Big Solutions for Little Patients

Specialized medical devices and tablet-based apps are designed to help even the smallest of patients.
BLUE SUNFLOWER Nature's beauty isn't limited to what can be seen in everyday life. Researchers using clean room facilities at Georgia Tech's Institute for Electronics and Nanotechnology (IEN) are often impressed by what they see at the nanometer and micrometer scales. IEN senior research engineer Devin Brown provided the image of this structure, which was produced by accident while he was studying the pattern order exposure effects on silicon from the electronic resist material hydrogen silsesquioxane. "I find it interesting that these 'mistakes' in fabrication are often more beautiful than the intended patterns," he wrote. The overall diameter of the sunflower is just 575 microns; the outer droplets are about eight microns in diameter and decrease to about one micron toward the center. Photo by Devin Brown.
ZINC OXIDE SPHERE This structure, which resembles a soccer ball, was formed from merged zinc oxide nanowires. These piezoelectric structures are normally used in nanogenerators to recover wasted mechanical energy but grew together to form this sphere. Image provided by Jamey Gigliotti and Zhong Lin Wang.
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AFFECTING LIVES

GEORGIA TECH RESEARCH HELPS SICK CHILDREN, IMPROVES SECURITY, PREPARES STUDENTS

Georgia Tech research affects people’s lives, and this issue of Research Horizons magazine offers some excellent examples of the impact our faculty and students have each day.

Our cover story explores the many ways in which we’re helping improve the lives of sick children. Working closely with partners like Children’s Healthcare of Atlanta and Emory University, we’re developing new medical devices for children, creating new therapies to keep them healthy, and defining ways to use analytics and advanced computing to make health care smarter. We’re also looking to the future by educating the next generation of pediatric researchers, which helps fulfill Georgia Tech’s mission of improving the human condition.

Also in this issue, you will learn about Georgia Tech’s exciting work on keeping government, industry, and individuals safe from cyberattack. Across our campus, faculty and students are finding ways to mitigate today’s threats while preparing for what the future may hold.

Finally, you’ll get a peek inside some of the new corporate innovation centers that have recently opened on the Georgia Tech campus. A number of major corporations now have unparalleled access to everything Georgia Tech has to offer, which includes our highly talented students. In this article, the students explain how they are helping the companies meet their business goals and advance technology, all while gaining valuable real-world research experience.

Georgia Tech fuels an impressive innovation ecosystem that facilitates transformative opportunities, strengthens collaborative partnerships, and maximizes the economic and societal impact of the Institute’s research.

As you read this issue of Research Horizons magazine, you’ll see how we’re leveraging collaborative partnerships to create game-changing solutions to society’s most challenging problems.

As always, I welcome your feedback. Enjoy the magazine!

Steve Cross
Executive Vice President for Research
August 2015
Researchers have developed a cellular sensing platform that promises to expand the use of semiconductor technology in next-generation bioscience and biotechnology applications. Connected to cells or groups of cells, the sensor can monitor multiple physiological parameters to provide real-time characterization of a cell or tissue sample.

Based on a low-cost CMOS process, the technology could be used in the development of health care applications, including cost-effective pharmaceutical design, point-of-care devices, home-based medical diagnostics, and drug-screening systems. The research could also benefit defense-related sensing and environmental monitoring, providing low-cost, field-deployable sensors for hazard detection.

“Our research is intended to fundamentally revolutionize how biologists and bioengineers can interface with living cells and tissues and obtain useful information,” said Hua Wang, an assistant professor in the School of Electrical and Computer Engineering at Georgia Tech. “Fully understanding the physiological behaviors of living cells or tissues is a prerequisite to further advance the frontiers of bioscience and biotechnology.”

The research is part of the Semiconductor Synthetic Biology (SSB) program sponsored by the Semiconductor Research Corporation (SRC). — SEMICONDUCTOR RESEARCH CORPORATION

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**Face the Music**

Music may help some people relax when they’re trying to concentrate. But it doesn’t help them remember, especially as they get older. That’s the finding of a study that challenged adults to listen to music while trying to remember names. College-aged participants had no problems; the music didn’t affect their performance.

But the older adults remembered 10 percent fewer names when listening to background music as compared to silence.

The study tested effects on associative memory, which includes the ability to put a face with a name and remember it. Study participants looked at a series of faces and names and were asked if the person “looked like” the assigned name. The faces were shown again a few minutes later, when participants had to determine whether the name and face combinations were the same as before. Sometimes people did the test in silence. Other times they listened to non-lyrical rock music.

“Both age groups agreed that the music was distracting, but only the older adults struggled while it was playing in the background,” said Sarah Reaves, the Georgia Tech psychology graduate student who led the study.

“Older adults have trouble ignoring irrelevant noises and concentrating,” explained Audrey Duarte, Reaves’ advisor and an associate professor in the Georgia Tech School of Psychology. “Associative memory also declines with age. As we get older, it’s harder to remember what name went with a face or where a conversation took place.”

The research was published in *The Gerontologist Journal.* — JASON MADERER
THOMAS BOUGHER INVESTIGATES NEW WAYS TO TAKE THE HEAT OFF ELECTRONICS

Thomas Bougher is a doctoral student in Georgia Tech’s Woodruff School of Mechanical Engineering, studying how polymers can be engineered to transport heat. As an undergraduate and master’s student, he worked on improving combustion engines before going back to school to study nanotechnology — a field he saw as the future for new energy technologies.

WHERE ARE YOU FROM?
I’m from Columbus, Ohio. I went to Purdue University for my undergraduate degree and studied mechanical engineering. Then I went to the University of Texas at Austin to get a master’s degree in mechanical engineering.

WHY DID YOU CHOOSE GEORGIA TECH?
After my master’s degree, I worked for five years as a combustion engineer at Southwest Research Institute in San Antonio. I did a lot of work with diesel engines, such as reducing emissions and improving fuel economy. But I wanted to get into nanotechnology and new energy technologies. Georgia Tech has some really interesting research in that area. More specifically, there is a great community in nanoscale heat transfer, which is the focus of much of my work.

WHAT ATTRACTED YOU TO NANOTECHNOLOGY?
Studying nanomaterials is exciting because there are just so many things that we don’t know yet. With a little creativity and some fundamental science you can try a lot of new things and maybe discover something interesting. I’m part of the NanoEngineered Systems and Transport laboratory led by Associate Professor Baratunde Cola.

HOW ARE POLYMERS RELEVANT TO COOLING?
Polymers are typically thought of as poor conductors of heat — you make all sorts of insulation, like coolers, out of them. But if you engineer the polymers on a nanoscale, you can actually line up polymer chains in certain directions and make them pretty good thermal conductors. We looked at a way to do that through creating an array of nanotubes that are lined up for high thermal conductivity in a pure polymer form.

WHAT’S YOUR ADVICE FOR PEOPLE CONSIDERING A CAREER SHIFT?
It’s never too late to make a switch, but after a five-year break from school, getting back to books and classes was a little painful in the beginning, so don’t wait too long. — BRETTS ISRAEL
Researchers have developed a microfluidic device that captures clusters of tumor cells circulating in the bloodstream. Once captured, the clusters can be studied to help researchers understand their role in cancer metastasis and perhaps one day give doctors the information they need to tailor treatments to specific patients.

Called the Cluster-Chip, the device was developed by a Massachusetts General Hospital research team that included Fatih Sarioglu, now an assistant professor in the School of Electrical and Computer Engineering at Georgia Tech.

The device uses the unique physical properties of the clusters to capture them from blood samples being passed through the chip, which contains rows of triangular microposts. Single cancer cells and ordinary blood cells pass through without being captured. The flow rate is kept low to minimize the possibility that clusters will be broken or distorted.

“Cancer is an extremely heterogeneous disease, and even within the same tumor you can find cells with different surface antigens,” Sarioglu said. “Since we are capturing clusters because of their physical properties, this chip is directly applicable to all types of cancer.”

The research was reported in the journal *Nature Methods*.

— MASSACHUSETTS GENERAL HOSPITAL

*CAPTURING CANCER*

(Above) A three-cell tumor cell cluster is captured and held by the balanced fluid flow on either side of the triangular microposts on the Cluster-Chip. (Below) Close-up image shows the microfluidic device, which is designed to capture cancer cell clusters in blood samples.
HOW OIL BUGS BUGS

When oil from the Deepwater Horizon spill began washing ashore on Pensacola Municipal Beach in June 2010, populations of sensitive microorganisms, including those that capture sunlight or fix nitrogen from the air, began to decline. At the same time, organisms able to digest light components of the oil began to multiply, starting the process of converting the pollutant to carbon dioxide and biomass. Once the lightest fractions of the oil had been consumed, the organisms that had been digesting those compounds declined, replaced by others able to chew up the remaining heavier materials. A year after the spill, the oil had mostly disappeared and microbial populations buried in the beach sands looked much like they had before the spill, though there were as-yet unexplained differences.

That’s the progression observed by scientists who studied the oil’s impact on the complex microbial communities — which contain hundreds of different species of single-celled organisms — on this one Gulf Coast beach. Using advanced genomic identification techniques, they saw a succession of organisms and identified population changes in specific organisms that marked the progress of the bioremediation. They also identified the specific genes contained in the oil-eating microbes.

“We observed the succession of organisms whose populations rose and fell as the degradation of the oil proceeded,” said Kostas Konstantinidis, an associate professor in the Georgia Tech School of Civil and Environmental Engineering. “We also identified the indicator organisms that show the ecosystem’s response at different stages in the process. Knowing these indicators could help those who must manage these spills in the future.”

The research, reported in The ISME Journal and supported by the National Science Foundation and the BP/Gulf of Mexico Research Initiative to the Deep-C Consortium, provides a better understanding of the microbial succession process that follows such environmental perturbations. The project also involved researchers from Florida State University. — JOHNN TOON

Nanoscale Necklaces

Researchers have developed a technique for crafting nanometer-scale necklaces based on tiny star-like structures threaded onto a polymeric backbone. The technique could provide a new way to produce hybrid organic-inorganic shish kebab structures from semiconducting, magnetic, ferroelectric, and other materials that may provide useful nanoscale properties.

The template-based process grows amphiphilic worm-like diblock copolymers through a living polymerization technique in which the polymeric structures serve as nanoreactors that form laterally connecting nanocrystalline structures based on a variety of precursor materials. The nanodisks average about 10 nanometers in diameter and four nanometers in thickness, and are about two nanometers apart.

“Our goal was to develop an unconventional, yet robust, strategy for making a large variety of organic-inorganic hybrid shish kebabs,” said Zhiqun Lin, a professor in the School of Materials Science and Engineering at Georgia Tech. “This is a general technique for making these unusual structures. Now that we have demonstrated it, we believe there is a nearly endless list of materials we can use to craft these nano-necklaces.”

The research was reported in the journal Science Advances, a new member of the Science journal family. The work was supported by the Air Force Office of Scientific Research and the National Science Foundation. — JOHN TOON

Factoid
The Deepwater Horizon oil spill began on April 20, 2010, in the Gulf of Mexico on the BP-owned Transocean-operated Macondo Prospect. The U.S. Government estimated the total discharge at 4.9 million barrels. The well was declared sealed on September 19, 2010.

MICROPOSTS: MASSACHUSETTS GENERAL HOSPITAL; DEVICE: ROB FELT
OIL: MARKUS HUETTEL; NANOSCALE: ZHIQUN LIN
Increasing the number of connections on the edges of chips could move us closer to a quantum computer system

Quantum computers are in theory capable of simulating the interactions of molecules at a level of detail far beyond the capabilities of even the largest supercomputers today. Such simulations could revolutionize chemistry, biology, and materials science, but the development of quantum computers has been limited by the inability to increase the number of quantum bits, or qubits, that encode, store, and access large amounts of data.

