VIRGINIA TECH

ece

THE BRADLEY DEPARTMENT OF
ELECTRICAL & COMPUTER
ENGINEERING
2019

Small scale traffic solvers

Page 28

VIRGINIA TECH

JOY ASICO

About the cover

Tam Chantem (above), an ECE assistant professor based in the greater Washington, D.C. area, is designing a semi-automated emergency response system that can guide drivers through emergency situations. Her team, including graduate student Mahsa Foruhandeh (cover) built a testbed and a fleet of small robots to model how humans drive on highways and in traffic.

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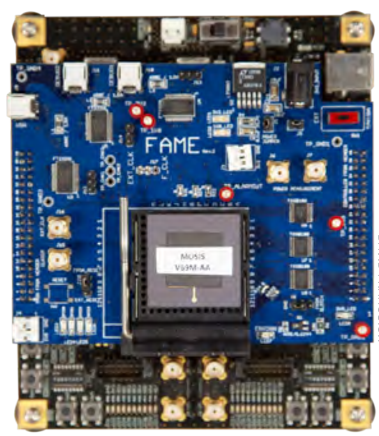
Editor: Scott Bailey
Produced by Uncork-it Inc.

What's inside

SHAWN SPROUSE

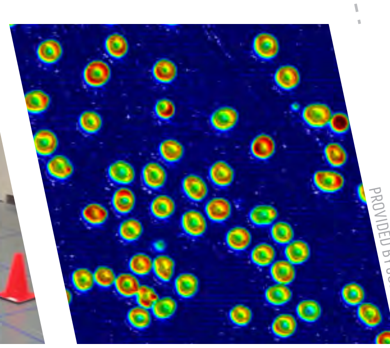
ELENA LIND, ECE assistant professor, builds instruments, develops inversion algorithms, and takes measurements to deduce what photons from the sun are telling us about the layers of atmosphere they move through.



DAVID FRANUSICH

PATRICK SCHAUMONT, ECE professor, and a team of researchers have found a way to lock down a small computer when it is turned off, keeping its data secret even if the computer has been stolen or disassembled.

PROVIDED BY HANNAH MOHR



PROVIDED BY JOE THOMAS

LEFT: Unmanned aerial vehicles (UAVs) navigate around obstacles–Webber Fellow Hannah Mohr's successful demonstration showcased the algorithms developed for obstacle avoidance.
RIGHT: Bradley Fellow Joe Thomas imaged red blood cells with quantitative phase imaging (QPI), a microscopy technique capable of quantifying the surface profile of cells and other samples.

from the

ece DEPARTMENT HEAD

I am pleased to report that the Bradley Department of Electrical and Computer Engineering (ECE) at Virginia Tech continues to be a destination for students at all levels and new faculty hires. In 2018 we greeted about 426 new sophomores into the Electrical Engineering (EE) and Computer Engineering (CPE) degree programs, with about 60 percent of them intending to pursue the CPE degree.

You may recall that we featured the "ECE Majors" for B.S. students graduating in 2020 and afterward in last year's annual report. At the time, we were targeting these new plans of study, consisting of 7-course bundles, for recruiting the freshmen from General Engineering. As part of the vast undergraduate curriculum revision that we had embarked on in our NSF Revolutionizing Engineering Departments (RED) grant, the "Majors" were considered an essential element to attract a broader cohort of engineering students.

Interestingly enough, however, it turns out that the "Majors" introduce a flexibility into our curriculum that is also very attractive to students applying to the College of Engineering from high school. This added benefit is a welcome change from the recent, nation-wide impression that ECE is just electricity, electronics, and electromagnetics.

Now here we are in Spring 2019 and the most popular majors within ECE are fast becoming Controls, Robotics & Autonomy, Machine Learning, Networking and Cybersecurity, and Energy and Power Electronics Systems. Some of these technical areas look very familiar to us, while others may be considered heresy in more traditional departments. And therein lies the point of the NSF RED grant strategy: ECE as a discipline is a huge umbrella encompassing a wide variety of technical fields. As a consequence, we now need students from many different backgrounds and experiences to reflect the place that ECE holds in the overall picture of engineering today.

With the announcement of Amazon's HQ2 in Northern Virginia and the increased interest in computer science and engineering, our new selection of academic pathways at the B.S. level has been a boon to the department in terms of visibility, differentiation and recruitment. Our freshman-level course entitled "Introduction to ECE Concepts," which is being offered for the first time this Spring semester, reflects this diversity in what we teach and the exciting careers paths that are possible in ECE. My thanks go to Tom Martin who has been leading this NSF RED effort and the whole faculty team that is making this program a reality.

Last year, we graduated 299 B.S.-degree students in EE and CPE, which is the most since 2002. The 58 Ph.D. students that were graduated in the 2018 timeframe represents a new all-time high. This is a testament to the strength of our graduate program ranked 10th in the country in terms of research expenditures by the 2017 NSF Higher Education Research & Development (HERD) survey.

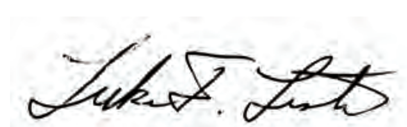
Even before Amazon announced its plans for Northern Virginia and the need for more master's-level employees, our department was planning a push to expand its Master of Engineering (MEng) program in both Northern Virginia and Blacksburg (see the full story inside this report). I am happy to tell you that we have hired four new faculty members who will start in August and will specifically focus on teaching and mentoring MEng students.

I am delighted to tell you that our graduate programs have been ranked in the top 20 in the U.S. for the third straight year. The EE program is now ranked 19th in the country, and computer engineering is placed at 18th. This sustained presence among the top graduate institutions has been fueled in large part by the aggressive faculty hiring that we have done in the past six years during which we have hired 35 full-time and 3 part-time faculty.

Just recently, five new faculty members started in the time period from November 2017 to January 2019, and they are profiled in the subsequent pages of this report. This latest cohort has had an immediate impact on our research by expanding our portfolio in the areas of remote sensing, power electronics, power systems, and cryptographic engineering. Furthermore, as I write this report, we have hired another seven faculty members who will officially start in August of this year.

As a major milestone for the department, August 2019 will most likely mark the month that we reach 100 teaching, tenured and tenure-track faculty in the department! To all the members of the faculty search committees over the past several years, I give you my deepest thanks for your dedicated effort and positive attitude in recruiting so many great new people to the department.

Thank you and go Hokies! ■



Luke Lester
Roanoke Electric Power Professor
ECE Department Head

from the chair of the advisory board

2019 ece Annual Report

In Spring 2018, I was honored to be elected to succeed Kenneth Schulz as the ECE Advisory Board Chair. During the years since my graduation, I have had a desire to give back to my alma mater. Both the Virginia Tech College of Engineering and the Corps of Cadets provided me the foundation for a wonderful 25-year Air Force career and successful second career in industry. When I was fortunate enough to be given the opportunity to pay it forward, I did not hesitate. I highly encourage all ECE alumni to help the department be the best it can be by increasing awareness of the highly ranked Virginia Tech ECE Department in our schools, by providing financial donations, or volunteering to assist with student projects.

The Virginia Tech ECE Advisory Board had another busy year serving the department. In 2019, we welcomed seven new members: Paige Kassalen from Covestro, Christine Whiteside from IBM, Adedoyin "Doyin" Adewodu, founder of Infrastructure Solutions International (INFRASI), Michael Bear from BAE Systems, Charles Dublin from Akamai Technologies, Air Force Lt. Col. Michael Pochet, and Brian Huber from Micron Technology. We thank outgoing board members Bernard Chau, Nathan Cummings, Peter Diakun, Steve Poland, and Dave Rea for their service to the department.

A key focus area of the Advisory Board in 2018 was the launch of the 12 new ECE Majors with the Class of 2020. We engaged more faculty to provide our industry perspective on the reformulation of the undergraduate curriculum which is fundamentally expanding the pathways in the professional formation of our ECE undergraduates.

The board provided input to Department Head Luke Lester to help prepare for continued growth of the ECE Department, including hiring faculty for new technology areas. We saw the size of the ECE Department and engineering class continue to grow from the 5th to the 4th largest ECE Department in the nation. To accommodate this growth and the inclusion of new technology areas, Dr. Lester hired new faculty members: Chen-Ching Liu, American Electric Power Professor and director of the Power and Energy Center, and Assistant Professors Elena Lind, William Diehl, Dong Dong, and Yuhao Zhang. The board also provided industry perspective on the exciting expansion of the Masters of Engineering program, both in the greater Washington, D.C. region and Blacksburg.

Going forward, the board looks forward to continuing to help Luke prepare for continued growth of the ECE Department and to contributing to making the department one of the highest ranked departments in the nation.

I would like to express my sincerest thanks to the board, our Vice-Chair Duane Blackburn, Member at Large Nam Nguyen, and Luke, for their support and the opportunity to serve the ECE department. ■

Lynne Hamilton-Jones *(BSEE '84, MSEE '89)*
Chair, ECE Advisory Board
Director, Advisory Services
LMI

ece expanded, expedited & enriched

Amazon plans accelerate ECE growth in D.C. region

For about 50 years, ECE has been steadily growing a presence in the greater Washington, D.C. region. In November, Amazon declared its intent to build an Arlington headquarters, Virginia Tech announced its Innovation Campus in Alexandria, and the department's long-range plans sprang into the foreground.

ECE currently has 18 faculty members already based in Arlington and Falls Church, and it graduates about 10 students a year from the Northern Virginia location.

"Independently of Amazon arriving, our plan was to grow to 20 faculty members in the next year or two," said Luke Lester, ECE department head. "Now I anticipate further personnel growth that will allow us to significantly increase the number of master's and Ph.D. degrees that are conferred in this location."

Master of Engineering Program

Expanding the Master of Engineering (MEng) Program in the Washington, D.C. region is central to this goal, said Lester. Beginning in the fall, the ECE department is offering MEng degrees that provide a curricular emphasis in three key ECE technology areas: cybersecurity, machine learning, and electronic power systems. The coursework and projects will be led by faculty members based in Northern Virginia, leveraging the research and teaching strength in both locations.

These professionally oriented degrees offer graduate students a strong academic foundation culminating in a project-based learning experience, which prepares them to meet the demands of the growing tech hub.

"You hear a lot about people writing apps and doing data analytics, computer science, and artificial intelligence," said Lester. But the reality, he said, covers a lot more ground.

"Data centers need to get more energy efficient. Power electronics and the management of power is critical," said Lester. "The physical layer matters—the bricks and mortar of the smart city, the components and racks of equipment that support the Internet of Things."

Opening a physical location within walking distance of Amazon, the National Science Foundation, and other innovation hot spots will draw Virginia Tech engineers into an abundance of opportunities that play to ECE's specific strengths and the university's Destination Areas.

CPES

A Center for Power Electronics Systems (CPES) laboratory is already up and running in Arlington, with four graduate students and three faculty members on site full time. The facilities, which are still being assembled, include offices and a modern power electronics lab that showcases the cutting-edge nature of the work, with resources to house at least 20 graduate students and up to five faculty members with supporting staff.

Hume Center

Focused on the challenges of cybersecurity, autonomy, and resilience in the context of national and homeland security, the Ted and Karyn Hume Center for National Security and Technology is already a university-wide center with a presence in the Virginia Tech Research Center—Arlington.

Gearing up for growth

By some metrics, the Virginia Tech College of Engineering is the fourth largest provider of engineering graduates in the nation—the ECE department alone has 94 faculty members.

"The department's strong presence in both Blacksburg and the greater Washington, D.C. region gives us a unique opportunity to offer faculty, staff, and students a choice of two very different, but very connected, areas," said Lester. "It's a great opportunity for the department. Right

SHAWN SPROUSE

LUKE LESTER (left), ECE department head, and **PAUL PLASSMANN** (right), ECE director of graduate studies, are on the team to expand ECE's presence across the Commonwealth.

BELOW Virginia Tech President Tim Sands welcomes the more than 50 members of the Commonwealth Cyber Initiative's Blueprint Advisory Council and Working Groups at the Virginia Tech Research Center–Arlington.

now, we graduate close to 500 undergraduate and graduate degrees per year between the Electrical Engineering and Computer Engineering degree programs. Five years from now, we are projecting that number will surpass 700."

To accommodate the growth spurt, the department is hiring. The D.C. region program will initially be supported by three staff members—an operations manager, a pre-award administrator, and an administrative assistant—along with two program directors (Blacksburg-based and D.C.-based) who start in July.

ECE's expanded program will be marketed to young professionals, among others, who are trying to secure and improve career prospects in the greater Washington, D.C. region. Currently, domestic applicants constitute only 15 percent of MEng applicants, said Paul Plassmann, ECE assistant department head and graduate program director.

As added incentive, MEng students focusing on cybersecurity, electronic power systems, or machine learning can accelerate their degree and complete the minimum 32 credit hours in a 12-to-15-month period. This accelerated option will initially allow ECE to make three of its strong research areas more visible and accessible to potential students and collaborators.

In addition, according to director of ECE graduate studies Paul Plassmann, the vision for the program leverages all academic options. These include one- and two-year students, undergraduate/graduate-program students, part-time professionals, and those who start in the MEng program but are wooed by research and the Ph.D. program—which, historically, is about 25 percent of ECE's MEng students.

Fulfilling the land grant mission

Many universities, especially land grant universities, were established "out on the land," away from cities, explained Lester. Now these universities are looking toward major metro areas as a way to pool resources and concentrate talent.

"Using the expertise and credibility we already have, we can leverage the state's investment and the university's investment to bring about a world-class research effort," said Lester.

The tether between Blacksburg and the greater Washington, D.C. region will benefit both areas, broadening options for research opportunities, heightening the program's profile, and increasing student interest and retention in both locations. ■

RAY MEESE, VIRGINIA TECH

JOY ASICO

THE NEW CPES LAB showcases the hands-on, cutting-edge power electronics research being done from the benches.

Two locations, one lab

CPES expands into the greater Washington, D.C. region

For the uninitiated, "power electronics laboratory" may evoke a drab scene: a basement workspace. Flickering fluorescents. Wires piled haphazardly and trailing on the floor.

That vision dissolves with one peek into the CPES Center for Power Electronics Systems' new lab in the greater Washington, D.C. region at the Virginia Tech Research Center—Arlington.

"The work we do is incredibly exciting and cutting-edge," says Igor Cvetkovic, CPES technical director. The new lab, he explains, embraces those attributes. "This space is different from a conventional engineering lab."

The lab is sleek: floor-to-ceiling windows on three sides, custom benches with stainless steel frames and glass tops.

"We want to show the energy—teamwork energy, creative energy," says Cvetkovic. "We want passersby to see what we're doing here and rethink any preconceived notions about power electronics."

Virginia Tech's School of Architecture + Design helped design the space to showcase the hands-on work being done from the benches. In another studio project, architecture students and the Washington-Alexandria Architecture Center are working to design something grander.

"They've developed master plans for a campus dedicated to transdisciplinary energy research and outreach for the 21st-century world, equipped with high voltage labs several stories high, design studios, energy museums, and housing for students and faculty," says Christina DiMarino, CPES assistant director.

Energy systems initiative

The Electronics Energy Systems Initiative (EESI) is a cross-college cooperation with the goal of envisioning and enacting a carbonless future. EESI's mission is to create sustainable and enjoyable energy systems that meet current and future demands, according to University Distinguished Professor Dushan Boroyevich, CPES director and associate vice president for research and innovation.

The new CPES lab is mobilizing to carry out this mission.

In the thick of it

One perk of the lab is its proximity to the new Amazon headquarters and the nation's capital with its federal agencies and international embassies.

"Part of the land-grant mission is to be a global land-grant university," says Boroyevich. "We're working to fulfill this mission by increasing our visibility with federal agencies, foreign sponsors, and other potential partners."

In addition to increasing visibility and encouraging collaboration, the new lab is well situated to boost recruitment.

"We can now offer graduate students, visiting scholars, and professors an urban environment," says Boroyevich.

But the CPES metropolitan offshoot will maintain and strengthen ties with the Blacksburg lab.

In addition to a constant flow of new students and visits from faculty members who have offices in both locations or are taking sabbatical, more and more courses will be offered online, and the day-to-day activities of the labs in both locations will be livestreamed. "Technology is here to help," says Cvetkovic. ■

CPES: It's electric

The power industry is bracing for a tidal wave of demand for electrification—electric vehicles, data centers, heat pumps, motor drives, renewable energy, and grid applications.

