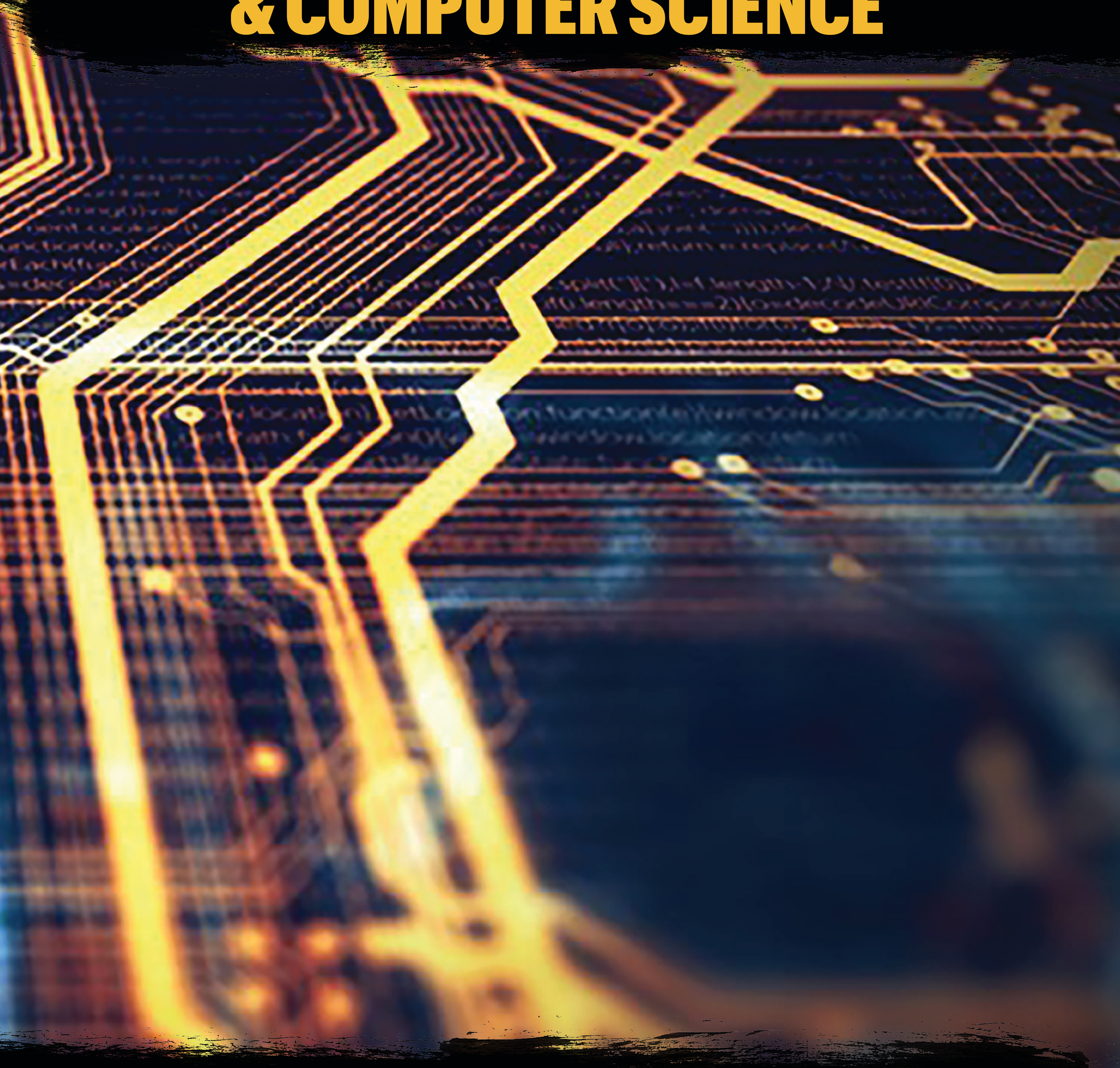
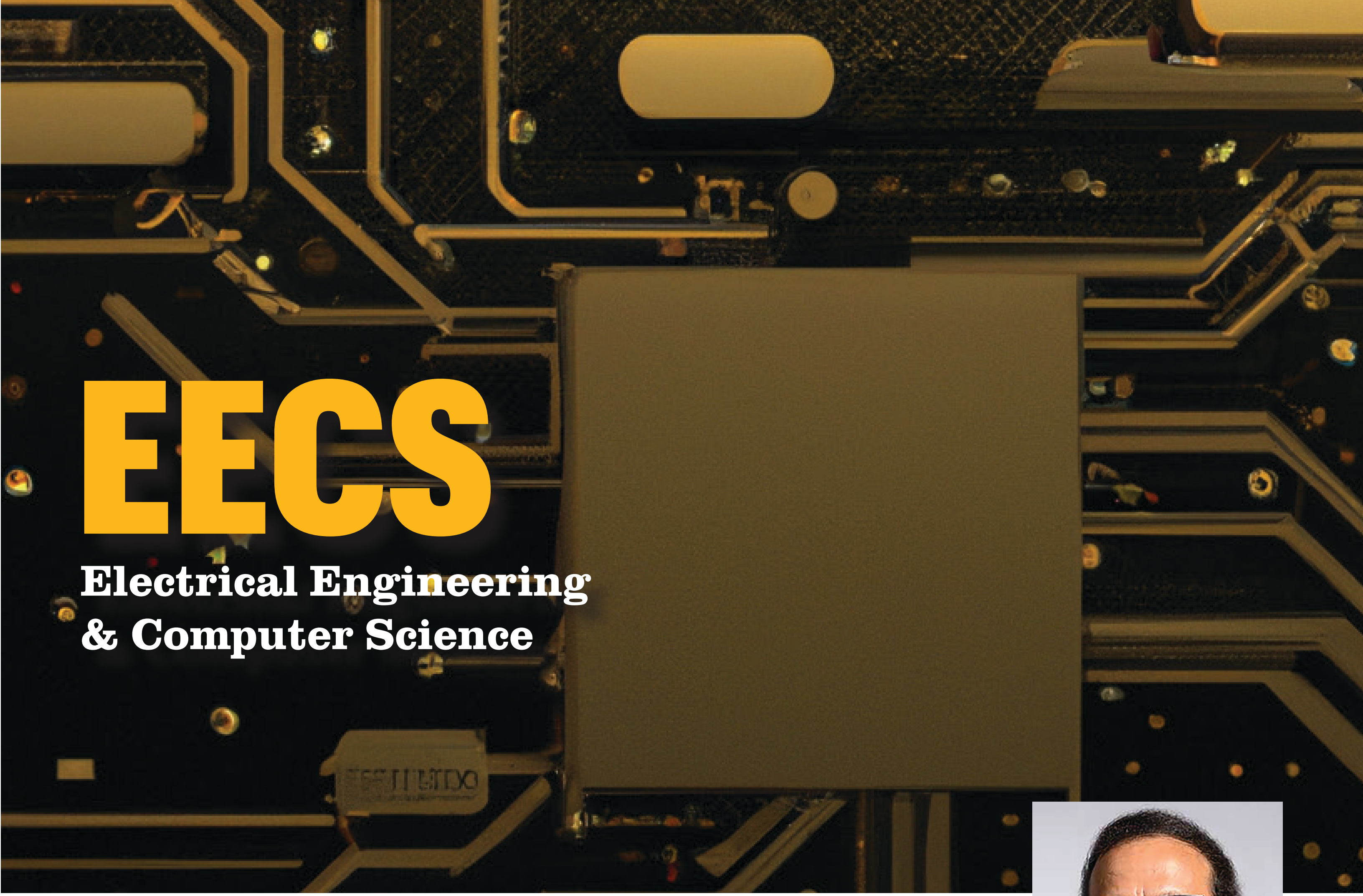
2022 ANNUAL REPORT

ELECTRICAL ENGINEERING & COMPUTER SCIENCE



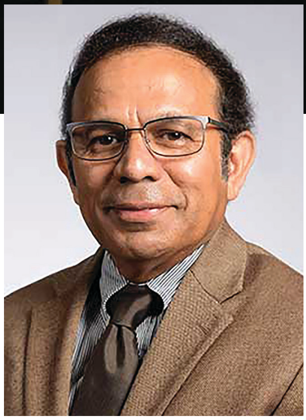
College of Engineering
University of Missouri

What's Inside



EECS

Electrical Engineering & Computer Science



Syed Kamrul Islam

Chair,
Electrical Engineering
and Computer Science

The Department of Electrical Engineering and Computer Science leads Mizzou Engineering when it comes to research activities. This past year, we had nearly $12 million in committed research awards, and more than $13 million in expenditures by shared credit. These awards support the investigation and advancement of areas such as artificial intelligence and machine learning, cybersecurity around IoT, geospatial big data and healthcare technology. Many of the discoveries we've made over the past years have now been patented and are being incorporated into day-to-day life.

