VIRGINIA TECH

ece

THE BRADLEY DEPARTMENT OF

ELECTRICAL
& COMPUTER
ENGINEERING

2016

AUGMENTING PERCEPTION

VirginiaTech
Invent the Future®

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Editor: **Scott Bailey**

from the Chair of the

ADVISORY BOARD

Steve Poland
Chair
ECE Advisory Board

THE VIRGINIA TECH ECE Advisory Board has had another fulfilling year serving the department. In 2014 the Advisory Board helped Gino Manzo and the department introduce the new two-semester Capstone senior design course. Successful for both students and project sponsors, the Board is pleased to see that the course has now expanded into the master's level and increased participation from 61 students in 2014-2015 to 99 students in 2015-2016. We expect it will continue to grow and differentiate Virginia Tech ECE students for years to come.

Over the last year the board assisted the department head with evaluating the Virginia Tech Masters of Information Technology (MIT) degree and how to best position the program for continued success. In comparing the MIT program to peer programs at other major US universities, it became clear that Virginia Tech's offering was unique and significant in both its size and scope. We concluded that growth opportunities exist by further leveraging the strengths and synergies of the ECE, computer science and business programs. As a result, Kendall Giles has been hired as professor of practice and will be working to further expand and update ECE's offerings in this area, especially in cybersecurity.

Going forward, the board looks forward to continuing to help Luke Lester prepare for continued growth of the ECE Department and to contributing to the exploration of new majors within the B.S. degree program including the future "destination areas" currently being planned by the provost.

This was a unique year in that we did not have any board terms expire, but we did have the pleasure of adding new members Duane Blackburn with MITRE Corporation and Charlie Schulz with TESSCO Technologies. Welcome Duane and Charlie!

As a final note, this is my last year as chair of the ECE Advisory Board and I would like to express my sincerest thanks to the board, our Vice-Chair Ken Schulz, and Luke, for their support and the opportunity to serve the ECE department these last two years.

Steve Poland (BSEE '92, MSEE '94)
Chair, ECE Advisory Board

from the ece DEPARTMENT HEAD

Luke Lester
Department Head

THE BRADLEY DEPARTMENT OF Electrical and Computer Engineering continues to grow at a steady pace. In 2013 the number of undergraduates entering either the electrical engineering or computer engineering degree program was 241.

In the past two calendar years that number has nearly doubled to about 450 per year, consistently representing 20 percent of the College of Engineering's new majors. Our impressive growth to at least 1,100 ECE undergrads overall is a testament to the renewed desirability of Virginia Tech EE and CPE degrees and the dedication of our faculty and staff in providing a high quality and engaging undergraduate experience.

We have also grown our graduate program to approximately 580 students, primarily through an increase in Masters of Engineering (MEng) students. Graduate students are finding this pathway to be very attractive for professional preparation. By incorporating MEng students into our two-semester, industry-sponsored major design experience, we are also allowing MEng students to capitalize on a course sequence that exposes them to a customer-driven environment while simultaneously requiring them to devise a rigorous technical solution.

At the same time, the College of Engineering overall is attracting approximately 2,200 new engineering students in the next academic year. As I mentioned last year, this substantial growth comes with challenges in terms of classroom space and having a sufficient number of faculty members to teach this large cohort of students. Fortunately, we have had authorization to hire up to nine new faculty members for the department during this current academic year. As of the writing of this message, we have recruited one instructor, one professor of practice and four assistant professors as part of our faculty recruitment plan and our size of tenured/tenure-track female faculty has nearly doubled in the past two years.

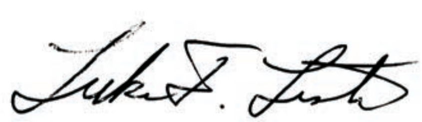
The unifying themes for most of our recent hires have been cyber-physical systems and cybersecurity. In fact, we are making a concerted effort to grow our computer engineering faculty more broadly this year, with up to seven of our new positions targeted for this general area. Nowadays, computer engineering is the growth side of the department and entering undergraduate majors are split 50/50 between EE and CPE.

We are also excited to announce that we brought on board three new academic and career advisors in ECE Student Services in October 2015, which brings our total number of advisors to five. Our feature on page 4 introduces our advising team and explores the wealth of experience they bring to counseling our ECE students.

Our new "Focus on Research" publication that is now published every fall semester, combined with the accessibility of our faculty's research publications through Google Scholar has paid off with enhanced visibility of our department. Once again I am pleased to tell you that in the U.S. News and World Report rankings, our graduate program in electrical engineering has improved to 19th in the country and computer engineering to 23rd.

Inside, you will also find stories on how our ECE undergraduates are engaging in teams that help integrate our technology in hybrid electric and Formula 1-style automobiles, and a piece on a fun computer engineering course on computer games. We have a special feature on how our ECE research teams are developing technology that augments human perception and enables us to see and understand things at scales that are beyond the human senses. From developing nano-scale imaging for medical advances, to large sensing stations that help us understand the magnetic fields around our planet, we are applying technology that will help improve lives and understanding in many areas.

Our continued progress on the research front and sustained growth in graduate and undergraduate enrollment shows that Virginia Tech ECE is a preferred degree program nationally and internationally. Go Hokies!



Luke Lester
Department Head

SUPPORTING STUDENT SUCCESS

A team of dedicated advising professionals provides specialized support for the department

> “We may be able to tap into things happening with a student that he or she might not feel comfortable disclosing to an administrator or faculty member.”
>
> - JoAnna Lewis

JOANNA LEWIS IS UNDETERRED BY a task that takes her back and forth across campus multiple times. Because of her tenacity, a student on the other side of the world was able to return to Virginia Tech to finish her degree.

“She couldn’t get her visa renewed, even though she brought documents on the approved list,” Lewis explained. Lewis worked with the Registrar’s Office to obtain the correct document the embassy would accept, but the Registrar’s Office would only send it USPS—which could take weeks.

Lewis persuaded the Registrar’s Office to release the letter to her. She then hand delivered it to Virginia Tech’s Graduate School, who sent it via an international courier system. The student, who lived in a remote part of China, waited in a Beijing hotel room for her documents.

When she returned to Blacksburg, she told Lewis, “I wouldn’t have been able to come back if you didn’t exist.”

“That’s what drives me,” Lewis said.

That drive, and dedication to service, is something the entire advising staff has in common. Each of the advisors—Leslie Pendleton, Mary Brewer, Nicole Gholston, Kimberly Johnston, and JoAnna Lewis, find fulfillment in helping students flourish.

“We are a resource,” Jaime De La Ree, associate professor and assistant department head, said. “Advisors are in the department to support all the activities of our students, and provide the best possible guidance, and often more than that.”

HELPING THE WHOLE STUDENT

“We’re in the business of student success,” Mary Brewer, academic and career advisor, said. Each student is assigned an advisor, and all advisors work with both undergraduates and graduate students.

While some departments may assign teaching and research faculty advising duties, ECE’s structure removes a level of stress for students who may be intimidated about disclosing a personal problem to a professor he or she reveres. “We look beyond the grade, at the person,” Brewer said.

“All of our faculty advise,” Leslie Pendleton, an advisor and instructor in the department, said. “Teaching and advising merge.” Faculty members serve as technical advisors, helping students match their academic interests—from embedded systems to alternative energy systems—to a career track. The professional advising team takes care of everything else.

“I can help you navigate the often-confusing ‘other’ parts of being a student such as how to pay fees,” JoAnna Lewis said. “Focus on your studies. Don’t be afraid to contact us and ask questions.”

ADVISORS ARE ALWAYS reaching out—but it is up to the student to take the first step. "They have to come in, we can't go get them," Mary Brewer said.

Advisors can also help smooth over issues that arise for faculty in the classroom. "If a student is missing classes or suddenly stops turning in homework or assignments, we can provide support for that," Mary Brewer said. "We know the resources that are available, and understand university issues and policies."

The advisors also understand what it is like to feel overwhelmed, and want to help students before they take any extreme actions. "I had a former student who panicked and dropped all of her classes," Kimberly Johnston, academic and career advisor, said. In the heat of the moment, that brash move may feel like the only option. "But it can impact your enrollment, your student loans, and your status if you're an international student," she explained. "If you talk to an advisor, you can avoid unnecessary stress and paperwork."

Johnston works to create a home away from home in her office, and she has a soft spot for international students. "They've left their lives and their families, and have the added pressure of an intense program," she said.

"International students are a little harder on themselves," she adds. "They're very driven, and set high expectations for themselves. I've found myself saying—'it is okay to enjoy yourself on a weekend,' or 'you don't have to take 18 credit hours every semester.'"

While working in a former position, Johnston had an Ethiopian work-study student. She wrote multiple letters over many months to the Ethiopian embassy so the student's parents could get visa approval to attend her graduation.

"The best feeling in the world is when students graduate and move on to the next phase," Johnston said. "There is no feeling like it in the world. It is a true honor to work with these students."

HITTING THE WALL

One student Brewer advises was working hard, "and he could talk about what he had learned accurately and intelligently," she said. But he was failing his tests and his homework. The student and his instructor were stumped. Brewer noticed some familiar patterns and gave him a referral for educational testing. He was diagnosed with a learning disability.

"He was down on himself at first. He

IT IS EASY TO SEE why students might buckle under the pressure of demanding coursework and more adult responsibilities. The advising team provides an extra level of support to help weather these challenges.

was ready to give up,” Brewer explained. With added support, the student was able to accept his differences—he wasn’t unintelligent, he just had a disconnect. “He started using his accommodations as soon as he could, retook the class he was failing, and got a higher grade,” she said. “His instructor noticed a whole different ability from him.”

“Next May, I get to watch him graduate,” Brewer adds, with a smile.

Leslie Pendleton worked closely with a student who left Tech after completing his undergraduate degree, but he then returned a few years later for graduate school. “He was very smart, but struggled,” she explained. When he ran up against problems that seemed unusual, she directed him to testing which gave a new diagnosis to illuminate some of his difficulties. She helped him come to accept his new reality, and connected him to other support services.

Toward the end of his graduate program, she helped him organize the literature review for his Master’s thesis using a tool he could understand—a Venn diagram. She also helped him work backward to create a plan and timeline, including the individual steps he needed to complete his thesis. One weekend when his parents visited, the student invited Pendleton to a celebratory dinner with his parents. “His mother said, ‘I don’t know what he would have done without you all this time’, and she and I cried together,” Pendleton said.

A RELATIONSHIP CAN MAKE ALL THE DIFFERENCE

Efficient advising is one of the first steps to student success and retention. A study at Portland State University showed that students were more satisfied when they have access to professional advisors, not just faculty advisors.

ECE’s advising department embraces the concept of developmental advising, which advocates building relationships between student and advisor, and they follow guidelines and strategies outlined by the National Academic Advising Association.

“We look at their emotional and psychological needs as they matriculate through their programs from the sophomore year onward through graduation,” Leslie Pendleton said. “I want to know how students are doing socially and psychologically as they pursue their rigorous academic programs.”

The advisors’ ultimate goal is to help students take responsibility for their own decisions and actions. In their late teens and twenties, many undergraduates experience massive emotional and intellectual development in a relatively short span of time. The independence that college requires of students can open up to become a fulcrum in their lives. “They question authority more, see gray areas, and do real critical thinking,” Brewer said. This, combined with the weight of new demands—academic, social, and emotional—can become too much to bear.

The advising team knows how to ask the right questions and give students the most appropriate referrals due to their backgrounds, training, and experience. Develop-

JAIME DE LA REE

ing relationships, however, is the most important component.

While working as an advisor at another university, Nicole Gholston scheduled weekly check-ins with a student who was struggling academically. "We would talk about her classes and some steps she could take to improve, but I didn't think it was getting through," Gholston said.

At the end of the semester, the student handed her a card. "She'd written, 'I want to thank you for believing in me before I believed in myself. I wouldn't have made it through without your encouragement.'"

TAKING THE FIRST STEP

Virginia Tech president Timothy Sands has committed to increasing student enrollment substantially over the next few years, and with that in mind, the advisors are thinking outside the box and working to connect with students outside of traditional methods.

Whether the preferred communication is email, phone, or in-person, "you can still develop a relationship and be responsive," Jo-Anna Lewis said.

Regardless of format, however, it is up to students to take the first step. "We reach out to them, but they have to make an appointment," Brewer explained. "Part of the advising relationship is creating teachable moments and helping students learn to be proactive, and to advocate for themselves." Getting in touch with their advisors can be a small—but critical—first step in that direction.

"We're here to make a student connection," Kimberly Johnston said. "We are committed to preparing our students for the real world, and we want to help them manage their time, think critically, and take responsibility."

"I'm interested in students beyond their ID number," Nicole Gholston added. "I love hearing their stories." More than anything, ECE's advising team wants students, and faculty, to see them as a resource to help in many aspects of their lives.

"It can help just to know that someone cares beyond how you did on that project," Mary Brewer said. "Nothing a student can say will surprise me. They might be struggling with their sexual identity, diagnosed with cancer, have a parent die, had a really bad breakup, or their home country could be in turmoil."

Overall, the department is excited to provide a high level of service. "I believe our advisors can masterfully guide our students," De La Ree said. ece

> "There's no substitute for forming a relationship. I have put my heart and soul into helping our students."
>
> - Leslie Pendleton

ENGINEERING PROFESSIONALISM

LESLIE PENDLETON TEACHES Engineering 2014, Engineering Professionalism. This course is a first introduction to some of the critical "non-technical skills" students will need to have when they enter the workforce, including communication, ethics, and teamwork, and work on nuts-and-bolts issues, like developing resumes and practicing interview skills. Pendleton also requires 15 hours of community service. "Many of my students tell me it is the most gratifying experience of their undergraduate experience," Pendleton said. And they come to realize and understand why most employers expect their engineers to give time to science, technology, engineering, and math (STEM) outreach programs in their communities.

DRIVING CARS INTO THE FUTURE

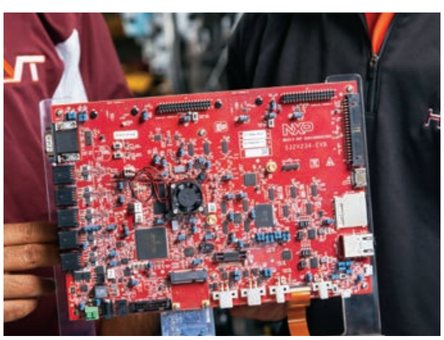
DAWN OF THE HYBRID MUSCLE CAR

PEOPLE WHO BUY CAMAROS are usually looking for fast and furious—stereotypically, they're more concerned with horsepower than conserving power.

But the students working on the Virginia Tech Hybrid Electric Vehicle Team (HEVT) are designing and building a hybrid option for those people who want a sleek, loud muscle car that doesn't guzzle gas.

"We're working on a V8 engine because we want to keep the torque and the roar while saving energy and boosting performance," said Matt Nikkel, a junior in computer engineering and a member of HEVT's Advanced Driver Assistance Systems (ADAS) sub team.

HEVT competes in EcoCAR, a four-year competition sponsored by General Motors and the U.S. Department of Energy that challenges teams from 16 schools across the nation to create an innovative, cost-effective hybrid vehicle that maintains consumer acceptability and safety without sacrificing performance.



THE HEVT STUDENTS are among the first to work with a brand new NXP microcontroller board, which they will use to run their programs.

STUDENTS Matt Nikkel, Hrusheekesh Warpe, Bowei Zhao, Karan Kant, and a 2016 Chevrolet Camaro like the one the HEVT team is turning into a hybrid electric vehicle.

GM donated a conventional 2016 Chevrolet Camaro, and the team is converting it into a hybrid vehicle, said Hrusheekesh Warpe, a graduate student in computer engineering who works with the ADAS sub team.

