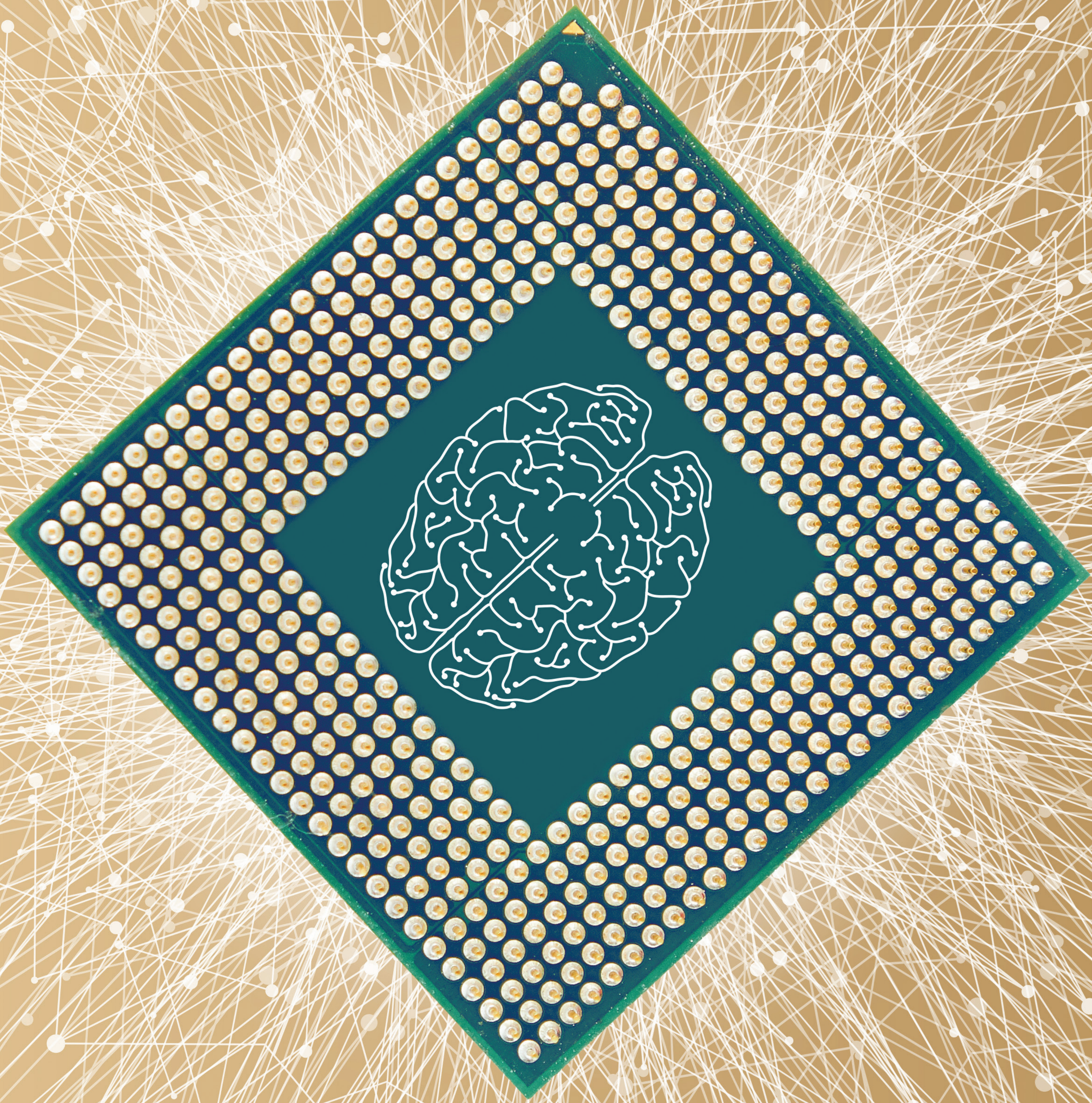
MIT MECHE

MechEConnects

Summer 2018

Engineering Intelligence



MechEConnects

News from the MIT
Department of Mechanical Engineering

Summer 2018 | ► meche.mit.edu

Massachusetts Institute of Technology

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On April 21st, MechE graduate students put on their dancing shoes and enjoyed stunning views of Boston at the Sixth Annual Mechanical Engineering Gala in the Samburg Conference Center. Image: Yi Zhao

About MechE

One of the six founding courses of study at MIT, mechanical engineering embodies the motto “mens et manus” – mind and hand. Disciplinary depth and breadth, together with hands-on discovery and physical realization, characterize our nationally and internationally recognized leadership in research, education, and innovation.

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Cover:
Image: Chelsea Turner, MIT

Mechanical engineers are uniquely positioned to advance artificial intelligence and machine learning research.