"To meet the needs of our drastically changing landscape, a flexible, reliable, resilient, and secure power system is essential," says Christina DiMarino. "Power electronics and advanced materials can make this happen."

With a new lab in the greater Washington, D.C. area, the Center for Power Electronics Systems (CPES) is set to serve as a linchpin as we pivot toward electrification worldwide; DiMarino is set to steer it.

Her first weeks as an assistant professor involved coordinating with government and industry contacts in Arlington, advancing high-density, high-speed, silicon-carbide (SiC) power module packaging, developing a hands-on course on electronics packaging, and helping to get the new hardware-focused lab up and running.

With natural light streaming in, and almost every wall a window, "the lab is an open book," said DiMarino. "Anyone can walk by and see what we're doing. It's an opportunity to interact with other centers, labs, departments, and colleges."

Module packaging research

As a doctoral student and research faculty member in the ECE department, DiMarino worked alongside other researchers from Virginia Tech and the University of Nottingham on the packaging of high-voltage silicon carbide (SiC) transistors. Now, as an assistant professor, she is pushing this research further.

Wide bandgap power semiconductors—specifically SiC power devices with voltage ratings exceeding 10 kV—can switch higher voltages faster and with lower losses than existing semiconductor technologies, explained DiMarino. This drastically reduces the size, weight, and complexity of medium-voltage systems. However, these devices also bring new challenges.

"Current power module packaging is limiting the performance of these unique switches," said DiMarino.

She is leading a transdisciplinary project to address the electrical, thermal, and reliability challenges, as well as electrostatic and electromagnetic interference issues associated with a high-speed 10 kV device.

"By pooling our knowledge in packaging, materials, thermal, semiconductor devices, power electronics, electromagnetics, and high voltage, we can overcome these barriers and hasten the adoption of these game-changing devices," said DiMarino.

Power electronics building blocks

DiMarino is also part of a team developing modular power electronics units, which "thanks to the flexibility of their connection, can be used in a variety of applications," she explained.

The goal of the project, sponsored by the Office of Naval Research, is to quintuple the power density of power electronics building blocks by increasing integration at the package level. ■

JOY ASICO

ASSISTANT PROFESSOR

Christina DiMarino

- Joined ECE January 2019
- Assistant Director, Center for Power Electronics Systems, 2017-present
- Rolls-Royce Graduate Fellow, 2016-2017
- Webber Fellow, 2012-2015
- Ph.D., electrical engineering, Virginia Tech, 2018
- M.S., electrical engineering, Virginia Tech, 2014
- B.S., engineering, James Madison University, 2012

FutureHAUS Dubai
Your next house

Last summer, a neighborhood of the future sprang up on a strip of Dubai desert. It was the site of the 2018 Solar Decathlon Middle East competition, which included one small solar home that produced more energy than it used overall.

That house was designed and built by the FutureHAUS Dubai team, an interdisciplinary collaboration that involved students and researchers from Virginia Tech's College of Architecture and Urban Studies who led the project, College of Engineering, Myers-Lawson School of Construction, Pamplin College of Business, College of Liberal Arts and Human Sciences, and College of Science. "We won!" said Igor Cvetkovic, technical director of the Center for Power Electronics (CPES) and the power electronics lead on the project.

"This project demonstrated how, if we trust each other and work together, interdisciplinary teams can achieve incredible things," said Cvetkovic. "We created something completely new that ended up being the best of its kind in the world."

The competition was the result of a joint effort by the United States Department of Energy and the United Arab Emirates' Dubai Electricity & Water Authority. Of the 15 international university teams competing, Virginia Tech was the only one based in the United States.

Virginia Tech's win follows almost two decades of research, two years of focused design and development, and more than a month in Dubai—where two dozen students and faculty members erected, tested, debugged, adjusted, and perfected their solar house.

Practicing new power perspectives

Cvetkovic, three ECE undergraduate students—Matt Erwin (CPE senior), Elif Patton (EE senior), Michaela Goldammer (EE senior)—and four CPES graduate students—Vladimir Mitrovic, Joshua Stewart, Hao Xue, and Sarah El-Helw—worked closely with team members from the School of Architecture + Design. Together they interlaced FutureHAUS Dubai with a state-of-the-art electronics infrastructure that demonstrated the transformative capabilities of advanced power electronics in the home.

The FutureHAUS power infrastructure included 14-kilowatt solar arrays and a 14-kilowatt-hour energy storage system. The solar array and batteries fed excess energy into the grid via an 8-kilowatt bidirectional power inverter.

For safety reasons, all teams used standard power electronics technology—converters, batteries, chargers, and solar panels. But the Virginia Tech team had their own spin on implementation; they designed a system that used commercial technology in unconventional ways.

"We disabled standard modes of operation in the equipment we used and implemented our own controls—that's how we went beyond other teams," explained Cvetkovic. "The competition rules did not allow for the use of power electronics prototypes and, although that would have been an ideal fit for CPES, we still pushed boundaries further than anyone else."

FutureHAUS challenged the building industry by demonstrating the use of advanced manufacturing concepts, prefabricated structures, and modular-cartridge design to redefine conventional practices of modern energy-efficient building with plug-and-play capability.

"You could literally snap house cartridges together like LEGO® blocks, and have a home put together in a few hours, with all electrical, mechanical, and plumbing infrastructure interconnected," said Cvetkovic. "You would just step inside and enjoy."

DC-powered wall

FutureHAUS is a 900-square-foot house, and the Virginia Tech team looked beyond their immediate goals by engineering some elbow room. They installed a moving wall powered by direct current (dc) that transformed one room into two.

The wall, which moved along a hidden rail, was outfitted with an entertainment system. By using dc to power it, the team was able to seamlessly and efficiently deliver low voltage to what they called "flex space."

"Moving toward dc for domestic applications is slowly becoming an industry-wide trend, and we were able to show how this form of power distribution can be safely implemented in a home and work great," said Cvetkovic. "This was innovation executed safely."

The Solar Decathlon committee evidently appreciated the demonstration. In addition to winning first place overall, the team made a strong showing in the subcontests: first place in architecture, first place in creative solutions, second place in energy efficiency, second place in interior design, third place in sustainability, and third place in engineering and construction.

But the work didn't stop with the competition. CPES researchers have continued to improve upon and expand the power electronics technology on brilliant display in FutureHAUS Dubai.

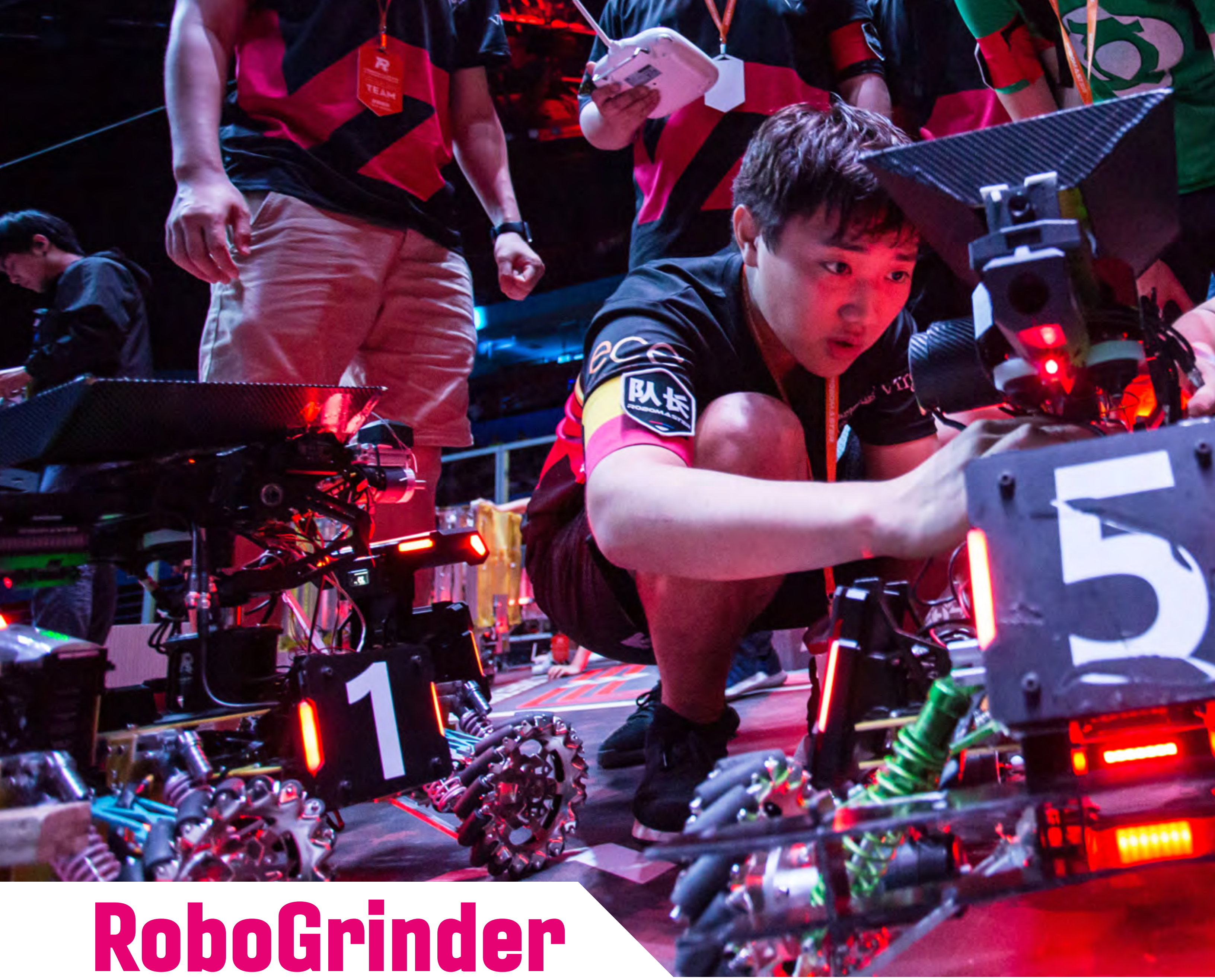
"It was an amazing and very gratifying experience, and that's what university is about. Opening new doors and learning from each other in a great interdisciplinary atmosphere," said Cvetkovic. "But stay tuned. There's more coming." ■

JOY ASICO

ABOVE Igor Cvetkovic (right), technical director of the Center for Power Electronics, was the power electronics lead on the FutureHAUS Dubai team.

LEFT Engineering some elbow room: FutureHAUS Dubai featured a direct current-powered moving wall, which transformed one room into two.

ERIK THORSEN



RoboGrinder

Building a robot from scratch–overnight.

Living with 15 roommates–in a three-bedroom house.

Forgoing Friday night parties, weekend activities, and holiday breaks–to create a competitive team of robots.

These and other self-inflicted rigors, which captain Yipin Zhou admits to with a laugh, demonstrate the passion exhibited by the Virginia Tech RoboGrinder team, which placed in the second tier of the final RoboMaster Robotics competition in July 2018.

Sponsored by Chinese-based company DJI, RoboMaster is a robotics competition that pits university teams against each other in a tournament that combines technical prowess with team strategy.

As one of the international teams in the 2018 tournament, RoboGrinder had an extra set of hurdles: they had to scramble to find affordable parts on their tight schedule, and much of the team relocated to China for two-and-a-half months to unpack, assemble, and test their seven robots.

Home base in China was a small apartment in Foshan, about 60 miles from where the competition would be taking place. Space was so tight that the teammates slept among their robots. (Although, this wasn't exactly unusual, says Zhou, who described similar sleeping conditions during late night lab sessions in Blacksburg.) By day, they taught local students in exchange for air-conditioned work space in a nearby high school. By night, they built robots.

Their dedication paid off during the July international regional competition where they placed among the grand prize winners.

Three days later, international and Chinese finalists (the latter of whom had emerged from the Chinese regional competition two months earlier) faced off in the final tournament.

In the ring

Every team in the 2018 Robomaster competition had seven robots in the ring: three infantry robots, a hero, a guard/sentry, an aerial drone, and an engineer robot. They engaged in brutal exchanges of

Yipin Zhou (left), CPE junior, tests the wires on the control board, while Jason Lu (right), a computer science senior, adjusts the gimbal during a three-minute break between bouts at the RoboMaster Robotics competition in China.

projectiles—small rubber balls—on a battleground studded with obstacles, attempting to score hit points and take out the other team's base.

Equipped with a grabbing mechanism to pick up buckets of ammo, the hero robot was powered by an STM32-embedded system, which controlled the air cylinder, chassis motor, and gimble motor.

The three nimble infantry robots were deployed to catch and trap the enemy hero robot. RoboGrinder's infantry model was equipped with a custom supercapacitor, which allowed the team to bump up the chassis power to 900 watts—far exceeding the 80 watts achieved by competing teams using off-the-shelf components.

The team used linear actuators to control their 2018 engineering robot. This made it easy to control, says Zhou, but slow—a critical flaw for the robot that served as the mobile arsenal.

The guard robot, which defended the base, employed computer vision to detect the enemy, and the aerial drone with the shooting mechanism on the bottom provided support from above.

With the exception of the fully autonomous guard robot, the machines were remotely controlled off-ring. But who got to drive?

"We picked the person who had the most first-person shooting (FPS) games experience," says Zhou. "He had like 2,000 FPS hours. And he did a great job."

Post-game

After the tournament concluded, the students packed up their robots and shipped them overseas—back to the U.S. Three months later, the packages were finally delivered on November 6—a Friday night.

"No one went out to any parties or anything that night," says Zhou. "We were getting our babies back!" A group of students spent the whole night disassembling them and worked late into the next morning to get them running again.

Back in Blacksburg

In 2016, the multidisciplinary team had nine members. But after the 2018 competition, an interest meeting drew about 200 students, and the official team roster swelled to about 90 members—35 members from ECE, 30 from mechanical engineering, and the rest from computer science, math, physics, architecture, finance, business, and industrial and systems engineering.

RoboGrinder veterans have been conducting tutorials to get new students up to speed. A computer science/computer engineering double major, for instance, has been offering C++ lessons to his teammates, while a mechanical engineering major holds regular CAD modeling sessions.

Students are involved in one or more of RoboGrinder's four branches: ECE, mechanical engineering, computer vision, and operations/outreach.

In November, the team approached Alexander Leonessa, a professor in mechanical engineering and in ECE by courtesy appointment, who agreed to act as advisor.

"It's inspiring to work with a team with so much motivation and focus," says Leonessa. "Their achievements have already made all of us proud, and I am sure they will accomplish great things this year."

Besides the extra expertise and professional guidance, the team now has access to an off-campus space, where they can plan their own battlefield, and to the Trec Lab Machine Shop.

With these resources, the extra training, and the reinforced team, RoboGrinder has sights set on even higher honors in the 2019 Robomaster competition. But, as Zhou is quick to point out, the real win comes from working together to apply engineering.

"We hope our team can become a platform for any Virginia Tech student. Our working environment is also a really good learning environment." ■

Fitting in with the brain

Above: Xiaoting Jia was awarded an NSF CAREER grant to develop a multifunctional neural interface device that is highly flexible, scalable, clinically translatable, and bio-friendly.

Top right: Jia and her team are using a custom-built femtosecond laser micromachining setup to etch and pattern the fiber surfaces, creating multi-site 3D fiber-based electrical, optical and microfluidic neural interfaces for the first time.

As brain science advances, researchers are refining their maps of the brain's twisting neural passages. But many functional networks remain elusive. What causes brain-related diseases like Parkinson's, autism, and Alzheimer's? How can we prevent them or mitigate their affects?

Neural implant devices are helping researchers answer these questions, but progress has been slowed by the engineering challenge of creating a deep brain neural interface that matches the brain's complexity.

Xiaoting Jia, assistant professor, is rising to the challenge. She is developing a multifunctional neural interface device that is highly flexible, scalable, clinically translatable, and bio-friendly.

Jia was awarded a National Science Foundation (NSF) Faculty Early CAREER Award for this project. The CAREER grant, one of the NSF's most prestigious awards, is given to faculty members who are expected to become academic leaders in their field.

As the technology has evolved in recent years, microelectrode sensors have given researchers a direct channel for recording and affecting brain activity. Newer generations of neural interface devices are increasingly sophisticated, according to Jia. They feature improved spatial resolution and can sense and stimulate across more electrode channels.

"But metrics like functionality and bio-friendliness are hard to achieve and scale at the same time on current device platforms," said Jia. "This is where we are focusing."