In a paper published in the Journal of Applied Physics, a team of researchers at the Georgia Tech Research Institute (GTRI) and Honeywell International have described a new device that allows more electrodes to be placed on a chip.

“To write down the quantum state of a system of just 300 qubits, you would need $2^{300}$ numbers, roughly the number of protons in the known universe, so no amount of Moore’s Law scaling will ever make it possible for a classical computer to process that many numbers,” said Nicholas Guise, the GTRI research scientist who led the research. “This is why it’s impossible to fully simulate even a modest-sized quantum system, let alone something like chemistry of complex molecules, unless we can build a quantum computer to do it.”

While existing computers use classical bits of information, quantum computers use “quantum bits” or qubits to store information. Classical bits use either a 0 or 1, but a qubit, exploiting a weird quantum property called superposition, can actually be in both 0 and 1 simultaneously, allowing much more information to be encoded.

Since qubits can be correlated with each other in a way that classical bits cannot, they allow a new sort of massively parallel computation, but only if many qubits at a time can be produced and controlled. The challenge the field has faced is scaling this technology up, much like moving from the first transistors to the first computers.

One leading qubit candidate is individual ions trapped inside a vacuum chamber and manipulated with lasers. The scalability of current trap architectures is limited because the connections for the electrodes needed to generate the trapping fields come at the edge of the chip, and their numbers are therefore limited by the chip perimeter.

The GTRI/Honeywell approach uses new microfabrication techniques that allow more electrodes to fit onto the chip while preserving the laser access needed. This work was funded by the Intelligence Advanced Research Projects Activity (IARPA). — AMERICAN INSTITUTE OF PHYSICS
RESEARCH HORIZONS

FRONT OFFICE

Every Step Counts

Experts suggest that adults get 150 minutes of moderate exercise per week, but that may be too ambitious for many middle-aged and older individuals. That’s one key observation made by physical activity and health experts who published a recent paper in the British Medical Journal.

While all adults, even those over the age of 65, should strive to attain the weekly goal of 150 exercise minutes, the authors argued that individual goals must be realistic, taking into account possible physical limitations and established patterns of inactivity.

“Only about one in 10 adults aged 40 and older in the United States and the United Kingdom is getting what is considered to be sufficient exercise,” said Phillip Sparling, a professor emeritus in Georgia Tech’s School of Applied Physiology.

Sparling and colleagues made the case that any increase in physical activity, even small amounts, will be beneficial. For sedentary individuals, a gradual transition to increased activity may be the most practical way to improve health. “For example, adding five to 10 minutes per day of light walking and standing is a good start, building up to 30 minutes per day during the course of a month,” Sparling said. — JOHN TOON

PATENTLY OBVIOUS

Prior economic research suggests that inventors filing patents would want to keep their know-how a secret as long as possible. But a recent study examining nearly two million U.S. patents upends this common wisdom. Researchers found that since early publication became an option in 2000, U.S. inventors have chosen by more than five-to-one to disclose their inventions’ technical details prior to patent approval. And those patents kept secret disproportionately cover the lowest value inventions.

“Do small U.S. inventors really value secrecy for their most impactful discoveries? Our findings are that overwhelmingly, and in every category we can test, they do not,” said Stuart Graham, study co-author and an associate professor of strategic management in Georgia Tech’s Scheller College of Business.

The study, co-authored with Deepak Hegde of New York University, was published in the journal Science. The research was sponsored in part by the Ewing Marion Kauffman Foundation. — BRETT ISRAEL

Factoid

DNA nanotechnology is the design and manufacture of artificial nucleic acid structures for technological uses. Instead of carrying genetic information for living organisms, these nucleic acids are used as engineering materials.

ASSEMBLY SOLUTIONS

Scientists are using the programmability of DNA to assemble complex, nanometer-scale structures. Until now, however, production of these artificial structures had been limited to water-based environments, because DNA naturally functions inside the watery environment of living cells.

Georgia Tech researchers have now shown they can assemble DNA nanostructures in a solvent containing no water. They also discovered that adding a small amount of H₂O to their solvent increases the assembly rate and provides a new means for controlling the process. The solvent, a mixture of glycerol and choline chloride, may also facilitate the production of more complex DNA structures by improving the assembly process.

“DNA nanotechnology structures are getting more and more complex, and this solvent could help researchers that are working in this growing field,” said Nicholas Hud, a professor in Georgia Tech’s School of Chemistry and Biochemistry. “We can also take the structures that were assembled in this solvent mixed with water, remove the water by applying vacuum, and have the DNA structures remain intact in the water-free solvent.”

The research could open up new applications for DNA nanotechnology and help apply DNA technology to the fabrication of nanoscale semiconductor and plasmonic structures. Sponsored by the National Science Foundation and NASA, the research was reported in the journal Angewandte Chemie International Edition. — JOHN TOON

Nicholas Hud is a professor in the School of Chemistry and Biochemistry at Georgia Tech, and director of the NSF/NASA Center for Chemical Evolution, which is supported by the NSF Centers for Chemical Innovation Program and the NASA Astrobiology Program.
Twenty-five years ago, the Internet was largely the province of academic and military researchers. The World Wide Web had just been proposed, and the notion of a “smartphone” was off in the future. Personal computers largely operated on the desktop.

Against that backdrop, then-Georgia Tech president John Patrick Crecine and other campus visionaries saw potential. They launched Georgia Tech’s College of Computing in 1990, making the Institute the second university in the nation to have a college devoted to the discipline of computing.

In 2015, the wisdom of that decision seems clear. “In 25 short years, the College of Computing has become a leader and a champion for research endeavors across the spectrum of computing — from theory to robotics to machine learning, from high-performance computing to networking and cybersecurity, and from human-computer interaction to social media — while at the same time establishing a reputation as a premier innovator in computing education,” said Zvi Galil, now dean of the college. “These are tangible contributions to the 21st century digital age. We’ve done this through the hard work of amazing students, brilliant faculty, and dedicated staff, together with a relentless drive to improve the world around us through computing.”

Today, the college has 4,552 students, up from 791 at its founding. It has attracted more than $370 million in research awards since 1990 and moved into a second new building in 2006. Among the highlights of the past 25 years:

- Developing key research areas in cybersecurity, robotics, human-computer interaction, machine learning, networking, data science and high-performance computing, and theory.

- Spinning off several major companies, including Damballa, which sniffs out malware in enterprise systems, and Pindrop Security, which helps prevent telephone-based fraud.

- Helping create major research organizations, including the Graphics, Visualization, and Usability (GVU) Center; the Georgia Tech Information Security Center (GTISC); and a predecessor to the current Institute for Robotics and Intelligent Machines (IRIM).

Added Galil: “I don’t know what the world will look like in another 25 years, but I do know it will bear Georgia Tech’s meta-tags.” — JOHN TOON
La Niña-like conditions in the Pacific Ocean off the coast of Panama were closely associated with an abrupt shutdown in coral reef growth that lasted 2,500 years, according to a new study. The findings suggest that changes in climate similar to those revealed in the study could cause similar coral reef collapses in the future.

The study found cooler sea temperatures, greater precipitation, and stronger upwelling — all indicators of La Niña-like conditions — during a period in which coral reef accretion stopped in this region around 4,000 years ago. For the study, researchers traveled to Panama to collect a reef core and then used the fossil corals within the core to reconstruct what the environment was like as far back as 6,750 years ago.

“Investigating the long-term history of reefs and their geochemistry is difficult to do in many places, so this was a unique opportunity to look at the relationship between reef growth and environment,” said Kim Cobb, an associate professor in the School of Earth and Atmospheric Sciences at Georgia Tech. “This study shows that there appears to have been environmental triggers for this well-documented reef collapse in Panama.”

Published in the journal *Nature Climate Change*, the study was sponsored by the Geological Society of America, the American Museum of Natural History, and the Smithsonian Institution’s Marine Science Network. The study was done in collaboration with the Florida Institute of Technology. - BRETT ISRAEL

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**Microneedle Patch Could Boost World Vaccination**

A microneedle patch being developed by Georgia Tech and the Centers for Disease Control and Prevention (CDC) could make it easier to vaccinate people against vaccine-preventable diseases such as measles. The patch is designed to be administered by minimally trained workers and to simplify storage, distribution, and disposal compared with conventional vaccines.

The microneedle patch measures about a square centimeter and is administered with the press of a thumb. The underside of the patch is lined with 100 solid, conical microneedles made of polymer, sugar, and vaccine that are a fraction of a millimeter long. When the patch is applied, the microneedles press into the upper layers of the skin, dissolving within a few minutes, releasing the vaccine.

“Each day, 400 children are killed by measles complications worldwide. With no needles, syringes, sterile water, or sharps disposals needed, the microneedle patch offers great hope of a new tool to reach the world’s children faster, even in the most remote areas,” said James Goodson, Ph.D., epidemiologist from the CDC’s Global Immunization Division. “This advancement would be a major boost in our efforts to eliminate this disease, with more vaccines administered and more lives saved at less cost.”

Georgia Tech and the CDC recently completed a study showing that the microneedle patch produces a strong immune response in animals. Microneedles research has led to a human clinical trial of flu vaccination that is underway now, and more clinical trials are in the works.

“We think this collaboration with the CDC is an excellent example of how advances in engineering can be used to address important public health problems,” said Mark Prausnitz, a Regents Professor in the School of Chemical & Biomolecular Engineering at Georgia Tech. Prausnitz served as one of the principal investigators on the study. - CENTERS FOR DISEASE CONTROL AND PREVENTION
SECURITY NOW

Researchers are working to ensure the security and trust of field programmable gate array devices

Field Programmable Gate Arrays (FPGAs) are integrated circuits whose hardware can be reconfigured — even partially during run-time — enabling users to create their own customized, evolving microelectronic designs. They combine hardware performance and software flexibility so well that they’re increasingly used in aerospace, defense, consumer devices, high-performance computing, vehicles, medical devices, and other applications.

But these feature-rich devices come with potential vulnerabilities — the very configurability of an FPGA can be used to compromise its security. The slightest tweak, accidental or malicious, to the internal configuration of a programmable device can drastically affect its functionality. Conversely, when security and trust assurances can be established for these devices, they can provide increased, higher-performance resilience against cyberattacks than difficult-to-assure software-based protections.

A research team at the Georgia Tech Research Institute (GTRI) is studying a range of security challenges involving these devices.

“Because FPGAs are programmable and they tightly couple software and hardware interfaces, there’s concern they may introduce a whole new class of vulnerabilities compared to other microelectronic devices,” said Lee W. Lerner, a researcher who leads the GTRI team studying FPGA security. — RICK ROBINSON

Viral Cooperation

Warring armies use a variety of tactics to gain the upper hand. Among them: Attacking with a decoy force that occupies the defenders while an unseen forcelaunches a separate attack that the defenders fail to notice.

A study published in the journal Proceedings of the National Academy of Sciences suggests the Hepatitis C virus may employ a similar tactic to distract the body’s natural defenses. After infecting patients, Hepatitis C evolves many variants, among them an “altruistic” group of viral particles that appear to sacrifice themselves to protect other mutants from the body’s immune system.

Reported by researchers from Georgia Tech and the Centers for Disease Control and Prevention (CDC), the findings could help guide development of future vaccines for the virus, which affects an estimated 170 million people worldwide.