The ADAS team, which is part of HEVT's electrical division, is using computer vision and artificial intelligence to save energy. They are currently working on a microcontroller-based stereovision system to detect objects and alert the driver of possible collisions.

By implementing principles of machine learning and computer vision, the stereovision group is training their system to identify cars, stop signs, license plates, and other traffic cues. They've been using object identification algorithms, including cascade object detectors and template algorithms, to draw meaning out of the images recorded by the camera.

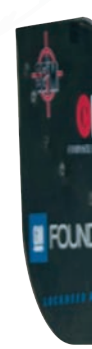
"By warning the driver to start braking early, we hope to recover some of the electrical energy that would be lost during hard braking," explained Nikkel.

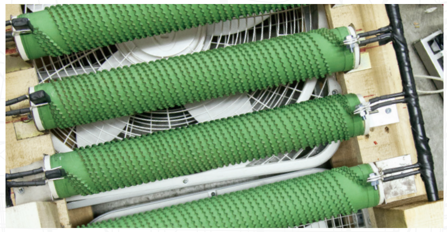
The students are using a brand-new NXP microcontroller board to run their prototype programs.

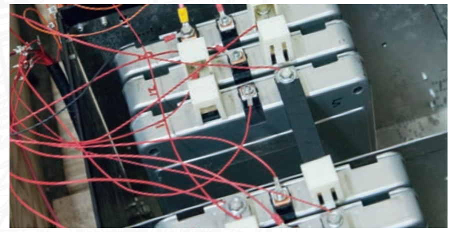
The initial software for the board, which was donated to them by NXP, had some bugs. Instead of waiting for the latest firmware, the ADAS team decided to tackle it themselves.

"After reading code and moving through a couple thousand files, we were able to turn on the board display and let the camera initialize and broadcast," said Bowei Zhao, a junior in computer engineering. "We're some of the few people in the world working on this board—it's very cool."

"What we're doing in HEVT isn't just college stuff," said Zhao. "We've been told that what we do here has future ramifications for how General Motors and the Department of Energy integrates these technologies, and it can affect how the world reacts to new technology in advanced vehicles." ece







THE ELECTRIC FORMULA

GETTING UP TO SPEED

AS CARS EVOLVE TO REQUIRE more electrical systems and computerized components, automotive companies are looking to draw more electrical engineers into the fold. This trend is reflected in the annual international competition sponsored by SAE, an automotive engineering society, which challenges students to design, build, and test a Formula 1-style race car. Virginia Tech has competed for the past 28 years, and until recently, the team focused only on traditional gas cars.

But in 2013, the SAE competition added a new category in which the students build an electric Formula 1-style car. So this year, alongside its gas-powered vehicle, Virginia Tech will debut its prototype of an electric race car.

The entire team has nearly 100 members, about 10 of whom work predominantly on the electric team.

"It's a new thing, this electrification of the motor sports industry," said Danny Lloyd, a junior in electrical engineering who is working on the electrical powertrain sub team. "A lot of electrical engineers want to go into computer programming, but many don't realize that there's this whole field starting to grow in the automotive industry."

The team spent the past year retrofitting an old combustion car chassis, and when Brammo Inc., the American producer of electric traction motors and batteries for motorcycles, provided them with a preproduction model of its three-phase AC induction motor, progress kicked into high gear. The team expects to have a rolling vehicle this semester.

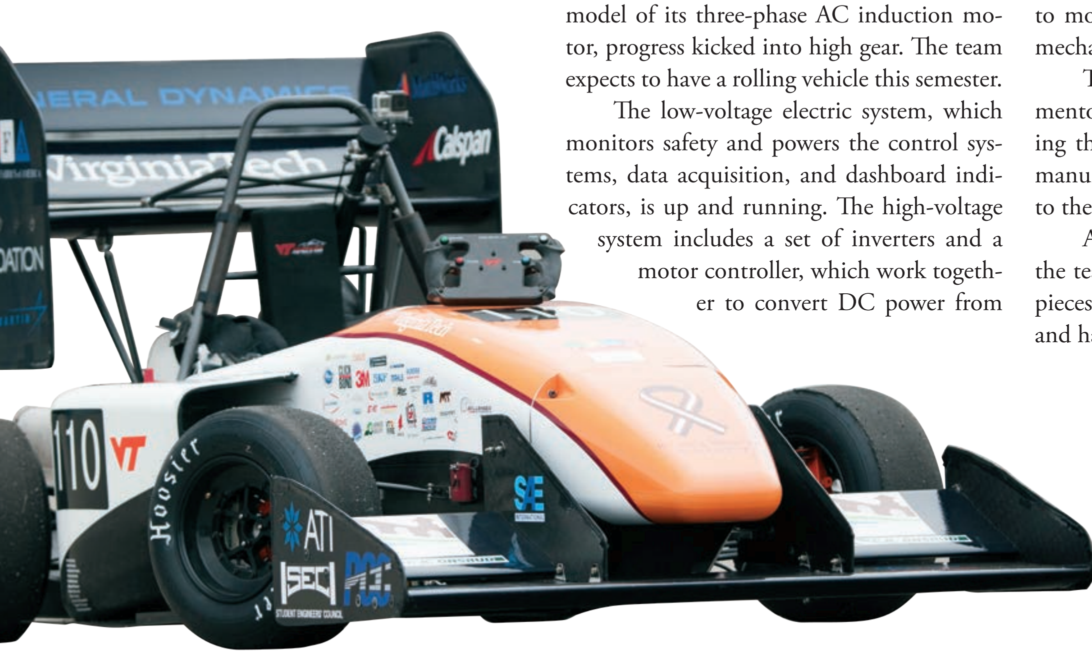
The low-voltage electric system, which monitors safety and powers the control systems, data acquisition, and dashboard indicators, is up and running. The high-voltage system includes a set of inverters and a motor controller, which work together to convert DC power from the batteries to three-phase AC power.

The team is still developing a safe way to mount the 100 V battery so drivers and mechanics are protected.

The tremendous effort students and mentors have put into this prototype is laying the groundwork for next year's team to manufacture an electric race car they can take to the summer 2017 competition.

As the prototype nears the finish line, the team is looking forward to seeing all the pieces come together as a finished vehicle—and having a chance to drive it. ece

TOP LEFT: The resistor bank for the electric formula project uses resistors more than a foot long.
TOP RIGHT: The team has been testing the batteries it plans to use to understand their limitations.
ABOVE: Neil Moloney (BSEE '17) and Danny Lloyd (BSEE '17) with prototypes of the car's systems. They are testing each system independently before assembling the vehicle.



THE CAR used for the most recent stage of the gas-powered formula-style car project. The electric version will be similar in appearance.

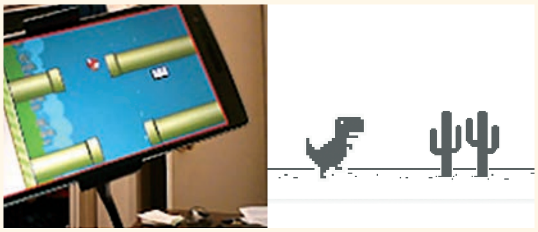
ECE 5554:

TEACHING MACHINES *TO SEE*

ON A COLD DAY in early December, the lobby of Goodwin Hall was crowded with posters, students, and interested members of the public, all talking animatedly about computer vision. Teaching machines to see was the subject of a fall 2015 ECE course, taught by Assistant Professor Devi Parikh. More than 80 undergraduate and graduate students completed the course, which culminated in a final project that asked them to apply their lessons to real world problems.

“To see is to know what is where by looking.”

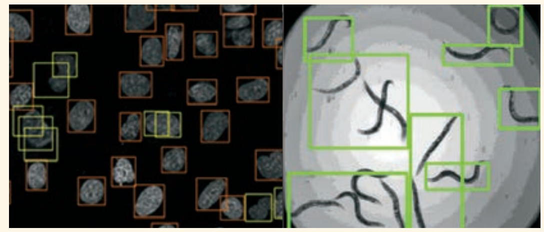
–*David Marr*



Flappy Bird: tap-to-jump game solver using computer vision

Aravind Premkumar (MSCPE ’17) and Sonal Pinto (MEng CPE ’17)

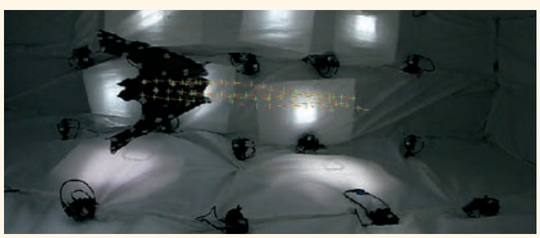
Flappy Bird is a simple game where the user navigates a bird through a series of obstacles. Tap-to-Jump games like Flappy Bird and TRex Runner —the game you can play in Google Chrome when there is no Internet—rely on hand-eye coordination. Aravind Preshant Premkumar and Sonal Pinto outsourced the playing to a computer. Working off webcam-recorded videos of each game, they used MATLAB to build algorithms for image acquisition and processing, and a capacitive actuator, which worked like a button to register taps.



Identifying and counting cells

Divya Bala (MSCPE ’16), Joshua Stuckner (Ph.D. MSE ’19), Swazoo Claybon (MSEE ’17)

In order to diagnose and treat diseases like cancer, doctors and researchers must first identify cells, often by analyzing microscope images.Manually, it can become critically time consuming. Swazoo Claybon, Divya Bala, and Joshua Stuckner used a micrograph and a magnified image of cells in an attempt to provide information about cell type and number. In their first model, they trained a high-level image classifier, and developed class specific detection algorithms. Their second approach involved a generic cell detector followed by classification.



Tracking of fiducial markers for bat flight motion capture experiments

Matt Bender (Ph.D. ME ’17), Mincan Cao (MEng CPE ’16), Yu Wei (MEng EE ’17), and Shaoxu Xing (MSME/MSEE ’16)

Bat flight mechanics make excellent inspiration for flapping wing Micro-Air Vehicles. Matt Bender, Mincan Cao, Yu Wei, and Shaoxu Xing developed a three-step method for identifying marker locations and tracking points. First, they isolated the bat’s body from the image background by using a frame differencing approach, which produces a bounding box containing the bat. Next, they computed filter bank responses within the bounding box to determine the location of features. Finally, they implemented a Kalman filter-tracking algorithm to track the points.

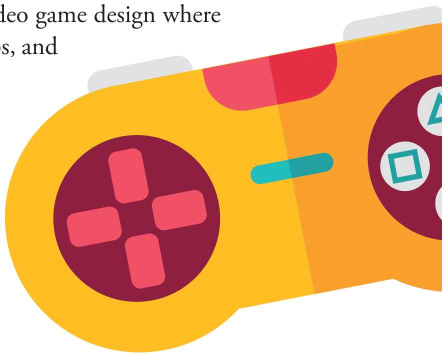
Hand tool recognition and classification

Brian Cesar-Tondreau (Ph.D. ME ’20), Alfred Mayalu (Ph.D. CPE ’18), Joshua Moser (MSME ’16)

This team looked into a wearable device that would “look” around a lab and automatically identify tools. As a proof-of-concept for this idea, they developed software that would be able to recognize and classify a set of hand tools using feature descriptors such as scale-invariant feature transform (SIFT), and a machine-learning system like a Support Vector Machine (SVM). They found that the best results came from using SIFT in conjunction with a border angle feature space. However, even with a model that had an accuracy above 70 percent, some tools, like hammers, were still classified incorrectly.

ECE 4525: GAME CRAFT

DESIGNING GAMES strays from traditional software development because successful game creation ties together diverse perspectives that include computer graphics, game architecture, game mechanics and interaction, software development, strategy, and artificial intelligence. ECE Professor Michael S. Hsiao teaches a course on video game design where he acts as a guide for students who brave the mazes, shoots, hoops, and labyrinths of game design.



Building the skills

Over the course of the semester-long class, students learn to integrate domains in order to create fun, engaging games from first concept to implementation.

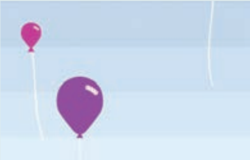
- Develop game engine components, game content pipeline, game programming techniques + module design patterns
- Design 2-D modeling + animation
- Design collision detection + player interaction
- Apply AI, computer graphics, networks, etc.
- Design 3-D modeling + animation.

Mastering the basics

In the first half of the semester, students design and develop simple games that address the fundamental concepts of game design.

- Game loop + architecture
- Action + user interaction
- Tilemaps + mazes
- Perspectives + views
- FSM / state-based design
- Motion + physics (linear + angular)
- AI for modeling intelligent behavior
- Particle systems
- Graphs, search + traversal
- Fuzzy logic
- 3-D graphics

Applying the lessons

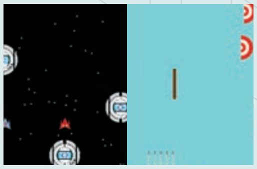


BALLOON POPPERS

3-D OBJECTS

SHOOT-'EM-UPS

CAT-AND-MOUSE



DODGE BALL, SLING SHOT

Fall 2015 ECE 4525 Final Projects

For the final project, the students implement more sophisticated games. Typically, the games would include tilemaps, perspective/views, state-driven design, some physics, particle systems (explosions, etc.), and AI for controlling non-player characters.

AUGMENTING PERCEPTION

OUR SENSES ALLOW US to tap into the world. What we can touch, taste, hear, see, and smell defines what we know. But our biology also limits us. We can sense only a small fraction of the information at hand. One theme in electrical and computer engineering research is expanding and extending what we can perceive and understand. From the nano-architecture of the brain, to the depths of the ocean and the far reaches of the atmosphere, ECE research seeks to augment human senses with technology that can model and map the body, gauge real-time health information, visualize the insides of objects, and autonomously communicate for strategic observation. By teaching machines to act as extensions of our perception, we redefine our capabilities and bring a sharper, more complete picture of reality into focus.

AN INSIDE JOB

Interfacing with the body at the nanoscale

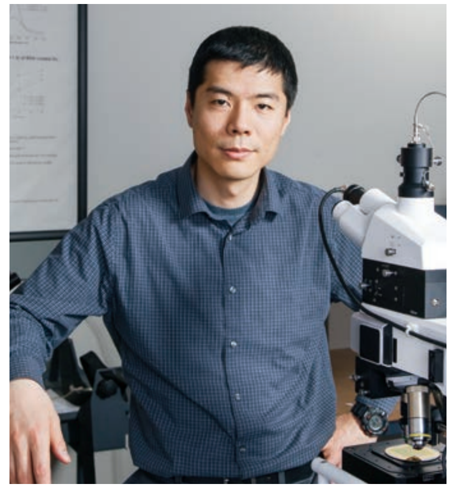
NANOPHOTONIC microporous scaffolds are being tested as flexible, bio-friendly devices to monitor biological signals in real-time.

OUR BODIES ARE CONSTANTLY sending signals, alerting us to what we need, but this only helps us if we can decode them quickly enough to react. Wei Zhou envisions a miniature piece of technology that measures the spatiotemporal evolutions in the body's own molecular vibration states or local charge distributions to transmit health information in real-time.

Zhou, an ECE assistant professor, is currently working on a nanoscale photonic device that concentrates and manipulates light with the potential to be integrated into the human body for real-time monitoring of bio-signals.

This technology can be used for healthcare applications, including blood glucose monitoring, which is crucial for diabetes management.

Zhou's research lays the groundwork for the next-generation of bio-integrated nanosystems that incorporate both nanophotonics and nanoelectronics onto the same platform.

