson Distinguished Scholar (2007) and a recipient of an NSF Presidential Young Investigator Award (1991). Cruz co-founded Mushroom Networks in 2004.

VICTOR C. ANDERSON :: EMERITUS PROFESSOR (1922 – 2012)

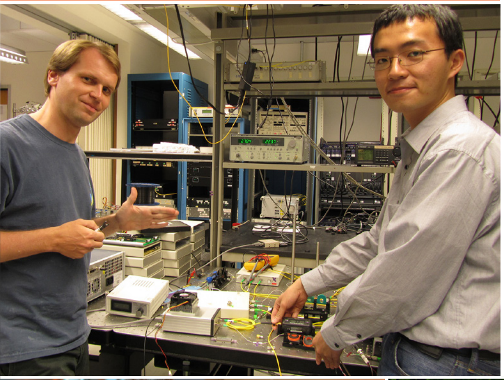
Victor Anderson was best known as a research oceanographer, but from 1968 to 1990 he had a parallel appointment as a professor of applied physics and information science in the Applied Electrophysics department. During and after World War II, Anderson worked on the Manhattan Project, first at UC Berkeley's Radiation Laboratory, then from 1943 to 1947 at Los Alamos. Later Anderson enrolled in UCLA and joined the University of California's Marine Physical Laboratory (MPL) at the Scripps Institution of Oceanography in La Jolla. He earned his PhD in 1953 from UCLA and eventually rose to associate director of MPL. Joining the UCSD faculty in 1968, Anderson developed a graduate acoustics course and an undergraduate electroacoustics lab course after outfitting an acoustic laboratory with $150,000 provided by the campus to furnish equipment for a new engineering building. In 1982 Anderson and his wife anonymously established the Victor Alderson Chair of Applied Ocean Science (now held by V. Ramanathan, a world-renowned atmospheric scientist). In 1986 Anderson received the Admiral Charles B. Martell Technical Excellence Award for his work on technologies for the U.S. Navy.

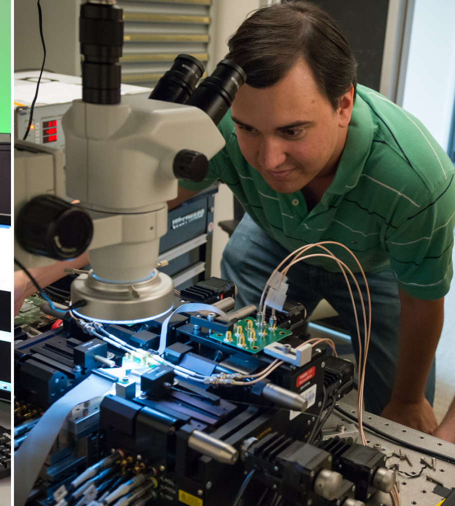
WALTER H. KU :: EMERITUS PROFESSOR (1935 – 2012)

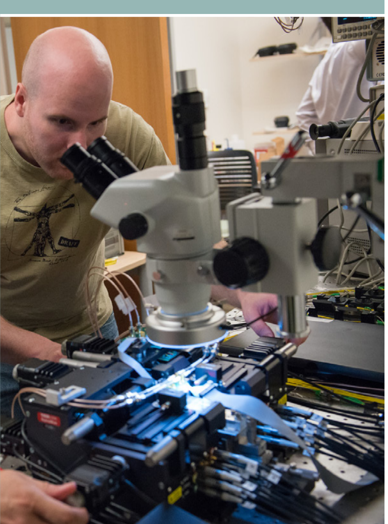
Walter Ku was an internationally known scientist in the field of electronic systems and systems controls. His research interests included high-speed integrated circuits and systems, as well as the design and fabrication of monolithic silicon and compound-semiconductor IC's for signal processing and secure communications systems. After earning his undergraduate degree at the University of Pennsylvania, Ku received his MS and PhD from the Polytechnic Institute of Brooklyn in 1962. He spent the next seven years at GT&E Sylvania Applied Research Laboratory in Massachusetts. From there Ku joined the faculty at Cornell University in 1969, and in 1977 became the inaugural holder of the Naval Electronic Systems Command Research Chair Professor at the Naval Postgraduate School in Monterey, Calif. After spending the 1983-'84 academic year as a visiting professor at UCSD, Ku joined the university's Electrical Engineering and Computer Science department in 1985. Prof. Ku became the founding director of the NSF Industry/University Cooperative Research Center on Ultra-High-Speed Integrated Circuits and Systems.

JACK KEIL WOLF :: PROFESSOR (1935 – 2011)

Jack Wolf was world-renowned for his pioneering contributions to information theory, coding theory, and communication theory. Through a combination of engineering innovation, student mentoring, and technical leadership, Wolf played a highly influential role in the development of modern information technology. Highlights of his work include the proof of the Slepian-Wolf theorem on efficient distributed source coding, the invention of practical approaches to trellis-coded modulation, and the application of advanced signal processing and coding techniques in magnetic recording. Throughout his 27-year career at UCSD, Wolf was affiliated with the Center for Magnetic Recording Research, where he was one of the founding endowed chairs. He also maintained a long-term affiliation with Qualcomm Corporation. Wolf received many major technical awards, including the IEEE Communication Society Edwin H. Armstrong Achievement Award, the IEEE Information Theory Society Claude E. Shannon Award, the IEEE Hamming Medal, and the Marconi Society Prize. He was a member of both the National Academy of Engineering and the National Academy of Sciences. Wolf was also passionate about teaching and received the UCSD Distinguished Teaching Award. In his honor, colleagues, former students, and friends have established the Jack Keil Wolf Endowed Chair in Electrical Engineering and the Jack Wolf Endowed Scholarship.



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