Dear Alumni, Students, Faculty, and Friends,

In February, MIT announced the launch of the MIT Intelligence Quest – a cross-disciplinary initiative that seeks to further understand human intelligence and how we can develop artificially intelligent tools for the betterment of society. In his letter to the MIT community announcing the Quest, President L. Rafael Reif outlined the two big questions it seeks to answer: “How does human intelligence work in engineering terms? And how can we use that deep grasp of human intelligence to build wiser and more useful machines to the benefit of society?”

Mechanical engineers are uniquely positioned to advance artificial intelligence and machine learning research. We operate at the intersection of hardware and software. To develop intelligent machines, we first need to outfit them with the sensors that measure everything about their surroundings – from spatial dimensions to temperature, sound, and force. That requires expertly designed hardware. To make sense of the thousands of data points these sensors generate, we need software and algorithms that help machines decide what to do next.

Many of the labs in MIT’s Department of Mechanical Engineering are working on both hardware and software that improve artificially intelligent technologies. Whether it’s robots that help companies sort their warehouse inventory, neural networks that teach computers how to recognize faces, or unmanned vehicles that explore uninhabitable environments, many MechE researchers are developing technologies that perfectly align with the Intelligence Quest’s mission to build “more useful machines to the benefit of society.”

In this issue of MechE Connects, we hear from faculty members, students, and alumni who are working in various capacities to advance intelligent technologies. Much of the research they are conducting in artificial intelligence and machine learning could someday have a massive impact on our everyday lives.

Before you read the latest issue, I’d like to let you know that this will be my final MechE Connects as Department Head. As of June 30th, I will be stepping down as Department Head and returning full time to teaching and research. In the coming weeks, you’ll receive more information on my replacement. In the meantime, I want to take this opportunity to thank you all. It has been a pleasure to work with and learn from so many of you over the past five years.

We hope you enjoy this issue of MechE Connects. As always, thank you for your continued support and friendship.

Sincerely,

Gang Chen, Carl Richard Soderberg Professor of Power Engineering and Department Head

Revolutionizing Everyday Products with AI

How artificial intelligence and machine learning can enhance the products we use in everyday life