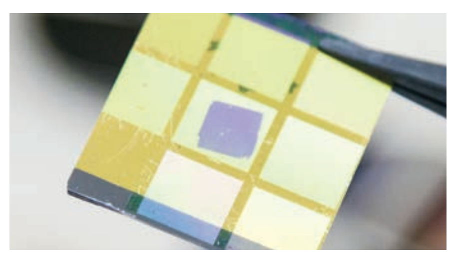


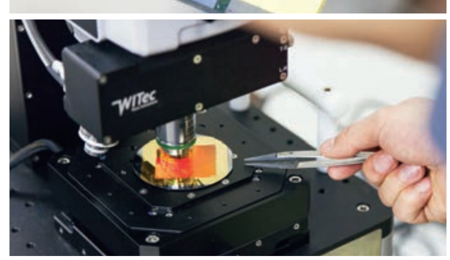
WEI ZHOU

While other researchers have started to develop such devices for healthcare applications in vitro, Zhou's research targets biomedical applications *in vivo*—such as implantable nanophotonic biosensors within human tissues.

"Nanoscale photonics within biological systems is a highly unexplored area," said Zhou. "We're working on achieving the human–machine interface in an elegant and seamless way."

The nanophotonic devices can be thought of as nano-lenses or nanoantennas that concentrate light into a nanoscale spot beyond the diffraction limit. When photons of light interact with innate vibration states of biomolecules, the photons will be absorbed or scattered. While most of the scattered photons retain their original energy, a few of them are inelastically affected. Their





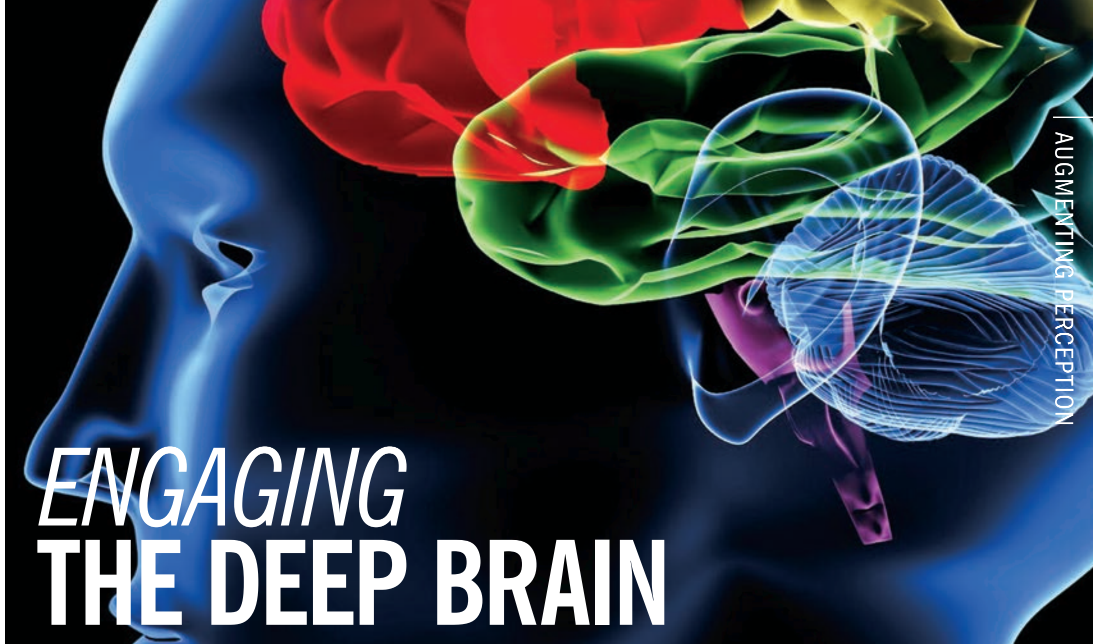
energy shifts either up or down. This phenomenon, which is called Raman scattering, provides information about the biological signals in the body. Zhou's device takes advantage of these physical properties to enhance the inelastic scattering of the molecule, which provides a real-time biochemical signal in the body.

The next step will involve patching nanoelectric components together with the nanophotonic devices, which could exploit charge-based bio-signals as an additional way to gather health information from the human body in real-time.

"This complementary capability will introduce a much more powerful strategy for interfacing with the biological environment for sensing purposes and signal conversion," said Zhou. The hybridization of photonics and electronics will provide a fail-safe for the measurement in very complicated biological environments, meaning electronics can take over in situations where photonics are faulty, and vice-versa.

To craft this hybrid bio-integrated platform, the members of Zhou's team are challenging themselves to find solutions to problems related to aspects in both biomaterials and device-physics. For starters, the body must not reject the components. Zhou has been testing a flexible microporous substrate as a body-friendly alternative to the harder, more rigid substrates typically used. The device's surface chemistry also needs to recognize the molecule being targeted, glucose for instance, and be able to detect it over a long period of time. And the device must be able to perform in biological fluids without degrading.

The device will be similar enough to biological tissue that the body might not regard it as foreign. Zhou hypothesized that the body may go so far as to adopt the scaffold, growing cells around it. The artificial scaffold incorporated with nano-enabled biosensors then becomes a natural part of the body. ece



ENGAGING THE DEEP BRAIN

THE HUMAN BRAIN—THE THREE pounds of spongy gray matter in our skulls—stores more information than a supercomputer and feeds our imaginations. But neurological illnesses affect more than 50 million Americans annually and cost more than $500 billion to treat. ECE Assistant Professor Xiaoting Jia is developing flexible, multifunctional brain implants that can be manufactured at a low cost and may herald the next generation of technology for treating Parkinson's disease, depression, stress, or other neurological disorders.

Current neural interface devices—sensors that can be implanted in a brain—have been used to alleviate some of these symptoms, but they are bulky, hard and rigid, made from metal or silicon. The brain's soft, fragile tissue is easily damaged by unyielding devices, which can also fail after long term implant.

Jia, with help from students and faculty collaborators, has been working on devices that seamlessly integrate into the brain's architecture—a flexible, multifunctional fiber that can not only read the electrical signals from neurons inside the brain, but also send optical, chemical, and electrical stimulation into the nervous system.

"Our flexible fiber devices mimic the compliances of brain tissue, causing less damage," said Jia. "They are an ideal platform for long term implant."

Although she's still in the early stages of research, Jia envisions a deep brain neural interface device that can interact naturally and gently with the human nervous system.

Active neurons transmit electrical signals, which can be recorded by an electrode placed nearby. Jia and her team can thread a single fiber with thousands of nanoscale electrodes or micro-scale drug delivery channels, which allow them to track the signals and interact with the brain at different locations.

"Most of our fibers are on the order of tens to hundreds of microns—comparable to a human hair—and they can be smaller," Jia said, selecting a translucent strand from a nest of fibers.

Using macroscale machining, they fab-

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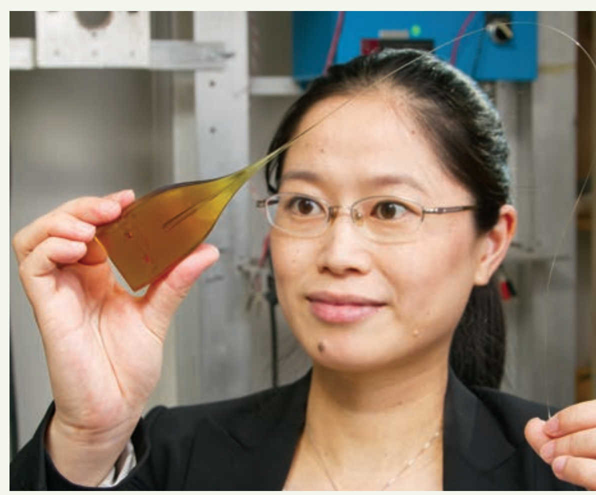
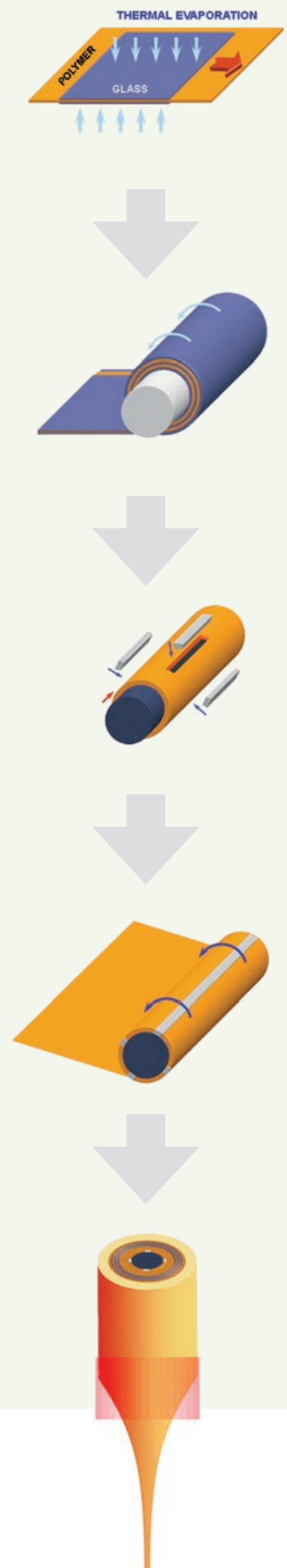


XIAOTING JIA

FIBER MANUFACTURING

THE MACROSCOPIC PREFORMS contain electrodes, drug-delivery channels, or other features made from composite materials and metal with a low melting point. The template is carefully heated and stretched from a fiber draw tower. The final product is a thin fiber containing the same cross-sectional features, but shrunk by a factor of 200.



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ricate a large template of the fiber, called the macroscopic preform. The preform is a small block of polymer studded with electrodes, channels, or other features made from composite materials and metal with a low melting point. The template is carefully heated and stretched from a fiber draw tower.

The final product transforms a one-foot by one-inch block into a thin fiber hundreds of meters long.

"We end up with exactly the same cross-sectional features—which can include some complex geometries like electrodes, optical wave guides, or drug delivery channels—shrunk down by a factor of 200," said Jia.

Jia held up the preform, an amber slab tapering off into a long thread, like a Hershey's kiss. Consecutive drawing steps, she explained, can reduce the features' dimensions even further.

Because one device requires only a centimeter of fiber, each drawing can create hundreds of thousands of devices. The process generates a scalable, low-cost product that could eventually save lives.

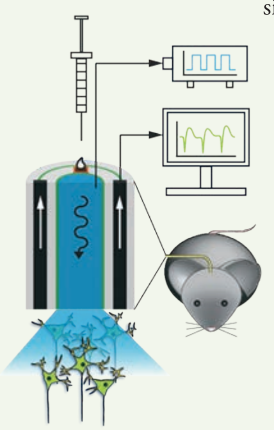
Jia and her team are still in the beginning phases of the trials. Currently, the device is being tested at Virginia Tech Carilion Research Institute, where the group has inserted centimeter-long fibers into the prefrontal cortex of mouse brains.

"By sending certain stimulation, it's possible to affect the movement of the mouse," said Jia. "The device can also be implanted in other areas, like the regions that control memory or fear."

They are injecting dyes through the drug delivery channels to observe how they diffuse. This is laying the groundwork for research on drug delivery for people who are suffering from epilepsy or tumors. A neural interface device like the one Jia is developing would allow for more control over where and when drugs are released in the brain, and could minimize dangerous side effects.

This two-way interaction could also be used to pinpoint where neurons are malfunctioning, and then prompt the device to send stimulation to modify the activity.

"A device like this would bridge the gap between engineering and biology, harnessing the strengths of both to improve quality of life," Jia said. ece



NEURAL INTERFACE DEVICES can record electrical signals and send information into the brain. This two-way interaction can identify problem areas, and then prompt the device to respond accordingly.

BEYOND BONES

Bringing X-rays into focus

IF THE DOCTOR ORDERS A CT SCAN of your broken wrist, you know what to expect: An X-ray machine conjuring ghostly images of joints and bones. Or you know X-rays from the airport: a security official scrolling through pictures of transparent luggage and rejecting your toiletry kit because you exceeded the liquid limit.

ECE Assistant Professor Yunhui Zhu works with X-rays, but she is looking beyond bones and bags, to the future of imaging. She is combining different physical properties of X-rays to enhance their capabilities, granting researchers a sharper, richer look within.

Doctors and TSA agents make use of a specific characteristic of X-rays: their attenuation. As X-rays travel through the body, they are absorbed in different amounts by different tissues. Bones and other hard materials easily absorb this type of radiation, and the images are based on the varying intensity of the X-rays.

"People love X-rays because they have a strong penetrating ability and they let them see what's happening inside," said Zhu. "But traditional X-ray technology is extremely limited. It produces very fuzzy images, and there are many materials that hardly absorb X-rays at all."

Most notably, Zhu said, there are liquid explosive materials that can't be detected by airport security equipment, and state-of-the-art breast cancer scans often can't pick up potentially cancerous lumps in breast tissue.

Instead, Zhu is investigating little-used properties of the radiation, particularly their phase, which takes advantage of how the light waves bend through tissue, and small-angle scattering, which exploits how the X-rays bounce off a sample and scatter.

Combined with attenuation, these propagations of light bring X-ray images into much sharper focus. Zhu's test images have already increased the contrast by a thousand times.

TECHNOLOGY

In the field of X-ray imaging, the source of the light is key. Conventional applications in airports and hospitals use ordinary X-ray tubes. They have a relatively large volume and, according to Zhu, they yield less accuracy.

Barring the use of a synchrotron, which would be too large and expensive for her uses, Zhu has been advancing her techniques by shrinking, focusing, and cooling her light source, which allows for phase and scatter imaging with higher resolution. She's also been experimenting with arrays of light sources, modulating how the light is shining in terms of spatial patterns and pulses.

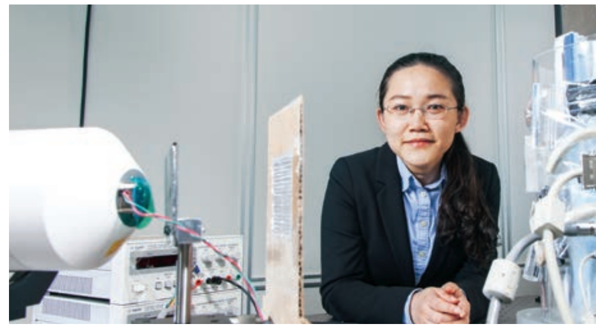
Arrays also work well for 3-D X-ray reconstruction, which is another of Zhu's goals. A 3-D reconstruction is based on stacked projection images from different angles and a 3-D reconstruction algorithm. An array set up around a sample (or a patient) makes for a faster, more accurate image.

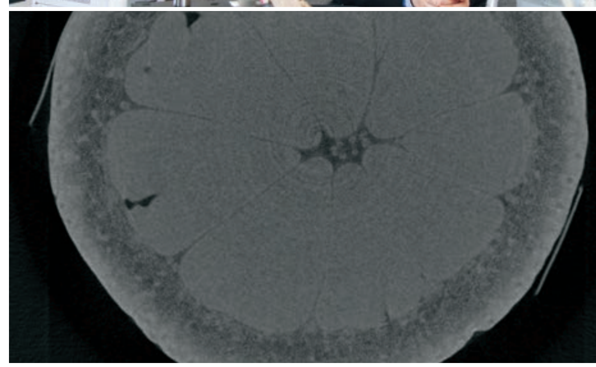
APPLICATIONS

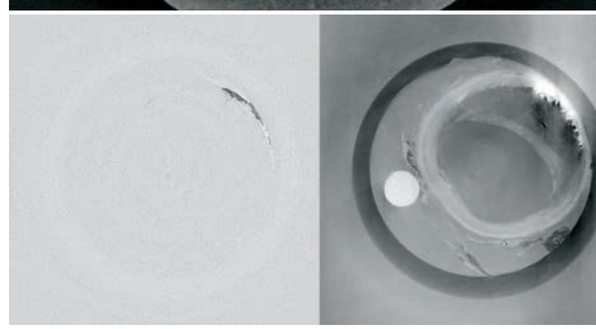
While the applications of X-ray phase imaging research are wide-ranging, Zhu is currently focusing on two projects.