We were thrilled to welcome five new faculty members to EECS this past fall and look forward to their achievements at Mizzou. Our faculty continue to earn accolades for their work. We added another faculty member to our growing list of Curators' Distinguished Professors this past year, added another AIMBE fellow to our roster and celebrated Faculty Alumni Award and MU mentorship award recipients.

We celebrated student and alumni successes this past year, too. Congratulations to Michael Melton, Esquire, BS EE '81, JD '84, for receiving a 2022 Missouri Honor Award and to Lorraine Stipek, BS EE '86 for receiving a Citation of Merit Award, both of which were presented in March. I invite you to take a few moments and explore more about the exciting activities happening in EECS at Mizzou.

Ushering in a New Era of Artificial Intelligence

A Mizzou Engineering team is hoping to lead artificial intelligence (AI) into a new era by foregoing real-world data in favor of simulated environments.

"State-of-the-art AI is based on a 70-year-old combo of neural networks and supervised learning. This approach is flatlining, in part, because it's not scalable," said Derek Anderson, associate professor of electrical engineering and computer science. "We are at a technological convergence point where simulation software, content and computing resources are available and can be used to make photorealistic computer-generated imagery that can fool a human and can be used to train AI."

Artificial neural networks — the current reigning champion of AI — were first discovered in the 1940s, but at the time researchers couldn't do much with them partially due to a lack of computing resources and access to training data. Technological advances over the last decade have made it possible to now train limited functionality neural networks on a specific domain. However, a major bottleneck remains, in that it's difficult to get large amounts of diverse, accurately labeled data to train general-purpose AI.

First, getting AI to recognize an object currently requires someone to collect and label thousands or millions of images to feed into a network, a process referred to as supervised learning. While it's possible to get a lot of data from video footage captured by a drone, someone still must go through each frame and label objects in the image before a computer can learn to detect them. While there are alternative emerging theories, state-of-the-art object detection and localization needs labeled data.

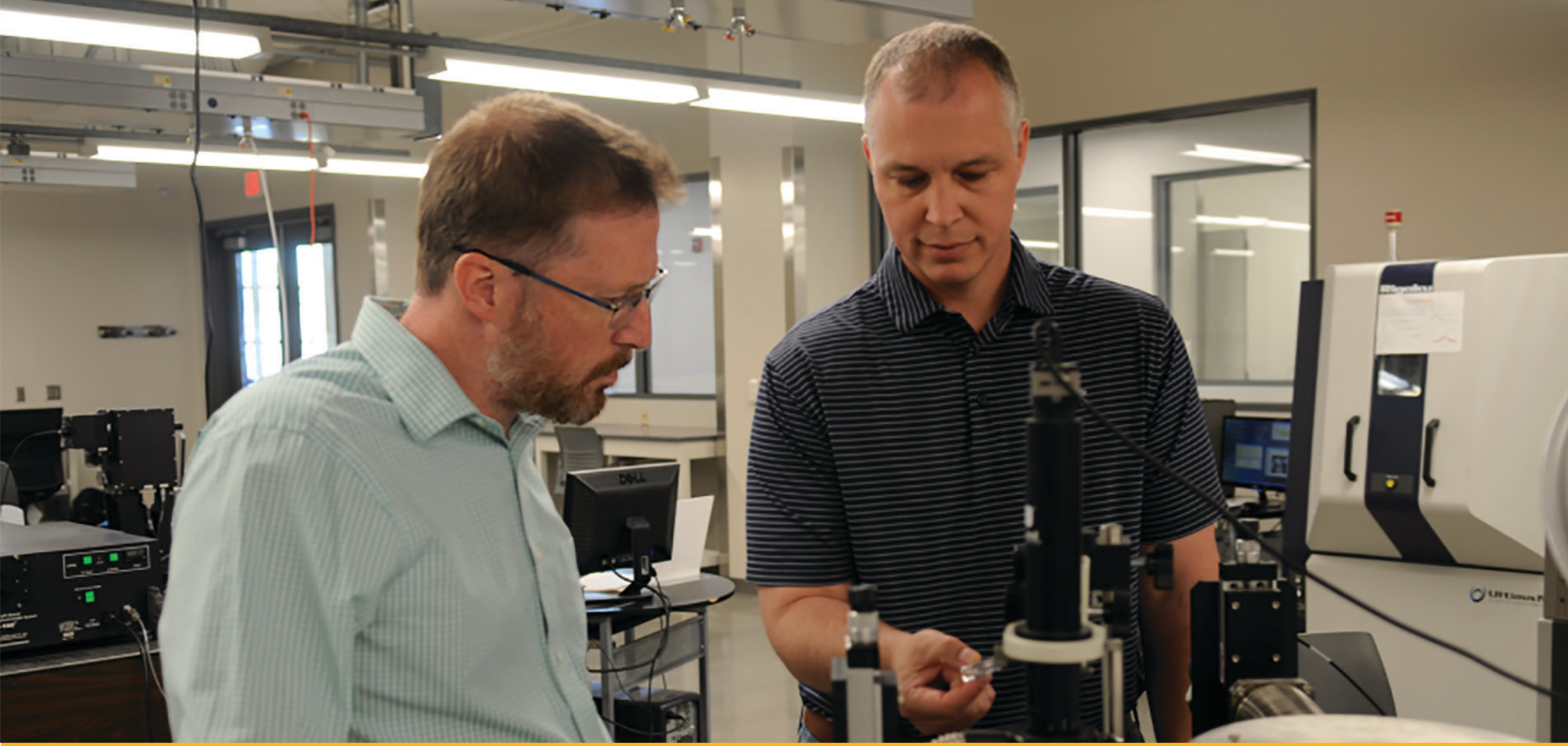
The other problem with real-world imagery is that it doesn't provide "ground truth," or data that is completely true. Labels are spatially ambiguous, material properties are not always recorded, and shadows are not annotated. Without that ground truth, researchers do not know where AI works or breaks.

"Getting data from the real world is problematic," Anderson said. "We collect a lot of data we don't know much about, and we're trying to use that to train AI. It's not working."

These are a few of the reasons why Anderson's team in the Mizzou Information and Data Fusion Laboratory (MINDFUL) have begun using gaming components, instead.

In a simulated world, researchers can manipulate environments to train the computer to recognize an object or learn a behavior in any number of scenarios. And they've found that they can collect and label data in weeks as opposed to years.

"Deep learning is state-of-the-art right now in computer vision, but in the real world, you get poor or no ground truth for a lot of the things we want to know," said Brendan Alvey, a PhD candidate working in the MINDFUL Lab. "And it takes a lot of time and money to collect and label the data. Simulation makes it a lot easier."



Integrating AI into Material Development

An EECS team at Mizzou is using artificial intelligence to "work smarter, not harder."

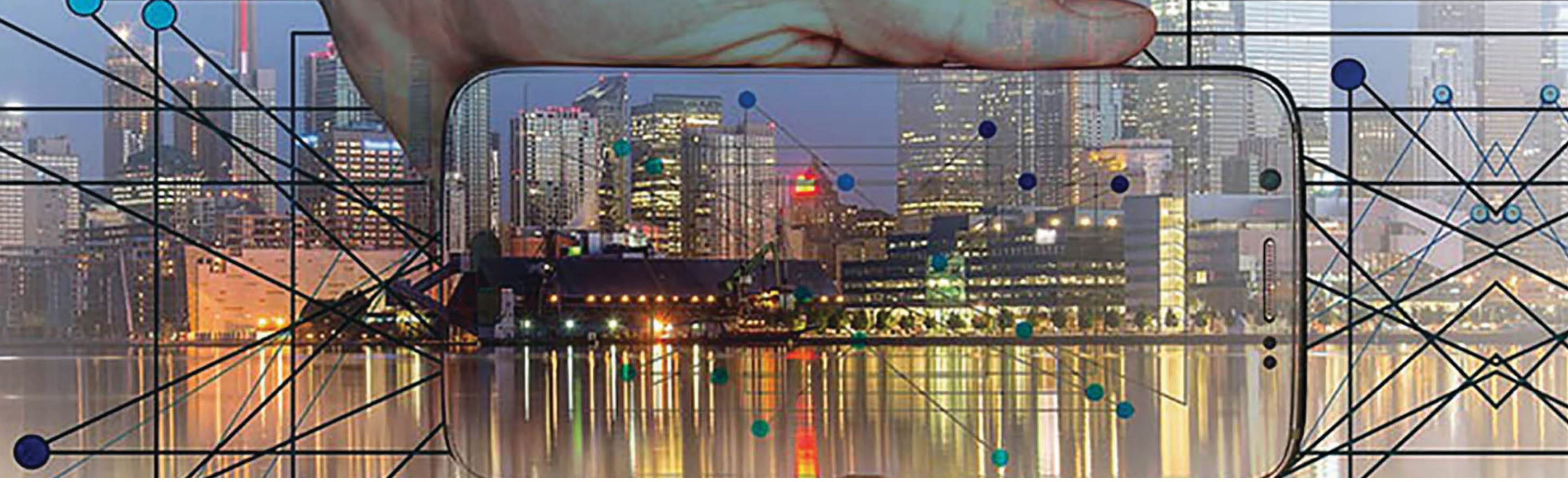
Supported by a two-year, $4.875 million grant from the U.S. Army Engineer Research and Development Center (ERDC), Associate Professor Derek Anderson and a collaborator, are developing a theoretical framework around "explainable AI" to describe how the next-generation of AI can be integrated into the innovation process for designing new and existing materials — while also securing the trust of humans along the way.