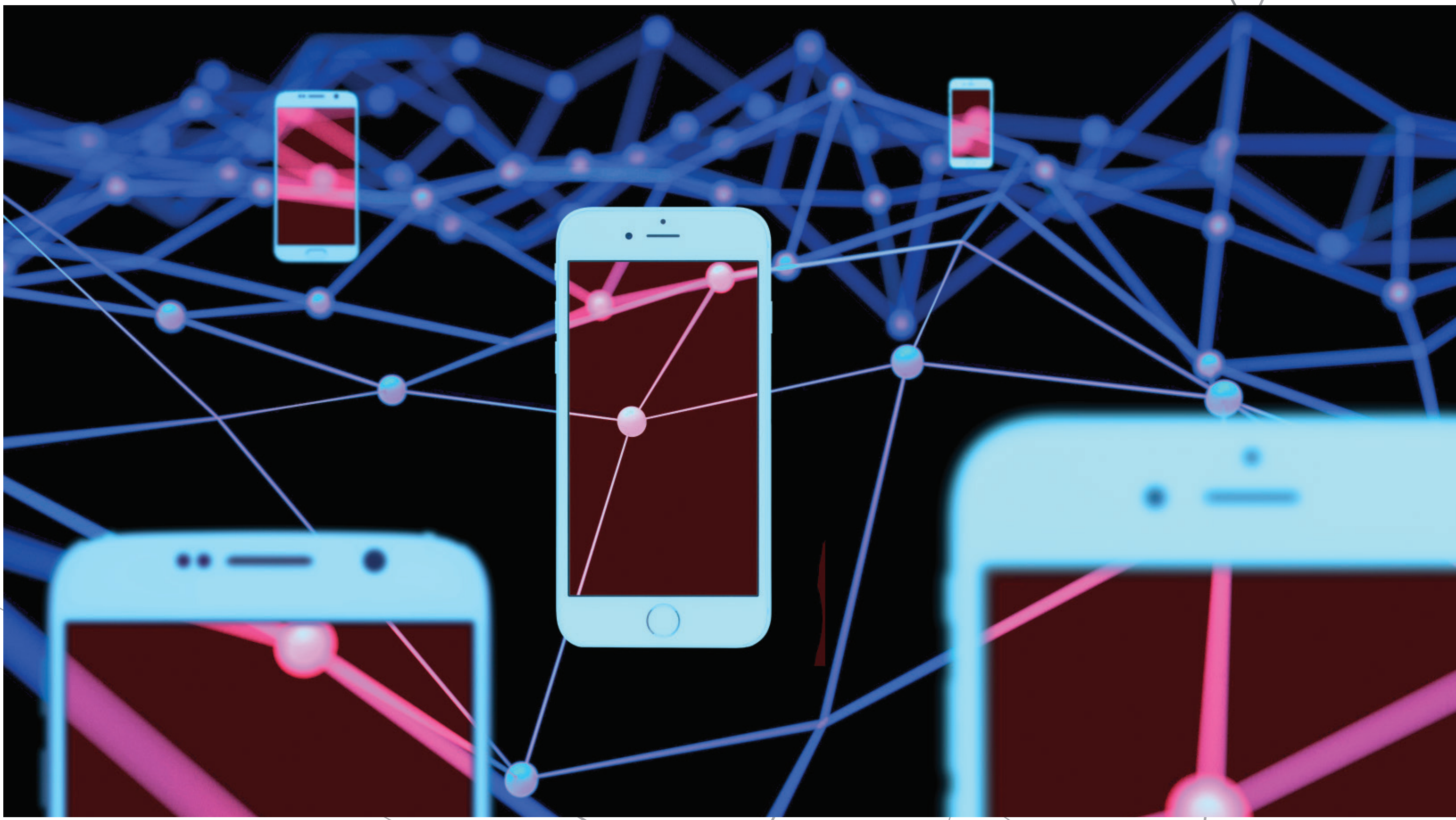


Image: Chelsea Turner, MIT

By Mary Beth O'Leary

"Who is Bram Stoker?" Those four words demonstrated the amazing potential of artificial intelligence. It was the answer to a final question in a particularly memorable 2011 episode of *Jeopardy!*. The three competitors were former champions Brad Rutter and Ken Jennings, and Watson, a super computer developed by IBM. By answering the final question correctly, Watson became the first computer to beat a human on the famous quiz show.

"In a way, Watson winning *Jeopardy!* seemed unfair to people," says Jeehwan Kim, Class '47 Career Development Professor. "At the time, Watson was connected to a super computer the size of a room while the human brain is just a few pounds. But replicating a human brain's ability to learn is incredibly difficult."

Kim specializes in machine learning, which relies on algorithms to teach computers how to learn like a human brain. "Machine learning is cognitive computing," he explains. "Your computer recognizes things without you telling the computer what it's looking at."

Machine learning is one example of artificial intelligence in practice. While the phrase 'machine learning' often conjures up science fiction typified in shows like *Westworld* or *Battlestar Galactica*, smart systems and devices are already pervasive in the fabric of our daily lives. Computers and phones use face recognition to unlock. Systems sense and adjust the temperature in our homes. Devices answer questions or play our favorite music on demand. Nearly every major car company has entered the race to develop a safe self-driving car.

For any of these products to operate, the software and hardware both have to work in perfect synchrony. Cameras, tactile sensors, radar, and light detection all need to function properly to feed information back to computers. Algorithms need to be designed so these machines can process this sensory data and make decisions based on the highest probability of success.

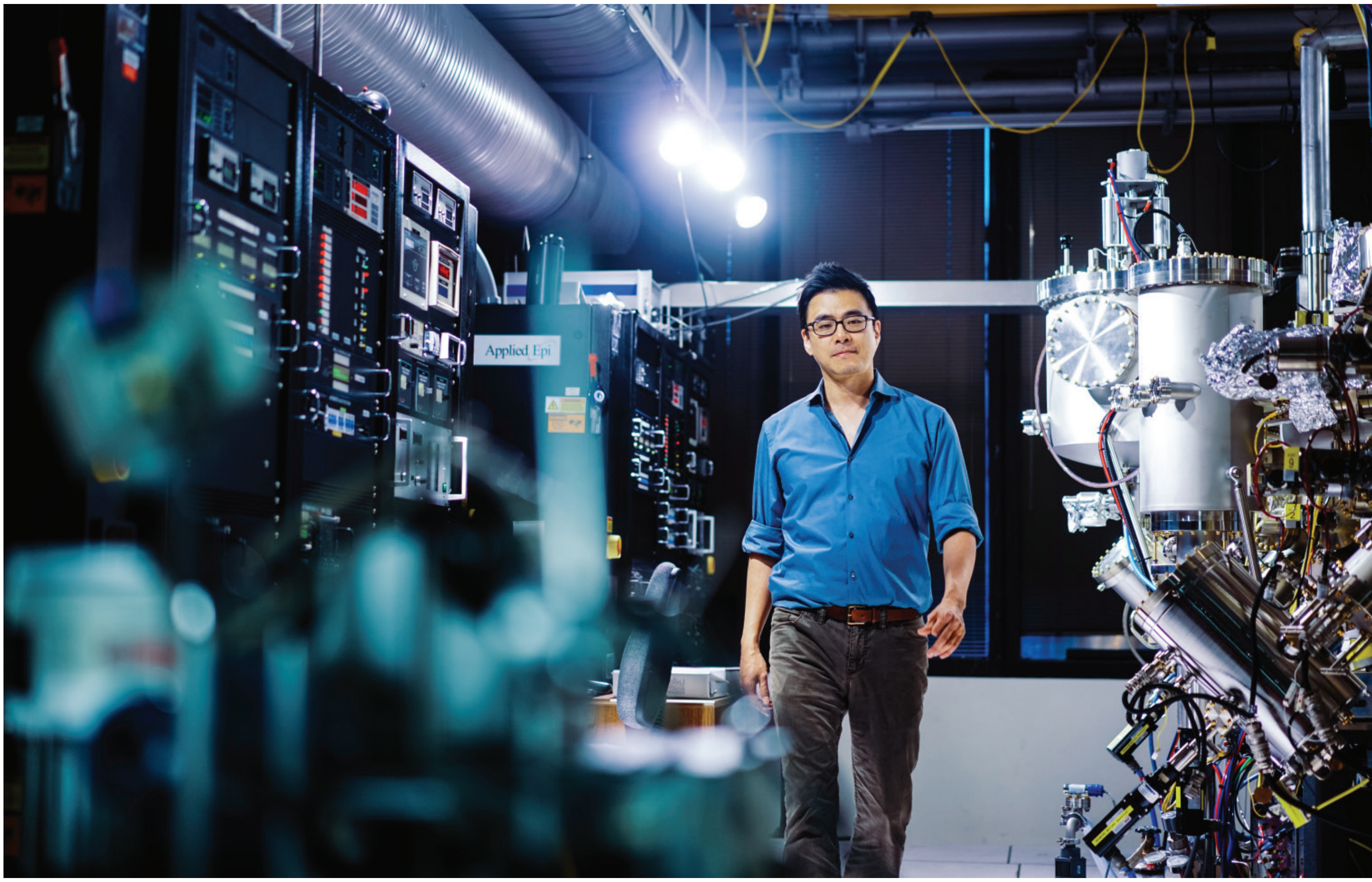
Kim and others at MIT's Department of Mechanical Engineering are creating new software that connects with hardware to create intelligent devices. Rather than building the sentient robots romanticized in popular culture, these researchers are working on projects that improve everyday life and make humans safer, more efficient, and better informed.