Multifunctional and bio-friendly

Multifunctional devices can switch specific neurons off and on, and they can modulate local biochemical environments and activities. But what qualifies a neural implant as bio-friendly?

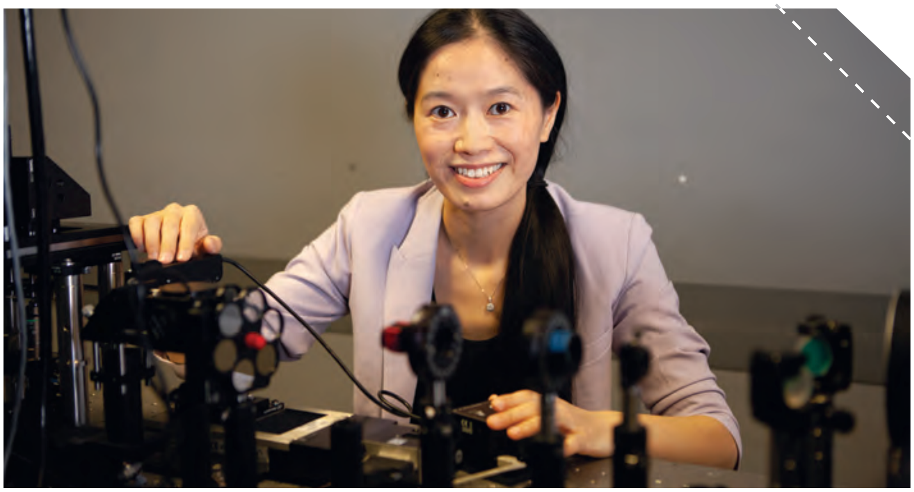
According to Jia, bio-friendly devices are flexible and biocompatible, can be produced cost-effectively in large quantities for experimentation, and translate easily to the human brain.

SHAWN SPROUSE

Flexible and biocompatible

To assimilate gently into delicate brain tissue, an implant must be supple and responsive, said Jia. A flexible implant minimizes tissue damage and any chance of probe misplacement or device failure. To achieve this quality, Jia and her team are developing electrode probes made out of polymers and carbon nanomaterials—"highly flexible interfaces, ideal for stimulating and recording neurons," said Jia.

These materials are also biocompatible, which means they minimize scarring and neuron death, and are more chemically stable than silicon or other low-melting-point metals used in existing multielectrode sensors, said Jia.



SHAWN SPROUSE

Scalable and translatable

To create scalable devices, Jia's team is using a technique called fiber drawing, which allows them to integrate optical, electrical, microfluidic and other features into a single fiber. They start with a hand-sized version of the probe—called a macroscopic preform—that contains carbon-based electrodes along with several other features.

After carefully heating the preform, the researchers stretch it from a tall tower (a fiber drawing tower), which pulls the preform into a long, thin strand. During the thermal drawing, the carbon nanofibers line up lengthwise within the strand, which improves the electrical conductivity while still maintaining flexibility and biocompatibility.

By repeating this whole process in multi-step drawings, the device can be multiplexed to create hundreds of functional channels. The probes themselves come from thin, cross-sectional slices of the strand, which contain nano-sized versions of the original features.

"For the first time, we can fabricate aligned carbon nanofiber-based electrodes inside polymer fibers in a scalable manner, and potentially use that as miniaturized neural recording devices without sacrificing conductivity," said Jia

Because the fiber drawing method continuously draws fiber strands containing electrodes and other functional components, electrodes can easily extend to larger lengths, added Jia. "This is a key step for moving from small animal tests to human clinical trials."

Impact

Jia and her team are collaborating with neuroscientists and chemical engineers to put these devices to work treating brain tumors.

"The multifunctional fiber probe provides us with a powerful tool for studying and treating tumors," said Jia. "Not only does it provide an ideal drug delivery path, but it also allows for real-time monitoring and assessment of tumor characteristics."

Outreach and education

All CAREER awards have an educational component, and Jia has designed modules for undergraduate courses and learning opportunities for K–12 students. Biomedical device design projects will be incorporated into undergraduate base courses, and students will showcase their work to K–12 classes. Jia's team will also be collaborating with the Institute for Creativity, Arts, and Technology (ICAT) and the Center for the Enhancement of Engineering Diversity (CEED) to introduce biomedical devices and nanotechnology to children of all ages.

The project will clear the path for the next generation of neuro researchers and the next generation of neural interface devices. ■

SHAWN SPROUSE

ASSISTANT PROFESSOR

Yuhao Zhang

- Joined ECE August 2018
- Postdoctoral associate, Massachusetts Institute of Technology (MIT), 2017–2018
- Ph.D., electrical engineering, MIT, 2017
- M.S., electrical engineering and computer science, MIT, 2013
- B.S., physics, Peking University, China, 2011

Emerging power devices

The clamor for smaller, more efficient electronic devices is so constant that many consider it background noise. Yuhao Zhang, an assistant professor at the Center for Power Electronics Systems (CPES) and his colleagues, hear the cries, and are examining the most fundamental building blocks of power electronics devices in order to meet the demand.

Zhang works at the intersection of three research areas: semiconductor devices, materials, and power electronics. His work bridges the gap between new materials and applications, and spurs momentum in both directions.

"We're creating devices that can't be purchased on the market or obtained from other companies, and advancing their practical applications in real-world power systems in data centers, electric vehicles and consumer electronics," he said.

Emerging materials for emerging devices

The majority of today's commercial power devices are made of silicon (Si). Many emerging power devices in research and development are based on a group of materials called wide bandgap semiconductors or ultra-wide bandgap semiconductors. These devices use materials such as silicon carbide (SiC), gallium nitride (GaN), diamond, and the less-studied gallium oxide (Ga_2O_3). With a much larger bandgap, these materials can sustain at least 10 times the voltage of silicon with less power loss, explained Zhang.

"Overall, these materials can achieve 1,000 times higher performance compared to silicon devices—and they allow for switching at a higher frequency," said Zhang. If the system's switching frequency is higher, then the capacitors and inductors—which take up the majority of the volume of these devices—can also be smaller, significantly reducing the system's volume.

"For example, power electronics devices based on wide bandgap semiconductors can shrink the size of a laptop charger to one cubic centimeter," said Zhang. "These devices can significantly increase the efficiency and decrease the size of the overall system."

Zhang is trying to expand the application space of these materials in power electronics. He has already begun fabricating novel GaN and Ga_2O_3 devices in the clean room.

Emerging devices for emerging applications

Zhang's work isn't just on the small side. When data centers step down electricity from the grid (480 V ac to 1 V dc), approximately one third of the total energy is lost in the conversion. By incorporating new devices like those CPES researchers are developing, Zhang expects the overall efficiency of power delivery to increase by at least 10 percent, which would pack a punch.

"Recent estimates claim that if we can increase overall power conversion efficiency by just 1 percent, the amount of energy we would save every year is equivalent to five nuclear power plants," said Zhang.

Whatever the physical size of the devices that will use Zhang's technology, the energy and space savings will be huge. ■

Modularity and electrification: meeting current and future demands

From the power grid to public transportation to the family car—we're due for an electronics upgrade.

Dong Dong, an assistant professor in ECE, is developing high-power high-frequency power electronics components, controls, and systems to enable a sprawling multi-decade, multi-industry infrastructure upgrade.

Many components on the power grid, for instance, have been deployed for almost a century, and Dong foresees "a huge opportunity for us to replace aging assets with our research outcomes."

Integrating, managing, and storing renewable energy resources across every sector of the grid is a formidable challenge, said Dong. Power conversion systems connect renewable resources to the grid, and Dong is working closely with power systems experts to combine cutting-edge technologies in both fields. They are developing new tools to help accelerate the transition from the traditional grid to a new grid that could be composed almost entirely of renewable assets.

Dong is also working on systems that can take full advantage of energy from renewable assets. For example, microgrids, electronic energy routers, and solid-state power substations—which are composed of innovative power electronics, sensors, and cyber solutions—can reduce complexity, increase efficiency, and add functionality and security.

The trend of electrification is lighting up applications in many other sectors of society, notably electric vehicles—cars, planes, trains, and boats. By replacing the mechanical components with power electronics systems, we can distribute propulsion components, shrink engine size, and cut carbon dioxide emissions, said Dong.

Modular high-frequency power electronics

According to Dong, industry engineers have traditionally used high-voltage devices with slower switching speeds to build the large power conversion system for high-power applications, said Dong. His research on wide-bandgap semiconductors and their applications is pushing the boundaries on high-power applications.

"These devices make your system respond faster and react to load demand quickly and precisely," said Dong. "Wide-bandgap devices have a much lower switching loss, so efficiency improves, and will ultimately help reduce cooling system cost, size, and complexity."

In his work, Dong uses a modular approach. He steers clear of designing "gigantic systems," and focuses on breaking a system down into modular pieces.

"With the modular approach, we can move on to medium- to high-voltage high-power conversion applications with what we learned from high-frequency switching power supplies," said Dong.

"We can optimize submodules and build larger high-power high-voltage systems—like LEGO® blocks." And this modularity will make system design easier.

"It allows us to decouple system complexities and improve development cycles."

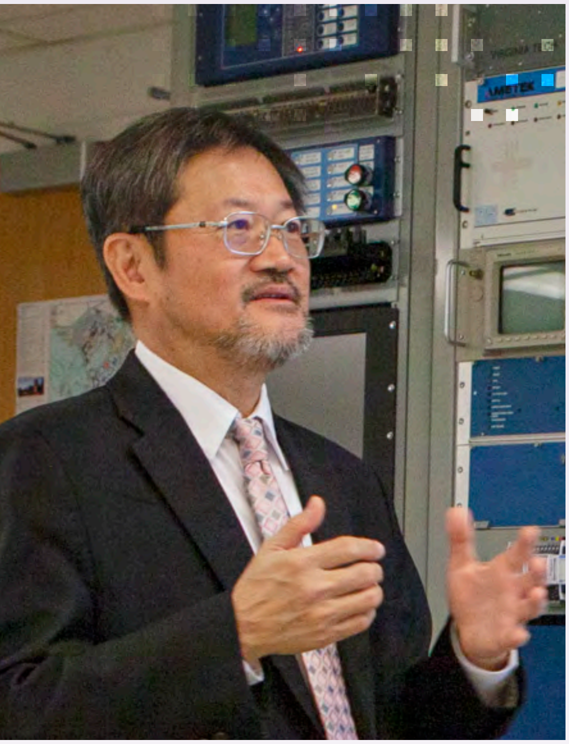
The risks and costs associated with each project are also reduced, and "we can apply the same modules for various applications with different requirements for frequencies and power levels," said Dong. "We can even populate the entire electric power system in the future with such an approach." ■

SHAWN SPROUSE

ASSISTANT PROFESSOR

Dong Dong

- Joined ECE August 2018
- Research scientist, GE Global Research Center, 2012-2018
- Research assistant, Center for Power Electronics Systems, 2007-2012
- Ph.D., electrical engineering, Virginia Tech, 2012
- M.S., electrical engineering, Virginia Tech, 2007
- B.S., electrical engineering and automation, Tsinghua University, Beijing, 2007



SHAWN SPROUSE

AMERICAN ELECTRIC POWER PROFESSOR

- Joined ECE January 2018
- Boeing Distinguished Professor of Electrical Engineering, Washington State University, 2011-2017
- Professor, University College Dublin, Ireland, 2008-2011
- Palmer Chair Professor, Iowa State University, 2006-2008
- Professor & associate dean of engineering, University of Washington, Seattle, 2000-2005
- Power and Energy Society Outstanding Power Engineering Educator Award, 2004
- IEEE Third Millennium Medal, 2000
- IEEE Fellow, 1994
- Ph.D., electrical engineering, University of California, Berkeley, 1983
- M.S. electrical engineering, National Taiwan University, Taiwan, 1978
- B.S., electrical engineering, National Taiwan University, Taiwan, 1976

Shaping the power grid of the future

Already a national and international leader in power grid research and education, Virginia Tech's power systems program is positioning itself to continue the tradition of global leadership.

Chen-Ching Liu, the American Electric Power Professor, took the helm of the Power and Energy Center in January 2018. With his fellow researchers, Liu has been cultivating industry relationships and cross-disciplinary partnerships to establish a new vision.

"We are mobilizing the program to shape the future power grid, or as we've been calling it, the cybergrid," said Liu.

The cybergrid is supported by four main components: measurement, power electronics, cybersecurity, and decentralization. Liu's group is building a testbed that integrates these components along with their associated technologies.

Each of the components will have to work independently and collaboratively. "As we figure out better control resources and strategies for the different components, we will be developing their ability to work with each other and bring the whole system together," explained Liu.

"These four components together represent cybergrid challenges with enough work to keep all of us busy for many years," said Liu.

Detecting cyber intrusions of the power grid

Liu's team is using the testbed to investigate how cyber intrusions like falsified control commands can be detected and stopped. In this project, the researchers use relation-based models and algorithms to identify collaborative attacks. They are also developing techniques to defend the supervisory control system against falsified measurements that use the power grid's communication systems.

Restoring critical services with distributed energy

With funding from the U.S. Department of Energy and the Pacific Northwest National Laboratory, Liu and his team are exploring the resiliency of power distribution systems in the event of a natural disaster or catastrophe.

They are focusing on restoring critical services after a catastrophic outage where the utility system is severely damaged. In this situation, microgrids and distributed energy sources would be tapped to serve the critical load.

"We have proposed a new metric for resiliency based on the total megawatt-hours that the system is able to provide to critical services during system restoration," said Liu.

With the explosion of potential dangers and opportunities of the cyber grid, the solutions to these challenges will be what ensures the reliable power system of the future. ■

Ozone at every level

Photons from the sun are constantly streaming into the atmosphere, being absorbed and re-emitted on their path to Earth's surface. Elena Lind, ECE assistant professor, builds instruments, develops inversion algorithms, and takes measurements to deduce what those photons are telling us about the layers of atmosphere they move through.

"I want to understand what we humans do to the environment, and what consequences our actions have—not just today but in the long term," she said.

Lind is specifically interested in ozone (O_3) and its precursors, both in the stratosphere (peak at 25 km) and near the surface. The naturally occurring and oft-championed stratospheric ozone protects the Earth from deadly ultraviolet light. "Near surface ozone is bad ozone compared to stratospheric ozone," said Lind. "It destroys materials, harms plants, and causes and exacerbates human health issues like asthma. It's ozone that was cooked up from pollution."

Chemicals detrimental to ozone chemistry include nitrogen oxides (e.g. NO and NO_2). These gases help ozone formation near the surface (where it shouldn't be) and ozone destruction in the stratosphere, where we desperately need it. "It works against us every time," said Lind.

Near the surface, nitrogen oxides come from fossil fuel and biomass burning. In the stratosphere, they come from nitrous oxide (N_2O), which has commercial applications but is also produced by bacteria in soils and ocean. As we use more nitrogen-based fertilizers in agriculture, we contribute to nitrogen oxides in the stratosphere, said Lind.

Using a technique called ultraviolet-visible differential optical absorption spectroscopy (DOAS), Lind is investigating NO_2 and other pollutants related to ozone by measuring the attenuation of solar radiation as photons travel through the atmosphere and into instruments on the surface.

Analysis and instrumentation

When dealing with emissions and atmospheric modeling, both the datasets and the margins of error are huge, said Lind. Lind and her team are using advanced atmospheric modeling, inversion algorithms, and machine learning techniques to interpret the data, create models, and verify results.

"This is a multistep process, and if you don't understand the instrument itself, there will be a lot of errors that propagate through analysis," said Lind. "So, I build my own."

Lind has two DOAS instruments that are capable of autonomous simultaneous measurements of several gases (e.g. O_3, NO_2, formaldehyde, sulfur dioxide, bromine monoxide): one research-grade and one field-grade. The latter is part of the Pandonia Global Network, which is sponsored by the European Space Agency (ESA) and NASA.

Lind is currently building a backscatter polarization aerosol LIDAR to describe vertical aerosol distribution in atmosphere. She is also the local PI for NASA's Aerosol Robotic Network radiometer that measures total aerosol optical depth in the atmosphere.