One of the goals is finding a way to accelerate the discovery process by helping make better quality materials in a shorter period of time. To do this, the team is starting with how to integrate AI and machine learning into the process.

"One of the more pressing challenges in the development of new materials, or optimization of existing materials, is the time required by the processing and characterization steps," said Matt Maschmann, an associate professor in mechanical and aerospace engineering. "Making discoveries takes quite a bit of time and money. For instance, each step of a process may take a day or longer to accomplish. Therefore, in a traditional laboratory environment, scientists will repeat a process multiple times in an attempt to obtain a specific structure or property for a material guided by intuition and previous knowledge. However, if we can introduce machine learning algorithms and AI into the process, it could drastically reduce the time needed to obtain material properties of interest. My hope is this project will greatly increase the rate of discovery for developing materials while also increasing our fundamental understanding of these processes."

While Maschmann focuses on the integration of AI and machine learning into materials processing, Anderson, an associate professor of electrical engineering and computer science, is working alongside him to help make AI more intelligent by determining how to better integrate human knowledge into the artificial world. For instance, Anderson said while material scientists, chemists and physicists have vast knowledge about the physical world, most AI and machine learning do not yet share that same level of intelligence.

"Therefore, we're looking at how do we design the next-generation of AI and machine learning to take advantage of the existing knowledge that people have," Anderson said. "Then, we want to use that knowledge to intelligently grow AI to be able to design smarter materials. While our efforts are focused on the 'explainability' side, and helping scientists and domain experts understand how these processes work, we hope to make AI smarter for everyone's benefit in the process."



Developing Smart Security for Smart Devices

Modern society is inundated with different types of smart devices designed to make people's lives easier, from virtual assistants to household appliances and health-monitoring devices — not to mention smartphones. While each device has some amount of built-in security to help combat the threat of cyberattacks, the increased prevalence of these devices in recent years has created an industry-wide need for a new, "smart" approach to protect all smart devices from cyberattacks, since the mass-production of these devices by different manufacturers prohibits them from being managed manually for security purposes.

In response to this need, Greg L. Gilliom Professor of Cyber Security, Prasad Calyam and his team received a two-year, approximately $500,000 cybersecurity research grant from the National Security Agency (NSA) to develop a flexible, add-on security feature that allows different types of smart devices to intelligently learn from past cyberattacks while having a minimal need for direct human intervention. Their approach will also incorporate a collaborative network among the developers of these devices for sharing solutions in order to better respond against potential attacks in the future.

"It's plausible that these devices can be compromised and used to launch large-scale attacks," said Calyam, who is the principal investigator on the grant. "For instance, we have seen hackers take control of people's home-based internet routers to launch massive attacks against major internet providers in recent years. Our challenge is developing a way to automate the process of securing smart devices, because it is not practical to do so manually at the large scales of deployment we are seeing in homes, businesses and government — there are no screens that can display a security problem or prompt a user to update the software on many of these devices."

Calyam, who also directs the Center for Cyber Education, Research and Infrastructure at Mizzou, said commercial developers do not yet have the security techniques needed to keep up with the changing nature of cyberattacks, which furthers the need for this type of research and related technologies.

"Each device can use different kinds of security protocols, so determining which is the right approach to protect a device from unauthorized access is not clear because often times we don't fully understand the changing threat being presented, and we don't learn how a particular security approach will be able to handle that changing threat," Calyam said. "Having too much or too little security is not ideal in response to a threat, so the key aspect in our approach is being able to use machine learning techniques to customize the response, while coupling that with use of trusted threat intelligence platforms based on blockchain to adapt to the need presented by the attack. We believe our approach will help make smart security better for smart devices."

The grant, "Automated and Intelligent Threat Detection and Defense of Future IoT Edge/Cloud Systems," was awarded by the National Security Agency's National Centers of Academic Excellence in Cybersecurity, through their Cybersecurity Research Innovation 2021 Program. Calyam is collaborating with Jianli Pan, an associate professor in computer science at University of Missouri-St. Louis, who is a co-principal investigator on the grant.

Improving Mixed-Reality Environments

Mixed reality platforms immerse users into virtual environments that can be used to map out drone flights, simulate aircraft training, assess traffic in real time and plan infrastructure projects. But before users can fully experience the benefits of a realistic virtual environment, there are some challenges to solve.

A Mizzou Engineering team recently tested the capabilities to create photorealistic renderings for virtual reality (VR) using the Unity game engine software. They discovered that conventional software practices need to be transformed to meet the needs a user might have while accessing these environments. For instance, recreating a scene for a Microsoft HoloLens will require re-tooling to produce a high-quality user experience in a full-scale facility.

Specifically, the team attempted to develop a new software that can create large-scale virtual models in the CAVE on campus. Funded through a National Science Foundation grant, the CAVE (computer assisted virtual environment) consists of adjustable walls, a floor and motion sensors to provide virtual 3D surroundings.

"This was the first paper regarding the CAVE facility that we presented," said Prasad Calyam, Greg Gilliom Professor of Cyber Security and director of the Mizzou Center for Cyber Education, Research and Infrastructure, where the CAVE is located. "We were happy to see it was accepted at an international IEEE conference."

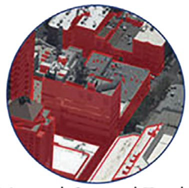
The group specifically looked at 3D modeling of urban cities using aerial images of Columbia, Missouri, and Albuquerque, New Mexico. These images were collected by EECS Professor Kannappan Palaniappan and his team from the Computational Imaging & Visualization Analysis (CIVA) Lab.

The researchers used 3D point clouds that were created from the images, then turned those point clouds into a mesh. In computer graphics, a triangular mesh is the collection of vertices, edges and planar faces that make up a 3D object.

"The idea was how do we make 3D models of cities in immersive environments, which is different from modeling on a desktop scale," Calyam said. "We showed how city scale meshes appeared based on how they are developed from point clouds and how the end user experiences it, either in the CAVE or through the HoloLens." Authors also made specific recommendations on which techniques to use depending on intended applications, such as city planning, gaming or planning drone flights.

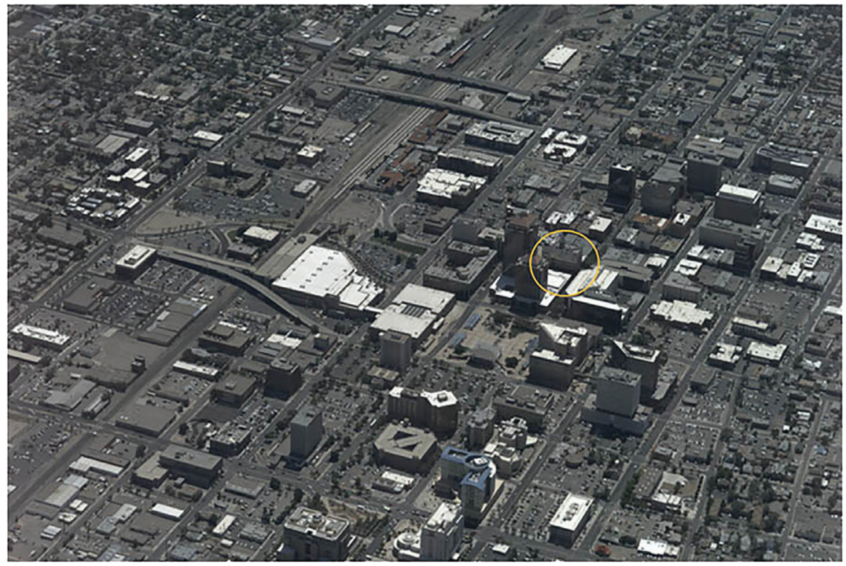
"This paper developed an end-to-end workflow for creating urban scale real-world environments that can be experienced in the CAVE or using the HoloLens," Calyam said. "It was the first to address the entirety of a city-to-synthetic environment pipeline for different applications using city-scale data."