Making Portable Devices Smarter

Jeehwan Kim holds up sheet of paper. If he and his team are successful, one day the power of a super computer like IBM's Watson will be shrunk down to the size of one sheet of paper. "We are trying to build an actual physical neural network on a letter paper size," explains Kim.

This early prototype of IBM's Watson, located in Yorktown Heights, NY, was originally the size of a master bedroom. The cognitive computing system was built to answer questions like a human and famously won the quiz show *Jeopardy!*. Image: IBM

Associate Professor Jeehwan Kim hopes to one day build a 'brain-on-a-chip' – creating a physical neural network that can process a vast amount of information at once. Image: Lillie Paquette, MIT



To date, most neural networks have been software-based and made using the conventional method known as the Von Neumann computing method. Kim however has been using neuromorphic computing methods.

"Neuromorphic computing means portable AI," says Kim. "So, you build artificial neurons and synapses on a small-scale wafer." The result is a so-called 'brain-on-a-chip.'

Rather than compute information from binary signaling, Kim's neural network processes information like an analog device. Signals act like artificial neurons and move across thousands of arrays to particular cross points, which function like synapses. With thousands of arrays connected, vast amounts of information could be processed at once. For the first time, a portable piece of equipment could mimic the processing power of the brain.

"The key with this method is you really need to control the artificial synapses well. When you're talking about thousands of cross points, this poses challenges," says Kim.

According to Kim, the design and materials that have been used to make these artificial synapses thus far have been less than ideal. The amorphous materials used in neuromorphic chips make it incredibly difficult to control the ions once voltage is applied.

In a *Nature Materials* study published earlier this year, Kim found that when his team made a chip out of silicon germanium, they were able to control the current flowing out of the synapse and reduce variability to one percent. With control over how the synapses react to stimuli, it was time to put their chip to the test.

"We envision that if we build the physical neural network with this material, we can actually do handwriting recognition," says Kim. In a computer simulation of their new artificial neural network design, they provided thousands of handwriting samples. Their neural network was able to accurately recognize 95 percent of the samples.

"If you have a camera and an algorithm for the handwriting data set connected to our neural network, you can achieve handwriting recognition," explains Kim.

While building the physical neural network for handwriting recognition is the next step for Kim's team, the potential of this new technology goes beyond handwriting recognition. "Shrinking the power of a super computer down to a portable size could revolutionize the products we use," says Kim. "The potential is limitless – we can integrate this technology in our phones, computers, and robots to make them substantially smarter."

Making Homes Smarter

While Kim is working on making our portable products more intelligent, Professor Sanjay Sarma and Research Scientist Josh Siegel hope to integrate smart devices within the biggest product we own: our homes.

One evening, Sarma was in his home when one of his circuit breakers kept going off. This circuit breaker – known as an arc-fault circuit interrupter (AFCI) – was designed to shut off power when an electric arc is detected to prevent fires. While AFCIs are great at preventing fires, in Sarma's case there didn't seem to be an issue. "There was no discernible reason for it to keep going off," recalls Sarma. "It was incredibly distracting."

AFCIs are notorious for such 'nuisance trips,' which disconnect safe objects unnecessarily. Sarma, who serves as Vice President for Open Learning, turned his frustration into opportunity. If he could embed the AFCI with smart technologies and connect it to the 'Internet of Things,' he could teach the circuit breaker to learn when a product is safe or when a product actually poses a fire risk.