Lind is working to understand a process with so many unknowns that she can't focus on just one aspect of the problem. She and her team are working at every level, from instrumentation to analysis, in order to bring new knowledge to one of Earth's most pressing concerns. ■

PROVIDED BY ELENA LIND

ASSISTANT PROFESSOR

Elena Lind

- Joined ECE November 2018
- Research associate, Goddard Space Flight Center/NASA, University of Maryland, College Park, 2013-2017
- Research associate, Washington State University, 2010-2012
- Ph.D., civil engineering, Washington State University, 2010
- M.S., environmental engineering, University of Idaho, 2002
- B.S., chemistry and chemical technology, Moldova State University, 1998

SHAWN SPROUSE

Prepping for revolutionary tech changes

Space @ Virginia Tech to answer growing need for trained engineers

The same technologies and advances that have upended many Earth-based industries are poised to revolutionize satellite communications, space travel, and the study of other planets and stars. The changes have already begun, and the need for engineers trained in the field is growing rapidly, according to ECE Professor Scott Bailey, who was recently named director of Virginia Tech's Center for Space Science and Engineering Research.

Virginia Tech, he said, is well positioned to be a leader in educating this workforce.

Technological changes

Machine learning, shrinking instrumentation, new fabrication technologies, imaging technology, and computing and communications advances are informing new approaches that will rapidly change how we do things in space, according to Bailey. Greater demand for internet by satellite and satellite communications add to the challenge.

Smaller instrumentation and the move to smaller satellites, such as CubeSats, are already changing missions, he said. "Any single satellite is much less expensive. We're launching more of them."

Then, there is space junk. "That's going to increase exponentially because of the number of devices we're putting in orbit." During the career lifetime of today's graduates, a whole new industry will arise to deal with space junk, he predicted.

A paradigm shift in space science

In addition to technology advances, Bailey described a paradigm shift unfolding in space science. "Where we once measured small changes in the brightness of a star to determine the presence of orbiting planets, now we will look directly for the atmospheric signal from those planets—the same way we now study Earth," he said.

The excitement over the New Horizons images is a start, he said. "We may not have pictures that are quite so cool, but our science results will be."

Virginia Tech is a part of that shift in space science, he said.

Training students in the field

The Center for Space Science and Engineering Research has an international research reputation and is well positioned to be an educational leader, Bailey said. Space@VT, as the center is nicknamed, was officially founded in 2007 with Wayne Scales, the J. Byron Maupin Professor of Engineering, serving as director until this year. Today, the center includes 25 tenure-track and research faculty members from ECE and the Department of Aerospace and Ocean Engineering (AOE).

Projects in the center are typically driven by scientific inquiry into issues like dusty plasmas, space weather, Earth's magnetic field, noctilucent clouds, upper atmospheric physics, plus spacecraft dynamics and control, propulsion, GPS, and environmental interactions. In pursuing the science, the center's students and research teams have built and launched rockets and satellites, plotted trajectories and selected stars for navigation points, traveled to Antarctica establishing magnetometer base stations, and worked on Earth-based space weather radars in the SuperDARN chain.

Wayne Scales (left), former director of Virginia Tech's Center for Space Science and Engineering talks with the new director, Scott Bailey (right). Scales recently accepted a new position as special assistant to the dean of engineering.

Curriculum innovation to meet the demand

Practical education driven by scientific inquiry is a valuable model for education, according to Bailey. "Our graduates are in demand," he said. However, in order to meet the growing need for graduates, "We are innovating our curriculum and in five years want to graduate 50 master's students annually," he added.

This is possible by expanding in Blacksburg and in the greater Washington, D.C. region, where many industry partners are located.

Since being named director in February, along with co-director and AOE professor Jonathan Black, Bailey has been meeting with industry partners and government laboratories to understand the skills and background they seek in new hires. "These organizations are all telling us that most graduates from universities need more experience in safety and systems engineering," he said.

"We can do this. We already have the system in place." The difference, he said, would be to establish educational programs that ensure that undergraduate and graduate students gain a systems engineering perspective.

A key goal for Space@VT has always been increasing the diversity of people in the field. "As we are growing, we want to increase our efforts in that area. This means we must build on the work that Wayne Scales initiated and reach out to people from underrepresented groups to encourage them to consider a career in space science and engineering."

Diversity is crucial in a field where there are complex problems to solve and multiple paths forward. ■

From a student's dream to international success

Virginia Tech's Center for Space Science and Engineering Research began life in 1985 as a graduate student's dream. When Wayne Scales, the J. Byron Maupin Professor of Engineering, was a Ph.D. student at Cornell, he wanted to create an interdisciplinary center that educated students by pursuing scientific inquiry–striving for excellence in both science and engineering.

"When I came to teach at Virginia Tech, my friends and professors at Cornell told me I was crazy for going into a vacuum with no supporting faculty members or infrastructure," he recalled.

"Today," he said, "we are one of the very few groups in the country with the potential that we have. I think that's because we integrate science and engineering, plus perspectives from the intelligence and defense communities. We are very well positioned."

When Scales first joined the ECE faculty in 1992, he was the only space science faculty member in the College of Engineering. By 2000, two AOE faculty members were conducting research in the field. "Within a few years, we conceived of what became Space@VT." Scales served as the center's director until this year.

"We've been very fortunate to bring in very talented faculty members who have contributed," Scales said. While proud of his role in creating the center, "I'm most proud of the impact we've had on students," he said. "We have 60 to 70 grad students and many undergraduates who work with our center every year."

Scales recently accepted a position as special assistant to the dean of engineering. His new goal: to develop bold visions to help drive Virginia Tech's expansion. ■

Cutting the security tradeoff

THERE'S ALWAYS A TRADEOFF between security and efficiency. The goal of security research is to make that tradeoff as small as possible, so that security can be integrated easily into every at-risk device, from server farms to household appliances to smart sensors.

In these endeavors, ECE researchers often find that they can concurrently make significant improvements to the efficiency of the system at the same time–making security overhead negligible, or even arriving at a net gain in efficiency.

On demand rerandomization

Is your software under attack? Consider moving it.

This deceptively simple answer to certain malicious attacks holds both potential and challenges for realistic security, says Changwoo Min, ECE assistant professor.

An insidious method of attacking software is to take existing lines of code and execute them in a different order, to do something not intended by the software developer, explains Min. This technique, known as code reuse, is one of the attacks Min and his team are defending against.

To make it even harder to defend, an attacker doesn't necessarily need to be able to read the code in order to attack in this way. "An attacker can infer the code based on how the system is reacting," says Min. This can happen when the attacker does something to the code or system, then figures out what code is running based on how the system responds—for example, by watching the power use or timing.

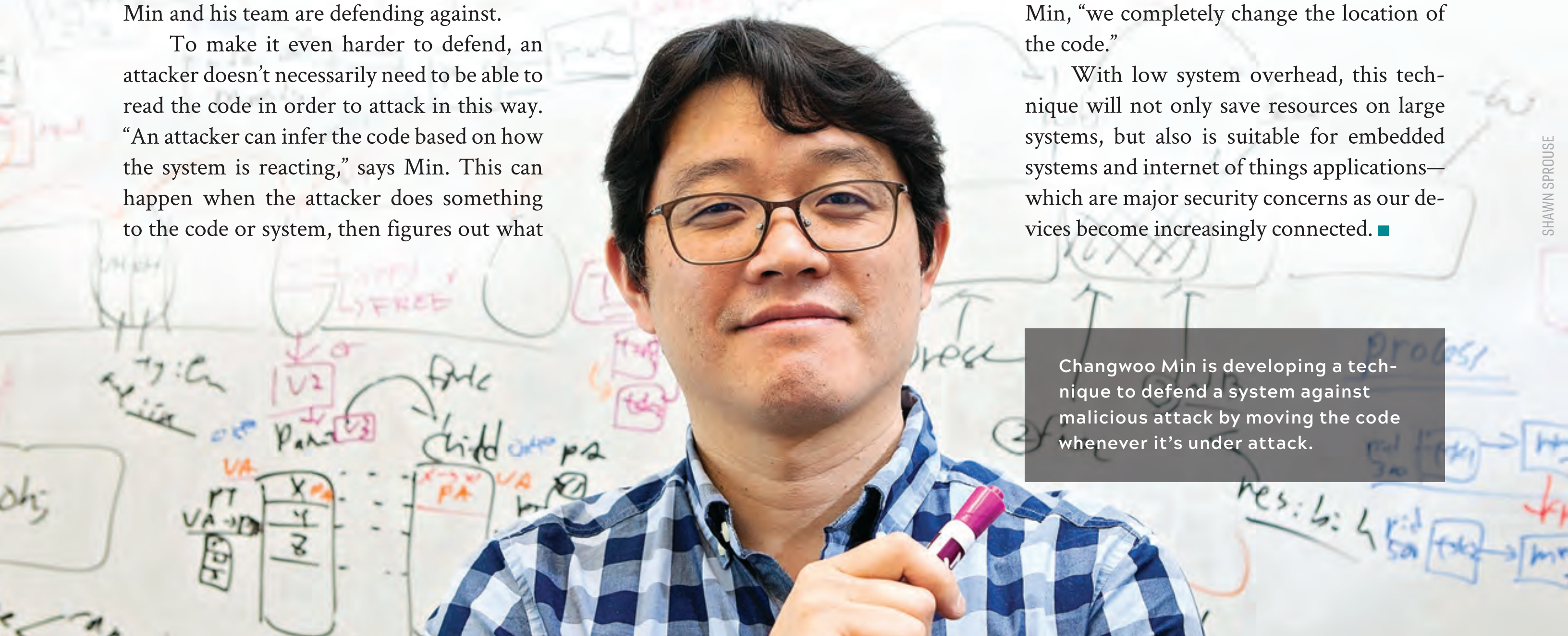
The good news is that this kind of attack is time consuming, and if you change where the code lives in memory, a method called rerandomization, the attacker has to start from scratch each time.

A simple solution is continuous rerandomization, where the code is constantly shifting locations. Doing this, however, requires many CPU cycles of overhead to keep the code moving.

Min and his team are developing an equally secure system that addresses this challenge by only moving the code when it's under attack.

The first step is to know when the system is under attack—which is not straightforward when an attacker is just listening. The system always has an expected response time, explains Min, and that time will be longer when the system is under attack, or the system will crash entirely. "Then," says Min, "we completely change the location of the code."

With low system overhead, this technique will not only save resources on large systems, but also is suitable for embedded systems and internet of things applications—which are major security concerns as our devices become increasingly connected. ■



SHAWN SPROUSE

Changwoo Min is developing a technique to defend a system against malicious attack by moving the code whenever it's under attack.

Security in isolation

Fearful of being overheard, we don't tell secrets in a crowded room. However, we do expect our computer programs to function securely on top of a crowded operating system (OS). Binoy Ravindran, ECE professor, and Pierre Olivier, ECE research assistant professor, are questioning this expectation.

Whether software is running in the cloud or on a personal computer, there are security risks for any application sharing hardware and software resources with other applications, explains Olivier. The more software running, the more opportunity there is for someone to exploit it.

Under the current model, all applications running on an operating system share hardware device drivers, explains Ravindran. "But most applications do not need all the devices. For example, a networking application probably doesn't need to write to USB devices." All these applications, however, regardless of their needs, run on the same operating system, with the overhead of many unnecessary drivers.

To counteract these risks and reduce the attack surface, Ravindran, Olivier, and their team are securing software by reducing the code overhead using unikernels. "Unikernels are very simple operating systems that only run a single application within a virtual machine, loading only the libraries necessary for the application," explains Olivier.

Isolation, according to Olivier, is the key to success. As long as applications are sharing the same operating system, there are opportunities for one program to attack another. With every application running on its own operating system, this fear is mitigated.

"We are addressing this problem by designing a custom OS for every application," explains Ravindran. However, coding for these unikernels could put a burden on software developers, he says. In a project called Hermitux, the team is lightening this burden.

"The challenge is to take legacy Linux applications and automatically run them in the context of a unikernel," says Ravindran. "Hermitux doesn't even need your source code," he continues. "It is executed at runtime." The hope, according to Olivier, is that "developers will think more about unikernels now that there are no extra steps for them."

A unikernel isn't the right answer for every application, however, and some are best run on a full operating system, especially if they need access to most of the device drivers, notes Olivier. "We have to trade off some compatibility to keep it lightweight."

A lightweight system carries substantial benefits. Unikernels can run securely on hardware platforms that might not have enough resources for a full virtual machine, and start up in milliseconds instead of the noticeable wait time of a full system. This means that if a program on a unikernel crashes, it can restart without a noticeable delay—and many of them can be running, in isolation, on the same hardware.

According to both researchers, unikernels have the potential to supplement other security measures for a large impact, without making software development more difficult. ■

Binoy Ravindran (far left), Pierre Olivier (top center) and a team of graduate students are working to improve security for applications that share hardware resources with other applications.

SHAWN SPROUSE

Energy-starved security

Recent estimates report that by 2020, up to 50 billion devices will be connected to the internet. ECE researchers are questioning how to power all of them.

What if smaller devices could be powered by renewable energy? A solar cell, or a battery that runs on vibrations or heat? We would never have to charge our batteries again. Researchers and industry experts are increasingly looking to these instruments, called energy harvesters, to help shoulder the mounting demand for power.

But today's small-scale energy harvesters don't provide enough power to run complex cryptographic operations in real time. An energy harvester first has to accumulate enough energy to initiate the protocol, which hinders response times.

In short, sustainably powered miniature computers are either insecure or too slow to be useful.

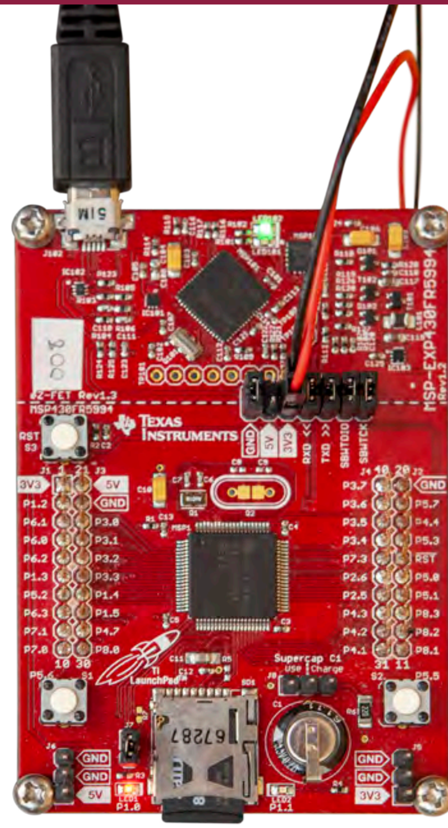
"Neither of these is acceptable," says Patrick Schaumont, who, along with fellow ECE professor Dong Ha, received a $850,000 National Science Foundation grant to maintain information security in the energy-starved operating environment of embedded connected devices.

Inconsistent power sources

Collecting renewable energy means dealing with an inconsistent or intermittent power source. The sun sets. The engine turns off and cools down. The person stops walking.

To optimize cryptographic algorithms and protocols in the face of unreliable power supplies, Schaumont and his team are developing techniques to generate and securely store "coupons"—tiny pre-computed packets that hold the results from cryptographic algorithms.

When the energy harvesters have a little extra energy at the end of a long car ride or a sunny day, that energy is funneled into the prep work of coupon generation, which speeds up online encryption and computation as new data comes in. ■

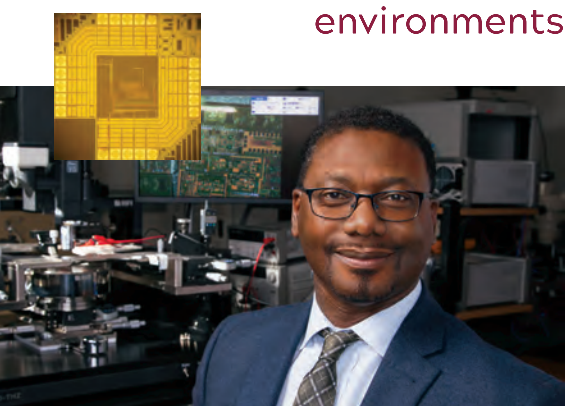


SHAWN SPROUSE

SCHAUMONT and his team developed a chip to demonstrate a platform for tamper-resistant embedded software design.

Multicore security:

investigating threats to Network-on-Chip environments



DAVID FRANUSICH

PAUL AMPADU and his team are investigating how Networks-on-Chips are vulnerable and how to fortify them.

Communications becomes a bottleneck as we push for more cores in even basic computers, according to Paul Ampadu, an ECE professor trying to solve this challenge. Even the newer models of smart phones have eight cores, and the trend shows no signs of stopping.

"Why? Because we have demanded more performance, more efficiency, more power, and we want it all on ever-smaller systems," said Ampadu.