The first seeks to mitigate the discomfort and inaccuracy associated with breast cancer screenings. "Breasts are soft tissue, and to get a good image, they are mashed and distorted in painful ways," said Zhu. "By using phase imaging, the patient wouldn't have to be put through such a difficult procedure, and the images will be more accurate."

She is also interested in applying the new techniques to monitor and improve the printing process for 3-D printed materials, which are good candidates for this type of imaging. "If I can track the stress distribution inside the 3-D configuration in any parts—metal, carbon, and nylon—that will be a tremendous thing for materials and mechanical engineering," said Zhu. ece





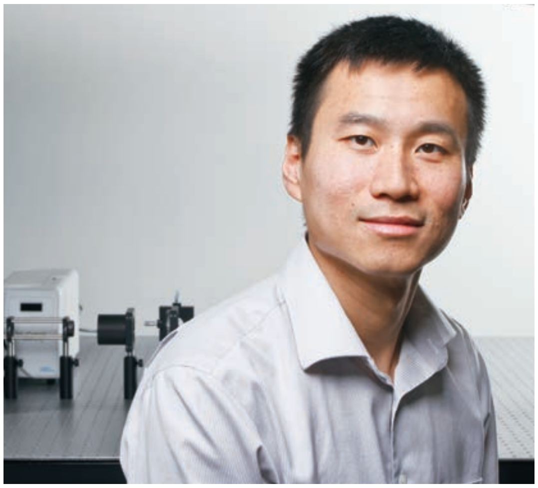


TOP: Yunhui Zhu investigates new ways of enhancing X-ray technology by combining lesser-used properties of propagation. **MIDDLE:** There wouldn't be much to see of a lime using traditional X-ray imaging. But a combination of phase and attenuation provides a stronger signal. **BOTTOM:** Using only X-ray attenuation, the image is basically noise (left), but Zhu's techniques result in more information per photon. After tracking the phase signals, the layers of the artery come into stark relief (right). *X-ray images created in collaboration with the 3-D optics lab at the Massachusetts Institute of Technology.*

A CLOSER **LOOK**

Improving fertilization outcomes with imaging

YIZHENG ZHU is looking at the morphology of sperm, eggs, and embryos, creating images like the one above to help improve outcomes for *in vitro* fertilization.



INFERTILITY AFFECTS MORE THAN 10 percent of the population, and *in vitro* fertilization (IVF) is the primary treatment. Although more than 300,000 births worldwide are the result of IVF each year, the success rates are low, making the process emotional, time-consuming, and expensive, according to Yizheng Zhu, an assistant professor in ECE.

Zhu hopes to improve success rates and reduce cost by creating better imaging technology. With better and less expensive imaging, doctors could quickly ensure that the most viable sperm, eggs, and embryos are used.

IVF typically involves removing eggs from a woman, fertilizing them in a laboratory with sperm, and implanting multiple fertilized eggs into the woman's uterus, hoping that one or more will lead to pregnancy. According to Zhu, a couple will have to go through this process an average of three times to succeed once. "Couples go through an emotional rollercoaster, and it involves a lot of physical and financial stresses," Zhu says. "We're developing a special optical microscope to assess the quality of sperm cells and embryos, which we hope will improve the success rate."

Zhu's research focuses on developing fiber-optic-based technology to image specimens that range in size between nano scale and nearly visible. "We develop techniques that can help the treatment or diagnosis of diseases by using optical imaging technologies," he explains.

He uses the intrinsic properties of specimens, such as thickness and density, to detect light in a non-fluorescence way. He focuses on morphology and detecting the tiny changes between an object and its surroundings.

Imaging plays an important role in determining the quality of sperm, eggs, and embryos, Zhu explains. The imaging challenge is complicated by the need for different techniques to image these specimens. "We're trying to develop an integrated, shared platform that can do all three kinds of imaging with the same equipment," says Zhu. "The cost will go down and the usability will be increased." His team has already developed the different techniques needed, and have promising preliminary results. "The next step is to integrate them. There is great potential," says Zhu. The three systems share many components, including the light source and the

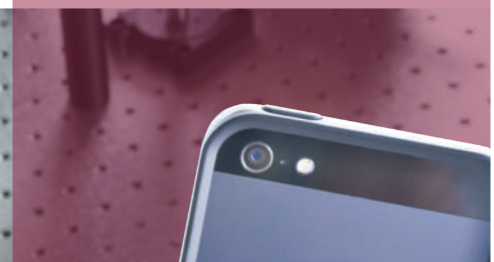
EACH PART of *in vitro* fertilization, sperm, eggs, and embryos, requires different imaging techniques. Yizheng Zhu is creating a platform that can use many of the same components to image all three.

detector, making integration possible.

Sperm cells can be particularly difficult to image, Zhu explains, because they move at high speeds. "A lot of current technologies can't keep up with sperm cells, or their quality is not great. You need high sensitivity to capture the details of morphology [the form]." Zhu has developed a system to capture this detail at acceptable speed.

"The next step is to study how morphology is related to the quality of the sperm cell," he says, and he is specifically looking at the sperm heads. "Because of the special organization of DNA inside the head, light oscillates in different directions and travels at different speeds," says Zhu. "The integrity can be related to this anisotropic behavior called birefringence." Birefringence occurs when light travels at different speeds depending on the direction of oscillation. By measuring birefringence, Zhu can estimate the quantity and quality of the DNA in the sperm head.

Because this research is at an early stage, Zhu's team is currently working with samples from pigs and cows. Once they prove the process works, they can proceed to human testing. Eventually, Zhu envisions IVF imaging becoming an automatic process, with samples flowing through microfluidic channels while being analyzed and selected by a computer. "These are very sensitive samples that don't usually live outside the human body, so you want to keep them in a friendly environment with minimal human interference," says Zhu. ece



SMARTPHONE *MEDICAL*

ONE OF YIZHENG ZHU'S OTHER projects is to build a microscope that can be used as a smartphone attachment for imaging biological agents. "Smartphones are everywhere now. They have a very high quality imaging system," says Zhu, "The camera is small, with good speed and quality."

Zhu believes personal electronics will be a force in the future of medical care, as high quality medical devices become accessible to patients. "We're going to lower healthcare costs by reducing the equipment cost," says Zhu. Eventually, he hopes this technology will also improve healthcare in areas with few resources, such as third-world countries. A smartphone with an attachment could collect medical data, and relay the information to a doctor in another location who could make a diagnosis.

"This is under the umbrella of next-generation mobile healthcare," he explains. "Many people now have devices to test blood sugar levels at home." Eventually, people might have other cheap, portable medical devices in their own hands, like the small microscopes Zhu is developing, which can be used to examine blood. "That will make things very interesting," he says.

REVERSE ENGINEERING *THE BRAIN'S* SOFTWARE

ABOVE: Rosalyn Moran images and models the human brain to understand how it changes with age. **BELOW:** Images of the brain's different responses for younger and older subjects.

ROSALYN MORAN IS STUDYING how our brains react to their environment by modeling the brain's 'software' using machine learning techniques.

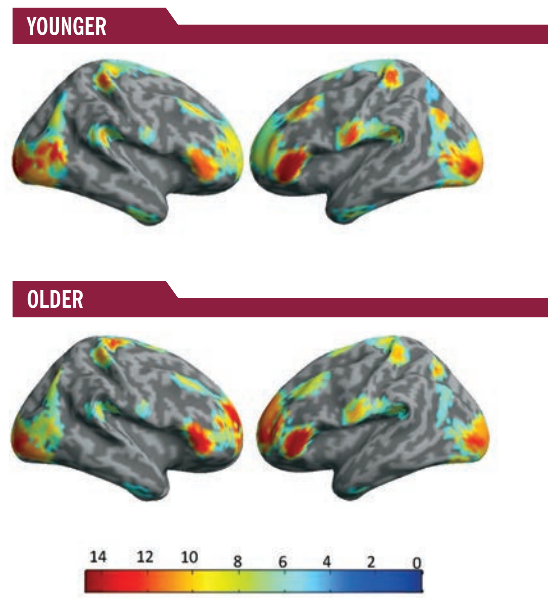
"We use computational theories to expand our ideas of what the brain is by looking at the algorithms and software running in our brains. We're trying to look in the black box that is our brain and see what's really going on," says Moran, who has a joint appointment as an assistant professor in electrical and computer engineering and the Virginia Tech Carillon Research Institute.

Moran's main focus is on understanding how "the aging brain is a function of its environment and the length of time it has been in its environment." She is modeling this via computer algorithms, using deep learning techniques. Deep learning uses hierarchies in artificial systems that can learn deeper and more abstract concepts. Moran is looking into whether the aging brain, like these models, has a better grasp of high-level concepts. "As you age, you get deeper and deeper into the hierarchy, and you can grasp more and more abstractions," according to Moran. "This can have good and bad effects."

To study deeper abstractions, Moran and her collaborators reviewed a neuroadjusted automaton game that is one of the tasks set up for the Roanoke Region Brain Study, which is scanning hundreds of brains of all ages. In this game, proposers must split a pool of money between himself or herself and a receiver. If the receiver accepts, they both get the money. If the receiver rejects the offer, neither gets the money. According to Moran, this is a basic study of game theory and concept of fairness.

In the study, the results of this game differed by age. As the proposers became more and more greedy (offering smaller and smaller sums to the receivers), younger players started to refuse the offers more often. Older players, however, were more likely to accept even low offers. The question that arose, says Moran, is whether this proves more abstract thinking or whether people simply become more forgiving as they age.

"What we found is that you get learning signals that go deeper and deeper in the older participants," says Moran. "They can see different groups of people, and notice the



SOLVING FOR SEROTONIN

MORAN IS ALSO INVOLVED with research to understand electrochemical reactions in the human brain, particularly in the brains of Parkinson's patients. She and her team are analyzing voltammetry data from the human brain, which gives researchers an electrochemical way to measure chemicals in the brain. If you run a voltage near a substance, it will lose or gain an electron, Moran explains, so you see a current change depending on the concentration of the chemical. "We do this when patients are about to have their deep-brain sensors implanted," she says.

The chemicals the team is analyzing are dopamine and serotonin. Serotonin, Moran explains, is important because of its role in expression. "Serotonin suppressors are used by many people for depression treatments, and we still don't know the basics of what it actually does in the human brain."

When the patients are having their deep-brain sensors implanted, they play

DAVID HUNGATE | DOMINION IMAGES

THE HUMAN BRAIN TO THE ROBOTIC BRAIN

WORKING WITH ECE associate professor Chris Wyatt, Moran is helping to move her theoretical models of the human brain into artificial brains. "We are trying to develop adaptive robots that can learn their environment and change their own states," says Moran. "They should be able to act to make their predictions come true."

Their prototype model is the traditional control theory inverted pendulum. "After working with a set of preprogrammed error corrections, it should be able to learn its own error correction," explains Moran. "If we take a pendulum that wants to be upright and put it in different environments, it should be able to learn how to correct for different environments," such as wind.

difference between a more or less generous group." Younger participants, however, "can't distinguish these different environments and [do not] adapt their behavior."

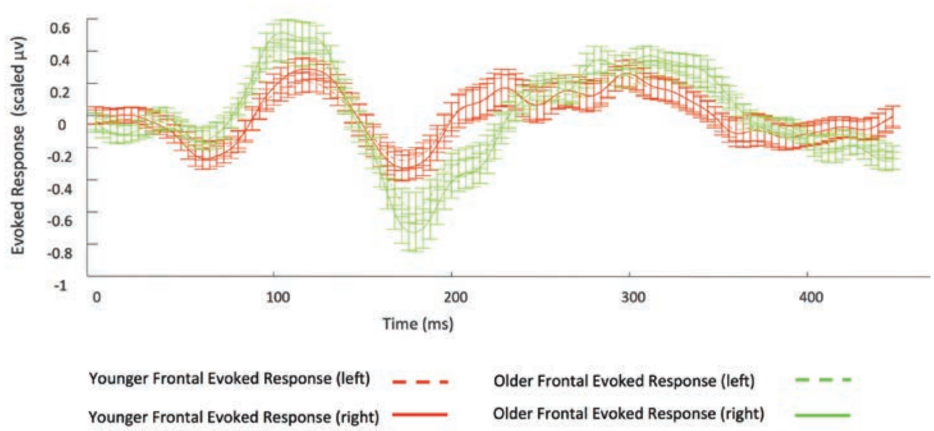
"The interesting effect that you see is that you're more economically rational, and it seems to be an effect of being able to learn deeper and deeper interactions." Presumably, she continues, this is because older people have simply had more social interactions.

"Now we're looking at the brain regions responsible for this behavior." Moran is building a model of the brain and will compare it to an MRI model. "We might expect activity in regions of interest such as the prefrontal cortex in the older individuals, and we also expect to see interactions with the mid brain regions," like those that control dopamine and serotonin.

The prefrontal cortex is implicated in decision making, planning, and moderating social behavior. Dopamine and serotonin are implicated in risk/reward and happiness.

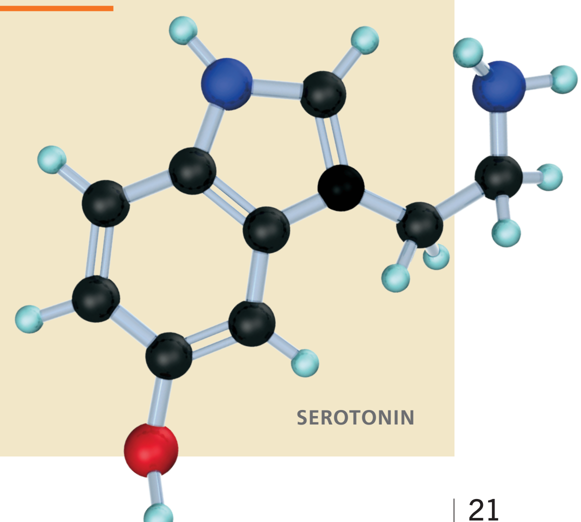
Using expectation maximization, machine vision, and pattern recognition, her team hopes to discover how the brain learns to adjust to these situations. This might, Moran notes, be similar to how an artificial brain learns. ece

THE GRAPH BELOW SHOWS how the brain reacts differently to stimulation as it ages. Moran has discovered that learning signals go deeper in older brains.

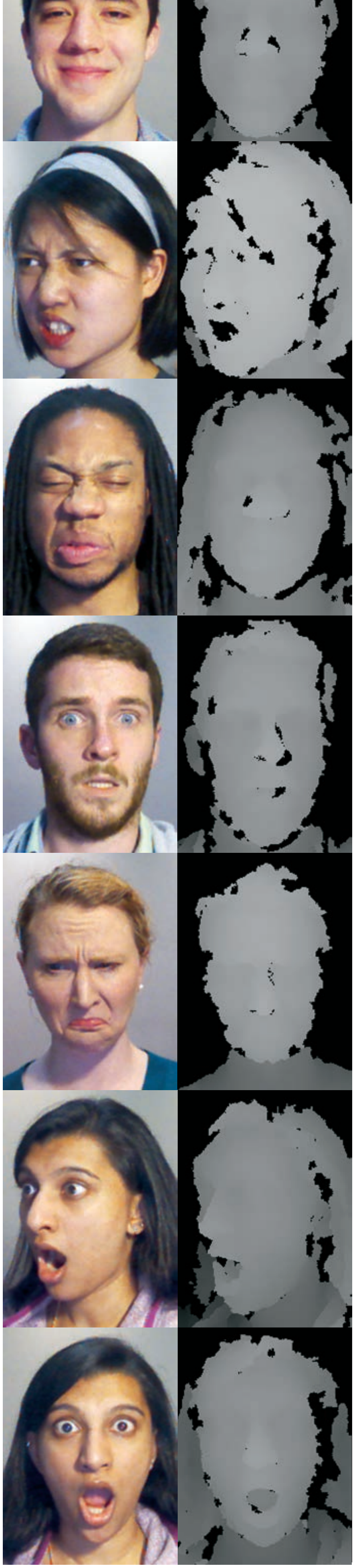


a market investment game, explains Moran. "We use historical things, like the 1929 stock market. Serotonin measurements seem to become more active when things are going badly." The game can go badly in two ways: either a person bets a lot of money and the market drops, or doesn't bet enough and the market increases.