“The members of viral populations in Hepatitis C don’t act like separate entities; the different variants work together almost like a team,” said Leonid Bunimovich, a Regents Professor in the Georgia Tech School of Mathematics. “There is a clear separation of responsibilities, including variants we call ‘altruistic’ because they sacrifice themselves for the good of the whole viral population. These variants seem to draw the immune system attack on themselves.”

The scientists first developed a mathematical model for how the virus variants and immune system antibodies interact. They then used the model to analyze and explain data gathered from a group of Hepatitis C patients, some of whom had been followed for as long as 20 years.

The virus evolves differently in each person, producing a mix of genetically related variants. The variants and the antibodies form a complex network in which an antibody to one variant can react to another variant — a phenomenon known as cross-immunoreactivity.

“The virus variants do not communicate directly with one another, but in this system of viruses and antibodies, they interact through the antibodies,” Bunimovich explained. “When one antibody-producing cell responds to one variant, and then to another, that is a form of interaction that affects both variants. An indirect interaction occurs when the virus variants interact with the same antibody in the network.” — JOHN TOON
Professors Bernard Kippelen and Seth Marder of the Center for Organic Photonics and Electronics (COPE) at Georgia Tech are developing light-emitting diodes (LEDs) using organic elements — principally carbon, hydrogen, oxygen, and nitrogen — that abound in Earth’s biosphere.

The resulting organic LEDs (OLEDs) are both flexible and shatterproof. They could replace or augment digital displays currently used in cell phones and TVs, while also offering new ways to light everything from a tiny medical probe to entire interior surfaces.

Most digital devices today use displays made with indium tin oxide that is deposited onto a glass substrate. Such displays are generally both inflexible and brittle. Moreover, the relatively high price of indium, a rare earth element, adds significantly to manufacturing costs.

By contrast, the COPE team uses low-cost, Earth-abundant organic materials to fabricate a display surface that can produce plentiful light from a small amount of electric current. The researchers deposit exceedingly thin metal foils and films of organic molecules on a very thin plastic substrate. The total device has a thickness of about 100 nanometers — much thinner than conventional displays, which can be up to a millimeter thick.

COPE’s current device fabrication method involves evaporating organic molecules using extreme heat and then depositing them onto a plastic substrate. In the future, however, OLED light-emitting surfaces could be manufactured using roll-to-roll printing processes. This approach promises to yield large display surfaces capable of showing video or providing customizable lighting sources covering entire walls or ceilings.

Because they’re flexible, OLEDs can also conform to curved surfaces. That capability would allow them to serve as light-emitting surfaces in tight places such as medical catheters, or to provide illumination for optics and protective gear used during surgery.

COPE’s approach also promises environmental benefits. The organic materials used by the light-emitting foil and its substrate can be designed to be biodegradable. Unlike conventional displays, which may contain elements that are toxic and costly to recycle, an OLED display could be recycled by simply being dissolved in water at room temperature. — RICK ROBINSON
Invisible Touch

By analyzing such parameters as the force applied by key presses and the time interval between them, a new self-powered, non-mechanical intelligent keyboard could provide a stronger layer of security for computer users. The self-powered device generates electricity when a user’s finger tips contact the multi-layer plastic materials that make up the device.

“This intelligent keyboard could change the traditional way in which a keyboard is used for information input,” said Zhong Lin Wang, a Regents Professor in the School of Materials Science and Engineering at Georgia Tech. “Every punch of the keys produces a complex electrical signal that can be recorded and analyzed.”

Conventional keyboards record when a keystroke makes a mechanical contact, indicating the press of a specific key. The intelligent keyboard developed in Wang’s laboratory records each letter touched, but also captures information about the amount of force applied to the key and the length of time between one keystroke and the next. Such typing style is unique to individuals and so could provide a new biometric for securing computers from unauthorized use.

In addition to providing a small electrical current for registering the key presses, the new keyboard could also generate enough electricity to charge a small portable electronic device or power a transmitter to make the keyboard wireless.

An effect known as contact electrification generates current when the user’s fingertips touch a plastic material on which a layer of electrode material has been coated. Voltage is generated through the triboelectric and electrostatic induction effects. Using the triboelectric effect, a small charge can be produced whenever materials are brought into contact and then moved apart.

The research was reported in the journal ACS Nano. It was sponsored by the U.S. Department of Energy’s Office of Basic Energy Sciences. — JOHN TOON

Factoid

Electrochromism is a process by which a material changes its electro-optic properties through the application of an electric potential across the material. Typically, these electro-optic changes occur in the visible region of the spectrum with the material switching colors upon a change in applied potential.

Rainbow Connection

Artists, print designers, and interior decorators have long had access to a broad palette of paint and ink colors for their work. Now, researchers have created a broad color palette of electrochromic polymers, materials that can be used for sunglasses, window tinting, and other applications that rely on electrical current to produce color changes.

By developing electrochromic polymer materials in a range of primary and secondary colors and combining them in specific blends, the researchers have covered the color spectrum — even creating four shades of brown, a particularly difficult color combination.

The materials could be used to make sunglasses that change from tinted to clear in a matter of seconds, at the press of a button. Other uses could include window tinting, signage, and even greeting cards that change color through the application of low-voltage electrical current.

Supported by BASF, the research was reported in the journal ACS Applied Materials & Interfaces. The work was done in the laboratory of John Reynolds, a professor in the School of Chemistry and Biochemistry and the School of Materials Science and Engineering at Georgia Tech.

“We’ve demonstrated the ability to create virtually any color we want by mixing different electrochromic polymers, just like mixing paint,” said Anna Österholm, a research scientist in Reynolds’ lab. “Using a simple coating method or even inkjet printing, we can create films that change color with the application of a voltage.” — JOHN TOON

Anna Österholm is a research scientist in the Georgia Tech School of Chemistry and Biochemistry. Her research focus is on electrochemical-based devices for charge storage and electrochromics.
SIGHT INSIGHTS

Scientists have determined the three-dimensional structure for a key part of a protein that is associated with glaucoma and identified regions of this domain that correlate with severe forms of the disease.

The new crystal structure is of the olfactomedin (OLF) domain in myocilin, a protein implicated in glaucoma. Many proteins have OLF domains, but mutations in the OLF domain of myocilin are linked to early-onset glaucoma. Despite decades of research, scientists don’t completely understand what biological role myocilin plays or how these mutations create forms of myocilin that build up in the eye.

“Now that we have the 3-D visual picture, we can map the mutations and understand why they can be bad for the protein,” said Raquel Lieberman, an associate professor in Georgia Tech’s School of Chemistry and Biochemistry. Glaucoma, the second leading cause of blindness worldwide, is a group of diseases that damage the eye’s optic nerve and cause vision loss.

The study was sponsored by the American Health Assistance Foundation, the Glaucoma Research Foundation, and the National Institutes of Health (NIH). It was published in the journal *Human Molecular Genetics*. — BRET ISRAEL

Research Horizons wins gold

Research Horizons magazine has won a gold award for magazine publishing improvement in the Circle of Excellence award competition sponsored by the Council for the Advancement and Support of Education (CASE). The award recognizes the recent redesign of the magazine, which included a new cover, a new section of short news items, and a focus on improved photography and illustration.

“The design models innovation and research,” CASE judges wrote of the magazine. “The new issues feature a very contemporary, clean design with appealing white space, photos, and type, and good use of font variety and better paper. The shorter stories are so much easier to read and easier to get into for readers who skim, and the mix of long and short stories is interesting.”

There were 36 entries in the award category. — JOHN TOON

SAVING PLATINUM

A new fabrication technique that produces hollow platinum nanocages with ultra-thin walls could dramatically reduce the amount of the costly metal needed to provide catalytic activity in such applications as fuel cell electrodes.

The technique uses a solution-based method for producing atomic-scale layers of platinum to create hollow, porous structures that can generate catalytic activity both inside and outside the nanocages. The layers are grown on palladium nanocrystal templates, then the palladium is etched away to leave behind structures approximately 20 nanometers in diameter, with between three and six atom-thin layers of platinum.

Use of these nanocage structures in fuel cell electrodes could increase the utilization efficiency of the platinum by a factor of as much as seven, potentially changing the economic viability of the fuel cells.

“We can get the catalytic activity we need by using only a small fraction of the platinum that had been required before,” said Younan Xia, a professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. Xia also holds joint faculty appointments in the School of Chemistry and Biochemistry and the School of Chemical and Biomolecular Engineering at Georgia Tech. “We have made hollow nanocages of platinum with walls as thin as a few atomic layers because we don’t want to waste any material in the bulk that does not contribute to the catalytic activity.”

The research — which also involved researchers at the University of Wisconsin-Madison, Oak Ridge National Laboratory, Arizona State University, and Xiamen University in China — was reported in the journal *Science*. — JOHN TOON
Modern mass spectrometry techniques have helped scientists identify more than 300,000 post-translational modifications (PTMs) in different families of proteins across numerous species. These PTMs come in many forms, resulting from the action of different enzymes, and are often indicators of how and where proteins contact one another to bring about different cell behaviors.

“Mass spectrometry is so effective that it has created an exponential curve in the knowledge of how proteins are modified,” said Matthew Torres, an assistant professor in the Georgia Tech School of Biology. “The rate at which we can detect new PTMs has now far surpassed the rate at which we can understand what they do from a classical biochemical approach. You have so much information that you don’t know where to begin.”

To address this issue, Torres and graduate students Henry M. Dewhurst and Shilpa Choudhury have developed and tested a new informatics technology that analyzes existing data repositories of protein modifications and 3-D protein structures to help scientists identify and target research on “hotspots” likely to be important for biological function.

Known as SAPH-ire (Structural Analysis of PTM Hotspots), the tool could accelerate the search for potential new drug targets on protein structures and lead to a better understanding of how proteins communicate with one another inside cells.

“SAPH-ire predicts positions on proteins that are likely to be important for biological function based on how many times those parts of the proteins have been found in a chemically modified state when they are taken out of a cell,” Torres explained. “SAPH-ire is a tool for discovery, and we think it will lead to a new understanding of how proteins are connected in cells.”

The tool and its testing were reported in the journal *Molecular and Cellular Proteomics*. The research was supported by the National Institute of General Medical Sciences (NIGMS), which is part of the National Institutes of Health (NIH). — JOHN TOON
IN A FLASH

HAWC Tracks Cosmic Visitors

In the shadow of Mexico’s Sierra Negra volcano, an array of 300 silvery water-filled tanks is capturing the calling cards left by powerful visitors from our galaxy and beyond.

The tanks are the most visible components of the High Altitude Water Cherenkov Observatory (HAWC), a one-of-its-kind facility designed to gather information about high-energy gamma rays entering the Earth’s atmosphere.

Information about these gamma rays, which shower the Earth with charged particles, could expand our knowledge of black holes, supernovae, and other cosmic gamma ray sources. Built through a partnership between the United States and Mexico, HAWC adds yet another component to the toolbox of techniques astrophysicists can use to study the universe.

“We are conducting a survey in space and in time,” said Ignacio Taboada, an associate professor in Georgia Tech’s School of Physics who was involved in the design and construction of HAWC and now serves as science analysis coordinator for the facility. “There are regions of the sky that nobody has examined in detail. We may find something entirely new, especially outside the galactic plane.”

Through HAWC, scientists will gather information on gamma rays that carry about a trillion times more energy than the photons that enter our eyes and allow us to see. When one of these gamma rays collides with Earth’s upper atmosphere, it produces a shower of particles that rain down through the lower atmosphere in a pancake pattern, at almost the speed of light.