EECS Team Designs Model to Detect Shadows


Manual Ground Truth


Analytical Ground Truth


Original Image



A Mizzou Engineering team has designed a physics-based model to automatically detect shadows in large-scale aerial images — a development that could lead to improvements in self-driving cars, drones and autonomous robotics. The research team published and presented their findings at the International Conference on Computer Vision (ICCV) Workshop on Analysis of Aerial Motion Imagery (WAAMI) last year.

While humans can make sense of shadows, artificial intelligence (AI) cannot easily detect objects in shadows unless it's trained to do so. Currently, some self-driving vehicles compensate for that by using lidar, which sends out laser beams to create three-dimensional representations of the surrounding environment.

"Algorithms aren't as capable as people, so it needs to be able to predict, 'this car, when it drives into a shadow, looks totally different than it does outside of the shadow,'" said Joshua Fraser, an EECS research scientist. "This is where shadow detection comes in. It's expensive to render and figure out where the shadows lie, so the idea is if we can train a neural network to predict the presence of shadows, then we can do it much more efficiently without having to build complete 3D models."

To train the neural network to recognize shadows, the group used aerial images of downtown Albuquerque, New Mexico, and Columbia, Missouri. The data set was unique in that it provided images at an altitude between low-flying drone images and high resolution satellite images, Fraser said. But unlike satellite images that depict scenes looking straight down, the city scaled images were collected from all angles, providing 360-degree representation of cities and more continuous temporal coverage. The team used those images to create accurate 3D point cloud reconstructions of the urban environment that can then be used in a game-engine or similar simulation environment to render shadows, generating accurate shadow masks to train the AI system. They also calculated the solar angles at specific times of day, factoring in not only data from images but also metadata such as latitude, longitude and time zone in order to calculate the sun's position to predict shadows.

"For astronomical calculations, you have to know the time accurately and you have to know the observer's viewing geometry, spherical coordinates with respect to a local coordinate system in order to get the Sun's path on the celestial sphere which varies with date," said Kannappan Palaniappan, EECS professor and director of the Computation Imaging & VisAnalysis Lab.

The research was partially funded by Army Research Laboratory cooperative agreement.

Filiz Bunyak, EECS assistant professor, has used the model and praised the team for helping automate the process

"Shadows are an important aspect of video analytics for detection of objects that will be analyzed and tracked," she said. "The team did a great job developing a physics-based system that gives you exact boundaries of shadows without labor intensive processes."

Engineering Team Devises New Way to Design Particle Accelerators

A Mizzou Engineering team is working to find an alternative way to design particle accelerators, making them easier and more affordable to manufacture for medical and commercial applications.

One reason they're so expensive is that they have to be hand crafted, EECS Professor Scott Kovaleski said. Additionally, they use radiofrequency generators, which require pricey sources of electrons.

Kovaleski and collaborator Matt Maschmann, an associate professor in mechanical and aerospace engineering, believe carbon nanotubes could provide an affordable alternative. Carbon nanotubes, or CNTs, are tiny tubes of rolled carbon.

"If we can move to carbon nanotubes, the manufacturing process starts to look like it does for semiconductors and computers, which obviously have gotten cheaper over time," Kovaleski said. "If we can make those carbon sources of electrons a viable, useful thing, it opens up this opportunity to proliferate that technology and make it more available and more capable."

But first, researchers will need to figure out how to grow the perfect carbon nanotube configuration for the job. Scientists know how to make CNTs in the lab, but they've not yet figured out how to control their properties and behaviors when they grow in mass quantities.

That's where Maschmann comes in. In his laboratory and using instruments in the Materials Characterization and Fabrication facility, part of the MU Materials Science & Engineering Institute (MUMSEI), Maschmann is using both simulated and physical environments to determine what properties a CNT would need to have to best work for radiofrequency generators.

"The whole idea is that we want to generate devices that emit electrons," said Maschmann, co-director of MUMSEI. "In order to do that, you apply a high electric field, high enough to extract electrons from the materials. One of the benefits of CNTs in particular is there is a geometric effect to pulling electrons off of materials. CNTs are very narrow in diameter, and that actually causes a localized electric field enhancement, making it easier to draw electrons off of them."

By looking at CNT growth in both physical and simulated space, the team can experiment with different characteristics more easily, without having to go through physical tests each time. That's important because the team isn't sure yet exactly what properties a CNT needs to possess to best serve this purpose.

"There's a lot of physics and modeling that need to happen," Maschmann said. "We want to make them as efficient as possible with respect to electron emission — so high current, low voltage."

Kovaleski will test Maschmann's CNT samples in an experimental environment to identify the parameters that best perform. Then, partners at Stanford Linear Accelerator Center will test them in the field.

The team outlined the project at the IEEE International Conference on Plasma Science this spring.

EECS Researchers Help Locate Remote Bomas Through Geospatial AI

There's a large swath of land in east Africa populated by homesteads known as bomas. While it's estimated that more than a million Maasai people occupy this area, these bomas are made up of between 10 and 200 occupants, many of whom lack access to health care, education and clean water. The non-profit organization Humanity for Children (HFC) has resources such as mobile health clinics that could help, however some bomas are so remote, the group doesn't know where to find them. That's where EECS at Mizzou Engineering comes in. Keli Cheng, a PhD student in computer science, and Assistant Professor Grant Scott have devised a way to train artificial intelligence (AI) to identify bomas using Google Earth — a tough task for the human eye as the huts blend in with trees and other geographic features. To apply machine learning, researchers manually scanned Google Earth imagery of Tanzania and determined criteria for positively identifying bomas and the fences that surround them.

"We used two types of data to train deep neural networks," Cheng said. "Once the machine learned what bomas look like and what other parts to identify, we used it to rescan our map and get precise locations of bomas."

The work is trickier than it sounds. Satellite images are captured from more than 300 miles above the Earth. That creates massive data sets that are far beyond a human's ability to thoroughly review. That means Cheng had to train machine learning algorithms and apply geospatial AI components to produce maps from the massive collection of imagery, pinpointing exact locations of bomas across thousands of square miles.

Collaborators from the Center for Applied Research and Engagement Systems (CARES) at MU Extension stood up a specialized web mapping interface to deliver the geospatial AI results to HFC.

While the goal was to simply locate these homesteads, HFC President Bob Hansen said the work will have a greater impact. In addition to sending mobile health clinics to diagnose and treat prevalent diseases such as malaria, dysentery and HIV, the organization can now focus on intervention and education.

"When we showed our Tanzania colleagues the map that Mizzou Engineering researchers created by applying AI to the satellite maps, they were absolutely amazed by the number of bomas and their distance from clinics and schools," Hansen said. "We are now taking each of the bomas that the researchers identified and sending our staff to travel there by motorcycle or foot to interview people regarding health and education. By working together, we are creating a demonstration project that can be duplicated in other remote areas, whether they are in Africa or other places around the world." And it demonstrates the power of engineering research.

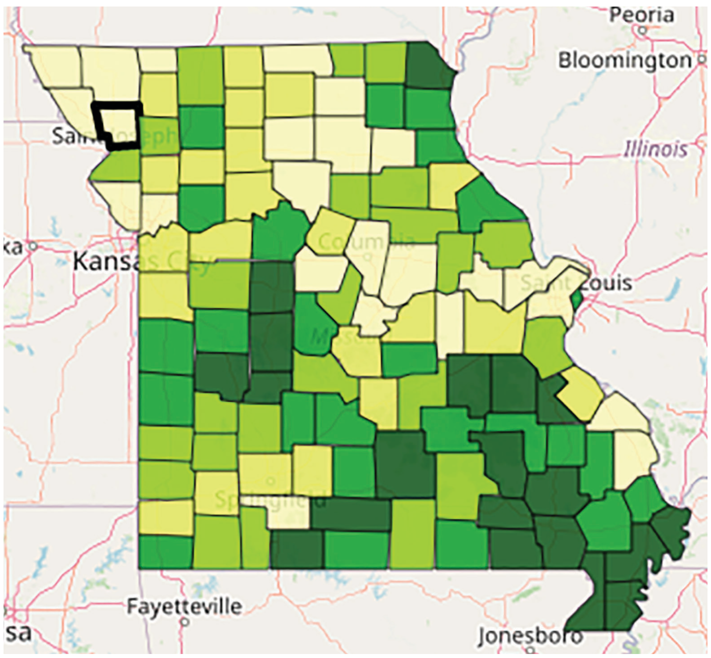
"This is a great opportunity to show how geospatial AI systems can be developed and leveraged to benefit humanity, even half a world away," Scott said. "Keli's work is a wonderful example of how our exceptional graduate students are creating impactful research with international implications."