"Think of it like a virus scanner," explains Siegel. "Virus scanners are connected to a system that updates them with new virus definitions over time." If Sarma and Siegel could embed similar technology into AFCIs, the circuit breakers could detect exactly what product is being plugged in and learn new object definitions over time.

If, for example, a new vacuum cleaner is plugged into the circuit breaker and the power shuts off without reason, the smart AFCI can learn that it's safe and add it to a list of known safe objects. The AFCI learns these definitions with the aid of a neural network. But, unlike Jeehwan Kim's physical neural network, this network is software-based.

The neural network is built by gathering thousands of data points during simulations of arcing. Algorithms are then written to help the network assess its environment, recognize patterns, and make decisions based on the probability of achieving the desired outcome. With the help of a $35 microcomputer and a sound card, the team can cheaply integrate this technology into circuit breakers.

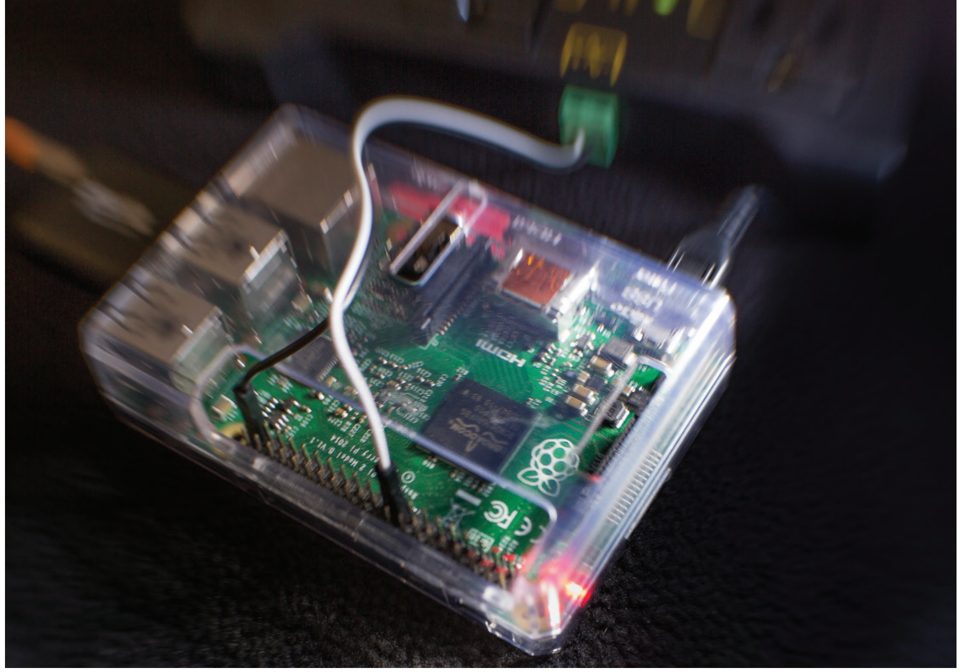
As the smart AFCI learns about the devices it encounters, it can simultaneously distribute its knowledge and definitions to every other home using the Internet of Things.

"Internet of Things could just as well be called Intelligence of Things," says Sarma. "Smart, local technologies with the aid of the cloud can make our environments adaptive and the user experience seamless."

Circuit breakers are just one of many ways neural networks can be used to make homes smarter. This kind of technology can control the temperature of a house, detect when there's an anomaly such as an intrusion or burst pipe, and run diagnostics to see when things are in need of repair.

"We're developing software for monitoring mechanical systems that's self-learned," explains Siegel. "You don't teach these devices all the rules, you teach them how to learn the rules."

Smart, local technologies with the aid of the cloud can make our environments adaptive and the user experience seamless.



Using a small microcomputer and a soundcard, Professor Sanjay Sarma and Research Scientist Josh Siegel developed a device that can connect circuit breakers to the 'Internet of Things.' The device can help AFCIs learn and update object definitions to prevent 'nuisance trips' and make homes safer. Image: John Freidah

Making Manufacturing and Design Smarter

Artificial intelligence can not only help improve how users interact with products, devices, and environments, it can also improve the efficiency with which objects are made by optimizing the manufacturing and design process.

"Growth in automation along with complementary technologies including 3D printing, AI, and machine learning compels us to, in the long run, rethink how we design factories and supply chains," says Associate Professor A. John Hart.

Hart, who has done extensive research in 3D printing, sees AI as a way to improve quality assurance in manufacturing. 3D printers incorporating high-performance sensors, that are capable of analyzing data on the fly, will help accelerate the adoption of 3D printing for mass production.

"Having 3D printers that learn how to create parts with fewer defects and inspect parts as they make them will be a really big deal – especially when the products you're making have critical properties such as medical devices or parts for aircraft engines," Hart explains.

> Combining the power of a portable neural network with a robot capable of skillfully navigating its surroundings could open up a new world of possibilities for human and AI interaction.