At times, these particles may pass through HAWC’s water-filled tanks, creating a flash of blue light known as Cherenkov radiation. That light, sometimes just a handful of photons, will be captured by four photomultiplier tubes located at the base of each light-tight tank. By measuring the intensity of the light and comparing the nanosecond differences in its arrival times at different tanks in the array, scientists will be able to compute the energy of the gamma rays and also the direction from which they came. — JOHN TOON

Swipe to Swarm

Using a smart tablet and a beam of red light, researchers have created a system that allows one person to control a fleet of robots with the swipe of a finger.

In use, a person taps the tablet to control where the beam of light appears on a floor. The swarm robots then roll toward the illumination, communicating with one another and deciding how to evenly cover the lit area. If the tablet is swiped to drag the light across the floor, the robots follow. If the operator puts two fingers in different locations on the tablet, the machines will split into teams and repeat the process.

“It’s not possible for a person to control a thousand or a million robots by individually programming each one where to go,” said Magnus Egerstedt, a professor in Georgia Tech’s School of Electrical and Computer Engineering. “Instead, the operator controls an area that needs to be explored. Then the robots work together to determine the best ways to accomplish the job.”

Egerstedt envisions sending a large fleet of machines into a disaster area, where the robots could search for survivors. Supported by the Air Force Office of Scientific Research, the work was reported in the journal IEEE Transactions on Robotics. — JASON MADERER
Researchers have realized one of the long-standing theoretical predictions in nonlinear optical metamaterials: creation of a nonlinear material that has opposite refractive indices at the fundamental and harmonic frequencies of light. Such a material, which doesn’t exist naturally, had been a research goal for nearly a decade.

Observation of “backward phase matching” — a phenomenon also known as the “nonlinear mirror” — provided evidence that this new type of metamaterial had been created in a waveguide material.

“Nonlinear optics is critically important to controlling light for information processing, sensing, and signal generation,” said Wenshan Cai, an associate professor in the Georgia Tech School of Electrical and Computer Engineering, who led the research team. “Our effort substantially expands the scope of nonlinear light-matter interactions in artificially structured media with engineered, unconventional linear and high-order material parameters.”

Engineered metamaterials could be especially useful in nonlinear optics, where materials with unconventional properties could make a difference anywhere light must be actively controlled.

“The linear responses of metamaterials have substantially augmented the linear properties available from naturally occurring materials,” noted Shoufeng Lan, a graduate student in Cai’s laboratory. “In the same way, studies of nonlinear metamaterials may have a revolutionary impact on the field of nonlinear optics. The unconventional electromagnetic parameters made possible by metamaterials will provoke us to rethink and re-evaluate many of the established rules of nonlinear optics.”

The research was reported in the journal *Nature Materials.* — John Toon

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**SWIMMING THROUGH SAND**

For swimming through sand, a slick and slender snake can perform better than a short and stubby lizard.

That’s one conclusion from a study of movement patterns in the shovel-nosed snake, a native of the Mojave Desert of the southwest United States. The research shows how the snake uses its slender shape to move smoothly through the sand, and how its slippery skin reduces friction. Both factors provide locomotive advantages over another sand-swimmer: the sandfish lizard native to the Sahara Desert of northern Africa.

The study provides information that could help explain how evolutionary pressures have affected body shape among sand-dwelling animals. And the work could also be useful in designing search-and-rescue robots able to move through sand and other granular materials with a minimal expenditure of energy.

Using X-ray technology to watch each creature as it moved through a bed of sand, researchers studied the waves propagating down the bodies of both the snakes and sandfish lizards. Granular resistive force theory, which considers the thrust provided by the body waves and the drag on the animals’ bodies, helped model the locomotion and compare the energy efficiency of the limbless snake against that of the four-legged lizard, which doesn’t use its legs to swim through the sand.

“We were curious about how this snake moved, and once we observed its movement, how it moved so well in the sand,” said Dan Goldman, an associate professor in the Georgia Tech School of Physics. “Our model reveals how both the snake and the sandfish move as fast as their body shapes permit while using the least amount of energy.”

Supported by the National Science Foundation and the Army Research Office, the research was reported in the *Journal of Experimental Biology.* — John Toon

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**LIGHT WORK**

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The research was reported in the journal *Nature Materials.* — John Toon
Not Monkeying Around

Researchers have developed a noninvasive method to image simian immunodeficiency virus (SIV) replication in real-time, in vivo. This approach, reported in the journal *Nature Methods*, is based on immune positron-emission tomography/computed tomography (PET/CT) and allows for the capture of viral dynamics of SIV, the animal model of human HIV infection. This approach has application to the study of immunodeficiency virus pathogenesis and drug and vaccine development, and could have use with human patients to identify viral reservoirs — potentially leading to new treatments for HIV/AIDS.

Francois Villinger, a researcher in the Yerkes Research Center’s Microbiology and Immunology Division, and Philip Santangelo, a researcher in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University, led the study with their respective teams and collaborators at the Emory School of Medicine. Using the nonhuman primate model of human HIV infection, their approach uncovered previously unappreciated sites of viral replication, such as in nasal tissue.

In addition, the methodology captured the wide variation in viral replication levels within select organs, including sections of the gastrointestinal tract, whether or not the subject was taking antiretroviral therapy. Finally, the methodology allows for repeat analysis of the viral dynamics, during acute infection, anti-viral therapy and upon cessation of therapy.

“Use of the technique could lead to a better understanding of viral dynamics in the body, which could help target new generations of therapeutics and diagnostics,” explained Santangelo. “This could help us find the regions where the virus is replicating and allow us to focus molecular diagnostics on the areas that are really important.” — YERKES RESEARCH CENTER

BUILDING STRONGER COMPOSITES

Carbon fibers are stronger and lighter than steel, and composite materials based on carbon fiber reinforced polymers are being used in a growing number of applications, including major sections of the new Boeing 787 aircraft. But scientists believe carbon fiber technology could produce even stronger composites.

Georgia Tech researchers have developed a new technique for producing carbon fibers that sets a new milestone for strength and modulus — a measure of stiffness. Their success stemmed from a new approach to spinning polyacrylonitrile, an organic polymer resin used to make carbon fibers.

“By using a gel-spinning technique to process polyacrylonitrile copolymer into carbon fibers, we have developed next-generation carbon fibers that exhibit a combination of strength and modulus not seen previously with the conventional solution-spun method,” said Satish Kumar, a professor in the Georgia Tech School of Materials Science and Engineering, who leads the project. “In addition, our work shows that the gel-spinning approach provides a pathway for even greater improvements.”

The gel-spun carbon fiber produced by Kumar’s team was tested at 5.5 to 5.8 gigapascals (GPa) — a measure of ultimate tensile strength — and had a tensile modulus in the 354 to 375 GPa range. The material was produced on a continuous carbonization line.

The research is part of a project sponsored by the Defense Advanced Research Projects Agency (DARPA) and was reported in the journal *Carbon.* — RICK ROBINSON
Wonders

Big advances in medicine are coming to the smallest patients. See how Georgia Tech and its partner organizations are improving the lives of children, from home health care to medical devices designed for kids.

Story by Brett Israel
Soon after turning 12 months old, Hudson Day stopped eating and drinking.

At the age of 10 months, he had been diagnosed with an interstitial lung disease, which required him to take supplemental oxygen full time. The disease, called NEHI (Neuroendocrine Hyperplasia of Infancy), was affecting his ability to eat. Hudson became anemic and lost so much weight in four days that an emergency medical airplane was called to fly him from his home in Jackson Hole, Wyoming, to Children’s Hospital Colorado. During his month-long stay in Denver, doctors inserted a feeding tube into Hudson’s stomach to keep him alive.

Hudson’s parents then enrolled him in feeding therapy programs at local medical centers, but progress was elusive.

“Nothing was really working for him,” said Melinda Day, Hudson’s mother. “The further away I was from getting food into his mouth, the more concerned I became.”

Melinda, an Atlanta native, learned about the Atlanta-based Marcus Autism Center’s Feeding Disorder Program. Hoping it might help her son eat food again, she contacted Marcus and enrolled Hudson in a feeding therapy program. Hudson’s treatment at Marcus involved the use of a new app called iEAT, developed through a collaboration between the Georgia Institute of Technology and Marcus. Hudson’s feeding therapy was the first use of iEAT after clinical trials on the technology had been completed.

The feeding program was eight weeks long, during which time a multidisciplinary team used the app to track Hudson’s progress toward eating food and reducing his reliance on the feeding tube. The app suggested the next steps for Hudson’s feeding therapy based on positive or negative reactions to food in previous sessions.

Hudson finished the program by the time he turned 2. He has not needed the feeding tube since returning to Wyoming, and he is now eating 1,400 calories a day from a spoon.

Hudson also had a major breakthrough during the program: He ate a peanut butter and jelly sandwich. It was the first time he had chewed food.

“This program has been a complete life-changer,” Day said.

Georgia Tech scientists and engineers, in collaboration with Emory University, Children’s Healthcare of Atlanta, and Marcus Autism Center, are tackling one of the biggest challenges in pediatric medicine — the lack of medical devices and technologies designed specifically for children. Many medical devices used on children were designed for adults. And because the market for children’s medical devices is small, many companies shy away from building medical technologies for children.

Georgia Tech is helping to fill that gap in the market. From an app that allows parents to send pictures of their child’s potential ear infection to a doctor, to surgical tools tailored to a child’s physiology, the Institute is leading the push toward improving and saving children’s lives through technology.
Georgia Tech engineers, collaborating with a physician at Children’s, designed a new connector for the inside of the tubes used in Extracorporeal Membrane Oxygenation (ECMO) life-support equipment. The improved fluid mechanics minimizes the development of blood clots in patients using the machines.

“Children are not young adults,” said Ajit Yoganathan, a Georgia Tech Regents Professor and the Wallace H. Coulter Distinguished Faculty Chair in Biomedical Engineering, who is developing a device to treat pediatric kidney disease. “The physiology is different; the anatomy is different,” he added. “In many cases you need to design the device for the pediatric application because otherwise it’s tough to downsize adult devices for children. You must design devices for kids.”

Georgia Tech hosts important centers for pediatric research, including the nation’s first Center for Pediatric Nanomedicine, led by M.G. Finn, professor and chair of the School of Chemistry and Biochemistry at Georgia Tech; the Center for Transforming Pediatric Healthcare Delivery, led by College of Computing Professor Elizabeth Mynatt; and the Center for Pediatric Innovation, co-led by Robert Guldberg, Parker H. Petit Director’s Chair in Bioengineering and Bioscience at Georgia Tech, and Dr. Kevin Maher, associate professor of pediatrics at Emory and a pediatric cardiologist at Children’s.

“Because the relationship between Children’s and Georgia Tech exists, I can pick up the phone, talk to engineers, and actually bring them into the hospital to see the clinical problems that we’re dealing with,” Maher said.

Georgia Tech engineers, led by Dr. David Ku, a mechanical engineering professor, worked with Maher to design a new fluid mechanical geometry for the inside of tubes used in Extracorporeal Membrane Oxygenation (ECMO) life-support machines. The redesigned fluid mechanics minimizes the development of blood clots in patients using the machines.