"We find that serotonin helps you act on this bad information. Serotonin signals help you avoid those mistakes," according to Moran. This might, she explains, increase understanding of how we become depressed—if a person has no mechanism to indicate that something is bad and should be avoided, he or she might become depressed. Although much is still unknown, Moran believes that they are making good progress. "I think we've taken some useful steps forward, especially in differentiating dopamine from serotonin," she says.



SEROTONIN



SAMPLES of the RGB and corresponding depth images of the six basic facial expressions (happiness, surprise, anger, sadness, fear, disgust) in different poses.

MAKING FACES

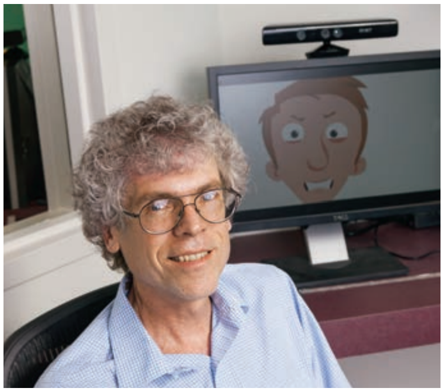
IMAGINE AN INEXPENSIVE, AT-HOME therapy program that could help children with autism spectrum disorder (ASD) become more fluent in emotional expression. ECE associate professor Lynn Abbott is developing a technology-based tool that can potentially provide this service. Abbott, his students, and postdoctoral researcher Amira Youssef, have been working closely with a group from the Virginia Tech Department of Psychology to build an interactive computer-assisted system to teach children with ASD how to recognize and reciprocate facial expressions of emotion.

Autism statistics from the U.S. Centers for Disease Control and Prevention identify around 1 in 68 American children as on the autism spectrum. Studies have shown that young children with ASD have trouble recognizing and expressing certain emotions, which can affect their ability to infer emotions expressed by others and communicate nonverbally over the course of their entire lives.

In their proposal, Abbott and his interdisciplinary team described how a better understanding of the normal development trajectory of facial expression recognition might help in early identification and possible treatment of affective disorders such as autism, depression, and anxiety disorders.

Before they became involved in this project, Abbott and his doctoral student, Sherin Aly, were applying principles of machine learning to train a computer to recognize facial expressions.

"We were looking for an application where this would be useful. Who needs an expression-recognition system?" said Abbott. "We talked to several parties only to discover that the Child Support Center, which is just about a block from here, was developing therapies or interventions that work with children who have developmental disabilities."



LYNN ABBOTT

After strategizing with Susan White, the assistant director of the Child Study Center and a faculty member in the Department of Psychology, they submitted their proposal. In 2015, the National Institute of Child Health & Human Development granted them funding for a two-year feasibility study to investigate if the technology was mature enough to support this kind of intervention.

"Most interventions with children who have ASD involve sessions with psychologists or therapists, which can get expensive," said Abbott. "Our long-term goal is a system that could be set up in your living room to be used as often as needed and tailored to individuals."

The exploratory study is piloting a system that requires only a computer and a Microsoft Kinect—an inexpensive motion-control console with a video camera and a depth sensor for capturing 3-D visual data.

> "Our long-term goal is a system that could be set up in your living room to be used as often as needed and tailored to individuals."

In the study, children are asked to watch and respond to images and videos on a computer equipped with a Kinect, which records and processes their facial expressions, and then provides feedback.

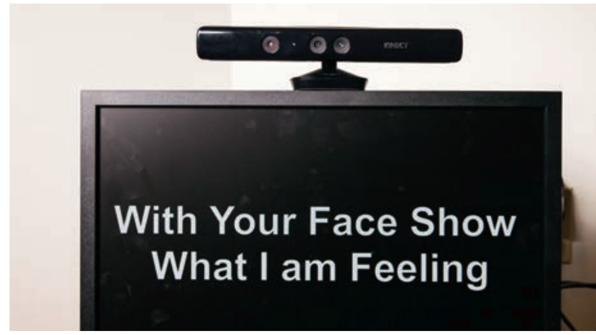
There are four levels to the Facial Expression Emotion Training (FEET) system, which are based on a wireframe representation of the face as sensed by the Kinect. The training starts with a simple, entertaining 2-D cartoon character making a happy, angry, frightened, or neutral face. The researchers ask the child to mimic the cartoon's expression, while the Kinect records them. The system "reads" the child's expression, and tells them if they are making the right face. Level two is an animated avatar exhibiting one of the four selected emotions, and level three contains video clips of a human actor. In all scenarios, the child tries to mimic the expression seen on the screen and receives feedback. While the first three levels are increasingly realistic faces, level four presents an emotionally charged situation and prompts the child to react. For instance, a picture of a birthday cake should elicit a smile, and a broken toy might call for a sad face.

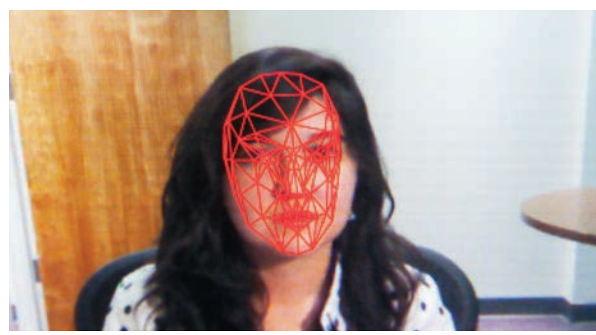
To determine if the child's expression is emotionally appropriate, Abbott and his team must first teach the computer what expressions are correlated to which emotions—a smile usually means happiness, a frown usually means anger, and so forth. To do this, they use "human coding", which means that their colleagues manually identify emotions for use in a large database of facial expressions. The results are fed into machine learning algorithms.

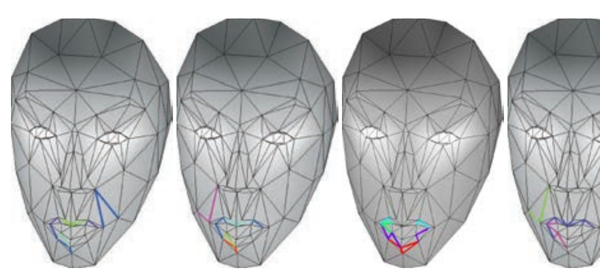
"We have spent a lot of time thinking about what parts of the face change when you display different emotions," said Abbott. "Sherin [Aly]'s dissertation focuses on the methods to decide which changes in the face are significant."

Aly applied support vector machines, a standard machine learning technique, and extracted three different types of geometric features within the wireframe that would indicate the emotion on a face—triangular surface area, distance between points, and angle measurement.

Before the study began, Aly conducted training sessions with more than 30 participants, who made facial expressions for the Kinect. The 3-D wireframe representations of their faces now populate one of the largest publically available datasets for Kinect facial expressions. ece







THE FACIAL EXPRESSION EMOTION TRAINING SYSTEM asks children to make the same expression as a face on the screen. A Microsoft Kinect takes video of the children and reads their facial expressions, giving them feedback on whether or not their expression matches the emotion on the screen. There are four levels, where the child sees anything from a cartoon to a video of a real person.

HUMOR *101*

A Virginia Tech research team tackles the algorithm of humor

ARE YOU SAD BECAUSE NO ONE laughs at your jokes? Take heart. The day is coming when a robot will! Or, then again, maybe it won't—even the computer thinks you're corny.

Members of a Virginia Tech research team are harbingers of this humor apocalypse. Arjun Chandrasekaran, a Ph.D. student in computer engineering, and Ashwin Kalyan, a visiting student from the National Institute of Technology Karnataka in India who will be starting as a Ph.D. student in fall 2016, are the lead authors on a paper entitled "We are humor beings: Understanding and predicting visual humor," which has gotten press in magazines like the MIT Technology Review and Newsweek.

The project investigates how a computer could learn to recognize and replicate humor in visual scenes. This is a collaboration between ECE's Computer Vision Lab and the Machine Learning and Perception Group, led by assistant professors Devi Parikh and Dhruv Batra, respectively. Parikh and Batra are co-authors of this study, along with Mohit Bansal from Toyota Technological Institute, and Larry Zitnick from Facebook AI Research.

COMPUTERS BEING TRAINED for humor quickly learned that humans and animals tended to make scenes humorous, so the computer usually chose to replace those types of objects when trying to make a scene less funny.

"Humor is such an important part of the human experience," said Parikh. "But, surprisingly, we still don't have a grasp on why one scene is funny while another is not —especially when it comes to visual humor."

Equipping a machine with a sense of humor may be a long way off, but the collaboration is approaching this task by presenting the computer with examples of scenes. They are accumulating a database of images that run the gamut from mundane to hilarious.

The team employs workers from Amazon Mechanical Turk, an online marketplace for work, to create their own funny scenes from clip art and include a short description of why they think the scenes are funny.

The team calibrated the database by asking workers to rate the funniness of each scene and found that, for the most part, everyone agreed on which images were actually funny. They also found that an unfunny scene could take on a comedic edge when the objects were switched around—substituting a raccoon for a man, for instance, or a piece of cheese for a cat.

To train an algorithm to spot the difference between funny and unfunny images, the team gave the machine two tasks: judge the funniness of a scene, and then alter the funniness of a scene by replacing an object within it.

The machine's algorithm beat the baseline, which means the computer had a general notion of what was supposed to be funny—certainly better than a random guess.

The model learned that, in general, animate objects like humans and animals are more likely to be sources of humor than inanimate objects, and therefore tended to replace these objects, the team reported. ece

Parikh wins NSF CAREER Award

for Visual Question Answering research

ECE ASSISTANT PROFESSOR Devi Parikh has earned a National Science Foundation (NSF) Faculty Early Career Development (CAREER) Award for her Visual Question Answering (VQA) research, a method of using images to teach a computer to respond to any question that might be asked. The techniques developed in this project have the potential to fundamentally improve the quality of life for the estimated 7 million adults with visual impairments in the United States.

VQA provides a new model through which humans can interface with visual data, and can lend itself to applications like software that allows blind users to get quick answers to questions about their surroundings.

Parikh's career goal is to enable machines to understand content in images and communicate this understanding as effectively as humans. The CAREER grant, which is the NSF's most prestigious award and is given to junior faculty members who are expected to become academic leaders in their fields, will bring her one step closer.

Parikh and her team are building a deep, rich database that will mold a machine's ability to respond accurately and naturally to visual images. Given an image and a question about the image, the machine's task is to automatically produce an answer that is not only correct but also concise, free form, and easily understood.

"To answer the questions accompanying the images, the computer needs an understanding of vision, language, and complex reasoning," said Parikh.

For an image of a road and the question "Is it safe to cross the street?" the machine must judge the state of the road the way a pedestrian would, and answer "no" or "yes" depending on traffic, weather, and the time of day. Or, when presented with an image of a baby gleefully brandishing a pair of scissors, the machine must identify the baby, understand what it means to be holding something, and have the common sense to know that babies shouldn't play with sharp objects.

The computer must learn these lessons one question–answer pair at a time; a lengthy, painstaking, and detailed process. With help from Amazon Mechanical Turk, an online marketplace for work, Parikh and her team will use this award to continue collecting a large dataset of images, questions, and answers, which will teach the computer how to understand a visual scene. The publicly available dataset contains more than 250,000 images, 750,000 questions (three for each image), and about 10 million answers.

> "Answering any possible question about an image is one of the holy grails of semantic scene understanding."

"Answering any possible question about an image is one of the holy grails of semantic scene understanding," said Parikh. "VQA poses a rich set of challenges, many of which are key to automatic image understanding, and artificial intelligence in general."

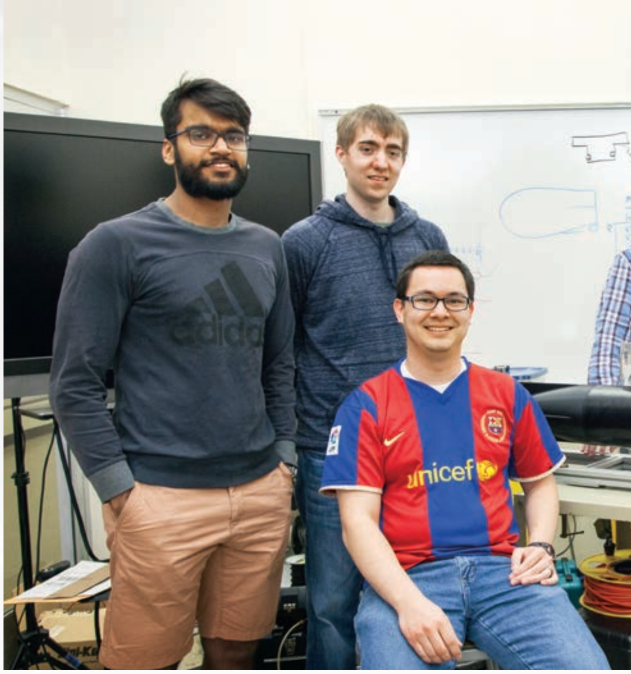
Teaching computers to understand images is a complex undertaking, especially if the goal is to enable the computer to provide a natural-language answer to a specific question. VQA is directly applicable to many situations where humans and machines must collaborate to understand pictures and images. Examples include assisting people with visual impairments in real-world situations ("What temperature is this oven set to?"), aiding security and surveillance analysts ("What kind of car did the suspect drive away in?"), and interacting with a robot ("Is my laptop in the bedroom?").

DEVI PARIKH

The NSF award also includes an education component, and Parikh considers VQA a gateway subject into the field as a whole. Like science fiction, VQA captures the imagination of both technical and non-technical audiences, said Parikh.

"This work can serve as a gentle springboard to computer vision and artificial intelligence in general," said Parikh, who has committed to improving the computer vision curriculum at Virginia Tech by introducing an emphasis on presentation and writing skills in her new Advanced Computer Vision course.

Parikh, who earned her Ph.D. at Carnegie Mellon University, has been with Virginia Tech since January 2013. She has been selected as a 2016 Alfred P. Sloan Research Fellow and received a 2016 Navy Young Investigator Grant. ece



RESEARCHERS in the Autonomous Systems and Controls Laboratory, including Abhilash Chowdhary, Stephen Krauss, and Scott Gibson, are developing underwater robots for search missions.

EYES UNDERWATER

WHETHER A TASK USES OUR HUMAN senses or robotic ones, resources are always limited. When the task is at the bottom of the ocean, resources are even more limited. ECE Professor Dan Stilwell and his team are addressing fundamental questions in search theory that are leading to new ways to deploy perception resources. With collaborators from aerospace and ocean engineering, including Professor Wayne Neu, they are developing new classes of autonomous underwater vehicles (AUVs) that will eventually be used for efficient subsea search.

Eventually, their research will lead to teams of robots that will be able to autonomously carry out a search mission in unknown waters. According to Stilwell, the robots might be looking for natural resources, airplane parts, or even underwater mine fields.