The very process of designing the structure of these parts can also benefit from intelligent software. Associate Professor Maria Yang has been looking at how designers can use automation tools to design more efficiently. "We call it hybrid intelligence for design," says Yang. "The goal is to enable effective collaboration between intelligent tools and human designers."

In a recent study, Yang and graduate student Edward Burnell tested a design tool with varying levels of automation. Participants used the software to pick nodes for a 2D truss of either a stop sign or a bridge. The tool would then automatically come up with optimized solutions based on intelligent algorithms for where to connect nodes and the width of each part.

"We're trying to design smart algorithms that fit with the ways designers already think," says Burnell.

Making Robots Smarter

If there is anything on MIT's campus that most closely resembles the futuristic robots of science fiction, it would be Associate Professor Sangbae Kim's robotic cheetah. The four-legged creature senses its surrounding environment using LIDAR technologies and moves in response to this information. Much like its namesake, it can run and leap over obstacles.

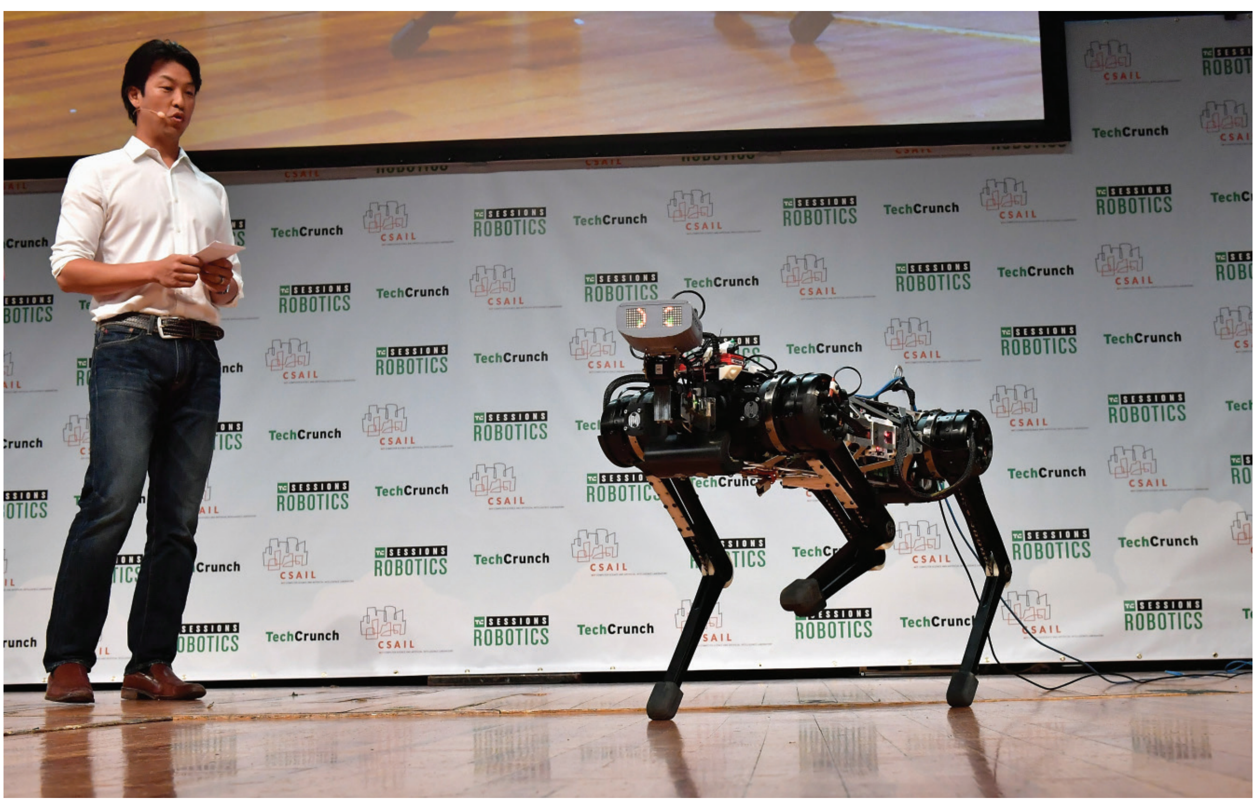
Kim's primary focus is on navigation. "We are building a very unique system specially designed for dynamic movement of the robot," explains Kim. "I believe it is going to reshape the interactive robots in the world. You can think of all kinds of applications – medical, healthcare, factories."

Kim sees an opportunity to eventually connect his research with the physical neural network his colleague Jeehwan Kim is working on. "If you want the cheetah to recognize people, voices, or gestures, you need a lot of learning and processing," he says. "Jeehwan's neural network hardware could possibly enable that someday."

Combining the power of a portable neural network with a robot capable of skillfully navigating its surroundings could open up a new world of possibilities for human and AI interaction. This is just one example of how researchers in mechanical engineering can one-day collaborate to bring AI research to next level.