ECMO machines were designed for adults but are used with children. The most common problem for patients on ECMO is the risk of clot formation. These clots
CellScope Oto is a smartphone attachment that allows parents to send an image of a child’s eardrum to an on-call physician for diagnosis. By allowing examination remotely, the device could reduce the number of late-night emergency room visits for suspected ear infections.
can be severe, causing strokes and even death, despite aggressive use of anticoagulation (non-clotting) medicines.

“Without the three of us working together, we wouldn’t have gotten anywhere,” said Ku, a Regents Professor of Mechanical Engineering and Lawrence P. Huang Chair Professor of Engineering Entrepreneurship. “The partnership brings the clinicians in touch with the engineers. We weren’t talking to each other about this project at all before.”

Development and testing of the ECMO technology continues, but this type of fluid mechanical design could also apply to several other types of technology used in pediatric cardiology, including cardiac pumps and in-dwelling catheters.

The ECMO project was funded by the Center for Pediatric Innovation and the Atlantic Pediatric Device Consortium. Other collaborative projects are funded by the Quick Wins program, which spun out of a partnership between Georgia Tech and Children’s (iEAT was also part of the Quick Wins program). The collaboration involves existing Children’s research centers, the Department of Pediatrics at Emory University, and faculty and researchers from academic and research units throughout Georgia Tech. The goal is to bring together physicians and engineers to solve pediatric medical problems.

Projects funded through Quick Wins focus on solving day-to-day issues that clinicians face in the care of their patients. That can be anything from process improvement to sensor technologies to mobile health solutions. The goal of Quick Wins is to develop a solution to a given challenge within 18 months.

“With this partnership, we are helping kids through innovative technology,” said Leanne West, the partnership’s chief engineer for pediatric technologies. “Our hope is to continue to strengthen the relationship between Georgia Tech and Children’s Healthcare of Atlanta and develop solutions to better serve patients. The partnership has already resulted in several ideas, and by working together things are starting to happen.”

Another device under development by Georgia Tech is for bedside dialysis for children. When critically ill children need kidney dialysis, doctors are forced to use adult-size dialysis equipment, which can withdraw too much fluid from a pediatric patient, leading to dehydration, shock, and loss of blood pressure.
Yoganathan's group, with funding from the National Institutes of Health, is working on a kidney dialysis prototype device that is much smaller than existing dialysis equipment and works in tandem with equipment that supplements the function of the heart and lungs for severely ill patients. The device can be used either for pure dialysis or for dialysis plus oxygenation as a part of continuous veno-venous hemofiltration (CVVH), which is a short-term treatment used in ICU patients with acute or chronic renal failure.

“What doctors are using right now for CVVH are adult devices that are not FDA-approved for use in children, but clinicians have no choice but to use the adult devices,” Yoganathan said. The team is currently working on a more robust prototype that can be used in the clinic, and they are hopeful for additional funding and the start of clinical trials soon. The Wallace H. Coulter Foundation is funding the next phase of development through the Emory/Georgia Tech Coulter Translational Partnership.

Georgia Tech engineers are looking beyond redesigning medical devices that are used in hospitals and toward developing innovative ways to bring doctors and therapists into the home. Apps like iEAT, which helped Hudson Day transition from a feeding tube to real food, were designed for the clinic, but researchers hope to have a second phase of development for a version that can be used in the home.

“I was extremely lucky in that I had family in the Atlanta area to help with travel, but not everyone can afford to travel and take the time off of work,” said Melinda Day, Hudson’s mother. “To have an app like iEAT and to be able to do the feeding program in your home is incredible.”

To help create and commercialize new pediatric devices, Georgia Tech, Emory University, Children’s Healthcare of Atlanta, and Virginia Commonwealth University have formed the Atlantic Pediatric Device Consortium (APDC). Funded by the FDA, APDC provides a national platform to translate ideas through its product development pathway all the way to commercialization.

One of the first projects from the Atlantic Pediatric Device Consortium is helping parents take the guesswork out of a common nighttime emergency — the ear infection. The device, called CellScope Oto, combines an app with a smartphone attachment that uses the phone’s light source and camera as an otoscope, which is a medical device used to look into the ears.

CellScope Oto is now available to parents in California, with plans to expand to other markets soon. Parents who have the CellScope Oto can call the CellScope Oto service to alert a physician if they suspect their child has an ear infection. The app will then guide them through an actual ear exam in the home, after which the on-call physician will contact the parent with a diagnosis. The goal for CellScope Oto’s developers is to improve quality of life for families while reducing health care expenditures.

“Ear infections are often really bad at night. What we’re trying to do with this system is to prevent unneeded emergency room visits,” said Dr. Wilbur Lam, an assistant professor in the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University, who is leading the development of the project.

One important issue in a child’s social and communication development is the need for parents and caregivers to talk to children from birth, said Dr. Jennifer Stapel-Wax, an associate professor of pediatrics at the Emory University School of Medicine.

The national Talk With Me Baby campaign is designed to train nurses to coach parents to talk to their babies in the first year of life because language builds brain development. To extend the reach of the program, Stapel-Wax and her partners teamed up with Georgia Tech engineers to create an app that encourages parents to talk to their children.

The app is meant to bridge the gap between pediatric visits for parents. The app will push notifications to parents about their baby’s development, such as milestones to watch for between birth and 12 months, activities to encourage language development, and videos to model language nutrition for babies.

“The app will give families easy access to this information, because it’s not always easy to find,” said Stapel-Wax. “The app will push it to them.”

The Talk With Me Baby app is expected to be available this summer for both iPhone and Android devices.

As children get older, they need to be able to use apps themselves, but kids with disabilities often have difficulty using popular tablet devices. When electrical and computer engineering professor Ayanna Howard saw this problem, she launched Zyrobotics, which develops mobile-accessible technologies for children with cerebral palsy, autism, and other challenges.

“We focus on designing technology that all kids enjoy, and that happens to be accessible, so children with special needs don’t feel excluded,” Howard said.

At the beginning of 2015, Zyrobotics began distribution of TabAccess, a Bluetooth switch interface that enables wireless access to iPad and Android tablets for children with special needs. The technology has been distributed to clinics and special education classrooms. TabAccess has a universal interface with three inputs so users can plug and play any sensor device — such as a button, joystick, or a force sensor — which allows for simulation of the swiping, touching, and pinching commonly used to control tablets.

“TabAccess is the interface to any device that a child might already be using,” said Howard. “It’s more universal to the wider needs of the target demographic.”
To get the best care for her three autistic children, Mandi Larkin used to drive three hours from her family’s home in Tifton, Georgia, to Marcus Autism Center in Atlanta. Today, Larkin’s children receive world-class medical care at her local hospital via a state-of-the-art telemedicine link to Marcus.

The recently improved telemedicine system was optimized by scientists at the Georgia Tech Research Institute (GTRI) and Cisco Systems, Inc., and now Marcus Autism Center’s telemedicine room is a showcase for providers of telemedicine. Improved video capabilities, an iPad control panel, and an ergonomic suite allow patients in rural Georgia to meet face-to-face with medical specialists in Atlanta.

“The accessibility to the doctors in Atlanta is the big thing,” Larkin said. “Not everyone has the means to make that kind of a drive. Telemedicine gives us access to the doctors that we normally wouldn’t have access to.”

GTRI’s telemedicine efforts are supported by a donation from Allen Ecker, a Georgia Tech alumnus and former executive vice president of Scientific Atlanta. Cisco, as a provider of telemedicine equipment at Children’s Healthcare of Atlanta, also donated equipment and software toward telemedicine enhancements at both Marcus Autism Center and Children’s.

“We wanted to ensure that the telepresence is at least as good as when you’re sitting in the office with a provider,” said Courtney Crooks, a senior research scientist at GTRI, who is involved in human systems integration for the project.

Dr. Felissa Goldstein, the primary doctor using the improved telemedicine system at Marcus, uses the system for providing early screening and continuing care for children with autism spectrum disorders. Goldstein had been using a telemedicine system in her office that had poor lighting, muffled sound, and poorly placed monitors that reduced eye contact. The new telemedicine system is now in a soundproof room with lighting designed to make Goldstein appear more natural.

An iPad now acts as the central control station for the telemedicine system. Goldstein can tap the iPad to control the camera. She can pan and zoom to follow children around the room as they play with toys, or tightly focus on the parents as they praise or discipline their children. The iPad is also enabled for touchpad tagging of behavioral events of interest that may occur during a session. If Goldstein needs to note a significant event, she can flag it in the system. Later, she analyzes the data to look for trends, such as how a symptom develops over time.

The research team is also involved in developing ways to use the system for other needs, such as tele-training, parent education, and dependent care in the military. Those applications are still under development, but the system’s value to families with children is already changing their lives.

“I think the doctor gets a little bit more interaction from the kids through the screen because they more or less shut down around new people,” Larkin said. “With telemedicine, to the kids, it’s just somebody on a TV screen talking to them. The doctor can see a little bit more and get a little bit more from them than if she was in the room in front of them.”

Physician meets engineer

When his laboratory works on challenging research problems, Dr. Wilbur Lam can easily envision how the solutions will help children with cancer or blood disorders. That’s because the issues he studies spring from patients he sees as a physician specializing in pediatric hematology and oncology at Children’s Healthcare of Atlanta.

Lam holds both an M.D. and a Ph.D. and splits his time between the Emory University campus and Georgia Tech, where he’s an assistant professor in the Wallace H. Coulter Department of Biomedical Engineering, operated jointly by the two institutions. His lab is in the Marcus Nanotechnology Building – an ideal place for studying blood flow at the microscale and developing medical devices based on microelectronics technology.

“We’re interested in the cellular biophysics of blood, and we often need to make our own devices to study blood cells and the diseases that alter them,” Lam said. “We do basic science as well as translational research, but it all begins and ends in the clinic with patients.”

Lam has many research interests, but some of his lab’s biggest successes have been medical devices. One, called AnemoCheck, was invented by Erika Tyburski when she was an undergraduate at Georgia Tech; however, its ability to measure anemia was evaluated in clinical trials at Emory. The other, CellScope Oto, attaches to smartphones and allows parents to send snapshots of their child’s eardrums to an on-call physician who can determine whether a midnight earache merits immediate attention.

Beyond his own research, Lam sees his role as building bridges between physicians and engineers. The two disciplines can be complementary, but they speak different languages and have different cultures and expectations.

“We are working on this bridge, trying to widen it and make it stronger,” he said. “We are constantly trying to connect people on the clinical side to the engineering side, and vice-versa. I play matchmaker.”

But bringing engineering and medicine together isn’t Lam’s only goal. He also represents biomedical engineering in CREATE-X, Georgia Tech’s initiative to build entrepreneurial confidence in its students.

“We have the raw material here to really establish a culture that helps undergraduates form their own startups, and we’re beginning to see that transformation,” he added. — JOHN TOON

Brett Israel is a former communications officer with Georgia Tech’s Institute Communications, where he covered life sciences and the environment. He now lives and works in Nashville, Tennessee.
As cybercriminals become more cunning, Georgia Tech researchers expand their arsenal of security innovations.
The rise of digital devices and technologies has dramatically increased online activities for individuals, businesses, and governments. And though this accelerated connectivity brings many benefits, it also creates a treasure-trove of data to plunder—along with new forms of foul play.

For example, while traditional bank robberies have declined dramatically since 1991, cyberheists are on the rise. Among these cyberbandits is a multinational gang known as Carbanak, which reportedly siphoned as much as $1 billion from bank coffers in 30 countries over a two-year period.