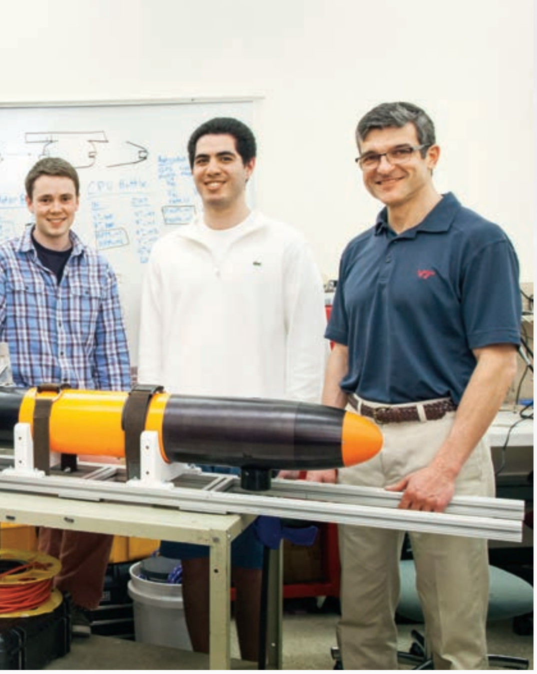
"At this stage it's a math problem," says Stilwell. "We assume that perception sensors are error prone, and that we cannot search exhaustively," he continues, "so we need the autonomous vehicles to make the best decisions possible about where to search, and they need to make these decisions without human intervention." To make the problem more challenging, the number of items to be discovered is unknown, so it's hard to determine when the search is complete.

These search robots will need to communicate with each other, which is particularly challenging underwater. The team has integrated acoustic communication systems into the robots which allows them to communicate by sound. Navigation, which is the process of determining location, is also difficult for an underwater robot. "When a vehicle goes underwater, you don't have GPS, so you need to find other methods," explains Rami Jabari, a masters student in electrical engineering. The team's navigation solution uses measurements from a variety of sensors that can be available at different times during a mission. Sensors that aid navigation include inertial sensors that measure the robot's acceleration and angular velocity, a Doppler velocity log that measures the speed of the AUV from the Doppler shift of sound after it bounces off the seafloor, and an acoustic range-tracking system that use acoustic signals to measure the range to beacons placed on the seafloor or on nearby boats. The team is also developing ways to incorporate measurements of the underwater terrain to aid navigation.

Although the underwater robots can communicate with each other and with a human operator, subsea communication is very unreliable, and the team must develop autonomy algorithms that assume no communication with a human operator. "When we turn our systems on, they disappear on purpose. Our sense of risk tolerance is lower than other laboratories," Stilwell says. Underwater robots must function in a very harsh environment, he adds. This impacts communication, propulsion, and control.

Not only do the search robots face communications limitations, but they also have severe energy limitations, according to Jack Webster, an aerospace and ocean engineering Ph.D. student in the lab. Underwater robots are powered by batteries, which must be placed in watertight housings designed to withstand the immense pressure of the ocean. This limits the space that can be devoted to batteries, and it makes energy efficiency a critical design goal, especially for propulsion.

PART OF THE CHALLENGE of working with underwater robots is creating systems that can withstand such a harsh environment, like their current prototype vehicle pictured here.



To address the challenge of efficient propulsion, Webster is investigating small propellers that operate at low speeds—speeds that have not previously been studied as thoroughly as the faster and larger propellers used in airplanes and ships. "I'm working on developing a computational fluid dynamics model of the propulsion system," says Webster. "We need to incorporate turbulence and similar effects, but small and slow propellers have been mostly ignored by researchers in the past, and there is significant uncertainty about what sort of model should work well for our application."

For the control system, electrical engineering doctoral student Scott Gibson is developing improved dynamical models of underwater robots and improved processes for acquiring them. Better dynamic models are needed to support the development of high-performance control systems, and Scott also hopes to significantly reduce the time and resources needed to develop a high-quality model. "The biggest challenge," according to Gibson, "is gathering data from vehicle maneuvers that unambiguously display the dynamics we are trying to identify. In the end, we hope to have new fundamental results on dynamical models for underwater vehicles, but also practical results on how to acquire and use the models."

Although much of this work is still at a fundamental level, the technology is progressing quickly, according to Stilwell, who expects some aspects of the technology to be ready for commercial deployment in a couple years. "We're close," he notes. ece

BOTS'-EYE VIEW

A GROUND-BASED ROBOT exploring a room can survey a floor plan and crawl under a table, but it won't be able to see off the roof. By working with an aerial robot, however, the two can collaborate to form a complete map of the area.

"Designing machines that can autonomously explore the environment and coordinate with other, possibly heterogeneous, robots is a notoriously hard problem in robotics," said ECE Assistant Professor Pratap Tokekar.

Heterogeneous systems like these, he explained, force the robots to make decisions about what kind of robot to send to explore which areas, and how much information they need to exchange.

The NSF's Computer and Information Science and Engineering Research Initiation Initiative recently awarded Tokekar a grant to explore this topic, specifically the coordination of different robotic sensors as they attempt to collectively observe an environment.

> "The robot needs to be able to look at the sensor data, run tools, take measurements, and view the world the way a human would."

One of Tokekar's current projects is a collaboration with researchers in plant pathology. He plans to use teams of both aerial robots and robotic boats to examine environmental hazards in water. The aerial robots will look down from above, observing patterns and mapping the contaminated area. The ro-

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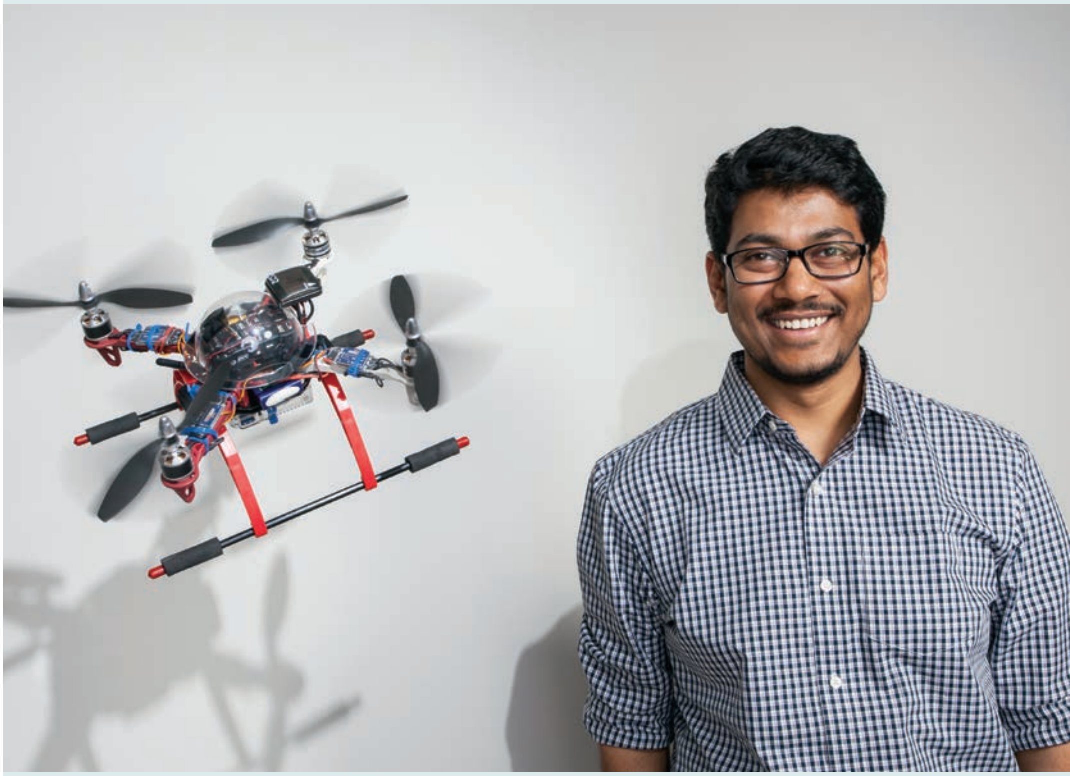
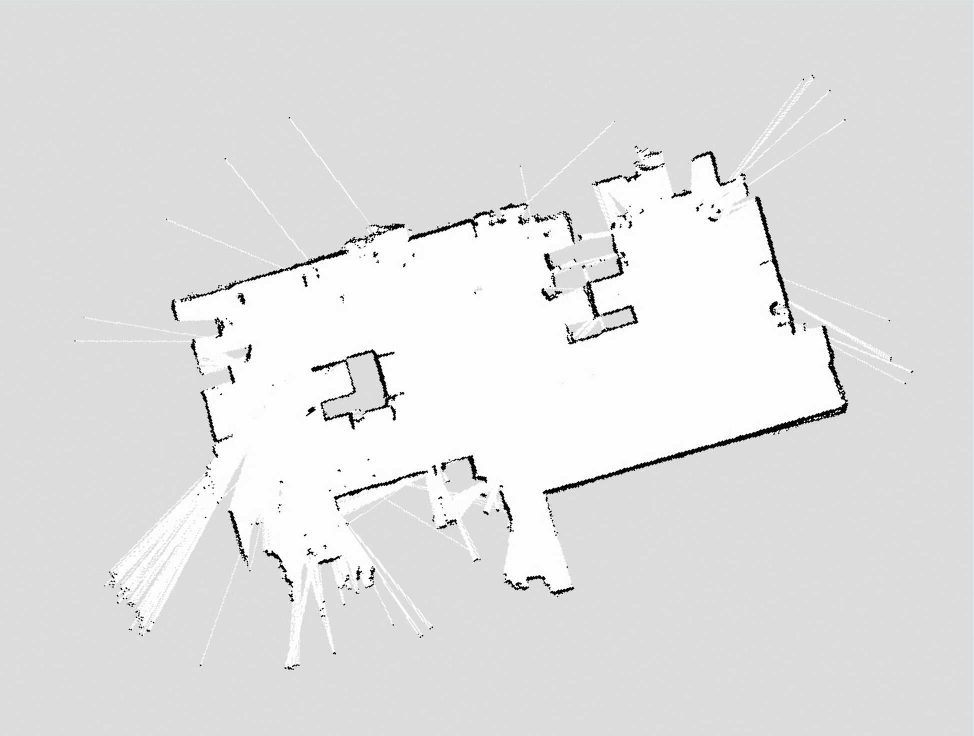


PRATAP TOKEKAR'S RESEARCH explores how heterogenous teams of robots—aerial, ground-based, and water-based—can sense their surroundings and autonomously decide what kind of robot should be deployed where.



ARAVIND PREMKUMAR (MSCPE '17) and **ASHISH BUDHIRAJA** (MSCPE '17) work in Tokekar's Robotics Algorithms & Autonomous Systems (RAAS) Lab.

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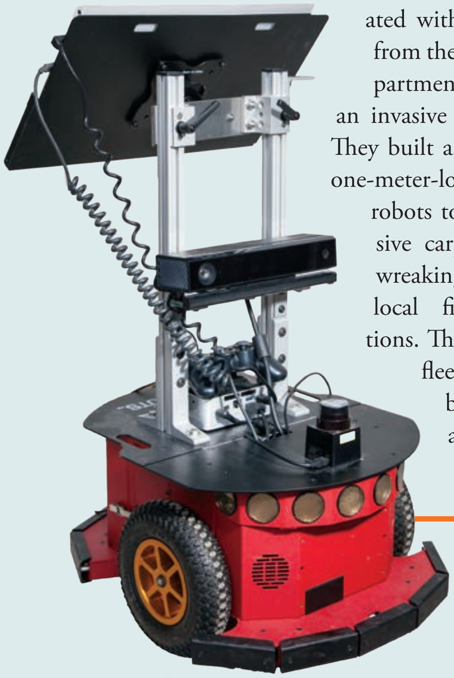
botic boats will then collect samples from areas specified by the aerial robots. "This could be used for applications like monitoring an oil spill," explained Tokekar.

This project builds on Tokekar's work as a Ph.D. student at the University of Minnesota, where he cooperated with researchers from the fisheries department to address an invasive fish species. They built and deployed one-meter-long aqueous robots to track invasive carp that were wreaking havoc on local fish populations. The automated fleet of robotic boats tracked and modeled the motion of the fish, and the data they collected will be incorporated into subsequent measures to curb the invaders.



Tokekar has also been researching how robots could be used in precision agriculture. He's been developing robots that regularly collect data on farms. They measure nitrogen content in the soil, map areas for targeted irrigation, and estimate annual harvests to assess the state of a farm.

For a robot to be able to autonomously decide how to behave in situations like these, it needs to make sense of a lot of information from multiple sources, explained Tokekar. Meeting this challenge requires knowledge from many disciplines, including mechanical engineering, electrical and computer engineering, and computer science. "If you can bring in tools and techniques from more than one area, the impact will be so much better," he said. "There is a strong interplay between machine learning, control systems, and robotics."

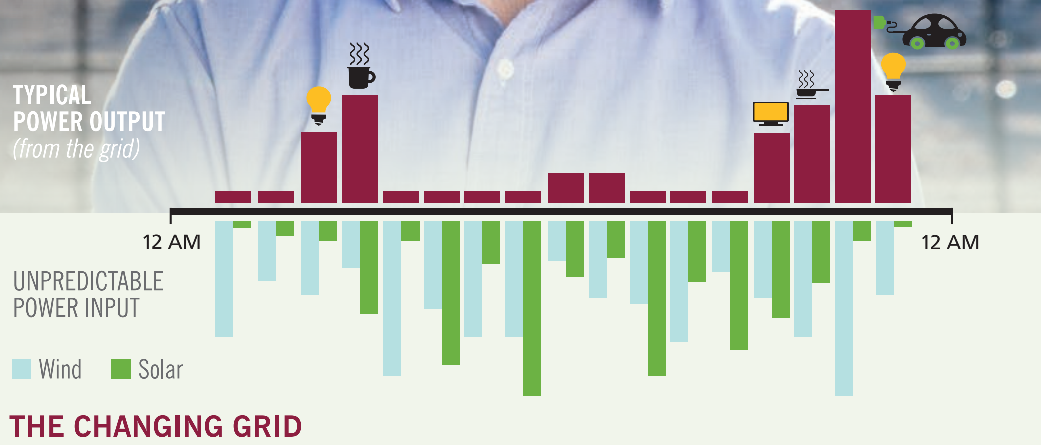
Currently, Tokekar is working with many techniques from combinatorial optimization, controls, and machine learning. "The robot needs to be able to look at the sensor data, analyze data, take measurements, and view the world the way a human would. This calls for machine-learning algorithms and incorporating computer vision," said Tokekar. "Of course, sometimes its just pure geometry."

One of Tokekar's challenges is balancing his efforts between fundamental research and practical applications. "We have to spend a lot of time getting the robots to work in the environments and conditions we want them to," Tokekar explained, "but since we're working on research, we need to make progress on the overall system. We have to step back and analyze the system in an abstract sense and come up with results that will work independent of the system." Finding the balance between these competing forces, he said, is a difficult task. ece

THE MAP OF THE LAB (above) was created using the ground-based robot (left) equipped with a laser range finder.

“We want our power system to be more green, more efficient...and to offer more participation for consumers to give back to the grid.”

MAKING THE GRID RESPOND



THE POWER GRID ON WHICH OUR society depends is a tangled network of interconnections that moves energy across continents. Aging infrastructure, a rise in domestic electricity consumption, and a trend toward incorporating more renewable energy has researchers seeking ways to modernize power systems.

ECE Assistant Professor Vassilis Kekatos studies how to smoothly integrate renewable sources and electric vehicles in a way that brings about a more reliable and efficient energy system. The integration of technologies and data processing to advance our power systems is often referred to as the smart grid, said Kekatos.

“We want our power system to be more green, more efficient, more robust, and to offer more participation for consumers to give back to the grid,” said Kekatos. “The grid needs to be more controllable and we need better situational awareness of it.”

By designing and employing optimization, real-time techniques, stochastic modeling, and tools from machine learning, Kekatos is seeking to model and predict the changing grid.

Kekatos likens the smart grid to a continent-wide electric circuit. Input from wind and solar introduces uncertainties into grid operation. In an effort to rapidly monitor grid conditions, Kekatos and his team have developed decentralized algorithms for processing measurements from synchrophasors—devices that measure the electrical waves on the grid, which were invented by members of the Energy Systems Group at Virginia Tech—or information collected from smart meters to deduce the state of the grid.