Researchers are meeting this demand for multicore platforms by developing more reliable, energy-efficient, heterogeneous Networks-on-Chip (NoC), a highly scalable upgrade to the conventional bus-based System-on-Chip (SOC) design. But, as more cores are integrated onto each chip, these new configurations present new security holes. Ampadu and his team are investigating how NoCs are vulnerable and how to fortify them.

With a mesh NoC topology, all nodes (cores) can access resources without a shared bus. One node can interact with any other via a series of simple hops. "We've cut back on direct connections between nodes," said Ampadu. "But that exposes the system to security threats."

An NoC environment is especially susceptible to noninvasive attacks like side channel attacks, where an attacker could use shared resources like routers to steal data or gather information to mount a more aggressive attack.

Approximation

Ampadu and his team, including graduate student Shenghou (Minux) Ma, are investigating techniques to defend NoCs, particularly for approximate computing applications.

Many applications that are well suited to run on NoCs will be making decisions, predicting trends, recognizing faces, and other tasks that require multiple iterations in parallel. These types of tasks lend themselves to approximation, said Ampadu. ■

PROVIDED BY WILLIAM DIEHL

Plugging leaks, keeping secrets

No matter how secure your device, it's going to leak information. All existing physical devices emit some signature, like radio waves, power signals, near-field communications, or similar phenomena —and if a signal is observable, the device is vulnerable.

William Diehl, who recently joined the department as an assistant professor, specializes in secure, efficient cryptography that protects both software and hardware from malicious attacks.

"A lot of major cybersecurity breaches occur at the traditional software level, due to misuse of protocols, malware, passwords, etc.," explained Diehl. "But an emerging portion are due to flaws in hardware."

Side-channel analysis

Diehl is investigating side-channel analysis of lightweight authenticated ciphers—an experimental type of symmetric key cryptography, which involves probing for active and passive side channel attacks.

"We've successfully developed new methodology for analyzing fault attacks against these varieties of ciphers," said Diehl. "Called fault intensity map analysis, it's one of the most efficient statistical analyses for fault analysis."

Diehl's team has simulated the technique and tested it on reconfigurable devices. Research of these vulnerabilities will help bolster defense of systems against cyberattacks that "cause fault, voltage, and clock malfunctions, observe the output, and make statistical inferences to steal people's keys," said Diehl.

Securing unmanned aerial systems

In collaboration with researchers from James Madison University, Diehl is also developing a layer of security that can be added to drones as they fly from node to node.

"It's not easy to do secure communication on cheap drones because of extra size, weight, and power needs," said Diehl. "We add an extra level of secret key encryption to achieve security, and implement a transformational technique called pairing-based cryptography."

Signatures Analysis Lab

Signatures are the foundation of Diehl's work. "Signatures could be anything we can find about a device," he explained. "Finding or locating malware in code or hardware, Trojan detection, watermarking, IP protection. We want to learn and characterize all the ways a device can be observed."

To develop secure, efficient cryptography, Diehl traces the paths an attacker would take, focusing specifically on vulnerabilities found in leaked power signals. He is currently building the Signature Analysis Laboratory to conduct voltage and current measurements, run algorithms, analyze data, tease out relationships, and search for secret keys on reconfigurable devices.

"The learning and design of these acquisition and analysis techniques is as valuable as the ultimate conclusion," said Diehl. "Without methodology, there are no results, just theory." ■

ASSISTANT PROFESSOR

William Diehl

- Joined ECE August 2018
- Ph.D., electrical and computer engineering, George Mason University, 2018
- Principal engineer, senior manager General Dynamics Mission Systems, 2015-2017
- U.S. Navy Cryptologic Officer and Surface Warfare Officer (Captain), 1991-2014
- M.S., strategic studies, Air War College, 2011
- Space systems certificate, Naval Postgraduate School, 2008
- M.A., international studies, Old Dominion University, 2004
- M.S., electrical engineering, Naval Postgraduate School, 2002
- Command and staff diploma, Naval War College, 2002
- Diploma in Persian-Farsi language, Defense Language Institute, 1997
- B.A., computer science and Russian language, Duke University, 1991

IN AVIATION, redundancy is built into every function to improve reliability. Left to right: Cameron Patterson and graduate students Joey Stamenkovich and Lakshman Theyya are boosting reliability in autonomous technology by developing drones that police themselves.

SHAWN SPROUSE

Playing by the rules

making sure machines don't go rogue

If we as a society are going to trust technology, we need to trust that technology doesn't mishandle a situation.

"We hardly trust human teenagers behind the wheel, and they take classes and practice until they are ready to pass a driving test," said computer engineering graduate student Joey Stamenkovich. "How can we instill trust for things that run by themselves?"

With Associate Professor Cameron Patterson and fellow graduate student Lakshman Maalolan, Stamenkovich is working to boost reliability by developing drones that police themselves—enforced by hardware already present on many high-end drones to override the existing controller if the drone violates certain rules.

Current FAA regulations cap drone altitude at 400 feet, forbid unauthorized drone activity within five miles of an airport, and limit drone operation to the operator's line of sight, "which makes things like patrolling a pipeline or home delivery difficult without a chase vehicle," said Patterson.

In commercial aviation, redundancy is built into every function—there is contingency management and backups for everything, including the pilot, explained Patterson. "We are going to need something equivalent for drones if they're flying outside of the operator's line of sight."

Sponsored by the National Science Foundation's Center for Unmanned Aircraft Systems and NAVAIR, the goal is to develop drone-constraining technology that would convince the FAA to relax these restrictions, said Patterson.

Student flier

When learning to fly an airplane, pilots spend many hours flying with an instructor, who is monitoring the situation and can take control of the craft at any moment. Similarly, the virtual "instructor" can force a compromised drone to stop and hover, take evasive action, land, or return home.

Patterson and his team are using field-programmable gate arrays (FPGAs), which can monitor all sensory input—drone position, direction, and velocity—and all application software outputs, which include control commands to climb, descend, or move in a specific direction.

Encoded with safety and perimeter rules, the hardware-implemented monitors are supplied with GPS coordinates every second.

"If, for example, the drone is approaching a boundary and not slowing sufficiently, the monitors will trigger, take control of the drone, and do something appropriate, like force it to hover or land," said Patterson.

The safety monitors can also be customized to enforce pitch-and-bank envelope protection, limits on speed, or other defining rules.

Implementation

"The way we implement these monitors is really the key," said Patterson. "They are isolated from the software, so even if the software crashes or gets hacked, the monitors will still be effective."

To prevent misunderstandings that can arise from informal specifications, desired system behavior is captured with linear temporal logic formulas. Each formula is synthesized into a hardware monitor that operates concurrently with all the other synthesized monitors. As a further measure, the monitor implementations are formally analyzed to make sure they are consistent with the original specifications.

"More than an end product"

"A holy grail of computing is establishing system correctness with a mathematical degree of certainty," said Patterson. "We generally can't do that because we implement things that are too complicated—with too many software layers, it becomes infeasible."

But by implementing isolated monitors that can be synthesized from mathematical expressions and then analyzed, Patterson's team achieves high confidence that they're correct. In other words: These monitors will be trustworthy.

"It's more than an end product," said Lakshman, a computer engineering graduate student. "The process is something that will help us make sure that whatever we develop is correct—it's a last line of defense during runtime and needs to be highly reliable."

This ability to enforce and verify behavior is what Patterson considers the main contribution of this work: "We found a way to apply formal methods to existing, complex embedded systems that were not designed with formal verification in mind." ■

Drones in the classroom

The self-policing drone technology incorporates all aspects of computer engineering: algorithms, computer architecture, software, hardware, and mathematics-grade verification. In Computational Engineering (ECE 2514), which will be offered for the first time in Fall 2019, students will program a virtual drone to familiarize themselves with the basic concepts of computer engineering. Students will use simulation tools to develop simple algorithms and data structures to control virtual drones in georeferenced environments. Student teams will also have the opportunity to conduct actual drone flights to collect data and see how their models work in reality. ■

SHAWN SPROUSE

Walid Saad is working on the foundations of the 6G wireless network, which will serve everything from autonomous vehicles to virtual reality.

SHAWN SPROUSE

Planning for 6G

The 5G wireless network is not yet deployed, but ECE researchers are already working on what comes next—6G.

According to Walid Saad, ECE associate professor, the movement from 2G to 5G has been driven by one consideration: the need for higher data rates. The next generation, however, will have to serve technologies with diverse needs—from autonomous vehicles to virtual reality.

These new technologies will require more than just high data rates, explains Saad, who was recently named IEEE Fellow for his contributions to distributed optimization in cooperative and heterogeneous wireless systems. "We still need high data rates, but we will also need reliable and low latency communication. We need reliability of 99.99999 percent or even more." 5G, he continues, should be able to deliver that reliability to static nodes and simple scenarios, but "we need to start thinking about what is next—autonomous vehicles, drones, and virtual reality."

Autonomous vehicle communication

Because of the safety considerations of autonomous vehicles, poor communication will have a greater impact than just a dropped call. "A car needs to control its speed and distance, gather data from various sensors, and exchange maps and information with other vehicles and nodes," says Saad.

Computation is also an issue. Computation for these systems is frequently done in the cloud, where there are more computer resources. With a strong communications system, however, computation could be distributed between many different vehicles or nodes. According to Saad, this means that joint design of communications, computing, and control is necessary for 6G.

In addition to these demands, moving nodes like vehicles pose particular challenges for current wireless technology. Millimeter wave technology, for example, allows for high-data rate communications, but is highly susceptible to blocking, explains Saad. If anything gets between the vehicle and a millimeter wave base station, communications are interrupted and become unreliable.

Drone communication

And then there are drones. "Now, we have antennas tilted downwards, and drones are served by the back lobe of antennas that are optimized for communication on the ground," says Saad. "We talk about areal spectral efficiency, a very common metric, but now we need to talk about volumetric spectral efficiency. 6G will be a three-dimensional system." All of these considerations need to be taken into account before the launch of 6G, because these are the technologies that will be incorporated.

Virtual reality communication

Applications like virtual reality and brain-computer interactions also pose unique challenges. "Virtual reality requires a lot of human interaction," says Saad. "You are moving around, moving your head, and your communications system should be able to maintain your experience in the virtual environment." This is another application that isn't just about data rates—it also requires a balance between efficiency and acceptable performance quality.

"We have shown that a brain does not discern between 1 ms and 2 ms," explains Saad. "We need to figure out the impact of brain perception on quality of service. If the user can't see the difference, the communications can stay at 2 ms and save power."

Enabling technologies of 6G

Enabling 6G is not just a matter of optimizing the physical layout and design of wireless nodes—the network itself needs to adjust. And the answer, according to Saad, might be in artificial intelligence (AI). "All of these applications together call for an AI-enabled wireless network. AI can enable 6G networks to not only learn, but to also think and self-sustain while using machine learning to adapt to the needs of different applications and environments." Saad envisions a 6G system where man-made structures (such as walls and buildings) can become active wireless transmitters. "Equipped with AI, they could provide truly pervasive communications while challenging the conventional antenna-mobile device paradigm."

These new technologies also come with new security concerns, and Saad and his team are trying to address those while the systems are being designed. Like most of his projects, Saad's security research involves the intersection between multiple fields. "There are two aspects to these attacks," says Saad. "Reliable communication and control systems that are not only robust against attacks, but can also adapt to faulty data." Saad notes that there are three aspects to security for autonomous systems: communication, control system, and artificial intelligence. "An attacker might attack just one, but all three need to be robust to an attack."

Because there will be applications in every field that use 6G networks, wireless researchers must reach into those fields to jointly design systems that work. ■

SHAWN SPROUSE

HARPREET DHILLON'S foundational work in communications and networking includes statistical modeling that will enable the technologies of the future.

Dhillon named Clarivate Analytics Highly Cited Researcher

The general public typically only hears about research in its final stages—when a specific product is in development—not at the fundamental theory stage. Harpreet Dhillon, ECE assistant professor and Steven O. Lane Junior Faculty Fellow, has been making the news with his fundamental contributions to wireless network theory. Dhillon was included on the Clarivate Analytics Highly Cited Researcher list in both 2017 and 2018 for his research on the mathematical underpinnings of wireless networks.

Clarivate Analytics, formerly Thompson Reuters, tracks research and publications in many fields ranging from agricultural science to space science. To be included on the Highly Cited Researchers list, individuals must have publications from the past 11 years that are among the top one percent in their field for number of citations.

Dhillon's research has contributed to the basic understanding of large-scale wireless networks. By answering fundamental questions in the field, his work acts as a foundation for the design and deployment of next-generation wireless networks.

His first highly cited paper came from his Ph.D. work at the University of Texas at Austin, where Dhillon advanced tools from the area of stochastic geometry to model large-scale heterogeneous wireless networks—and he has continued developing tools and models to study a variety of network configurations for the next generation of wireless networks.

Dhillon's research interests are broadly in communications and networking. Some of his current research projects include internet of things (IoT), heterogenous cellular networks, and smart and connected communities.

Dhillon's work has received numerous technical awards, including the 2016 IEEE Heinrich Hertz Award, the 2015 IEEE Communications Society Young Author Best Paper Award, and the 2014 IEEE Leonard G. Abraham Prize Paper Award.

Internet of things

The IoT is an emerging digital fabric that will integrate our physical world into computer networks by connecting billions of devices to the internet, according to Dhillon. "One of the key challenges is to power billions of small sensors that would make this digital fabric," says Dhillon, who has been exploring energy-harvesting solutions to make these devices self-sufficient. "In particular, we are exploring the possibility of using existing radio-frequency waves to power these devices."

Dhillon is also working on ambient backscatter communications, which allows these devices to operate at very low power by repurposing existing radio frequency waves for their own transmission.

Heterogeneous cellular networks

Dhillon continues to push the boundaries of heterogenous cellular networks. Driven by the consistently increasing demand for more capacity in the wireless spectrum, researchers are trying to find new ways of packing more signals into the same frequency bands—often by adding more base stations to the network. Dhillon is mathematically modeling and analyzing the performance of different base station configurations.

Smart and connected communities

Like IoT, vehicular communications will play a key role in the emergence of smart and connected communities. Whether operated by a human driver or fully autonomous, vehicles will need to communicate with each other and their environment. Because they need to maintain consistent communication on the move, while planning trajectories and maintaining a high degree of safety, vehicles pose particular communications challenges.

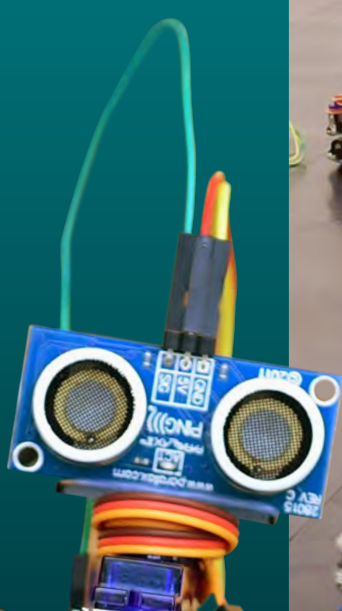
Dhillon's group is working on a statistical model for a vehicular network that can take various road patterns into account.

Dhillon's passion for math and engineering isn't just personally fulfilling. It's also providing frameworks for many of the technologies we will soon be taking for granted. ■

Automotive Algorithms

FOR DECADES, automobiles were predominantly composed of mechanical systems under the purview of mechanical engineers, who have kept our vehicles running efficiently. Now, complicated electronic systems, communication needs, new safety features, and automation are bringing more electrical and computer engineers into the field. Virginia Tech ECEs are tackling vehicular issues at every level—including traffic control, engine optimization, vehicle communication, and electric vehicle battery charging.

JOY ASICO



Tam Chantem (below) is designing a semi-automated emergency response system that can guide drivers through emergency situations.

JOY ASICO

Small scale traffic solvers

When an emergency vehicle comes screaming down the road, even levelheaded, law-abiding drivers can make rash, sometimes dangerous decisions. ECE's Tam Chantem, an assistant professor, is designing a semi-automated emergency response system that can guide emergency and civilian drivers on the best action to take in these situations. She and her team have built a testbed and a fleet of small robots that follow the time-continuous, car-following Intelligent Driver Model to capture how humans drive on highways and in traffic.

When traffic is interrupted by emergency signals, the way drivers react depends on certain factors like the time of day and the direction the emergency vehicle is traveling. Chantem and her team are mapping these situations and building models that reduce response time and increase the safety of all vehicles.