While we may be decades away from interacting with intelligent robots, artificial intelligence and machine learning has already found its way into our routines. Whether it's using face and handwriting recognition to protect our information, tapping into the Internet of Things to keep our homes safe, or helping engineers build and design more efficiently, the benefits of AI technologies are pervasive.

The science fiction fantasy of a world overtaken by robots is far from the truth. "There's this romantic notion that everything is going to be automatic," adds Maria Yang. "But I think the reality is you're going to have tools that will work with people and help make their daily life a bit easier."



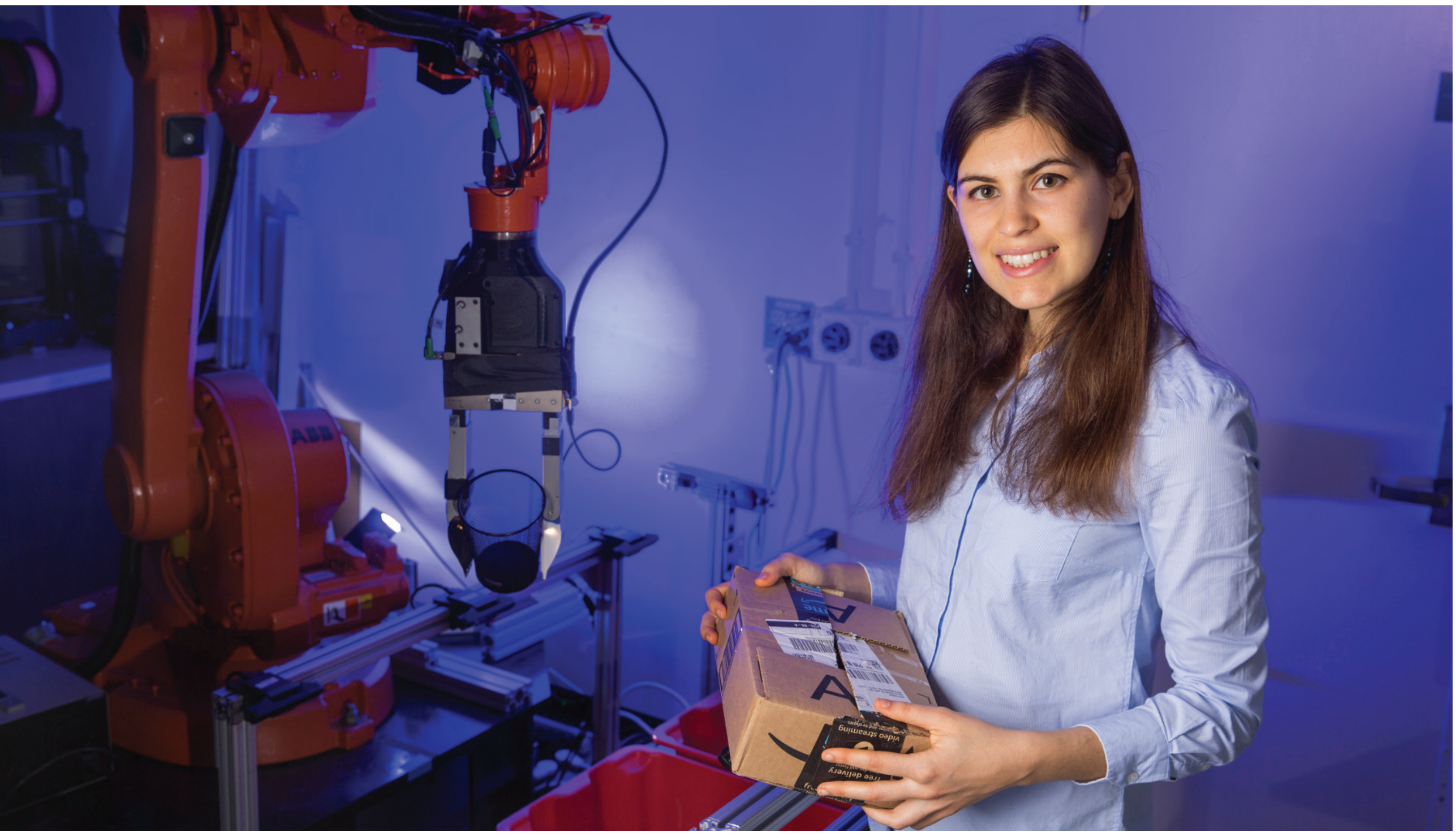
In July 2017, Associate Professor Sangbae Kim gave a demo of the latest iteration of his lab's robotic cheetah, Cheetah III, at the Tech Crunch Sessions: Robotics event in MIT's Kresge Auditorium. Image: Paul Marotta, Getty Images

Student Spotlight:

Maria Bauza, PhD Candidate

Teaching Robots How to Move Objects

By Mary Beth O'Leary



Graduate student Maria Bauza is developing machine learning algorithms and software to improve how robots interact with the world. Image: Tony Pulsone

With the push of a button, months of hard work were about to be put to the test. Sixteen teams of engineers convened in a cavernous exhibit hall in Nagoya, Japan for the 2017 Amazon Robotics Challenge. The robotic systems they built were tasked with removing items from bins and placing them into boxes. For graduate student Maria Bauza, who served as task-planning lead for the MIT-Princeton Team, the moment was particularly nerve-wracking.