Kekatos is experimenting with control systems to accomplish specific tasks. For instance, controlling different parameters allows your neighbor’s rooftop solar panel to produce energy at a set voltage and pump it back into the grid. But when the sunny day clouds over, there’s a large fluctuation in a matter of minutes or seconds, and this affects voltages for the rest of the neighborhood, and the power grid as a whole. Kekatos is looking for a way to correct the fluctuation and bring it back to a set level, thereby minimizing instability within the grid. He is currently researching a coordinated effort exploiting the power inverters that are already built into solar panels.

UNPREDICTABLE INPUT from solar and wind due to changing weather patterns can cause instability throughout the grid. Kekatos aims to stabilize and streamline our power systems.

“Tools from machine learning and big data inform the shape of our future energy systems,” said Kekatos. There are different variables that influence the power grid, including geographically specific prices in electricity markets, wind speeds, and weather patterns. Tools currently under development will exploit the patterns present in the data generated in transmission and distribution networks to respond in real-time to consumer behavior.

“Two decades ago, the Internet was realized by algorithms and TCP/IP protocols that control different layers of communications,” said Kekatos. “We are trying to bring that knowledge to power grids.” ece

DISCERNING WITH **DUST**

ARTIFICIAL DUST CLOUDS, like the one pictured here from Scales' Charged Aerosol Release Experiment in 2009, can help researchers understand how the atmosphere reacts to disturbances.

AS HUMANS, WE CONSTANTLY SENSE our environment, and make decisions based on what we notice. We taste something bitter and stop eating it. We smell pungency and move away from it. We hear thunder and get out of a swimming pool. We feel a strong wind and work to protect crops and houses. We see a tornado and take cover. But there is weather the human body cannot sense, and ECE's Wayne Scales is helping us to understand how it impacts our world and our technology.

Space weather can follow similar patterns to the weather on the earth's surface, but is too distant to observe without specialized equipment. However, it can affect our environment and disrupt our technology, particularly communications devices, such as GPS satellites. Scales and his team are working to understand why by studying the microphysics of the space environment.

To better understand processes in our environment, researchers actually stimulate the upper atmosphere by generating waves and turbulence either from the ground, by using high power radio waves, or by releasing chemicals, aerosols, dust, or charged particles from spacecraft. They then observe and measure how the environment reacts.

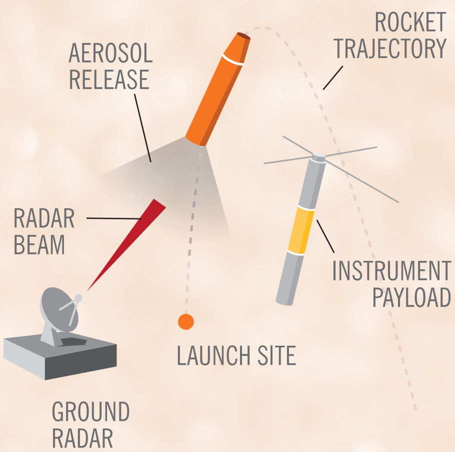
Their ground-based experiments use the High Frequency Active Auroral Research Program (HAARP) facility in Alaska. "It's the most powerful ground-based transmitter of its type in the world," explains Scales, and "it can produce 3 billion Watts of effective radiated power." He also performs experiments at the European Incoherent Scatter Radar (EISCAT) facility near Tromsø, Norway, another premiere active space experiment facility.

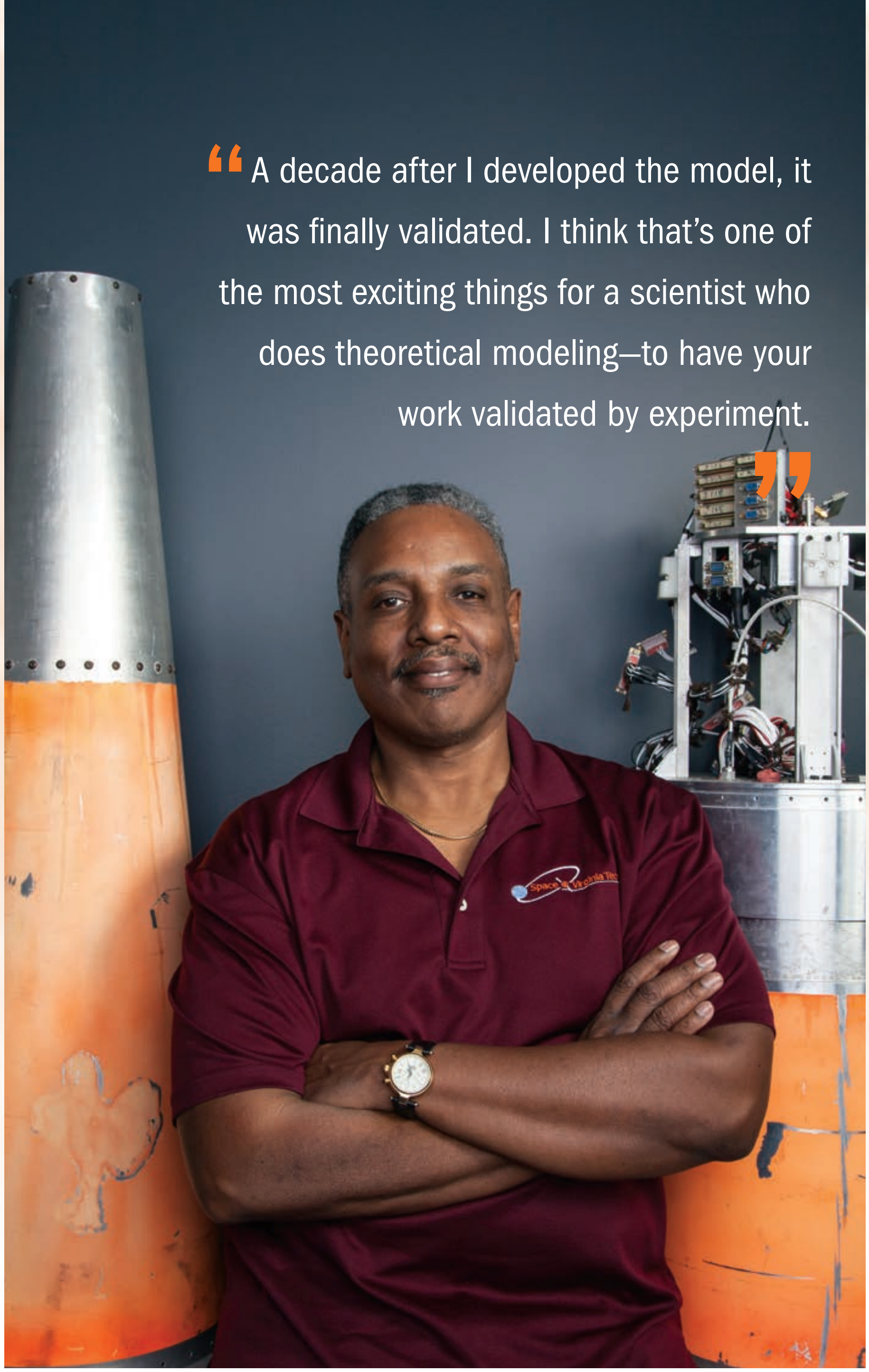
One of Scales' active experiments is to heat the natural dust layer that surrounds the earth. This dust layer is caused by meteor ablations, or the soot released when meteors burn up in the atmosphere, explains Scales. "The visual manifestation of this is noctilucent clouds," he continues, which are also called polar-mesospheric clouds when they are observed in space. "Scientists think these might be related to climate change." These clouds were first observed in the 1880s, and their frequency has been increasing since

MICHAEL KLEIMAN, US AIR FORCE

TOM GRYDELAND

SCALES USES the High Frequency Active Auroral Research Program facility in Alaska (left) and the European Incoherent Scatter Radar facility near Tromsø, Norway (right) to conduct some of his active experiments.





RIGHT: Wayne Scales is studying atmospheric dust, which can also be created by sounding rockets like this one.

then, possibly linked to human activity, according to Scales.

Using high-powered radio waves, researchers can heat these clouds and study the response of the associated turbulence using radar echoes. Scales has developed a model that can use these measurements to determine the size of the dust particles, their charge state, and their location. “We look at how the clouds evolve, how the dust particles are formed, how they grow, and the sedimentation of the particles. Once that’s understood, we can look at a global picture and see if this is related to global climate change,” he explains. “Active experiments [like these] give us initial conditions to more effectively study the physics and chemistry of the space environment,” says Scales, which provide a better understanding of its impact on critical technologies.

“Ten years ago, [this model] was just theoretical,” Scales notes. When he was developing the model, the results seemed unphysical, according to Scales. “I tried to step back and look at it from a fundamental physics standpoint, but it took me a while to justify it.” He was eventually able to prove that the results were based on the physics, and were not just an artifact of the model. “A decade after I developed the model, it was finally validated. I think that’s one of the most exciting things for a scientist who does theoretical modeling—to have your work validated by experiment.”

“As humans, we always have to assess our surroundings, and the space environment is part of our surrounding environment,” says Scales. Whether the effect of turbulence in space is harming our communications or actually a precursor of global change, he and his fellow researchers are helping us understand exotic natural phenomena that have significant impact on our daily lives. ece

> “This was a very challenging project, to deploy sophisticated instrumentation in such remote locations.”

ANTARCTIC FROST *AND* SPACE WEATHER

Virginia Tech instrument stations in Antarctica provide new evidence about space weather

ALMOST AS SOON AS VIRGINIA Tech researchers finished installing six data collection stations near the South Pole in January, their data provided new evidence regarding a controversial scientific phenomenon about Earth’s magnetic field and space weather.

ROBERT CLAUER

Space weather is driven by solar wind—an unbroken, highly variable, supersonic flow of charged particles exploded from the sun. When solar wind beats against the magnetic field surrounding the planet, it can create beautiful auroras, as well as electromagnetic impulses that can negatively affect navigation systems, telecommunications, and power grids.

“The solar wind interacts with Earth’s magnetic field in a manner similar to a fluid, but an electrically conducting fluid,” described Robert Clauer, a professor of electrical and computer engineering (ECE) at Virginia Tech, who heads the Magnetospheric Ionospheric Science Team.

His team has been monitoring the electric current systems in the magnetosphere—specifically currents that connect to the ionosphere. This region in the upper atmosphere is ionized—stripped of electrons—by solar radiation. When it’s summer in the Northern Hemisphere, there is more direct sunlight on the atmosphere, which means more atoms are ionized. This phenomenon creates a highly conductive environment in the summer months, and a poorly conductive one in the winter.

A chain of stations in Greenland allowed researchers to collect data in the Northern Hemisphere. Until recently, these data were divided into summer and winter, and the information gathered during the winter months was used to approximate what was happening in the Southern Hemisphere during the northern summer.

“We didn’t have a full picture of what was happening in the space environment because we could only observe one hemisphere, but magnetic field lines are connected to both hemispheres,” said Clauer. “It was important that we look at them simultaneously.”

So, armed with a $2.39 million grant from the National Science Foundation, Clauer and his team designed and hand-built six data collection stations, and installed them,

BELOW LEFT: Zhonghua Xu (left) and Mike Hartinger represent Virginia Tech in front of the solar panels at their camp in Antarctica.

BELOW RIGHT: Zhonghua Xu (left), Mike Hartinger, and Taikara Peek share a meal in the Endurance tent.

RIGHT: Mike Hartinger snaps a South Pole selfie in front of the Twin Otter Aircraft before flying out to deliver science cargo to a data collection site.

piece by piece, at the South Pole, initially for testing. Over an eight-year period, they placed them along the 40-degree magnetic meridian (longitude), deep in the polar cap areas under the auroras. These new stations — in the harsh environment of the remote east Antarctic plateau — are the southern counterparts to the Greenland chain.

"This was a very challenging project, to deploy sophisticated instrumentation in such remote locations," Clauer said.

The stations run autonomously and are powered by solar cells in the Antarctic summer and lead-acid batteries during winter. They contain a collection of instruments, including a dual-frequency GPS receiver that tracks signal changes produced by density irregularities in the ionosphere, and two kinds of magnetometers that measure the varying strength and direction of magnetic fields. The data is transmitted to Blacksburg, Virginia, via iridium satellites.

In January, the team completed installing the final station in the chain. Now, data from the complete chain in the Southern Hemisphere joins with data from the Northern Hemisphere. For the first time, observations confirmed that regardless of the hemisphere or the season, waves on the boundary of the magnetosphere produced by solar wind pressure changes are linked to both the northern and southern ionospheres by electric currents of the same magnitude.

"It's a bit of a surprise, because when you have a current, you usually expect a voltage relationship, where resistance and current are inversely related: high resistance equals small current; low resistance equals large current," said Clauer.

Instead, Clauer's team observed that the ionosphere—southern, northern, winter, summer—is subject to a constant current.

"This finding is a new part of the physics that we need to understand and work with," said Clauer.

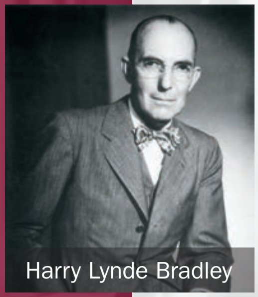
Clauer's team will continue collecting information from both sets of data stations. They hope to be operational throughout the 11-year solar activity cycle, depending on snow accumulation. They will be watching how the behavior of the sun and the solar wind changes over time, and how the earth's magnetic field responds to variations—all with the goal of building a detailed, reliable model of space weather.

Clauer hopes that reliable space weather forecasting will become as important for telecommunications, navigation, and power systems as today's winter storm warnings are for school systems.

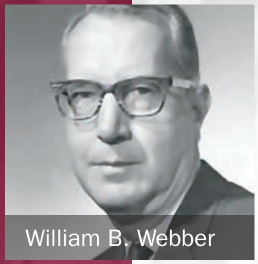
Virginia Tech team members include Michael Hartinger, research assistant professor of ECE; Zhonghua Xu, research scientist; Kshitija Deshpande (Ph.D. '14), postdoctoral associate; Dan Weimer, research professor of ECE; and graduate student Taikara Peek. Previous participants include Rick Wilder (Ph.D. '11), Lyndell Hockersmith, and Joseph Macon (MEng '13). ece

2015 | 2016

BRADLEY & WEBBER HONORS



Harry Lynde Bradley



William B. Webber

IN SPRING 1987, the late Mrs. Marion Bradley Via established a generous endowment for the enhancement of the Department of Electrical Engineering. This endowment was in honor of Mrs. Via's late father, Harry Lynde Bradley, who was a pioneer in the electric motor control industry and cofounder of the Allen-Bradley Company of Milwaukee, which is now part of Rockwell Automation.

In recognition of this endowment, the department is called The Bradley Department of Electrical and Computer Engineering. Income from the endowment funds undergraduate scholarships, graduate and postdoctoral fellowships, and professorships in the continuing effort to improve the quality of our ECE programs. These fellowships and scholarships are among the most competitive in the country.

IN 1994, 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 electrical or computer engineering.

SCHOLARS

CHRISTOPHER GOODKIND

BSEE '19, *Virginia Tech*

POTOMAC, MARYLAND

MEMORABLE MOMENT AT VIRGINIA TECH

Engineering Expo — I was extremely nervous and unaware of what to expect. I walked up to GE's booth and was critiqued for 15 minutes solely on my resume. Although very intimidating, it was a great learning experience.