"We can calculate the last possible moment a vehicle can safely cross an intersection," said Chantem. "And this feeds into the framework for how an ambulance can best navigate that intersection."

When they compare their techniques with current practices, Chantem and her team—assistant professor Ryan Gerdes and graduate students Pratham Oza and Mahsa Foruhandeh—have shown that their system can achieve faster travel times and provide more space around emergency vehicles.

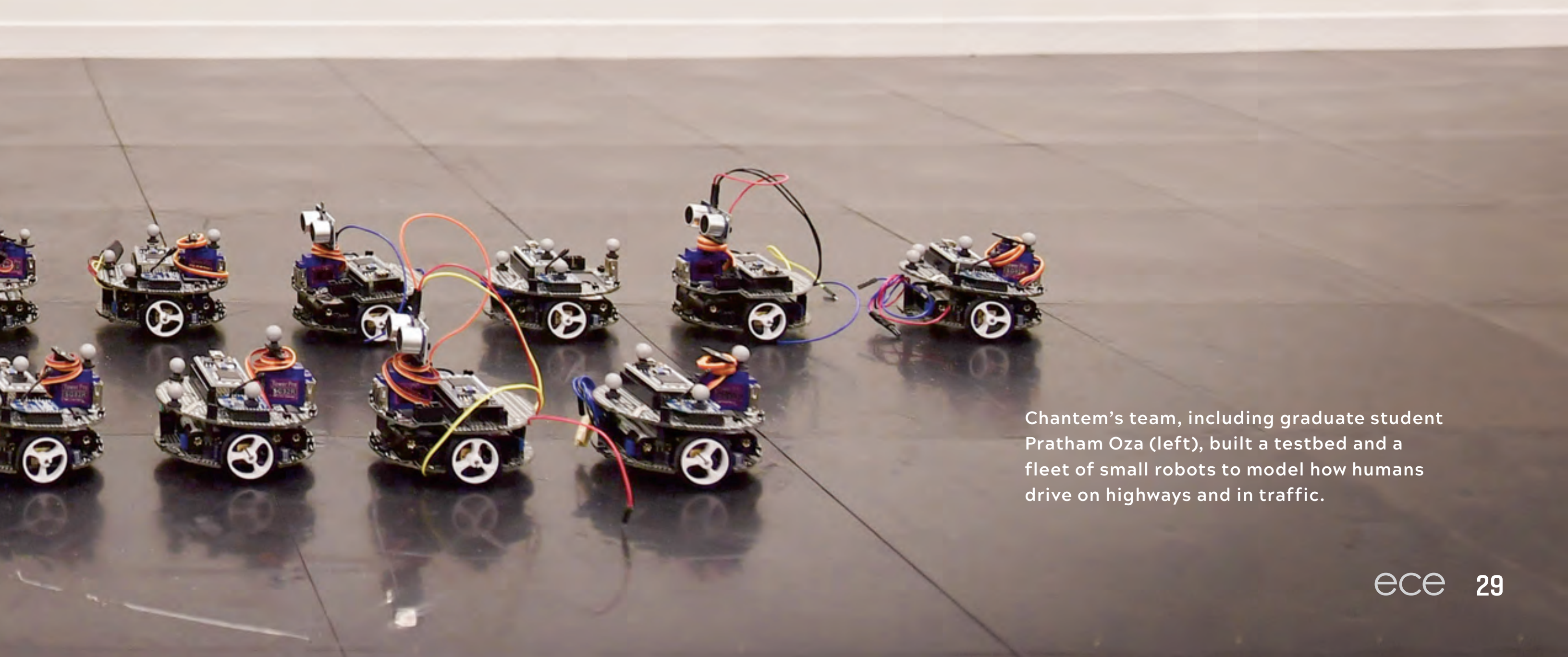
Security versus efficiency

"When you rely heavily on technology, you have to think about security from the outset," said Chantem. "We're essentially rethinking the way we design systems so they can be more resilient from the beginning."

If you can't do it from the beginning, there will be security holes that need to be addressed before the technology can be introduced on a wide scale, said Chantem.

Adaptive cruise control, for instance, can be used to form vehicle platoons—where autonomous vehicles cluster into a fleet, speeding up and slowing down as a unit. This allows more vehicles to pack into a smaller space, but it also exposes them to security risks, she explained. For instance, a malicious attacker could intentionally cause the system to shift operation back to humans.

"We have actually shown on our testbed that this technology is not safe enough yet, even if you have collision avoidance implemented in your vehicles," said Chantem, who is working to mitigate the risk. ■



Chantem's team, including graduate student Pratham Oza (left), built a testbed and a fleet of small robots to model how humans drive on highways and in traffic.

HAIBO ZENG'S research focuses on improving efficiency and safety of the internal combustion engine (pictured here). Zeng's findings also apply to electric and hybrid electric vehicles, and to the transportation sector as a whole.

GETTY IMAGES

Buffing combustion

The days of the internal combustion engine (ICE) may be numbered, but that number is still large. Internal combustion engines are the primary mode of power for today's vehicles, and the International Council on Clean Transportation projects that 3 billion more ICE vehicles will be sold before 2050.

"For vehicles powered by internal combustion, efficiency is critical," said Haibo Zeng, ECE assistant professor. "There is a lack of focus on ICEs, and a lot of room to improve," he said.

The improvement of internal combustion engine operation can have profound and immediate impact, according to Zeng. "Our work can improve both operational efficacy and vehicle safety, and the lessons we learn apply not only to ICEs, but also to electric and hybrid electric vehicles, and to the transportation sector as a whole."

Optimizing

When an engineer adjusts any parameter—routing, path planning, speed planning, or power train—it affects the engine map, which is a characterization of an engine's efficiency. To optimize the system, researchers should holistically consider all layers in the vehicle, not just individual components, said Zeng.

But if all the layers are considered in a holistic way, some critical design aspects, like timing requirements, become more difficult to optimize, Zeng said.

In the past, design engineers spent hours or days fine-tuning parameters, said Zeng. But now, the goal is to optimize on the fly, so the runtime of parameter optimization algorithms needs to match the dynamics of the vehicle, which is milliseconds to seconds.

Zeng and his team are developing algorithms to meet those requirements, and results are promising: "We have already shown that this type of speed is possible in a few cases," said Zeng.

Monitoring and enforcing safety

Zeng is also applying formal methods to improve functional safety and remove system design defects and implementation bugs, which can be caused by human error or from uncertainties in the environment.

But even in the absence of design defects, an ICE system is still vulnerable to cyberattack, said Zeng. "Today's cars rely heavily on connectivity, which is meant to increase comfort and safety, but it also opens the door to attackers."

To improve security, Zeng and his team are developing an advanced safety enforcement mechanism "safety guard" that can enforce system safety and make corrections in real time.

By building and housing the safety guard separately from the internal system, Zeng and his team will be able to protect the guard from malicious attack, keep it cost-effective, and allow it to oversee normal ICE operation without interfering with the system's normal function. ■

An advance warning system is just one possible feature of vehicle-to-everything communications (V2X) technology. Jung Min (Jerry) Park is studying V2X technologies and applications.

GETTY IMAGES

Extending a driver's situational awareness

It's late, and you're driving home through the darkness. The road curves ahead of you, but before you barrel around the corner, a notification flashes in the corner of your windshield: there's a crash ahead. You ease up on the gas and safely approach.

An advance warning system is just one possible feature of vehicle-to-everything communications (V2X) technology. "Right now, we've only got our eyes and our instincts," said Jerry Park, ECE professor, who is studying V2X technologies and applications.

Some of today's high-end vehicles, especially those that support autonomous and automated driving, are equipped with sophisticated sensors such as stereo cameras, LIDARS, and radars. V2X augments and enhances the capabilities of these sensors to broaden a driver's situational awareness to extend beyond line of sight.

In 1999, the U.S. Federal Communications Commission (FCC) allocated 75 MHz of spectrum in the 5.9 GHz band to support V2X technologies and applications. Soon after, spectrum regulatory agencies of other countries followed suit.

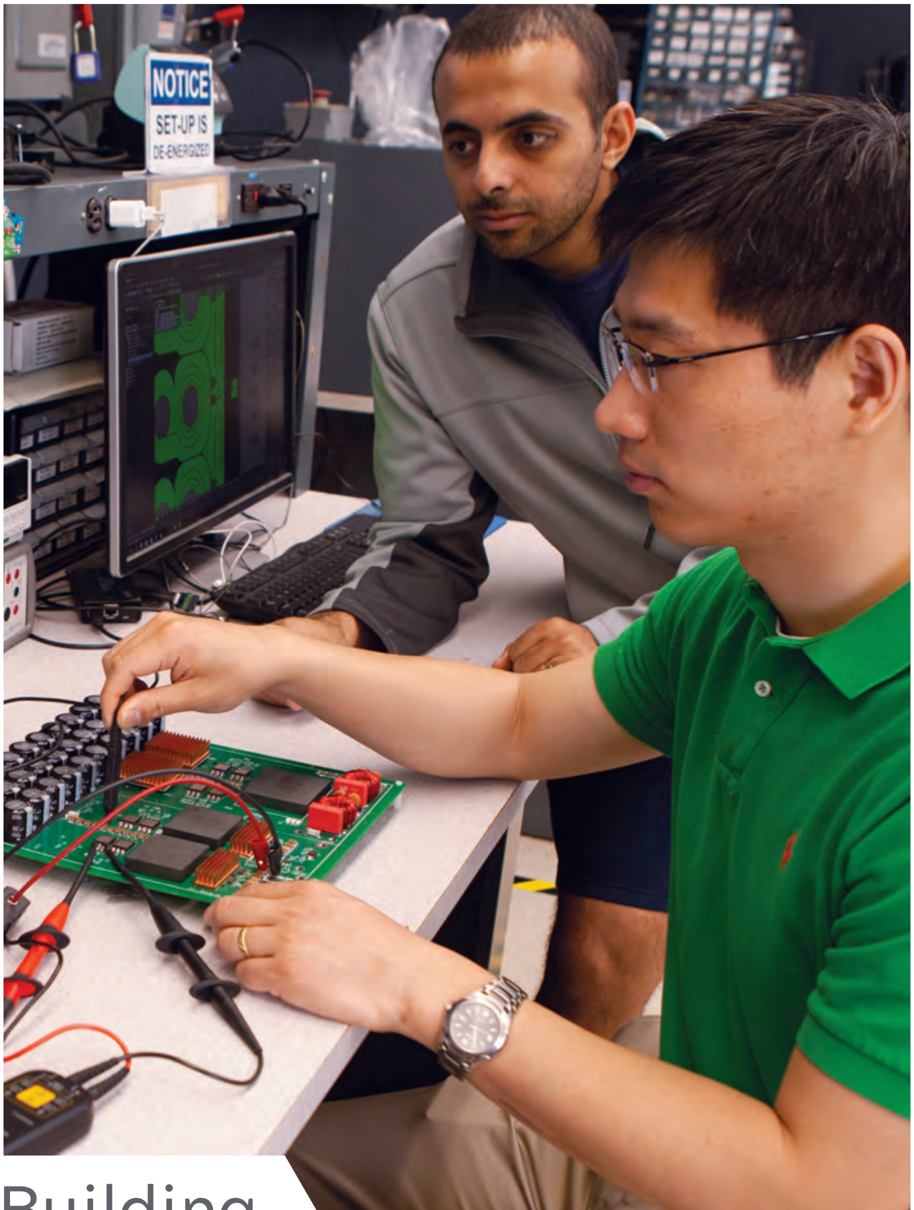
Park and his research assistants are studying a number of open problems in V2X, including a comprehensive evaluation of the pros and cons of two leading V2X technologies: Dedicated Short-Range Communications (DSRC) and Cellular V2X (C-V2X). Currently, there is no consensus among the industry stakeholders regarding which technology should be adopted to enable emerging V2X applications. The automotive and wireless industries are split into two camps, each camp favoring one technology over the other. "We don't know which one will win out over the other, or if they will coexist," said Park. "But we are studying the advantages and shortcomings of each technology, as well as what it would mean for them to coexist."

Park and his collaborators are also investigating the security and privacy issues specific to V2X applications. One potential threat to a driver's privacy is posed by the broadcast of safety messages which contain a vehicle's state and predicted path. "Someone could eavesdrop on and accumulate these messages in order to discover a particular vehicle's location or track its movement," said Park. "We are exploring techniques to protect a driver's location privacy while still supporting these safety applications."

The next evolutionary step for V2X technologies is enabling the next step of vehicular technology advancement: fully autonomous driving. ■

GETTY IMAGES

TO REDUCE CHARGING TIME and increase charging efficiency of electric vehicle batteries, Qiang Li developed a way to use a standard printed circuit board to build both transformer and inductor.



SHAWN SPROUSE

Building electric road warriors

As of October 2018, there were more than 1 million electric vehicles on American roads, according to the Edison Foundation. The latest models can travel between 150 and 300 miles per charge with a standard-issue battery. The problem, says ECE's Qiang Li, is the time it takes to recharge.

"The most popular charger right now is the overnight garage model," said Li who is an associate professor working in the Center for Power Electronics Systems. "Many companies are trying to develop high-power battery chargers, which would recharge a drained battery in an hour—but an hour is still too long."

Li and his colleague Fred Lee (University Distinguished Professor emeritus) together with their students have been developing techniques to cut charging times down to 10 to 30 minutes and increase the efficiency of both the chargers and the charging stations.

The key, said Li, is increasing the power and shrinking the charger size—both inside and outside the car.

To reduce charger size, Li is incorporating emerging semiconductor materials, including gallium nitride and silicon carbide, to increase switching frequency and reduce converter loss using soft-switching techniques.

Transformers and inductors are bulky elements inside a converter, and they are some of the more labor-intensive components to fabricate. Li developed a way to use a standard printed circuit board (PCB) to build both transformer and inductor and reduce their size significantly.

"Usually a PCB is only used as substrate, and the discrete transformer and inductor go on top," said Li. "I'm trying to build an integrated transformer and inductor in a PCB."

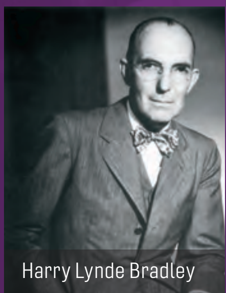
This reduces size and simplifies manufacturing.

"After we apply all this technology, we will eventually be able to decrease the size of a charger by half or even three quarters," said Li. "And we'll be able to make efficiency even higher."

Li and his team have already developed prototypes of the 7 kW on-board chargers and 25 kW off-board chargers. Besides working with industry partners to transfer this technology for commercialization, they are also working on a solid-state-transformer-based 400kW ultra-fast off-board charger. ■

2018 | 2019

Bradley & Webber HONORS


Harry Lynde Bradley

The late Mrs. Marion Bradley Via established an endowment for ECE in honor of her late father, **Harry Lynde Bradley,** who was a pioneer in the electric motor control industry and co-founder of the Allen-Bradley Company of Milwaukee, which is now part of Rockwell Automation. In recognition, the department is called The Bradley Department of Electrical and Computer Engineering. The endowment funds scholarships, fellowships, and professorships in an ongoing effort to improve our ECE programs.


William B. Webber

William B. Webber (EE '34) established a fund to encourage women engineers. Webber's career took him to Westinghouse, the U.S. Signal Corps, then to a booming company co-founded by an army buddy–Tektronix Inc. Today, the William B. Webber Fellowship is awarded to high achieving women pursuing a graduate degree in ECE.

2018 | 2019

Bradley & Webber FELLOWS

Benjamin Biggs

BSEE '18 Brigham Young University
Advisor: Daniel Stilwell

RESEARCH: Biggs is developing algorithms to maximize the effectiveness of search paths in a large search space where finding optimal paths is currently infeasible.

Jacob Black

BSEE '17 Virginia Tech
Advisor: Yizheng Zhu

RESEARCH: Black is developing new algorithms for demodulating phase in custom optical systems with a focus on applications for biological imaging.

Jon Bunting

BSCPE '17 Virginia Tech
Advisor: A. Lynn Abbott

RESEARCH: Bunting is exploring ensemble learning by distributing resource-efficient deep neural networks across a decision tree hierarchy.

Shane Erick Coyle

B.S. Electrical Engineering Technology
B.A. Physics '17 California University of Pennsylvania
Advisor: Bob Clauer

RESEARCH: Coyle is researching interhemispheric asymmetries in the ground magnetic response to solar-wind-magnetosphere-ionosphere coupling.