“The proliferation of online devices and services means that attack surfaces continue to expand—along with the amount of valuable data that is exposed,” said Bo Rotoloni, deputy director of the Information and Cyber Sciences Directorate at the Georgia Tech Research Institute (GTRI) and co-director of the new Georgia Tech Institute for Information Security and Privacy (IISP). “In addition, attribution is difficult, if not impossible. It’s easy for cybercriminals to hide their tracks versus brick-and-mortar bandits that go in with guns blazing.”

An interdisciplinary research center that launched in July 2015, the Institute for Information Security and Privacy connects security experts within GTRI, Georgia Tech’s College of Computing, Scheller College of Business, College of Engineering, and Ivan Allen College of Liberal Arts. “The idea is to address very complex problems in cyberspace and conduct research that has a positive societal impact,” Rotoloni said.

By sharing research talent and support infrastructure, the Institute for Information Security and Privacy provides a mechanism to better coordinate large-scale projects, said Wenke Lee, a professor in the College of Computing who serves as the other co-director. “We will enable researchers to move seamlessly between basic and applied research,” he explained. “Information security is an arm’s race, and this cross-campus partnership will enable us to stay in front.”

PUTTING THE STING ON MALWARE

Among cybersecurity challenges, malicious software (malware) threats continue to loom large. “In the past five years, commoditization of malware has grown because the investment is small for criminals,” pointed out Christopher Smoak, a research scientist and division chief at GTRI’s Cyber Technology and Information Security Laboratory (CTISL). “People can spend $25 to $50 to get point-and-click tools that not only build malware but also obfuscate it and make it more resilient.”

Enter Apiary, GTRI’s automated malware intelligence system, which allows members to anonymously submit suspicious files for fast analysis—as well as receive information about attacks on other organizations and how they responded.

The Apiary project began in 2010, and since then it has grown from a handful of members to a community of more than 120, including Fortune 500 companies, nonprofits, academic institutions, and government agencies. All members are carefully vetted and anonymity is strictly enforced.

The community involvement is an important piece, Smoak stressed: “Organizations are often reluctant to share information about how they got attacked because it’s akin to airing dirty laundry. And though they may not want to release information in a public arena, it’s critical from a technical perspective to help people in other industries learn from their experiences. Apiary provides a sort of crowd-sourcing threat intelligence.”

Apiary also serves as a research platform. “If someone has a new technique to reverse-engineer malware, they can run it against our repository, which has more than 140 million samples,” said Andrew Howard, CTISL’s director. “All we ask in return is that they share their intelligence.”

In contrast to other detection systems, Apiary features modular capabilities so GTRI can quickly add new technologies without needing to rebuild its analysis engine. Apiary also leverages a hardware-only analysis technique developed at Georgia Tech for transparent analysis, which prevents malware authors from knowing they’ve been outed.

Researchers are currently working to make Apiary more robust by adding machine-learning models as well as correlation techniques to uncover similarities between seemingly disparate malware. The goal is to provide greater context about the threats.

“Looking at just one file in a vacuum isn’t helpful anymore,” Smoak said. “The big impact comes from understanding the actors behind the malware and what their intentions are.”

IN THE WOODS

Another tool in GTRI’s cybersecurity arsenal is BlackForest. This open-source intelligence system blends sophisticated collecting with analysis capabilities to identify possible attacks—before they happen.

Organizations are often reluctant to share information about how they got attacked because it’s akin to airing dirty laundry.
“Although it may be anonymous, there’s a lot of information in social media and hacker forums about attack targets or new malware releases,” Smoak said. Attackers may use Twitter or Facebook to enlist others for distributed denial-of-service (DDoS) attacks, or malware authors may post new code to announce its availability and get feedback, he explained.

To expose malevolent activities, BlackForest crawls through the deep, dark Web looking for clues; then it builds a graph database to connect information. For example, it might link personas in different chat rooms who are working together or related in some way.

By automating the collection and monitoring of this kind of data, BlackForest enables security analysts to be more proactive. If an important persona speaks up about a piece of malware, analysts can take steps to protect their networks in advance. Or passwords, credit card numbers, or intellectual property might show up for sale, indicating that a company’s network has been breached.

Researchers are now making BlackForest even more robust by adding machine-learning models, which will enable the intelligence system to start recommending actions.

**PROTECTION BEYOND THE PERIMETER**

Although passwords and fingerprints can block illegal access to cellphones and tablets, they aren’t foolproof. Consider the 7-year-old boy who gained entry to his father’s cellphone by holding the device to his sleeping parent’s hand.

“Passwords are a one-time authentication that only protect the perimeter,” pointed out Polo Chau, an assistant professor in Georgia Tech’s College of Computing. “And if you get past that gate, you can do anything you want.”

Raising the bar on mobile security, Chau and a research team that included College of Computing professor Hongyuan Zha, and undergraduate students Premkumar Saravanan and Samuel Clarke, have developed LatentGesture, a new approach to authentication based on “touch signature.” For example, some people touch their screens harder or hit the edge of buttons rather than the center. Others may drag their fingers across the sidebar faster or move from the lower left to the top right. Tracking these minute differences, Chau’s technology establishes a touch signature for the mobile phone or tablet owner — and then constantly compares that ID with whoever is currently using the device.

In a lab study, LatentGesture, which is supported by National Science Foundation (NSF) funding, scored a 98 percent accuracy rate for smartphones and a 97 percent rate for tablets. Currently the researchers are making the technology more efficient and investigating how different movements and environmental settings, such as walking or lying on a couch, might affect touch signatures.

“This won’t replace the password,” Chau said. “It’s a complementary security technology that provides ongoing authentication in the background. Even if someone gets past the first line of defense, we can continue to monitor the user to ensure they really are who they claim to be.”

**GUILT BY ASSOCIATION**

In another project, Chau and graduate student Acar Tamersoy have developed a scalable patent-pending algorithm that can detect malware with extreme precision. Named Aesop, after the ancient Greek fabulist’s moral that “a man is known by the

**AESOP**

A malware detection algorithm, Aesop quickly determines a software file’s “goodness” or “badness” by analyzing its relationship with peer files.

**APIARY**

GTRI’s automated malware intelligence system allows members to anonymously submit suspicious files for fast analysis and receive information about attacks on other organizations.

**BLACKFOREST**

An open-source intelligence system, BlackForest crawls through the deep, dark Web to collect information and identify possible attacks before they happen.

**LATENTGESTURE**

A new approach to authentication, LatentGesture establishes a “touch signature” for mobile phone and tablet owners — then constantly compares this ID with whoever is using the device to make sure they’re the real McCoy.

**NETWORK SECURITY YARDSTICK**

Astrolavos Lab researchers have created a novel metric that enables security officials to independently evaluate their network risk over time and show how technology investments have mitigated risk of attacks.

**PHONEPRINTING**

This audio fingerprinting technology helps call centers verify where calls are truly coming from and what type of device is being used. In contrast to competing technologies that reduce fraud by 10 to 15 percent, Phoneprinting™ catches 90 percent of shysters.

**PHONEYPOT**

A pioneer of telephony honeypots, PhoneYPot demonstrates how to successfully lure voice-channel villains to successfully lure voice-channel villains and study their exploitation techniques.

**SIDE-CHANNEL SECURITY**

Researchers are investigating how to safeguard electromagnetic signals and power fluctuations emitted by computers and cellphones to protect them from hackers.

**TAIGA**

A new architecture that provides process resilience against cyberattacks on physical targets, TAIGA ensures stability regardless of what else may be happening within a computational system.
company he keeps,” the patent-pending technique determines a software file’s “goodness” or “badness” by analyzing its relationship with peer files.

Developed in collaboration with Kevin Roundy at Symantec Research Labs, Aesop leverages locality-sensitive hashing and graph mining techniques to quickly see how files relate to one another and establish a reputation score.

“Downloading an application, such as Microsoft Word, involves thousands of files,” Chau explained. “If a malware detection solution knew which files are related, it could label them simultaneously. Yet most current solutions don’t distinguish applications; all they see are files. To get around this blind spot, Aesop essentially reverse-engines files to uncover their relationships, which improves accuracy in labeling the files as good or bad.”

Aesop builds on previous reputational scoring that Chau did as an intern for Symantec while earning his graduate degree at Carnegie Mellon University. This earlier technique looked at the relationship between files and machines — assuming computers with good hygiene would attract fewer malicious files. Although the approach was successful, Aesop detects malicious files more accurately.

In fact, Aesop can identify 99 percent of benign files and 79 percent of malicious files at least a week earlier than current state-of-the-art techniques. In addition, it boasts a 0.9961 true positive rate at flagging malware and a 0.00001 false positive rate. Symantec is now deploying Aesop into its suite of security solutions.

DEFENDING THE VOICE CHANNEL

Among new landscapes for nefarious activity is the phone.

“Telephony used to be a closed and trusted system, but with the rise of smartphones and technologies like VOIP, telephony and Internet systems have converged,” pointed out Mustaque Ahamad, a professor in the College of Computing who serves as an external technical adviser to the Federal Trade Commission and recently won a Google Faculty Research Award to study telephony-based threats. “As a result, threats that we’ve been dealing with on the Internet side are now showing up in telephony.”

Issues range from annoying robocalling and voice spam to more malicious activities, such as phone fraud campaigns, voice phishing (vishing), and caller-ID spoofing.

To help combat these new threats, Ahamad and former Ph.D. student Vijay Balasubramanian developed an audio fingerprinting technology that can determine the true source of a phone call. Licensing the technology from Georgia Tech, the two researchers launched a startup company in 2011. Since then, Pindrop Security has been growing quickly and now counts more than 100 employees. (See sidebar story, next page.)

In other groundbreaking work, Ahamad and collaborators from New York University Abu Dhabi and industry recently built the first large-scale telephony honeypot — PhoneyPot — to lure voice-channel villains and study their exploitation techniques.

“Although honeypots are common on the Internet, they present greater challenges in the voice channel,” Ahamad observed. Among these: the expense of obtaining a large, diverse pool of threats that we’ve been dealing with on the Internet side are now showing up in telephony.
About one in every 3,000 calls to a financial call center is from a professional criminal trying to illegally transfer money or obtain credit cards under the guise of a spoofed ID. “Yet with our technology, clients can identify a fraudulent phone call in less than 30 seconds,” said Matt Anthony, vice president of marketing at Pindrop Security, an Atlanta-based startup based on technology developed at Georgia Tech.

Launched in 2011, Pindrop has grown quickly. At the beginning of 2015 employee headcount totaled 70, which increased to 100 by June. By the end of the year, Anthony estimates staff will number 175. The company initially targeted financial institutions, but now clients include retail companies and insurance firms.

Pindrop’s secret weapon is an audio fingerprinting technology that quickly analyzes more than 147 audio features to reveal where a call is really coming from — and what type of device is being used. For example, caller ID may show a call coming from a landline in Topeka, Kansas, but Pindrop can determine it’s really a VOIP line in West Africa.

In contrast to competing technologies such as voice biometrics, which reduce fraud by 10 to 15 percent, Pindrop’s Phoneprinting™ technology catches 90 percent of shysters. “Voice biometrics can validate that the caller is genuine, but it’s not very effective at identifying fraudsters — plus you need a prior recording of the individual,” Anthony explained. “In addition, phone criminals thwart voice biometrics by making so much background noise the biometrics become useless.”

Pindrop’s technology not only catches crooks but also enables call centers to give bona fide customers a better experience. “We score every phone call from 1 to 100,” Anthony said. “If you’re above 60, we assume you’re a bad guy, and the customer rep deals with you appropriately. Yet if you score below a certain number, then the representative can spend less time asking for authentication and resolve your issue faster, which saves time and money.”