The research team published their process and results in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. Co-authors include Lincoln Sheets from the Department of Health Management & Informatics, as well as Popescu, a Stanford University undergraduate student who resides in Columbia.

Web Resource Provides Health, Socioeconomic, Other Geospatial Big Data

A Mizzou Engineering team has developed a web resource that allows users to sort and view health, socioeconomic, accessibility and population data by county.

The Geospatial Analytical Research Knowledgebase (GeoARK) was supported by a RAPID grant from the National Science Foundation. Leading the effort is Chi-Ren Shyu, Paul K. and Dianne Shumaker Professor and director of the MU Institute for Data Science and Informatics.



While COVID-19 brought urgency for the implementation of this work, the project has wider applications and allowed researchers to demonstrate how they can turn massive amounts of geospatial data into accessible information within a single user-friendly interface.

Not only does GeoARK provide maps showing where COVID-19 is still a threat in Missouri, it also provides context by showing both compiled and individual potential risk factors. Visitors to the site can select a county and find the population density per square mile, households with those 65 and older, cancer rates, poverty rates, air quality and dozens of other parameters from any given area.

"For the first time, we can really address context, and by addressing context, I think we'll be better able to understand and position society, if you will, with regards to disparity, inequities and other big driving questions," said Tim Haithcoat, Deputy Director of the Center for Geospatial Intelligence at MU. "It's all about different data sets existing in the same space. Ultimately it helps answer complex questions and provides new information that researchers are asking for, policymakers are asking for, and citizens are demanding."

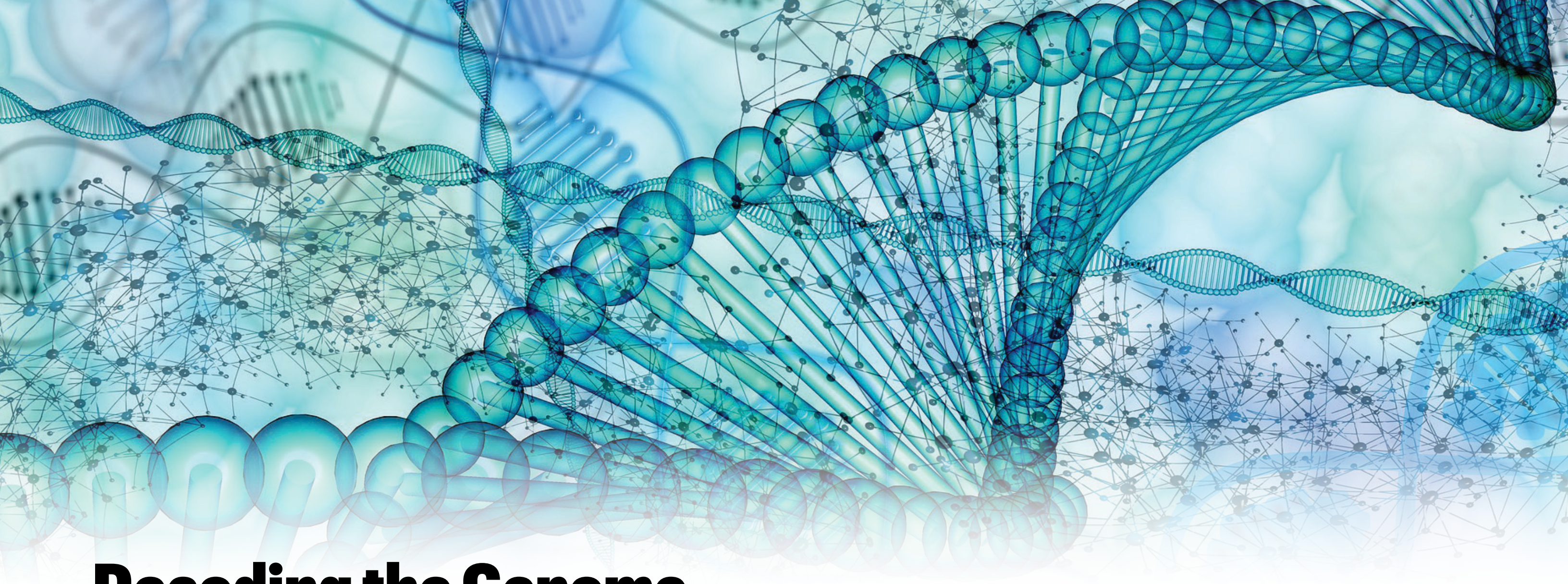
While the funding was specifically for Missouri, Shyu and Haithcoat have collected the same type of data from the U.S. Census, national databases and other public sources. They then associated that data with points located every tenth of a mile in every county in all 50 states.

"To put that into context, it would historically have taken a researcher an entire career to pull together that amount of information," Shyu said.

Knowing information about a population based on where they live is critical to understanding issues other than COVID. For instance, in a separate study, Shyu looked at how income disparities in a community correlate with health problems. In another recent study, the GeoARK system empowered researchers in North Carolina to advance health equity and access using telemedicine. Geospatial data can also help states better respond to other disasters by knowing more about the people in the area who are impacted.

"It's critically important to understand location as the starting point for studying many things, not only in health care, but also social sciences and other areas," Shyu said. "GeoARK can help answer many questions and help researchers and policymakers make decisions based on data. Our system is unique in that it links all of this information together for all stakeholders. They can answer research questions or policy questions that previously could not be answered."

Shyu and Haithcoat, along with co-authors Danlu Liu and Tiffany Young, outlined their geospatial big data ecosystem in a paper just published in the journal JMIR Medical Informatics.



Decoding the Genome

In the future, hospitals and clinics may be able to better manage diseases by pinpointing exactly how an individual's body will respond to treatment. But first, they need a fast, efficient and secure way to analyze DNA, or human genome sequences.

Enter Praveen Rao, an associate professor who has spent the past two years developing a software system for others to analyze and compare genomes more easily. Now, he has a two-year grant from the National Science Foundation (NSF) to expand upon that work.

Human genomes are essentially the blueprint of an individual's biological make-up. Because of their size, decoding that information currently requires massive amounts of computational power and storage and comes with a hefty price tag. But the information is vital to treating, curing and even preventing disease.

"Once you're able to analyze and know which genes are going to be affected, you can predict individual risks and prescribe or design better drugs and treatments based on genetic make-up," Rao said. "This idea of precision health care revolves around taking into consideration not only factors such as demographics but also genetic makeup and lifestyle. The power of biology and genomics combined with the power of computer science can make a huge difference to human life and how we look at and prevent or treat diseases."

In 2020, Rao received a RAPID grant to use NSF's CloudLab testbed to begin to democratize genome sequence analysis. The current grant will allow him to leverage NSF's new FABRIC infrastructure, which is an adaptive programmable research infrastructure consisting of cutting-edge storage, computational and network hardware nodes connected by high-speed optical links.

Within FABRIC, Rao will take advantage of graphic processing units and sophisticated programmable hardware to help accelerate analyzing mass amounts of genome data.

"We're going to show how we can develop new techniques and algorithms to further reduce the computing time it takes to analyze human genome sequences," Rao said. "Then, we plan to integrate that with MU research computing resources. Our eventual goal is that MU researchers and a broader community will be able to use the software platform to do large-scale, whole-genome sequence analysis."

In addition to making the process more accessible, Rao will study ways to ensure these massive data sets are securely processed with minimal computational overhead. Additionally, he is developing ways to perform genome analysis securely and efficiently across FABRIC and CloudLab testbeds.

By the end of the project, Rao will release open source software for large-scale, cost-effective genome sequence analysis. Additionally, he plans to develop new coursework around his findings and conduct a high school camp to introduce younger students to using computer science for genomics.

Research Team Joins C2SHIP Consortium

Mizzou has become the fifth university to join the Center to Stream Healthcare in Place (C2SHIP), a National Science Foundation (NSF) consortium focused on helping patients monitor and manage their health at home.

Marjorie Skubic, a Curators' Distinguished Professor in electrical engineering and computer science, along with co-principal investigators, were awarded NSF funding to lead the effort.