2018 | 2019
Bradley & Webber FELLOWS

Michael Emanuel

BSEE '18 Virginia Tech
Advisors: Dong Ha, Khai Ngo

RESEARCH: Emanuel works at the intersection of power electronics and analog integrated circuit design.

HONORS: Emanuel is ranked number one in the electrical engineering major for his graduating class.

Bryse Flowers

BSCPE '14 Virginia Tech
Advisors: R. Michael Buehrer, William C. Headley

RESEARCH: Flowers is researching the threats that adversarial machine learning poses to radio frequency machine learning systems. He is currently studying adversarial evasion attacks.

Janay Frazier

MSEE '18 Virginia Tech
B.S. Optical Engineering '16 Norfolk State University
Advisor: Elena Lind

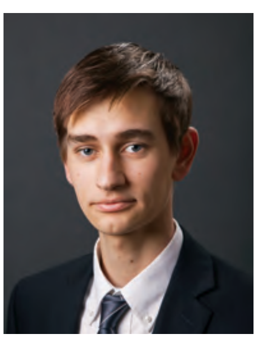
RESEARCH: Frazier is developing a high-resolution ultraviolet-visible spectroscopic remote sensing instrument to detect trace gases in the atmosphere, specifically formaldehyde gas formed in the lower atmosphere.

HONORS: *New Horizon Graduate Scholar, Ph.D. GEM Fellow*

Jack Geissinger

B.S. Engineering Science and Mechanics '18 Virginia Tech
Advisor: Alan Asbeck

RESEARCH: Geissinger is studying human motion prediction using deep learning. Based on the movement of sensors placed across a person's body, his system will infer what that person is going to do next.



Larkin Lee Heintzman

BSEE '15 Western Kentucky University
Advisor: Ryan Williams

RESEARCH: Heintzman researches multi-agent informative path planning, subject to generate topological constraints.

Paul Steven Kennedy

BSEE '17 Virginia Tech
Advisor: J. Michael Ruohoniemi

RESEARCH: Kennedy is researching software-defined radio for SuperDARN high-frequency radar.

Clayton Mangette

BSEE '17 Binghamton University
Advisor: Pratap Tokekar

RESEARCH: Mangette is developing algorithms that plan and coordinate autonomous vehicles in urban traffic scenarios. He is also a graduate advisor for Virginia Tech's Hybrid Electric Vehicle Team (HEVT).

Hannah Mohr

BSEE '17 Montana State University
Advisor: Jonathan Black

RESEARCH: Mohr is developing algorithms to help autonomous vehicles explore unknown environments. She has successfully demonstrated these algorithms on the VT SpaceDrones, locating a target with different obstacle configurations.

HONORS: *National Physical Science Consortium Fellow, 2017-2019*

Los Alamos National Laboratory FFLIE , 2015 - 2019

Jeffrey B. Persons, Jr.

B.S. Mechanical Engineering '06
Massachusetts Institute of Technology
Advisor: Jonathan Black

RESEARCH: Persons is improving machines' ability to make sense of their environments, combining nonparametric Bayesian inference with convolutional neural networks. He is also implementing path planning algorithms for unmanned aircraft.

HONORS: *New Horizons Graduate Scholar*

Member of Veterans@VT

Member of the College of Engineering Dean's Graduate Team

Amanda Redhouse

BSEE '18 York College of Pennsylvania
Advisor: Tom Martin

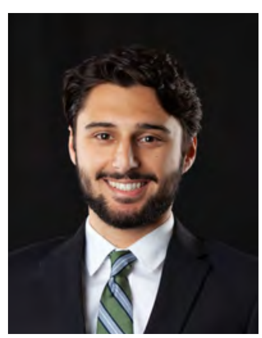
RESEARCH: Redhouse is developing a wearable technology to measure and assist upper-limb movements in children with mobility impairments. She is investigating the effectiveness of thread-based sensors to measure arm motions.

Ian Roessle, Lt.

M.S. Computer Science '13 Johns Hopkins University
BSCPE '08 California State University
Advisor: Binoy Ravindran

RESEARCH: Roessle is studying software binary analysis and verification. His recent breakthroughs include a large x86-64 model and toolchain for analyzing software binaries in a theorem prover.

HONORS: *2014 Edison Scholar, U.S. Navy Reserves*



Joe Thomas

BSEE '18 Virginia Tech
Advisor: Yizheng Zhu

RESEARCH: Thomas is researching biophotonics, specifically quantitative phase imaging (QPI), which is a microscopy technique capable of quantifying the surface profile of cells and other samples.

2018 | 2019 Bradley & Webber FELLOWS

Maymoonah Toubeh

B.S. Engineering '14 American University of Kuwait
Advisor: Pratap Tokekar

RESEARCH: Toubeh is researching safe and reliable robotics, focusing on the effects of uncertainty approximation in deep learning for risk-aware robot planning.

Natalie White

MSEE '18 Virginia Tech
BSEE '16 University of Tennessee, Knoxville
Advisors: Rafael Davalos, Xiaoting Jia

RESEARCH: White is developing methods for using electrical feedback to improve irreversible electroporation (IRE) treatments, which use pulsed electric fields to treat tumors.

HONORS: *Torgersen Graduate Research Award 2018*

Graduate Student Assembly Delegate 2018-2019

Oscar Yu

MSEE '18 Virginia Tech
BSEE '15 University of Texas at Austin
Advisor: Jason Lai

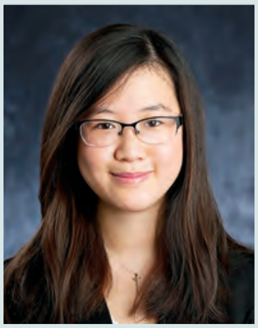
RESEARCH: Yu is researching high voltage power electronics with emphasis on dc-dc soft switching power conversion, synchronous rectification, and digital controls.

2018 | 2019 Bradley SCHOLARS

Danielle Lester

BSEE undergraduate

Lester wants to design solar panel technology. She recognizes the importance of solar energy for the future of business and the future of environmental health.



Maureena Ma

BSEE undergraduate

Ma hopes to develop medical technology. She is currently working on a study of penicillin and why it has outlived many other antibiotics. Her most memorable Virginia Tech experience was a drone project for the Foundations of Engineering course, where she created a delivery drone. She has found electrical engineering to be a good fit because it allows her to see connections between other fields of engineering and how they work together to create technologies.

Nathan Moeliono

BSCPE undergraduate

Moeliono chose to study ECE because he believes the technology has the capacity to do amazing things and is advancing every year. As a controls volunteer on the Virginia Tech BOLT electric motorcycle design team, Moeliono worked on designing the touchscreen dashboard of the bike and interfacing it with the CAN bus. He hopes to find himself in a position to make a wider impact with the things he creates.

Bradley ALUMNI

S = SCHOLAR
F = FELLOW

NAME	TITLE	COMPANY	LOCATION
JoAnn Adams S BSEE '94	Co-Owner	Big Fish Design	Centreville, Va.
Robert Adams F MSEE '95, Ph.D. '98	Professor, ECE	University of Kentucky	Lexington, Ky.
Shawn Addington F BSEE '90, MSEE '92, Ph.D. '96	Professor and Head, Department of Electrical and Computer Engineering	Virginia Military Institute	Lexington, Va.
Sarah S. Airey S BSCPE '01	Speech Scientist	Recordsure	Cambridge, U.K.
Christopher R. Anderson S/F BSEE '99, MSEE '02, Ph.D. '06	Associate Professor	United States Naval Academy	Annapolis, Md.
Matthew R. Anderson S BSCPE '04	Network Architect	Cisco Systems	Washington, D.C.
Nathaniel August F BSCPE '98, MSEE '01, Ph.D. '05	Senior Technical Lead and Staff Engineer	Intel Corporation	Portland, Ore.
Stephen P. Bachhuber F BSEE	Senior Member of Technical Staff	Qorvo	Greensboro, N.C.
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Optimization and Algorithms for Wireless Networks with Load and Receiver Characteristics Awareness
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Study on Frequency Locking Techniques Based on Envelope Detection for Injection-Locked Signal Sources
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Sohul, Munawwar Mahmud
Spectrum Opportunity Duration Assurance: A Primary-Secondary Cooperation Approach for Spectrum Sharing Systems
Committee Chair: Reed, J.H.

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Greedy Inference Algorithm for Structured and Neural Models
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Tanwir, Sarmad
Online Techniques for Enhancing the Diagnosis of Digital Circuits
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Tbaileh, Ahmad Anan
Robust Non-Matrix Based Power Flow Algorithm for Solving Integrated Transmission and Distribution Systems
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Tian, Zhipeng
Sapphire Fiber Optic Sensor for High Temperature Measurement
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Wang, Jun
Switching-Cycle Control and Sensing Techniques for High-Density SiC-Based Modular Converters
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Yamada, Randy Matthew
New Method for Directional Modulation Using Beamforming: Applications to Simultaneous Wireless Information and Power Transfer and Increased Secrecy Capacity
Committee Chair: Mili, L.M.

Yang, Duotong
Adaptive Decision-Trees-Based Regional Voltage Control
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Younes, Rabih Halim
Toward More Practical, Naturalistic, and Reusable Wearable Activity Classification
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Towards Interpretable Vision Systems
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Student awards

Mohammad Mozaffari
received the Virginia Tech Graduate School 2019 Outstanding Dissertation Award in Science, Technology, Engineering and Mathematics for "Fundamentals of Wireless Communications and Networking with Unmanned Aerial Vehicles."
Advisor: Walid Saad

Michael Kepler
was awarded the National Defense Science and Engineering Graduate (NDSEG) fellowship.
Advisor: Daniel Stilwell

Jorge Jiminez
was awarded the DoD Science, Mathematics and Research for Transformation (SMART) Scholarship.
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PATENTS ISSUED 2018

Systems, Methods, and Apparatus to Enhance the Integrity Assessment When Using Power Fingerprinting Systems for Computer-Based Systems
Patent 9,886,583, Issued Feb. 6, 2018
Inventors: C. Aguayo Gonzalez, J. Reed, S. Chen

Energy Storage for Power Factor Correction in Battery Charger for Electric-Powered Vehicles
Patent 9,914,362, Issued March 13, 2018
Inventors: K. Ngo, H. Wang

Method and Apparatus for Current/Power Balancing
Patent 9,923,560, Issued March 20, 2018
Inventors: C. Wang, Y. Mao, Z. Miao, K. Ngo

Portable Antenna
Patent 9,929,461, Issued March 27, 2018
Inventors: A.I. Zaghloul, W. Fraser, T.K. Anthony, A.J. Bayba

Time-Variant Antenna for Transmitting Wideband Signals
Patent 9,947,994, Issued April 17, 2018
Inventors: M. Manteghi, M. Salehi

Power-Cell Switching-Cycle Capacitor Voltage Control for Modular Multi-Level Converters
Patent 9,966,874, Issued May 8, 2018
Inventors: J. Wang, R. Burgos, D. Boroyevich, B. Wen

Estimating the Location of a Wireless Terminal Based on Radio-Frequency Pattern Matching and Cooperative Measurements
Patent 9,989,620, Issued June 5, 2018
Inventors: S. Gordon, S.R. Monir Vaghefi, R.M. Buehrer

Power Switch Drivers with Equalizers for Paralleled Switches
Patent: 9,998,111, Issued June 12, 2018
Inventors: L. Zhang, Z. Miao, K. Ngo

Hybrid Interleaving Structure with Adaptive Phase Locked Loop for Variable Frequency Controlled Switching Converter
Patent: 10,013,007, Issued July 3, 2018
Inventors: P.-H. Liu, Q. Li, F.C. Lee

Radio Frequency Anisotropic Patch Antenna and Polarization Selective Surface
Patent 10,014,581, issued July 3, 2018
Inventors: S.D. Keller, A.I. Zaghloul

Semiconductor Module Arrangement
Patent 10,032,732, Issued July 243, 2018
Inventors: C. DiMarino, M. Johnson, D. Boroyevich, R. Burgos

Wireless Communication Device Using Time-Variant Antenna Module
Patent 10,038,460, Issued July 31, 2018
Inventors: S.-Y. Suh, W. Kesling, M. Manteghi, M. Salehi, H. Skinner

Miniaturized Helium Photoionization Detector
Patent 10,048,222, Issued Aug. 14, 2018
Inventors: M. Agah, S.N. Sreedharan Nair

Multi-Step Simplified Optimal Trajectory Control (SOTC) Based on Only Vo and Iload
Patent 10,075,083, Issued Sept. 11, 2018
Inventors: C. Fei, F.C. Lee, W. Feng, Q. Li

Transmitting Wideband Signals Through an Electrically Small Antenna Using Antenna Modulation
Patent 10,097,217, Issued Oct. 9, 2018
Inventor: M. Manteghi

Low Profile Coupled Inductor Substrate with Transient Speed Improvement
Patent 10,109,404, Issued Oct. 23, 2018
Inventors: Y. Su, D. Hou, F.C. Lee, Q. Li

Transient Performance Improvement for Constant On-Time Power Converters
Patent 10,110,122, Issued Oct. 23, 2018
Inventors: S. Bari, F.C. Lee, Q. Li, P.-H. Liu

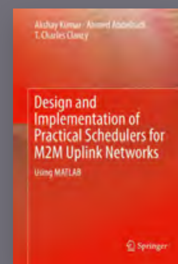
Parallel Devices Having Balanced Switching Current and Power
Patent 10,116,303, Issued Oct. 30, 2018
Inventors: Y. Mao, Z. Miao, K. Ngo, C.-M. Wang

Nano-Fabric Antenna
Patent 10,122,072, Issued Nov. 6, 2018
Inventors: A.I. Zaghloul, S.D. Keller

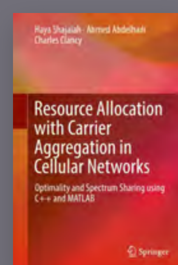
Time-Variant Antenna Module for Wireless Communication Devices
Patent 10,135,650, Issued Nov. 20, 2018
Inventors: S.-Y. Suh, H. Skinner, W. Kesling, M. Manteghi

High-Frequency Circulating Current Injection Control for High-Speed Switch-Based MMC
Patent 10,153,712, Issued Dec. 11, 2018
Inventors: J. Wang, R. Burgos, D. Boroyevich

Books Published



Design and Implementation of Practical Schedulers for M2M Uplink Networks Using MATLAB
A. Kumar, A. Abdelhadi, T. Clancy
Springer, 2018



Resource Allocation with Carrier Aggregation in Cellular Networks: Optimality and Spectrum Sharing
H. Shajaiah, A. Abdelhadi, T. Clancy
Springer, 2018

Electromagnetics, Vol. 1
S.W. Ellingson
VT Publishing, 2018

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Keynote Addresses

Dushan Boroyevich gave the keynote speech at IECON 2018, October 2018, Washington, D.C. T. Charles Clancy gave keynote speeches at the U.S. House of Representatives, Committee on Science, Space, and Technology, Subcommittee on Oversight, June 2018, Washington, D.C., and at the Energy and Commerce Committee, Communications and Technology Subcommittee, May 2018.

Dong Ha gave a keynote speech at the International SOC Design Conference (ISOCC), Nov. 2018, Daegu, Korea.

Fred C. Lee gave keynote addresses at IEEE WiPDA, May2018, Xi'an, China; Wuhan Power Supply Association Innovation Workshop, Oct. 2018, Wuhan, China; and the IEEE Power Electronics Applications Conference (PEAC), Nov., 2018, Shenzhen, China.

Guo-Quan Lu gave the keynote at the 10th International Conference on Integrated Power Electronics Systems (CIPS 2018), March 2018, Stuttgart, Germany.

Saifur Rahman gave keynote addresses at IEEMA Engineer Infinite Conference, March 2018, Delhi NCR, INDIA; IEEE ISGT Conference, May 2018, Singapore; IEEE Smart Cities Conference, Sept. 2018,Kansas City, Mo.; 111 Project Forum at Hohai University, Sept. 2018, Nanjing, CHINA; IEEE PES APPEEC Conference, Oct. 2018, Kota Kinabalu, Malaysia; IEEE PES EI2 Conference, Oct. 2018, Beijing, China; and National Power Systems Conference, National Institute of Technology, Dec. 2018, Trichy, India.