Pindrop Security

NEW TECHNOLOGY USES AUDIO FINGERPRINTING TO THWART PHONE FRAUDSTERS

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Phone numbers and routing calls, determining how best to engage callers to reveal their real agendas, and adhering to telephone recording laws.

Ahamad’s team obtained more than 39,000 phone numbers from a cloud-based telecom service provider to construct PhoneyPot. Over a seven-week period, they received 1.3 million unsolicited calls from 252,621 unique sources, and analysis of the calls revealed several abuse patterns, including debt collection, telemarketing, and DDoS attacks. Among trends, the researchers found that older phone numbers attracted more calls than newer ones.

The researchers presented a paper on PhoneyPot at the Internet Society’s 2015 Network and Distributed System Security Symposium in February. This paper, which outlines how to construct a successful telephony honeypot, won a distinguished paper award. (Several telephony honeypots now operate around the globe to collect intelligence on telephony attacks.)

Moving forward, Ahamad and Manos Antonakakis, an assistant professor in the School of Electrical and Computer Engineering and an adjunct faculty member in the School of Computer Science, are now studying an even newer phenomenon: cross-channel attacks.

Cross-channel attacks combine resources from both telephony and Internet channels. For example, a text message may trick smartphone owners into clicking a link that causes excessive charges on their phones — or lure them to a bogus website where they are conned into inputting credentials.

“This is a mutation of online abuse that now reaches our mobile devices,” Antonakakis said. “And it’s quite successful. Because mobile devices are smaller, you’re less likely to notice something fishy about a domain name or the method itself.”

Sponsored by the NSF, the research aims to gain situational awareness and develop techniques to mitigate attacks. “In addition, we want to understand how intelligence available from one channel can help us defend the other channel,” Ahamad said.

MEASURING NETWORK SECURITY

Earlier this year Antonakakis launched the Astrolavos Lab, which specializes in network security, anomaly detection, and data mining. Among recent milestones, the researchers have created a tool to show how companies’ technology investments have mitigated risk of attacks.

“Our metric solves a large problem in the security community,” Antonakakis observed. “Until now, the only thing available was ethical hackers — consultants who come in and try to attack existing infrastructure and then give their subjective opinion on how resilient the network is.”

Yet by leveraging large datasets and machine-learning techniques, Antonakakis’ team has been able to create an objective methodology that security officers can use to independently evaluate and score network resiliency. Currently they are testing the metric on Georgia Tech’s network.

In other security projects, Antonakakis’ team has been investigating the impact of botnets (networks of Internet-connected computers that are infected without their owner’s knowledge). Looking at the TDSS/TDLA, one of the largest mass infections to hit the online advertising community, the researchers revealed financial damages of more than $650 million. In contrast to one- or two-week snapshots, the team used four years of data from a major North America ISP — marking the first large-scale longitudinal study to measure botnet abuse.

“The extent of the abuse is a key takeaway,” said Antonakakis. “This is not only important for developing network policy and remediation strategies, but also to prosecute the people behind these criminal activities. Judges must be able to see how much damage has occurred.”

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The researchers are now creating a standardized unit to measure botnets and other mass infections — a project sponsored by the U.S. Department of Commerce’s National Institute of Standards and Technology. “This is important not only to understand the size of the botnet population and their impact, but also to help organizations more effectively prioritize their responses,” Antonakakis explained.

**IoT Integrity**

Currently an estimated 15 billion physical objects use the Internet to exchange data — a number expected to reach 50 billion by 2020. Known as the Internet of Things (IoT), this includes everything from cellphones and smart watches to heart-monitoring implants and home automation.

“Within the IoT community, embedded controllers are a growing security concern, especially those used in industrial control systems (ICS) to control physical processes. “Once locally connected, these devices are increasingly connected via the Internet,” said Lee W. Lerner, a researcher at GTRI’s CTISL. “Their security lags behind general computing devices like laptops, and Internet access makes them much easier to find and attack.”

Fallout depends on the specific device. “ICS environments are a primary concern from a nation-state level because that’s how attackers can harm critical infrastructure, such as energy utilities or manufacturing processes — things that can have devastating economic impact,” Lerner said, pointing to the StuxNet worm that infected programmable logic controllers in Iranian industrial facilities in 2010.

In response, GTRI is developing novel inspection tools and techniques to determine how trustworthy embedded controllers might be or if anything malicious has been inserted in their design. Another IoT initiative takes a proactive approach to security by building in integrity from the get-go.

In collaboration with Virginia Tech, GTRI has developed an architecture that provides process resilience against cyberattacks on physical targets. Known as Trustworthy Autonomic Interface Guardian Architecture (TAIGA), the design ensures stability regardless of what else may be happening within a computational system. “The idea is to develop a root of trust — a core computational component that will always perform the way the designer intended without any additional functionality,” Lerner explained. “It acts as a last line of defense, much like interlocks on mechanical equipment.”

Now that TAIGA has reached a level of maturity, researchers are developing lab experiments to demonstrate the design. Among these is a Johnny 5 robot, whose IP address will be accessible over the Web, and whose control system individuals will be encouraged to try to hack. Another experiment will feature a motor in an industrial control system that receives commands from higher-level units. GTRI visitors will be able to see how the motor remains protected under attack.

Beefing up security on embedded controllers is a different ballgame from protecting networks, data encryption, or how servers connect to devices. “We’re working at the leaf node — the computational component of the system that directly interfaces with physical processes or people,” Lerner explained. “We’re focused on information that is configuring the hardware or implementing control algorithms on these devices.”

**Offline Hazards**

Even when computers and smartphones are not connected to the Internet, they can be vulnerable to hackers due to the low-power electronic signals they emit. These “side-channel signals” include electromagnetic emissions, acoustic emissions, and power fluctuations, which can be measured up to a few yards away by a variety of spying devices. Electronic eavesdroppers can learn passwords and encryption codes — and even see what someone is writing in an email or Word document.

“Although side-channel emissions is not an epidemic, they have been abused — it’s just not as well known as hacking a computer,” said Alenka Zajic, an assistant professor in the School of Electrical and Computer Engineering who is investigating the phenomenon along with Milos Prvulovic, an associate professor in the School of Computer Science, and graduate student Robert Callen.

Among other milestones, the team has developed a way to measure the strength of side-channel emissions. In a test on three different laptops, the researchers found the largest signals occurred when processors accessed off-chip memory.

“It’s impossible to eliminate all side-channel emissions, so the idea is to determine which ones cause the largest threats and try to muffle them,” Zajic explained.

Building on this earlier work, the researchers are now developing algorithms to quickly evaluate spectral patterns and find system vulnerabilities in the frequency domain. For example, in one experiment, the researchers determined that the loudest side-channel emissions were generated by voltage regulators, memory refresh activity, and DRAM clocks. The research is sponsored by NSF and the Air Force Office of Scientific Research (AFOSR).

“What distinguishes our research is that we’re looking beyond breaking encryption to monitor software activity,” Zajic said. “We’re building analytic tools to understand why and how side-channel emissions occur. Once we have answers, they can be used in many ways — from protecting computers so they don’t leak to exploiting the side emissions to help with program debugging.”

T.J. Becker is a freelance writer based in Michigan. She writes about business and technology issues.
MULTITASKING MOTHs

How the hawkmoth tracks flowers in the dark has surprising applications for small airborne robots

BY JOHN TOON
PHOTOS BY ROB FELT
How the hawkmoth tracks flowers in the dark has surprising applications for small airborne robots.
to see things in the dark, but what if you also had to hover in mid-air while tracking a
flower moving in the wind? That’s the challenge the hummingbird-sized hawkmoth
(*Manduca sexta*) must overcome while feeding on the nectar of its favorite flowers.

Using high-speed infrared cameras and 3-D-printed robotic flowers, scientists have
now learned how this insect juggles these complex sensing and control challenges — all
while adjusting to changing light conditions. The work shows that the creatures can
slow their brains to improve vision under low-light conditions — while continuing to
perform demanding tasks.

What the researchers have discovered could help the next generation of small flying
robots operate efficiently under a broad range of lighting conditions. The research,
supported by the National Science Foundation and Air Force Office of Scientific
Research, has been reported in the journal *Science*.

“There has been a lot of interest in understanding how animals deal with chal-
lenging sensing environments, especially when they are also doing difficult tasks like
hovering in mid-air,” said Simon Sponberg, an assistant professor in the Georgia Tech
School of Physics and School of Applied Physiology. “This is also a very significant
challenge for micro air vehicles.”

Scientists already knew that the moths, which feed on flower nectar
during the evening, use specialized eye structures to maximize the amount of
light they can capture. They also sur-
mised that the insects might be slow-
ing their nervous systems to make the
best use of this limited light. But if they
were slowing their brains to see better,
wouldn’t that hurt their ability to hover
and track the motion of flowers?

Sponberg and colleagues at the Uni-
versity of Washington studied this ques-
tion using high-speed infrared cameras
and nectar-dispensing robotic flowers
that could be moved from side to side at
different rates. While varying both the
light conditions and the frequency at
which the flowers moved, the research-
ers studied how well free-flying moths kept their tongues — known as proboscises — in
the flowers.

They also measured real flowers blowing in the wind to determine the range of
motion the insects had to contend with in the wild.

“We expected to see a tradeoff with the moths doing significantly worse at tracking
flowers in low-light conditions,” Sponberg said. “What we saw was that while the moths
did slow down, that only made a difference if the flower was moving rapidly — faster
than they actually move in nature.”

In the experiments, the moths tracked robotic flowers that were oscillating at rates
of up to 20 hertz — 20 oscillations per second. That was considerably faster than the
two-hertz maximum rate observed in real flowers. Because the moths’ wings beat at a
rate of about 25 strokes per second, they had to adjust their direction of movement with
nearly every wing stroke — a major sensing, computational, and control accomplishment.

“This is really an extreme behavior, though the moth makes it look simple and ele-
gant,” Sponberg said. “To maneuver like this is really quite challenging. It’s an extreme
behavior from both a sensory and motor control perspective.”
Simon Sponberg, an assistant professor in Georgia Tech’s School of Physics and School of Applied Physiology, holds a hawkmoth being used in his research. In the wild, the hummingbird-sized insect flies during the evening.
In the natural world, light intensity varies 10 billion-fold from noon on a sunny day to midnight on a cloudy evening. Operating in that range of luminosity is a challenge for both moths and the sensors on human-engineered systems. Understanding how natural systems adjust to this range of conditions could therefore have broader benefits.

“If we want to have robots’ or machines’ vision systems that are working under this broad range of conditions, understanding how these moths function under these varying light conditions would be very useful,” Sponberg said.

To gather the data reported in this paper, the researchers used a robotic flower able to move in one dimension. Recently, they used the actuator devices from a 3-D printer to build a robotic flower that moves in two or three dimensions, providing an additional challenge for the moths. In future research, Sponberg and his colleagues hope to incorporate their robotic flower into a low-speed wind tunnel to study the moth’s aerodynamic functions—including the role of wing vortices and the flow-effect interaction of the insect’s wings with the flowers.

The hawkmoth has been studied extensively to investigate the fundamental principles governing the development and function of its neural system, noted Tom Daniel, a professor in the Department of Biology and co-director of the Institute for Neuroengineering at the University of Washington. Daniel’s research group has experimentally characterized the response of flying hawkmoths using a sensory input comprising the linear sum of sine waves.

Sponberg’s paper, based largely on data he collected at the University of Washington as a postdoctoral researcher, extends application of the “sum of sines” approach, Daniel said.