"The goal is to make innovative Care-In-Place technology available to the people who need it most by working with industry partners to accelerate commercialization," Skubic said. "Our aim is to give people options in how and where they age and to improve their quality of life."

Skubic is the director of the Center for Eldercare Rehabilitation and Technology (CERT), which will now be under the C2SHIP umbrella. CERT opened in 2006 with the goal of helping older individuals remain independent. Through CERT, researchers develop sensors that can detect fall risks, bed sensors that monitor vital signs and other devices that allow patients to track health issues while aging in place.

"The mission of C2SHIP is completely in line with what we've been trying to do at CERT for the past 16 years," Skubic said. "From the beginning, one of the missions we had was to address the needs of older consumers through innovative technology, and to give them access to this new technology requires the research to be translated into the commercial marketplace. This is exactly the framework NSF has set up."

C2SHIP is an NSF Industry-University Cooperative Research Center (I/UCRC), an initiative aimed to connect academic teams with industry innovators and government agencies. Other members of the consortium are the University of Arizona, Baylor College of Medicine, the University of Southern California and California Institute of Technology, as well as 21 industry partners that advise the group and invest in projects.

Becoming part of C2SHIP will have a broad impact on Mizzou as it will connect researchers from across campus to global collaborators. In addition to engineering, faculty from the Sinclair School of Nursing, School of Medicine, School of Health Professions, and College of Veterinary Medicine are involved in the work.

For students, being part of the consortium could open doors to employment and internships, Skubic said.

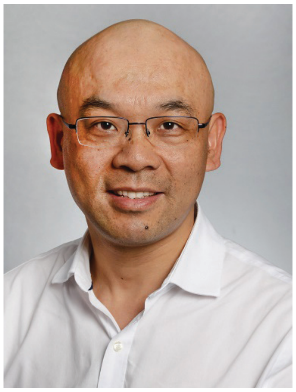
"For companies, part of their motivation for getting involved is having access to a trained workforce," she said. "They are engaging with students and recruiting for internships and, as things progress, will no doubt start hiring our graduates. It offers some tremendous opportunities for students."

The C2SHIP consortium also benefits from having Mizzou involved, as researchers associated with the project have expertise in medicine, nursing, occupational therapy, physical therapy, social work, physiological modeling, biomedical engineering, AI, informatics, cybersecurity, and veterinary medicine.

"MU brings some interesting capabilities to this group because of the diversity we have on campus," Skubic said. "We are looking forward to the exciting possibilities."

Co-PIs on the project are Prasad Calyam, Gilliom Professor of Cyber Security; Giovanna Guidoboni, professor and associate dean of research for engineering; Mihail Popescu, professor of health management and informatics in the School of Medicine; and Blaine Reeder, associate professor in the Sinclair School of Nursing.

System Would Speed Drug Development



Jianlin Cheng

William and Nancy Thompson Distinguished Professor

It can take more than a decade and some $2.6 billion to get a new drug to market. And if COVID-19 has taught us anything, it's that we can't always wait that long for life-saving treatments. Now, an EECS researcher at Mizzou has proposed a new deep learning system that would speed up drug development by more accurately predicting how drugs and proteins interact.

Jianlin "Jack" Cheng — William and Nancy Thompson Distinguished Professor— outlined the system in a paper published by Oxford University Press' Briefings in Bioinformatics. In the paper, he and his team examined existing computational approaches to predicting protein-ligand interactions and concluded that a more comprehensive system is needed.

Ligands are molecules such as drugs that bind to proteins and trigger a cellular response. In order to understand how a protein will respond to a ligand, researchers have to solve three problems.

First, they must know how the molecule will bind to a target protein. In order for a drug to effectively block activity, it has to bind strongly to a specific protein such as the spike protein in the coronavirus. Secondly, they need to know where the ligand will bind within the protein. Finally, they need to know what 3D structure the protein and ligand will take once they become a complex, as that shape determines the cellular response.

"Current machine learning methods tend to treat the three problems as separate problems," Cheng said. "But we think these three things are correlated, and we are proposing that they should be studied as a whole."

Cheng's research team is now working on developing such system. With a growing body of knowledge coming from existing computational systems and with a better understanding of how proteins develop into structures, it's the ideal time to train highly sophisticated deep learning architectures to predict these protein-ligand interactions,

Cheng was among the first to apply deep learning to predicting how proteins fold into specific structures, a problem that had vexed scientists for decades. In 2020, a Google-based company, DeepMind, largely solved the problem using an advanced end-to-end deep learning approach known as AlphaFold2.

"We can see how deep learning revolutionized the protein structure field when the protein prediction problem was largely solved," Cheng said. "A similar revolution can happen in this vital field. That's why we wanted to look at this from a fresh perspective and proposed some new ideas on where this field should go."

The other co-authors of this paper include Mizzou graduate students Ashwin Dhakal and Cole McKay, and John J. Tanner, professor of chemistry and biochemistry.

Researcher Develops Tools to Predict Where Proteins Localize

A Mizzou Engineer is developing computational tools that can be used to predict where proteins will localize within a cell. Using highly advanced deep learning, the resource could help researchers better understand how proteins function or, if positioned incorrectly within a cell, misfire and cause problems.

Dong Xu, a Curators' Distinguished Professor in EECS, has received nearly $650,000 from the National Science Foundation for the work. Ultimately, he hopes to create informatics infrastructure such as open-source software and a web server that can be used for other protein localization studies.

Proteins fold into three-dimensional structures that localize, or settle, in a part of the cell such as a cell membrane, nucleus or mitochondria.

Over the past couple of years, scientists have developed effective neural networks to predict what shapes proteins will fold into. However, it's also important to know where a protein will be located within a cell once it forms into the structure.

"Localization plays a key role in protein function," Xu said. "If a protein somehow localizes in a different position or incorrectly, it may cause diseases."

Current experimental methods used to determine subcellular location of proteins — such as tagging them with fluorescent biomarkers — are costly and time consuming.

Xu's system is the first to use graph-based neural network techniques to provide interpretable results for protein localization. Using cutting-edge machine learning technology and protein sequence data, protein-protein interaction information and single-cell data, the system is expected to provide more accurate, higher resolution insights into the localization process.

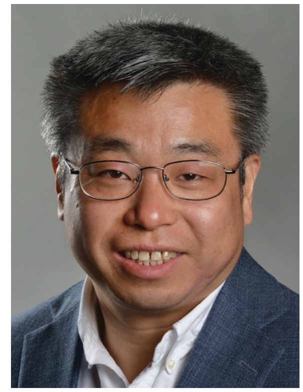
Specifically, the framework will help predict localization at the single-cell resolution. That will allow researchers to quantitatively predict the impact of protein mutation and interaction alteration for different cell types.

The work outlines general methods that can be used in other biological studies.

"We believe that by using the latest single-cell data and state-of-the-art machine learning methods, this project will provide a new generation of methodologies and bioinformatics tools for protein localization predictions, as well as a coding-free web platform for a wide range of studies including those involved in animal pathology and plant traits research," Xu said.

Additionally, the web tools can be used for education and training. Xu envisions high school and college courses using the resources to give students the opportunity to explore machine learning techniques as they're used in biological settings. The module will contain video lectures and online practice exercises.

Xu is collaborating with Yuexu Jiang, a postdoctoral fellow in electrical engineering and computer science, on the project. The research team outlined findings on their deep-learning framework in the Computational and Structural Biotechnology Journal.



Dong Xu

Curators' Distinguished Professor, Paul K. and Dianne Shumaker Professor

Software Allows Efficient Method to Mine Big Data

An EECS researcher has developed a new software structure that allows users to more efficiently mine big data. Chi-Ren Shyu, Shumaker Professor of electrical engineering and computer science and Director of MU Institute for Data Science and Informatics, was recently awarded a U.S. patent (No. 11,055,351) for the system, which has potential applications for commerce, healthcare and any organization that leverages large databases for decision making.

The work builds on association rule mining rules. If a customer buys bread at the store, then they are more likely to purchase milk, as well. Some companies, including Amazon, already have proprietary systems that make these connections. If you purchase a book from the online retailer, it will recommend similar books purchased by others who bought the same title.

Shyu's software structure is unique in that it can predict how many potential combinations can be formed within the data. If a store has 150,000 items in stock, for example, the system will tell you that there are 22.5 billion potential pairs of different combinations of what could end up in a shopper's cart. The system also predicts how much computing power you will need to search for the associations you want to make.

Finally, the model dynamically updates when additional data is received. So, information coming from a store's register would automatically be included in future searches.

"There could be trillions of combinations within large genetic networks, and that would take forever to run," Shyu said. "We need computer algorithms to help us deal with the number of items. This structure will help index patterns so we can find information from large data sets and quickly find those connections, then we can develop targeted treatments for those potential combinations."