HONORS & ACTIVITIES

Delta Sigma Phi, Executive Board
IEEE
Blacksburg Youth Recreational Basketball Coach

ELIZABETH HUTZ

BSCE '18, *Virginia Tech*

CHAGRIN FALLS, OHIO

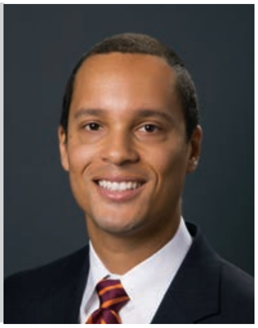
INTERNSHIP

Rockwell Automation, summer 2015 — I programmed PLC's using Ladder Logic to simulate a conveyor belt system, as well as execute motion control tasks. I also worked on a cost reduction team project to analyze a solar tracking system.

HONORS & ACTIVITIES

Dean's List all semesters
Society of Women in Engineering (SWE)

FELLOWS

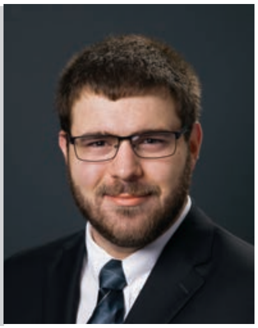


NOAH ALLEN

BSEE ’09, *Georgia Institute of Technology*; MSEE ’14, *Virginia Tech*
ADVISOR: Lou Guido

RESEARCH

Allen is working to further our understanding of conduction loss and breakdown mechanisms in Gallium Nitride transistors so that current designs can be improved to meet the needs of the high-power conversion market.



ANTHONY CARNO

BSCE ’15, *Bucknell University*
ADVISOR: Binoy Ravindran

RESEARCH

As part of the Popcorn Linux project, Carno is investigating dynamic binary translation as a means of enabling thread migration to occur between processors with different instruction set architectures at any time. Carno has constructed a prototype implementation to measure the costs of performing the migration.

RYAN CHAN

BSCPE ’15, Binghamton University - SUNY
ADVISOR: Masoud Agah

RESEARCH

Chan is working on redesigning and developing new technologies for monolithically integrating the functionality of a full scale gas chromatograph into a much smaller form.

MICHAEL COGSWELL

BSCS ’13, Virginia Tech
ADVISOR: Dhruv Batra

RESEARCH

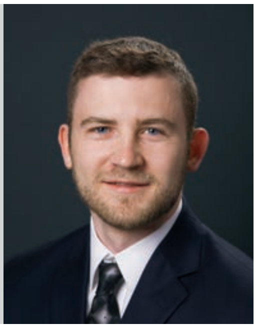
Cogswell is researching computer vision applications of deep learning, a subfield of machine learning that focuses on neural networks. He is specifically working on understanding neural networks in new ways and improving them by adding prior information from novel sources.

PAUL URI DAVID

BSEE '13, *Clemson University*
ADVISOR: Allen MacKenzie

RESEARCH

David is currently interning with Ettus Research in Santa Clara, California. When he returns, his research will focus on wireless communications and software-defined radios.



JACQUES DELPORT

BSEE '13, MSEE '14, *Virginia Tech*
ADVISOR: Virgilio Centeno

RESEARCH

Delport is investigating the use of intentional and controlled power system separation to help mitigate the effects of a cascading failure event on the power system. This work aims to increase the adaptability of the grid to improve its resiliency against blackouts.

KRISTEN HINES

BSECE '13, *Tennessee Tech University;* MSCPE '16, *Virginia Tech*
ADVISOR: Tom Martin

RESEARCH

Hines is researching wearable computing with a focus on Human-Centered Design with the E-Textiles Lab at VT. She is adapting fabric stretch sensors to an ambulatory monitoring suit and developing a construction safety vest for collision avoidance purposes.

CHRIS JELESNIANSKI

BSECE '13, *Rutgers University;* MSCPE '15 *Virginia Tech*
ADVISOR: Binoy Ravindran

RESEARCH

Jelesnianski is working on Virginia Tech's Popcorn Linux project, which aims to provide a system that runs on heterogeneous hardware and develop programs for that system. He is developing compiler support and automatically partitioning programs so that each part will run on the optimal type of hardware.

MARKUS KUSANO

BSCPE '14, *Virginia Tech*
ADVISOR: Chao Wang

RESEARCH

Kusano studies the application and improvement of a broad range of program analysis techniques, including symbolic execution, stateless/bounded model checking, and abstract interpretation. His research focuses on fundamental tasks in software engineering and programming languages.

VIRGINIA LI

BSEE '13, *Virginia Tech*
ADVISOR: Qiang Li

RESEARCH

For DC-DC converters, variable frequency controls are widely used to improve light-load efficiency, increase transient response speed, and reduce the amount of output capacitors by utilizing high-bandwidth designs. Li is working on ways to improve the existing current-mode control schemes to achieve the fastest response possible—a single-cycle load-transient response.

TAYLOR McGOUGH

BSCPE '14, *Virginia Tech*
ADVISOR: Patrick Schaumont

RESEARCH

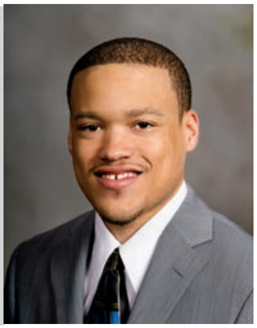
McGough is analyzing lightweight cryptographic ciphers as they apply to embedded and constrained environments. His research on optimization techniques include pre-computation of cipher elements, design for energy harvesting devices, and dynamic bit-sliced implementations.

CHRISTOPHER O'LONE

BSEE '12, MSEE '13, *Lehigh University*
ADVISOR: R. Michael Buehrer

RESEARCH

O'Lone's research applies the fields of estimation theory, convex optimization, and stochastic geometry towards localization in wireless networks. He is investigating how localization performance is affected by the unpredictable geometry of modern wireless networks.



TIMOTHY PIERCE, JR.

BSEE '13, *Hampton University*
ADVISOR: Alfred Wicks (ME)

RESEARCH

Pierce is working on techniques to fuse hybrid technologies with renewable energy sources such as solar and wind to produce a mobile power system capable of efficiently integrating them. Pierce's research focuses on the control algorithms that combine these multiple sources into a useful output.

ELLEN ROBERTSON

BSEE '14, *Virginia Tech*
ADVISOR: Gregory Earle

RESEARCH

Robertson is developing and testing instruments for CubeSats. She will also be involved in further development and testing of an instrument (SNeuPI) that will be used to detect and measure gravity waves in the ionosphere.

IAN ROESSLE

BSCS '08, *California State University-Los Angeles;* MSCS '13, *The Johns Hopkins University*
ADVISOR: Binoy Ravindran

RESEARCH

Roessle is developing tools to convert low level C code into a logical representation usable by theorem-proving tools when coupled with a performance specification. Roessle's research isn't probabilistic in nature and takes into account undefined or weakly defined portions of the C programming language.

JASON ZIGLAR

BSEE/Biomedical Engineering '05, *Duke University;* M.S. Robotics '07, *Carnegie Mellon University*
ADVISOR: Alfred Wicks (ME)

RESEARCH

Ziglar was the software lead for two projects in the Terrestrial Robotics Engineering and Controls (TREC) Lab. He is investigating perception systems that can handle uncertain and challenging environments by understanding the world around them and communicating with a remote human operator.

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(MSEE '04)

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(BSCPE '01)

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The following Fellows are completing their graduate degrees at Virginia Tech:

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STUDENT AWARDS

PROFESSOR Peter Athanas (advisor), Ali Sohanghpurwala, and Ryan Marlow.

Ryan Marlow (MS '14) and **Ali Sohanghpurwala (Ph.D. '15)**, with postdoctoral research fellow Krzysztof Kepa, won the 2015 VT Knowledgeworks Tech Transfer Challenge for their startup, Rapid Design Assembly.

Yuanyuan Guo (Ph.D. '15) won the Best Poster Award at the 2015 Materials Research Society (MRS) Conference for her poster, "In-Vivo Label-Free Microscopy Device Based on Field Effect Sensor and Polymer Fibers for Deep Brain Imaging."

Lanhua Zhang (Ph.D. '16), **Xiaonan Zhao (MS '15, Ph.D. '18)**, and **Rachael Born (MS '16)** of the Future Energy Electronics Center took third place in Google's $1 Million Little Box Challenge, a contest to build small power inverters that could advance renewable energy.

Nahid Farhady Ghalaty (Ph.D. '16) received a Best-in-Session Award for her presentation at SRC TECHCON 2015 in Austin, Texas. Her presentation was titled, "FAME: Fault-Attack Awareness Using Microprocessor Enhancements."

Laya Mohammadi (Ph.D. '16) won second place in the Student Paper Competition at the 2015 IEEE International Microwave Symposium in Phoenix, Ariz. Her paper was titled "Integrated C-Band (4-8 GHz) Frequency Tunable & Bandwidth Tunable Active Band-Stop Filter in 0.13-μm SiGe BiCMOS."

Christina DiMarino (Ph.D. '17) is one of three Virginia Tech students to win the Rolls-Royce fellowship, which includes a $30,000 stipend, full tuition and fees, health insurance, and a $2,500 travel budget.

CHRISTINA DIMARINO and Professor Dushan Boroyevich in the Center for Power Electronics Systems laboratory.

Anibal Sanjab (Ph.D. '18) won the Best Student Paper Award at the IEEE International Conference on Smart Grid Communications for his paper "Smart Grid Data Injection Attacks: To Defend or Not?" which was coauthored by Walid Saad.

Ph.D. DEGREES AWARDED 2014 2015

Anderson, Matthew Eric
APECS: A Polychrony based End-to-End Embedded System Design and Code Synthesis
Committee Chair: Shukla, S.

Chern, Kevin Tsun-Jen
GaN/GaInN TCO Schottky Barrier Solar Cells
Committee Chair: Guido, L.J.

Deshpande, Kshitija Bharat
Investigation of High Latitude Ionospheric Irregularities utilizing Modeling and GPS Observations
Committee Chair: Clauer, C.R.

Elbayoumi, Mahmoud Atef Mahmoud Sayed
Strategies for Performance and Quality Improvement of Hardware Verification and Synthesis Algorithms
Committee Chair: Hsiao, M.

Eldib, Hassan Shoukry
Constraint Based Program Synthesis for Embedded Software
Committee Chair: Wang, C.

Elhenawy, Mohammed Mamdouh Zakaria
Applying Machine and Statistical Learning Techniques to Intelligent Transport Systems: Bottleneck Identification and Prediction, Dynamic Travel Time Prediction, Driver Run-Stop Behavior Modeling, and Autonomous Vehicle Control at Intersections
Committee Chair: Rakha, H.
ECE Committee Co-chair: Abbott, A.L.

Eltrass, Ahmed Said Hassan Ahmed
The Mid-Latitude Ionosphere: Modeling and Analysis of Plasma Wave Irregularities and the Potential Impact on GPS Signals
Committee Chair: Scales, W.A.

Forsyth, Jason Brinkley
Exploring Electronic Storyboards as Interdisciplinary Design Tools for Pervasive Computing
Committee Chair: Martin, T.L.

Ganta, Dinesh
An Effort toward Building more Secure and Efficient Physical Unclonable Functions
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Gao, Bo
Coexistence of Wireless Networks for Shared Spectrum Access
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Headley, William C.
Spectrum Sensing in the Presence of Channel and Tx/Rx Impairments
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Hopkins, Michael Anthony
Dynamic Locomotion and Whole-Body Control for Compliant Humanoids
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Ibraheem, Ali Ahmed Younis
Implanted Antennas and Intra-Body Propagation Channel for Wireless Body Area Network
Committee Chair: Manteghi, M.

Imana, Eyosias Yoseph
Cognitive RF Front-end Control
Committee Chair: Reed, J.H.

Jain, Nikhil
Heterogeneous Integration of III-V Multijunction Solar Cells on Si Substrate: Cell Design & Modeling, Epitaxial Growth & Fabrication
Committee Chair: Hudait, M.K.

Jaksic, Marko Dragoljub
Identification of Small-Signal dq Impedances of Power Electronics Converters via Single-Phase Wide-Bandwidth Injection
Committee Chair: Boroyevich, D.

Khalifa, Ahmed Abdelmonem Abuelfotooh Ali
Collaborative Mobile Clouds: Architecture and Management Platform
Committee Chair: Hou, Y.T.

Kim, Woochan
Development of Bi-Directional Module using Wafer-Bonded Chips
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LaBella, Thomas Matthew
A High-Efficiency Hybrid Resonant Microconverter for Photovoltaic Generation Systems
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La Pan, Matthew Jonathan
Security Issues for Modern Communications Systems: Fundamental Electronic Warfare Tactics for 4G Systems and Beyond
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Lerner, Lee Wilmoth
Trustworthy Embedded Computing for Cyber-Physical Control Systems
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Lin, Ying-Tsen
Solar Spectral Irradiance with Solar Aspect Monitor
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Liu, Pei-Hsin
Advanced Control Schemes for High-Bandwidth Multiphase Voltage Regulators
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Love, Andrew Ross
A Modular Flow for Rapid FPGA Design Implementation
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Lutz, Collin C.
Switched Markov Jump Linear Systems: Analysis and Control Synthesis
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Monir Vaghefi, Sayed Reza
Cooperative Positioning in Wireless Sensor Networks Using Semidefinite Programming
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Formal Techniques for Designing Safety Critical Embedded Systems from Polychronous Models
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Nezami Ranjbar, Mohammad Rasoul
Novel Preprocessing and Normalization Methods for Analysis of GC/LC-MS Data
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Omran, Shaimaa AbdAlla Ezz Ibrahim
Control Applications and Economic Evaluations of Distributed Series Reactors in Unbalanced Electrical Transmission Systems
Committee Chair: Broadwater, R.P.

Palreddy, Sandeep R.
Electromagnetic Band Gap Structure (EBG) Analysis, Increasing Bandwidth and Applications with Antennas
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Prabhu, Sarvesh Pradeep
Techniques for Enhancing Test and Diagnosis of Digital Circuits
Committee Chair: Hsiao, M.S.

Rashidi Mehrabadi, Niloofar
On Methodology for Verification, Validation and Uncertainty Quantification in Power Electronics Converters Modeling
Committee Chair: Burgos, R.

Rezaiesarlak, Reza
Detection, Identification and Localization of Chipless RFID Tags
Committee Chair: Manteghi, M.

Sanchez Ayala, Gerardo
Centralized Control of Power System Stabilizers
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Shakeel, Hamza
Microfluidic Columns with Nanotechnology-Enabled Stationary Phases for Gas Chromatography
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Srivastav, Meeta S.
Variation Aware Energy-Efficient Methodologies for Many-Core Homogeneous Design Systems
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Su, Yipeng
High Frequency, High Current 3D Integrated Point-of-Load Module
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Tian, Ye
Knowledge-Fused Identification of Condition-specific Rewiring of Dependencies in Biological Networks
Committee Chair: Wang, Y.

Turcu, Alexandru
On Improving Distributed Transactional Memory
Committee Chair: Ravindran, B.

Turner, Hamilton Allen
Optimizing, Testing, and Securing Mobile Cloud Computing Systems For Data Aggregation and Processing
Committee Chair: White, C.

Wang, Niya
Unsupervised Signal Deconvolution for Multiscale Characterization of Tissue Heterogeneity
Committee Chair: Wang, Y.

Wen, Bo
Stability Analysis of Three-Phase AC Power Systems Based on Measured D-Q Frame Impedances
Committee Chair: Boroyevich, D.

Zeng, Huacheng
On Interference Management for Wireless Networks
Committee Chair: Hou, Y.T.

Zheng, Cong
Loosely Coupled Transformer and Tuning Network Design for High-Efficiency Inductive Power Transfer Systems
Committee Chair: Lai, J.S.

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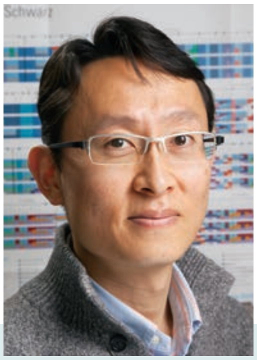

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