“Simon’s work took the formal methods of control theory to dissect out how neural circuits adapt to vast ranges of luminance levels,” he explained. “By looking at the time delays in the movement dynamics of a freely flying moth — interacting with the input of a robotically moved flower — Simon was able to extract the luminance-dependent processing of the moth’s central nervous system.”

Human engineered devices must often operate at various speeds and in different environments. Seeing how well an animal with a tiny brain is able to track complicated movements and adjust its performance to different light levels was a surprising result of the work, Sponberg said.

“This was an interesting example of how an organism can tune its brain to maintain its ability to gather food,” he added. “The moths do suffer a tradeoff by slowing their brains, but that tradeoff doesn’t end up mattering because it only affects their ability to track movements that don’t exist in the natural way that flowers blow in the wind.”

John Toon is director of research news at Georgia Tech and editor of Research Horizons magazine. He has been writing about Georgia Tech research and economic development activities for more than 30 years.
Involving Georgia Tech students in developing creative solutions to technology challenges is one of the major reasons why corporations are locating innovation centers in Technology Square.

Story by Péralte C. Paul
Photos by Rob Felt
when connecting your smartphone or tablet to the Internet from your friends’ homes is as seamless as doing the same from your own domicile or even motor vehicle, you might have Ceara Byrne to thank.

Byrne, who is slated to begin her doctoral studies in human-centered computing this fall at Georgia Tech’s School of Computer Science, is working on just such a project at the AT&T Foundry™ in Technology Square.

The South Texas native has been working at the Foundry since November 2014 as part of a 10-month-long internship at the telecommunications giant’s innovation center. There, she and other Georgia Tech students tackle challenges and look for solutions that AT&T can take to the marketplace.

The students are not only tasked with coming up with creative solutions to real-world challenges, but they’re also expected to identify other issues and come up with possible solutions.

“There’s nothing like being thrown into a project where they say ‘you will figure it out,’” Byrne said. “There’s been a lot of trust placed in me, and I think their experience with Georgia Tech students has been so positive because most of us do figure it out.”

AT&T is one of several major corporations that have opened innovation centers at Technology Square in recent years — in company with ThyssenKrupp, Panasonic, Coca-Cola Enterprises, and The Home Depot, among others. They have done so seeking to tap into a vibrant network of startup entrepreneurs and a culture of innovation and collaboration.

And while the nature of their respective industries is different, there is one key common driver for the companies’ presence at Technology Square: Georgia Tech students.

AT&T’s effort is part of its move toward being a technology company, not just a telephone business, said Joanie Twersky, the Foundry’s senior marketing manager. A component of that strategy is tapping into Georgia Tech’s students, who are not only potential employees, but also the next generation of leaders and customers.

“Part of the Foundry’s purpose is to embody openness and collaboration,” Twersky said. “The purpose is to make AT&T part of the Tech ecosystem here in Atlanta, and the talented ideas and energy that the students from Tech bring to the Foundry are very much in line with that vision.”

‘FRESH PERSPECTIVE’

The innovation centers that have clustered in Technology Square are decidedly different from research and development units typically found at a company’s corporate headquarters.

Sure, like corporate R&D departments, there’s a lot of study, analysis, and testing out of new ideas and solutions. But because they aren’t embedded at headquarters, there’s more flexibility and opportunity for creative problem solving.
"THEY TRUSTED US A LOT WITH OUR WORK. YOU'RE NOT JUST AN INTERN."

Samer Mabrouk, a Georgia Tech electrical engineering major, has worked on a variety of challenging projects at the Panasonic Automotive Systems innovation center in Technology Square. The students are given considerable latitude to develop innovative solutions to the problems they address.
“We deliberately said we wanted to break out of our corporate grind and process to create a group in this environment specifically to get out-of-the-box thinking,” said Thomas Felis, vice president of ThyssenKrupp Elevator Americas’ research innovation center at Technology Square.

The center, which opened a little more than two and a half years ago, is focused on the ideation stage of innovation. Being in Technology Square and embedded in its startup entrepreneurial culture helps support that core focus because most of the projects are on a three- to six-month cycle.

That quick pace is part of the appeal for the company wanting to be in a community of students, Felis said.

“We want to have that outside, fresh perspective beyond the corporate process and toolset, which can really hamper creativity,” he said. “Every project we do here has the potential to be commercialized. They become part of our portfolio used to evaluate new technologies and solutions for our customers.”

The innovation centers stress that their student interns are working on real-world projects that have potential to be implemented or commercialized. That was something that appealed to Andrew Evert, a rising senior pursuing a mechanical engineering degree at Georgia Tech.

“It’s definitely exciting,” said Evert, one of several interns hired by ThyssenKrupp Elevator for its summer program. “The possibility that something I’m working on could be used in thousands of elevators across the world for testing or analysis makes it interesting. I’m hoping to one day get into an elevator and see something that I’ve worked on. That would be really cool.”

One of the projects he’s working on is creating code for algorithms that control various aspects of the elevator rider’s experience. For instance, these algorithms address vibrations of the moving car as it travels between floors.

It’s challenging work, Evert said, but fun.

“It’s like a puzzle or game to try and take a task that you can easily say in words and then make a computer do it,” Evert said. “Specifically, this algorithm is multiple scripts and functions, some of which are almost a thousand lines long. They all work together to accomplish a task, so it’s kind of interesting and fun to fit it all together.”

Interns are given some parameters with the projects they are given, but not so much direction that they can’t show the full measure of their potential. That’s by design, said John Avery, a Georgia Tech alumnus who is engineering group manager at Panasonic Automotive Systems’ innovation center.

“Much of what’s done at the innovation center is centered on proof-of-concept development and the creation of software and hardware prototypes for clients.

“It’s real work; it’s not make work,” Avery said. “The stuff that they’re working on does get shown.”

Last year, for example, Samer Mabrouk, an electrical engineering major slated to graduate in December, worked on a prototype design for a presentation Panasonic was planning for an auto show and exhibition.

“We had to program and design the boards ourselves,” said Mabrouk, whose focus is embedded systems. As part of that work, he had to code and design buttons for a steering wheel and dashboard prototype and he also worked on creating the software for another board to use in testing.

This year, Mabrouk is working on a project designed to create a clearer auditory experience when signals are transmitted through wires between auto speakers and amplifiers.

“They trusted us a lot with our work. You’re not just an intern,” Mabrouk said. “If you can come up with something new, if you can make it look better, if you can make it work, they give you more space to do that.”

The students, who come to Panasonic via Georgia Tech’s co-op program, are paired up with mentors who give them guidance. Panasonic also gets to see how they might fare as potential full-time employees after graduation.

“They have to be able to figure out things that aren’t specified,” Avery said. “At the end of every semester we have a presentation day where they present to the senior management on what they’ve been working on for the previous semester. It’s a chance for them to take credit and ownership for what they’ve been working on.”

PUSHED BEYOND COMFORT ZONES

Students are also challenged to stretch their skills into areas where they might not have as much experience.

Pooja Srikrishnan, for example, said most of her projects had focused on hardware issues before she joined Panasonic as a co-op student this summer.

Now Srikrishnan, who is pursuing her master’s degree in electrical and computer engineering, is working on more software-related projects, such as a modular embedded initiative. It’s a customized hardware and software platform for Panasonic’s infotainment systems.

“Working on more system-level software that’s closer to the operating system is very challenging,” she said. As part of her project, she’s working with a cross-functional team whose members are on the software side.

“It’s a good learning experience, and I probably could not have gotten better mentors in this field because this skill set is something that every big company is going to expect you to have, but no one is going to teach you to do that.”

At the onset of the project, she was focused on correcting minor bugs in the systems, but now she is looking to implement a new feature and examining if the software will allow it to work or not.

“I think that having software as a skill set for a hardware person is just going to open up opportunities,” Srikrishnan said. “It lets you have some sort of experience where you say, I might
Co-op students Jacques Florence and Pooja Srikrishnan are expanding their skills by tackling challenging software and security projects at the Panasonic Automotive Systems Innovation center in Technology Square. The students, both working on advanced degrees at Georgia Tech, are contributing to different aspects of the same project.

not be a software guy, but I can transition, I can jump from role to role. It’s all a learning experience.”

One of her co-op colleagues, Jacques Florence, a doctoral student pursuing an electrical engineering degree, is assigned to the same modular embedded project, but he is tasked with security. His specific assignment is looking at integrating security between consumer and automotive electronics.

The challenge, Florence said, is that consumer electronics technologies have shorter development cycles than their motor vehicle counterparts. The idea is to develop a device that could update those motor vehicle electronics and do so securely.

“I feel like I’m doing something meaningful.”

“I feel like I’m doing something meaningful. I do. I can make my own design choices, and I learn a lot,” Florence said. “I feel like I’m doing something meaningful. I will have an impact on their products and on the future of automotive electronics.”

But beyond giving interns the opportunity to work on meaningful projects, innovation center leaders want them to seriously consider Atlanta as a place to build a career in technology.

Twerksy, of the AT&T Foundry, said she thinks the strategy is working and perceptions are changing.

When the Foundry first opened in 2013, she said, it received a handful of applications from students for its internship program. Applications to work at the Foundry have tripled since then.

“Long-term, that will hopefully mean being able to keep more talent here in Atlanta,” Twerksy said. “Not losing talent to other states, but keeping them right here in Atlanta where we need it.”

Péralte Paul is a business and technology writer in Georgia Tech's Institute Communications and the Enterprise Innovation Institute. He's a former newspaper reporter.
Microfluidic
(MI-KRÖ-FLÜ-'I-DIK)

Microfluidic devices manipulate small volumes of fluid, moving, mixing, separating, or otherwise processing liquids in structures that are built at the micron scale. Microfluidic technology provides the basis for lab-on-a-chip applications. At Georgia Tech, researchers are developing a wide range of uses for microfluidic technology. An article in this issue describes a microfluidic device designed to capture clusters of cancer cells from blood samples.

ECMO Machine
PAGE 28, SMALL WONDERS
Extracorporeal Membrane Oxygenation (ECMO) machines help seriously ill patients recover by temporarily taking over the work of the lungs and sometimes the heart. In patients who require this assistance, their blood is circulated through the machine, where carbon dioxide is removed and oxygen needed by the body is restored. At Georgia Tech, researchers are working with colleagues at Children’s Healthcare of Atlanta to develop improved tubing connectors designed to minimize the risk of blood clotting in young patients using the machines.

Voice Phishing
PAGE 39, PREVENTING THE CLICK UP
Voice phishing is the use of fraudulent schemes to gain access to private personal and financial information, such as credit card or bank account numbers, via the telephone system. Voice phishing is also referred to as “vishing.” This form of attack sometimes combines both telephone and Internet fraud. At Georgia Tech, security researchers are countering voice phishing fraud perpetrated against banks and other major organizations using audio fingerprinting, which allows them to determine the true source of a phone call and the type of device from which it is originating.

Hawkmoth
PAGE 42, MULTITASKING MOTHS
Hawkmoths are a family of insects distinguished for their excellent flying abilities. Some hawkmoths feed on the nectar of flowers, hovering in mid-air during evening hours and tracking the movement of flowers with rapid changes in direction. These hawkmoths, which can have wing-spans as broad as 10 centimeters, are often mistaken for hummingbirds, which feed on flower nectar during daylight hours. At Georgia Tech, hawkmoths are being used to study the challenges of vision and flight control under low-light conditions, issues relevant to micro-air vehicles and other small flying robots.
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