Walid Saad gave keynote speeches at the Sixth International Conference on Wireless Networks and Mobile Communications (WINCOM), Oct. 2018, Marrakesh, Morocco; the 1st ACM SIGSPATIAL International Workshop on Advances in Resilience and Intelligent Cities, Nov. 2018, Seattle, Wash.; IEEE Global Communications Conference (GLOBECOM), Workshop on Green and Sustainable 5G Wireless Networks, Dec. 2018, Abu Dhabi; and the IEEE Global Communications Conference (GLOBECOM), Workshop on Ultra-high Speed, Low Latency and Massive Connectivity Communication for 5G/B5G, Dec. 2018, Abu Dhabi.

Honors & Awards

Peter Athanas was Initiated into the ACM SIGDA Technical Committee on FPGAs Hall of Fame.

Harpreet Dhillon was named Clarivate Analytics Highly Cited Researcher.

Walid Saad was named IEEE Fellow for his contributions in distributed optimization in cooperative and heterogeneous wireless systems. He also received an IEEE Communications Society (ComSoc) Radio Communications Committee Early Achievement Award for contributions to fundamental results in radio communications, wireless resource allocation, and cooperative communications.

Guoqiang Yu was awarded an NSF CAREER Award to create mathematical models and computational tools for in vivo astrocyte activity.

Xiaoting Jia was awarded an NSF CAREER award. She was also awarded a 3M Non-Tenured Faculty Award (NTFA).

Best Paper Awards

K. Ramezanpour and P. Ampadu
"Reconfigurable Clock Generator with Wide Frequency Range and Single-Cycle Phase and Frequency Switching," IEEE International System-on-Chip Conference (SOCC), Sept. 2018, Arlington, Va.

A. Noetzli, J. Khan, A. Fingerhut, C.Barrett, and P. Athanas
"p4pktgen: Automated Test-Case Generation for P4 Programs," 4th Symposium on SDN Research (SIGCOMM 2018), March 2018, Los Angeles, Ca.

William M. Portnoy Award

C. DiMarino, M. Johnson, B. Mouawad, J. Li, D. Boroyevich, R. Burges, G.-Q. Lu, and M. Wang
"Design of a Novel, High-Density, High-Speed 10 kV SiC MOSFET Module," IEEE Energy Conversion Congress & Expo, Sept. 2018, Porland, Ore.

ECPE Young Engineer Award

C. DiMarino
"Fabrication and Characterization of a High-Power-Density, Planar 10 kV SiC MOSFET Power Module," International Conference on Integrated Power Electronics, June 2018, Nuernberg, Germany.

Outstanding Technical Paper Award

M Wang, Y. Mei, R. Burgos, D. Boroyevich, and G.-Q. Lu
"Effect of Substrate Surface Finish on Bonding Strength of Pressure-less Sintered Silver Die-Attach," IEEE ICEP, April 2018, Mie, Japan.

B. Zhou and W. Saad
"Optimal Sampling and Updating for Minimizing Age of Information in the Internet of Things," IEEE Global Communications Conference (GLOBECOM), Dec. 2018, Abu Dhabi, U.A.E.

C. Yi, L. Liu, J. Li, and K. Bai
"A Deep Learning Based Approach for Analog Hardware Implementation of Delayed Feedback Reservoir Computing System," 2018 IEEE International Symposium on Quality Electronic Design (ISQED), March 2018, Santa Clara, Calif.

M. M. Saad, R. Palmieri, and B. Ravindran
"Lerna: Parallelizing Dependent Loops Using Speculation," 11th ACM International Systems and Storage Conference (SYSTOR '18), June 2018, Haifa, Israel.

R. Shafin, L. Liu, J. D Ashdown, J. D. Matyjas, M. M. Medley, B. Wysocki, and Y. Yi
"Realizing Green Symbol Detection Via Reservoir Computing: An Energy-Efficiency Perspective," IEEE Global Communications Conference (GLOBECOM), Dec. 2018, Abu Dhabi, U.A.E. and IEEE Transmission, Access, and Optical Systems Technical Committee (TAOS) in International Conference on Communications (ICC), May 2018, Kansas City, Mo.

X. Wang, L. Liu, T. Tang, and L. Zhu
"Next Generation Train-Centric Communication-Based Train Control System with Train-to-Train (T2T) Communications," 2018 IEEE International Conference on Intelligent Rail Transportation (ICIRT), Dec. 2018, Marina Bay Sans, Singapore.

Alumni Best Paper

Gregory Durgin
(BSEE '96, MSEE '98, Ph.D. '00), earned a Best Paper Award at the IEEE International Conference on FRID 2019, along with his co-authors. Durgin is an ECE professor at Georgia Tech.

Editorships

ACM Transactions on Sensor Networks	Y. Tom Hou	Editor
IEEE/ACM Transactions on Networking	Y. Tom Hou	Editor
IEEE Journal of Emerging and Selected Topics in Power Electronics (JESTPE)	Rolando Burgos Jia-Sheng (Jason) Lai Qiang Li	Editor Editor Editor
IEEE Wireless Communications Letters	Harpreet S. Dhillon	Editor
MDPI Journal on Energies	Jia-Sheng (Jason) Lai	Editor

Area/Associate Editorships

IEEE Transactions on Cognitive Communications and Networking	Allen B. MacKenzie Walid Saad	Associate editor Associate editor
IEEE Transactions on Communications	Allen B. MacKenzie Walid Saad	Area editor Editor-at-large
IEEE Transactions on Green Communications and Networking	Harpreet S. Dhillon	Area editor
IEEE Transactions on Information Forensics and Security	Walid Saad	Associate editor
IEEE Transactions on Mobile Computing	Jung-Min (Jerry) Park Walid Saad	Associate editor Associate editor
IEEE Transactions on Neural Networks and Learning Systems	Lingjia Liu	Associate editor
IEEE Transactions on Wireless Communications	R. Michael Buehrer Harpreet S. Dhillon Walid Saad	Associate editor Associate editor Associate editor
Nature's Scientific Reports	William T. Baumann	Editorial board member
Sustainable Computing: Informatics and Systems (SUSCOM)	Tam Chantem	Special guest editor

Conference Chairs

Rolando Burgos served as Technical Program Co-Chair, IEEE ECCE 2018, Sept. 2018, Portland, Ore.

T. Charles Clancy served as General Chair, AFCEA Intelligence Symposium, March 2019, Springfield, Va.

Y. Tom Hou serves as Chair of IEEE INFOCOM Steering Committee.

Jih-Sheng (Jason) Lai served as Chair of the 2018 IEEE Asian Conference on Energy, Power, and Transportation Electrification (ACEPT), Oct./Nov. 2018, Singapore; and Chair of the 2018 IEEE Southern Power Electronics Conference (SPEC), Dec. 2018, Singapore.

Fred C. Lee served as Honorary General Chair, IEEE Power Electronics Applications Conference (PEAC), Nov. 2018, Shenzhen, China.

Lingjia Liu served as Co-Chair of the 7th International IEEE Workshop on Emerging Technologies for 5G and Beyond Wireless and Mobile Networks (ET5GB), Dec. 2018, Abu Dhabi, U.A.E., and served as Co-Chair of the Wireless Communications Symposium, IEEE Intl. Conf. on Commun., Kansas City, May 2018, Kansas City. Mo.

Guo Quan Lu served as Chair of the International Symposium on 3D Power Electronics Integration and Manufacturing (3D-PEIM) held in June, 2018, University of Maryland.

Exceptional national & international service

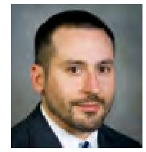
Dushan Boroyevich was selected as a Finalist Judge for the 2018 Innovate FPGA international competition.

Rolando Burgos was re-elected Chair of IEEE PELS Technical Committee on Power and Control Core Technologies for 2019-2020.

Igor Cvetkovic led the electrical and power management team of FutureHAUS to 1st place finish at the Solar Decathlon Middle East, sponsored by the Dubai Electricity and Water Authority and the U.S. Department of Energy.

Y. Tom Hou serves as a board Member, IEEE Communications Society Board of Governors and IEEE Communications Society Distinguished Lecturer.

Faculty Tenure & promotion



Charles Clancy was named the Bradley Professor of Cybersecurity.

Qiang Li was tenured and promoted to associate professor.

Allen MacKenzie was promoted to professor.

David McPherson was promoted to advanced instructor.

J. Michael Ruohoniemi was promoted to professor.

Wayne Scales was named the J. Byron Maupin Professor of Engineering.

Guoqiang Yu was tenured and promoted to associate professor.

Alumni Honors

ECE alumnus, **Mohammad Mozaffari** (Ph.D.'18), won the 2019 Outstanding Dissertation Award in the "Science, Technology, Engineering and Mathematics" category from Virginia Tech Graduate School. Mohammad's dissertation title is "Fundamentals of Wireless Communications and Networking with Unmanned Aerial Vehicles" and his advisor was Prof. Walid Saad.

ece FACULTY

A. Lynn Abbott
Associate Professor
Illinois '90

Masoud Agah
Virginia Microelectronics Consortium (VMEC) Professor
Michigan '05

Paul K. Ampadu
Professor
Cornell '04

Peter M. Athanas
Professor
Brown '92

Scott M. Bailey
Professor
Colorado '95

Joseph B. Baker
Associate Professor
Michigan '01

Arthur Ball
Instructor
Virginia Tech '09

Adam E. Barnes
Assistant Professor of Practice
Virginia Tech '95

William T. Baumann
Associate Professor
Johns Hopkins '85

A. A. (Louis) Beex
Professor
Colorado State '79

Dushan Boroyevich
University Distinguished Professor
Virginia Tech '86

R. Michael Buehrer
Professor
Virginia Tech '96

Rolando P. Burgos
Associate Professor
Concepción '02

Virgilio A. Centeno
Associate Professor
Virginia Tech '95

Thidapat (Tam) Chantem
Assistant Professor
Notre Dame '11

T. Charles Clancy III
Bradley Professor of Cybersecurity
Maryland '06

Kristie L. Cooper
Instructor & Associate Research Professor
Virgina Tech '99

Jaime De La Ree
Associate Professor & Assistant Department Head
Pittsburgh '84

Harpreet S. Dhillon
Assistant Professor & Steven O. Lane Junior Faculty Fellow
UT Austin '13

William Diehl
Assistant Professor
George Mason '18

Dong Dong
Assistant Professor
Virginia Tech '12

Gregory D. Earle
Professor
Cornell '88

Steven W. Ellingson
Associate Professor
Ohio State '00

Ryan M. Gerdes
Assistant Professor
Iowa State '11

Mona Ghassemi
Assistant Professor
Tehran '07

Kendall E. Giles
Assistant Professor of Practice
Johns Hopkins '07

Louis J. Guido
Associate Professor
Illinois '89

Dong S. Ha
Professor
Iowa '86

Peter Han
Assistant Professor of Practice
Missouri University of Science and Technology '95

Y. Thomas Hou
Bradley Distinguished Professor of ECE
NYU Tandon '98

Michael S. Hsiao
Professor
Illinois '97

Jia-Bin Huang
Assistant Professor
Illinois '16

Mantu K. Hudait
Associate Professor
Indian Institute of Technology '99

Xiaoting Jia
Assistant Professor
MIT '11

Mark T. Jones
Professor
Duke '90

Vassilis Kekatos
Assistant Professor
University of Patras, Greece '07

Jih-Sheng (Jason) Lai
James S. Tucker Professor
Tennessee '89

Luke F. Lester
Roanoke Electric Steel Professor & Department Head
Cornell '92

Qiang Li
Associate Professor
Virginia Tech '11

Elena Spinei Lind
Assistant Professor
Washington State University '10

Chen-Ching Liu
American Electric Power Professor
Berkeley '83

Lingjia Liu
Associate Professor
Texas A&M '08

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Harvard '90

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Cornell '03

Majid Manteghi
Associate Professor
UCLA '05

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Cornell MEng '76

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Carnegie Mellon '99

Jeffrey S. Mayer
Collegiate Associate Professor
Purdue '91

Theresa S. Mayer
Professor & Vice President for Research and Innovation
Purdue '93

Dave McPherson
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M.S. Virginia Tech '94

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Virginia Tech '88

Scott F. Midkiff
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Liege '87

Changwoo Min
Assistant Professor
Sungkyunkwan '14

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Rand Afrikaans '97

Marius K. Orlowski
Professor
Tuebingen '81

Jung-Min (Jerry) Park
Professor
Purdue '03

Cameron D. Patterson
Associate Professor
Calgary '92

JoAnn M. Paul
Associate Professor
Pittsburgh '94

Paul E. Plassmann
Professor & Assistant Department Head
Cornell '90

Ting-Chung (T.-C.) Poon
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Iowa '82

Saifur Rahman
Joseph Loring Professor
Virginia Tech '78

Sanjay Raman
Professor & Associate Vice President, National Capital Region
Michigan '98

J. Scot Ransbottom
Director of Design Projects
Virginia Tech '04

Binoy Ravindran
Professor
UT Arlington '98

Jeffrey H. Reed
Willis G. Worcester Professor
UC Davis '87

J. Michael Ruohoniemi
Professor
Western Ontario '86

Walid Saad
Associate Professor
Oslo '10

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Ahmad Safaai-Jazi
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McGill '78

Timothy D. Sands
University President & Professor
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Wayne A. Scales
J. Byron Maupin Professor of Engineering
Cornell '88

Patrick R. Schaumont
Professor
UCLA '04

Kenneth Schulz
Adjunct Professor of Practice
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Daniel J. Stilwell
Professor
Johns Hopkins '99

Pratap Tokekar
Assistant Professor
Minnesota '14

Jason S. Thweatt
Advanced Instructor
M.S. Virginia Tech '00

Joseph G. Tront
Professor
SUNY Buffalo '78

Anbo Wang
Clayton Ayre Professor
Dalian '90

Yue (Joseph) Wang
Grant A. Dove Professor
Maryland '95

Ryan K. Williams
Assistant Professor
Southern California '14

Christopher L. Wyatt
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Wake Forest School of Medicine '02

Yong Xu
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Caltech '01

Jason J. Xuan
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Maryland '97

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Illinois '06

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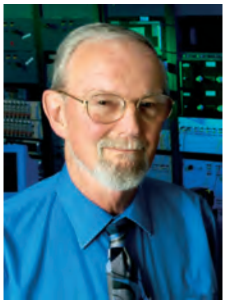
Berkeley '08

Yuhao Zhang
Assistant Professor
MIT, '17

Wei Zhou
Assistant Professor
Northwestern '12

Yizheng Zhu
Assistant Professor
Virginia Tech '07

Yunhui Zhu
Assistant Professor
Duke '13



IN MEMORIAM

James "Jim" S. Thorp, the Hugh P. and Ethel C. Kelly Professor Emeritus of Electrical and Computer Engineering died in May 2018. Thorp served as ECE department head from 2004 to 2009 and helped with the establishment of Virginia Tech's Center for Space Science and Engineering Research (see page 4), among other departmental initiatives. An expert in power systems, Thorp was a member of the National Academy of Engineering. In 2008 he and ECE's Arun Phadke received the Benjamin Franklin Medal in Electrical Engineering from the Franklin Institute for pioneering contributions to the development and application of microprocessor controllers in electric power systems.

RESEARCH FACULTY

Charles W. Bostian
Alumni Distinguished Professor Emeritus

Gary S. Brown
Bradley Distinguished Professor of Electro-magnetics Emeritus & Research Professor

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Postdoctoral Associate

Justin N. Carstens
Research Scientist

Cheng Wei Chen
Postdoctoral Associate

Carl B. Dietrich Jr.
Research Associate Professor

Raymond A. Greenwald
Research Professor

Michael D. Hartinger
Research Assistant Professor

Mohamed Karaoui
Postdoctoral Associate

Ibrahim Khalfallah
Postdoctoral Associate

Jaeho Kim
Postdoctoral Associate

Jong Woo Kim
Postdoctoral Associate

Bharat Simha Reddy Kunduri
Postdoctoral Associate

Fred C. Lee
University Distinguished Professor Emeritus

Yong Liu
Postdoctoral Associate

Praful. D. Mankar
Postdoctoral Associate

Robert W. McGwier
Research Professor and Director of Research, Hume Center

Anh Dung Nguyen
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Solmaz Niknam
Postdoctoral Associate

Ruslan Nikolaev
Research Assistant Professor

Stephen Noel
Research Associate

Pierre Olivier
Research Assistant Professor

Arun G. Phadke
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Amer Tahat
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Brentha Thurairajah
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Freek Verbeek
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Xiaoguang Wang
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Daniel R. Weimer
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Ming Xiao
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