EECS Researcher awarded three patents

EECS Associate Professor Mahmoud Almasri was awarded three patents for work around harvesting energy, improving camera imaging and coming up with a better way to produce microscopic sensors.

The first patent (No. 11,118,981) is for a method that improves the performance of thermal cameras. These use microbolometers to transduce infrared radiation. Microbolometers absorb infrared radiation, heating a material with a temperature-dependent resistance and changing its voltage. Integrating a metasurface into the microbolometer provides wavelength and polarization selective absorption. In addition, the metasurface can improve the electrical performance of the microbolometer. The spectral and polarization response can be specified pixel by pixel by adjusting the geometry of the metasurface. The resulting infrared arrays have a broad range of commercial and military applications such as material identification, discrimination between natural and manmade surfaces, industrial monitoring, medical diagnostics and emergency services.

The second patent (No. 10,989,867) is for optical fiber-based sensors including applications around measuring refractive index and using surface-enhanced Raman spectroscopy (SERS). Using self-assembled microspheres as an optical element to pattern photoresist facilitates a significant reduction in the fabrication cost of the sensors. This allows for the definition of arrays of nanoantennas on the cleaved tip of fibers. The nanoantenna patterned fibers have chemical and biological sensing applications.

The third patent (No. 11,005,352) is for wideband electrostatic and electromagnetic based energy harvesters for power generation from low frequency energy sources. The device uses the wasted energy associated with undesirable mechanical vibrations to power wireless sensors and actuators widely found in structures and that associated with various modes of transportation with frequencies lower than 100 Hz.

Team Devises Software to Assess Speech, Swallowing

Progressive neurological disorders such as Parkinson's disease, multiple sclerosis and ALS can cause dysfunctions that impair speech and swallowing. Right now, tests to monitor these problems rely on clinician judgement, which can be subject to human error.

Now, researchers at Mizzou have devised a set of software that clinicians can use to more precisely measure the level of speech dysfunction, enabling earlier diagnosis and tracking of neurological disorders. The team was recently awarded a U.S. patent (No. 10,959,661) for this technology.

The software works with oral-diadochokinesis, or oral-DDK tests conducted by speech language pathologists, which require rapid repetition of speech-based syllables to assess speech impairments. Researchers developed a patient tool that records oral DDK signals. Then, a machine learning-based system to automatically analyze the data. The suite of tools also includes interactive visualization and editing software that allows clinicians to inspect and, if necessary, correct the automated results.

"Through these software, we compute several clinically relevant outcome measures to differentiate normal and abnormal function of the oro-motor system," said Filiz Bunyak Ersoy, an assistant professor of electrical engineering and computer science.

Bunyak's research focuses on image analysis, computer vision and machine learning. EECS Professor Yunxin Zhao is also in the research group, focusing on the speech recognition side of the DDK task. The work of her team enhanced the functionality of the software that Bunyak and her students developed.

"By counting the rate and recognizing the correctness of syllable productions or deriving other analytics from a person being tested, we can potentially automate the 'normal' versus 'abnormal' decision process," Zhao said.

The technology is not yet licensed, but Bunyak said the goal is to make it available to hospitals and clinics to promote evidence-based medicine.

The medical aspect of the research is led by Teresa Lever from the School of Medicine and Mili Kuruvilla-Dugdale from the School of Health Professions. Lever and Kuruvilla-Dugdale are co-inventors in the patent and have been instrumental in design of these suite of tools.

The work has been supported by funding from the MU Coulter Biomedical Accelerator Program.

Building A Better Bed Sensor

There are a lot of companies making bed sensors that monitor your health while you sleep. Curators' Distinguished Professor Marjorie Skubic not only made one, she's also tried a lot of them.

The crowded market is one reason it took more than a decade for Skubic to patent the one she and her team designed. But the recently awarded patent confirms what she's known for years — that the hydraulic bed sensors developed at Mizzou Engineering are truly unique.

Skubic's now-patented (No. 11,013,415) bed sensors are made with a flexible tube of water that measures blood flow to capture heart rate, respiratory rate and cardio activity. What differentiates the product is that it was created for older adults, whereas many similar bed sensors on the market were made with young, healthy subjects in mind.

"Athletes and young people are trying to track sleep and overall health, and that's a completely different target population," said Skubic, a professor of electrical engineering and computer science. "Many of the other bed sensors provide nice signals for young, healthy subjects, which are easier to process."

Also included on the recent patent award are: Rantz, Mihail Popescu, Shuang Wang, Isaac J Sledge, Rainer Dane A Guevara, Elena Florea, and Jim Keller.

EECS Welcomes Five New Faculty Members

The Department of Electrical Engineering and Computer Science welcomed five new faculty members this semester:

Filiz Bunyak Ersoy is an assistant professor whose research focuses on image processing, computer vision, artificial intelligence and machine learning.

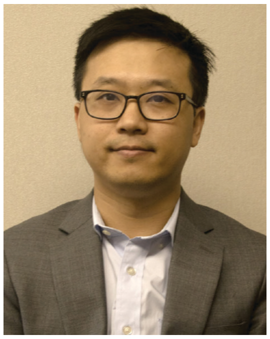
Qingyun Huang is an assistant professor and PayneCrest Faculty Scholar in Power Engineering whose research focuses on power electronics.

Mert Korkali is an assistant professor whose research focuses on power systems.

Ali Shiri Sichani is an assistant teaching professor.

Peifen Zhu is an assistant professor whose research focuses on clean energy, electronic/photonic materials, optoelectronic materials and devices, solid state lighting.

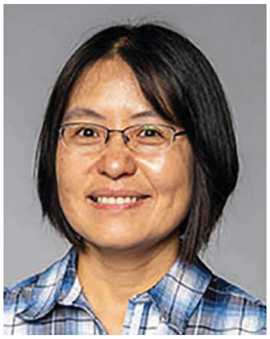
Filiz Bunyak Ersoy



Qingyun Huang

Mert Korkali

Ali Shiri Sichani



Peifen Zhu

Cheng Elected AIMBE Fellow

Jianlin “Jack” Cheng, William and Nancy Thompson Distinguished Professor, has been elected to the American Institute for Medical and Biological Engineering (AIMBE) College of Fellows for his outstanding and pioneering contributions to developing machine learning for modeling protein and genome structures.

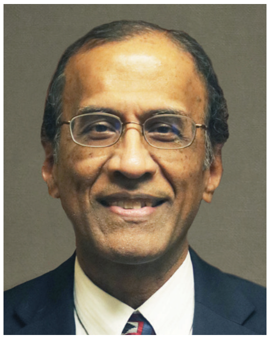
The College of Fellows is comprised of the top 2% of medical and biological engineers in the country. Cheng was nominated, reviewed and elected by peers and current fellows and was inducted at AIMBE’s Annual Event in March.

Cheng is internationally known for his work around using machine learning and artificial intelligence (AI) methods in bioinformatics, specifically deep learning models to advance the field of protein structure prediction. His method to predict protein residue-residue contacts was ranked No. 1 in the protein contact prediction competition at the 10th worldwide Critical Assessments of Structure Prediction (CASP10) in 2012, demonstrating deep learning as the best technology for protein structure prediction for the first time. His team continued to place among top groups in CASP11-14 from 2014 to 2020.

Cheng is a member of the American Association for the Advancement of Science, the Association for Computing Machinery, the Institute of Electrical and Electronics Engineers and the International Society for Computational Biology. In 2019, he was named one of the Top 100 Global AI Leaders in Drug Discovery and Healthcare by Deep Knowledge Analytics.

EECS FACULTY NEWS AND ACCOLADES

Palaniappan Named Curators' Professor



EECS's Kannappan Palaniappan has been named a Curators' Distinguished Professor, the highest honor bestowed by the University of Missouri System.

Palaniappan's groundbreaking work is in computational video analytics, including computer vision, deep learning, remote sensing, data visualization, high performance computing and biomedical imaging. He is director of the Computational Imaging and Visualization Analysis (CIVA) lab, which develops theory, algorithms, tools and software for visual scene perception and understanding across scale.

Earlier this year, Palaniappan was the inaugural recipient of the James C. Owens Excellence for Research Collaboration Award.

Shyu Receives Faculty Alumni Award

Chi-Ren Shyu, a professor in electrical engineering and computer science, has been honored with a 2022 Faculty Alumni Award from the Mizzou Alumni Association.

First celebrated in 1968, the awards highlight professional accomplishments, teaching and research and the contributions of exceptional individuals to the University's core mission.

"I am truly honored to be selected for the award," Shyu said. "Looking at the prior and current awardees, I feel fortunate to be among them and to have the privilege to work with many colleagues to foster interdisciplinary initiatives over my 22 years career at Mizzou."

Shyu is internationally known for his work around geospatial data science and informatics. His research encompasses health care, explainable artificial intelligence, quantum computing and spatial big data analytics. His expertise was essential in helping rural counties across Missouri coordinate resources and information around COVID-19. And he has been instrumental in furthering our understanding of Type 1 diabetes through the application of AI — a project aligned with Mizzou's NextGen Precision Health initiative.

Calyam Earns Walker Award for Mentorship

Prasad Calyam — Greg L. Gilliom Professor of Cyber Security — has been named the inaugural recipient of the Robin Walker Award for Graduate Student Mentoring at Mizzou.

The MU Graduate School and Fellowships Office established the award this year to recognize a faculty or staff member who effectively supported a graduate student's application for a globally or nationally competitive award. Calyam helped Roland Oruche, a PhD student in computer science, successfully apply for a National Science Foundation Graduate Research Fellowship (GRF) in 2021.

Hassan Selected for Rising Stars in EECS Workshop

Omiya Hassan, a PhD student in electrical engineering, was selected to attend Rising Stars in EECS, a prestigious academic career workshop held at the University of Texas at Austin in October.

Now in its 10th year, Rising Stars in EECS began at MIT and has been hosted by some of the top universities in the country since. The goal is to provide insights, guidance and mentorship to historically underrepresented graduate students interested in a career in academia.

"It is a very competitive workshop," Hassan said. "Getting accepted was a big deal for me. I was super excited and happy."

The event included special speakers, panels and mentorship opportunities to help prepare participants for faculty positions.

Hassan especially enjoyed the mentorship component. A mentor herself — Hassan received Mizzou's Undergraduate Research Mentor of the Year Award this past spring — she knows the value of that personal guidance.

In the Analog/Mixed Signal VLSI and Devices Laboratory under the direction of her advisor, Professor Syed "Kamrul" Islam, Hassan has worked with undergraduate and master's students to help them develop skills needed for research.

"I try to make the research as fun as possible, because I know research requires self-motivation," she said. "Research can be frustrating if you don't get the results you want, but I try to mentor them and give them ideas. If they are struggling or frustrated, I say let's work through it together."

Parvin Attends IREDEFINE Workshop

Dilruba Parvin is more prepared for a career in academia thanks to insights from the nation's top engineering chairs. Parvin, a PhD candidate studying electrical and computer engineering, recently attended the iREDEFINE Workshop, part of the 2022 ECEDHA Annual Conference in New Orleans.

ECEDHA (Electrical and Computer Engineering Department Head Association) hosts the iREDEFINE Workshop to connect women and underrepresented minority PhD students to professional mentors in hopes of encouraging them to pursue faculty positions.

During the three-day event, Parvin and roughly 30 other attendees heard from department chairs about navigating job searches, interview strategies, negotiation tactics and effective teaching methods. Parvin, whose research at Mizzou involves radio frequency-based energy harvesting system design, also presented her work projects during the first day of the event.

For Parvin, the workshop was especially timely, as she expects to finish her PhD at Mizzou this fall. She hopes to find a faculty position at an R1, or research-based, university, and was grateful to hear from chairs throughout the nation on what they look for in their faculty.

EECS STUDENT NEWS

Students Present At Neuroscience 2021

EECS students joined neuroscientists from around the world in December to exchange ideas and present new discoveries about the human brain as first authors at Neuroscience 2021, a prestigious international conference hosted by the Society for Neuroscience.

Presenters included Pete Canfield, a junior in computer science, and Greg Glickert, who has since started graduate studies in computer engineering. They were assisted by PhD students Ben Latimer, Ziao Chen and Dan Dopp. All of the students work in the Neural Engineering Lab on ways to mimic complex brain cells, waves and functions using computational models.

Canfield presented two papers at the conference, including work that builds on his previous development of methodology to simplify single cell design processes. The open-source tool is available for download from CyNeuro.org.

"Neurobiologists would like to use computer models of neuron they study but are not trained to develop them," he said. "Our modeling tool does all the iteration and parameter selection automatically. The idea is that biologists can provide their single neuron recordings directly as text data and our modeling tool will provide the model that fits the data, ready to run on their computer by a click of the mouse."

Canfield also presented a biologically realistic model of the CA3, a region located in the hippocampus associated with memory processes. He used his automation tool to generate theta rhythms, or oscillations that help us learn patterns or complete routine tasks.

"There's so much to reverse engineering the brain," Glickert said. "The hippocampus is only one section that I worked on; there are so many other things no one knows. Still, it felt good to present my findings after working on it for so long."

Two Students Selected For Mizzou '39 Award

Before graduating in May, two EECS students were selected for the Mizzou'39 Award, a prestigious honor that recognizes outstanding academic achievement, leadership and service to the University of Missouri.

Riley Jackson graduated with a degree in electrical engineering. At Mizzou, she was an undergraduate researcher investigating a power efficient hardware accelerator design for neural networks in the Analog/Mixed-Signal, VLSI and Devices Laboratory. Jackson now works at Apple as an Engineering Program Manager.

Rebecca Shyu graduated with a degree in computer science. At Mizzou, she was an undergraduate researcher for the Department of Biomedical Informatics and undergraduate research assistant in the Department of Health Care Policy at Harvard Medical School. She also served as an undergraduate research assistant at the Missouri Cancer Registry, Missouri Telehealth Network (Show-Me ECHO), and Department of Computer Science. Shyu is now a PhD student in biomedical informatics at Columbia University.

Melton Receives 2022 Missouri Honor Award

Michael Melton, Esquire, BS EE '81, JD '84, has received the 2022 Missouri Honor Award recognizing his outstanding contributions to Mizzou Engineering and extraordinary efforts to help support students and young alumni. The award is the highest accolade bestowed on an engineering graduate.

"I'm honored by this," Melton said. "I am very pleased and happy that the things I do with the University and outside of the University have been recognized."

Melton is an "extraordinary example illustrating how a great engineering education can lay the foundation for a remarkable professional and business career," his nominator said.

That career includes working as a registered patent attorney before starting his own company. Today, Melton is Founder, President and CEO of MEM Enterprises Group, which owns, operates and manages Taco Bell and Five Guys Burgers restaurants and commercial real estate. The portfolio of Taco Bell restaurants is the largest owned by an exclusively African American group, and the Five Guys portfolio includes the top two highest grossing locations in the United States.

Melton has also held the positions of Vice President and Director of Worldwide Semiconductor Licensing with Motorola, Deputy General Counsel with Texas Instruments and European Legal Counsel and Corporate Secretary of Texas Instruments Information Engineering International.

Stipek Receives 2022 Citation of Merit Award

Lorraine Stipek, BS EE '86, has received the College of Engineering's 2022 Citation of Merit Award recognizing her significant contributions to the industry and service to MU.

"I'm extremely honored," she said. "There have been so many incredible alumni who have graduated and have done some amazing things for the University. It's so gratifying because it means some of the things I've done have had a positive impact. And that feels great because all we want to do is have a positive impact."

Stipek has served on the Dean's Advisory Council, helped develop undergraduate labs, collaborated on energy projects with MU's research office and has spoken at Commencement and other engineering events.

Stipek began her career as a test engineer at McDonnell Douglas at a time when not many women were working in engineering. While there, she also earned a Master of Business Administration from Washington University. Stipek then joined National Instruments where she rose in the ranks from technical sales manager to executive leadership at the company's Texas headquarters.

More recently, Stipek oversaw the go-to-market strategy for a spin merger between Micro Focus and HPE Software.

Today, she serves as an Angel Investor for Southwest Angel Network.

TOTAL

880+

EECS STUDENTS

UNDERGRADUATE
626
STUDENTS

GRADUATE
255
STUDENTS

$11.9M

FY22 EECS Committed Research Awards

$13.2M

FY22 EECS Expenditures by Shared Credit

EECS LABS AND

17

RESEARCH CENTERS

FEATURED
2
RESEARCH CENTERS

CENTERS AND
3
SIGNATURE PROGRAMS

DEPARTMENT
12
RESEARCH LABS

1ST
Electrical Engineering Program
West of the Mississippi

60+
EECS Faculty Members
40 T/TT Professors

Mizzou is
1 of 34
AAU MEMBERS

Entering Freshman
30
Average ACT Score

Electrical Engineering
& Computer Science
University of Missouri

201 Naka Hall
Columbia, MO 65211

ENGINEERING.MISSOURI.EDU/EECS/