"It was super stressful when the competition started," recalls Bauza. "You just press play and the robot is autonomous. It's going to do whatever you code it for, but you have no control. If something is broken, then that's it."

Robotics has been a major focus for Bauza since her undergraduate career. She studied mathematics and engineering physics at the Polytechnic University of Catalonia in Barcelona. During a year as a visiting student at MIT, Bauza was able to put her interest in computer science and artificial intelligence into practice. "When I came to MIT for that year, I starting applying the tools I had learned in machine learning to real problems in robotics," she adds.

Two creative undergraduate projects gave her even more practice applying machine learning to robotics. In one project, she hacked the controller of a toy remote control car to make it drive straight. In another, she developed a portable robot that could draw on the blackboard for teachers. The robot was given an image of Mona Lisa and, after going through an algorithm, it drew that image on the blackboard. "That was the first small success in my robotics career," says Bauza.

After graduating with her bachelor's degree in 2016, she joined the Manipulation and Mechanisms Laboratory at MIT (known as MCube Lab) under Assistant Professor Alberto Rodriguez's guidance. "Maria brings together experience in machine learning and a strong background in mathematics, computer science, and mechanics, which makes her a great candidate to grow into a leader in the fields of machine learning and robotics," says Rodriguez.

For her PhD thesis, Bauza is developing machine learning algorithms and software to improve how robots interact with the world. MCube's multidisciplinary team provides the support needed to pursue this goal.

"In the end, machine learning can't work if you don't have good data," Bauza explains. "Good data comes from good hardware, good sensors, good cameras – so in MCube we all collaborate to make sure the systems we build are powerful enough to be autonomous."

To create these robust autonomous systems, Bauza has been exploring the notion of uncertainty when robots pick up, grasp, or push an object. "If the robot could touch the object, have a notion of tactile information, and be able to react to that information, it will have much more success," explains Bauza.

Improving how robots interact with the world and reason to find the best possible outcome was crucial to the Amazon Robotics Challenge. Bauza built the code that helped the MIT-Princeton Team robot understand what object it was interacting with, and where to place that object. "Maria was in charge of developing the software for high-level decision making," explains Rodriguez. "She did it without having prior experience in big robotic systems and it worked out fantastic."

Bauza's mind was at ease within a few minutes of 2017 Amazon Robotics Challenge. "After a few objects that you do well, you start to relax," she remembers. "You realize the system is working. By the end it was such a good feeling!"

> You just press play and the robot is autonomous. It's going to do whatever you code it for, but you have no control. If something is broken, then that's it.

Bauza and the rest of the MCube team walked away with first place in the Stow Task portion of the challenge. They will continue to work with Amazon on perfecting the technology they developed.

While Bauza tackles the challenge of developing software to help robots interact with their environments, she has her own personal challenge to tackle: surviving winter in Boston. "I'm from the island of Menorca off the coast of Spain, so Boston winters have definitely been an adjustment," she adds. "Every year I buy warmer clothes. But I'm really lucky to be here and be able to collaborate with Professor Rodriguez and the MCube team on developing smart robots that interact with their environment."

Alumni Profile:

Ryan Eustice, PhD '05

On A Mission to Build the Un-crashable Car

By Mary Beth O'Leary

Ryan Eustice's interest in self-driving cars began 12,500 feet below the surface of the Atlantic. As a PhD student in the joint MIT-Woods Hole Oceanographic Institution Program, Eustice focused on creating technologies for underwater vehicles to map and understand their environments.

"That's how I got into this line of work originally," explains Eustice, who is currently Senior Vice President of Automated Driving at Toyota Research Institute and Associate Professor at the University of Michigan. "From an engineering perspective, the focus would be on helping the robot better navigate and understand its surroundings."

At MIT and Woods Hole, Eustice would deploy robots on field cruises to take pictures or make a map of the seafloor using cameras, sonar, or LIDAR – short for Light Detection and Ranging. That map would then be used by a geologist or marine biologist for their research purposes. A breakthrough in his career came in 2004, when he had the opportunity to send one of his robots to the site of the Titanic wreck, 12,500 feet below the water's surface off the coast of Newfoundland. "I was able to produce a very accurate reconstruction and map of the wreckage using the downward looking camera imagery the robot collected."

Professor John Leonard, who served as Eustice's co-advisor while he was a PhD student, found Eustice's work ethic infectious. One day, Leonard was facing a deadline to write some paragraphs for the literature review of one of Eustice's important papers. "I said I would try to write a few paragraphs – and Ryan said 'Do or do not, there is no try,'" recalls Leonard. "I stayed late that night and wrote the paragraphs before going home."

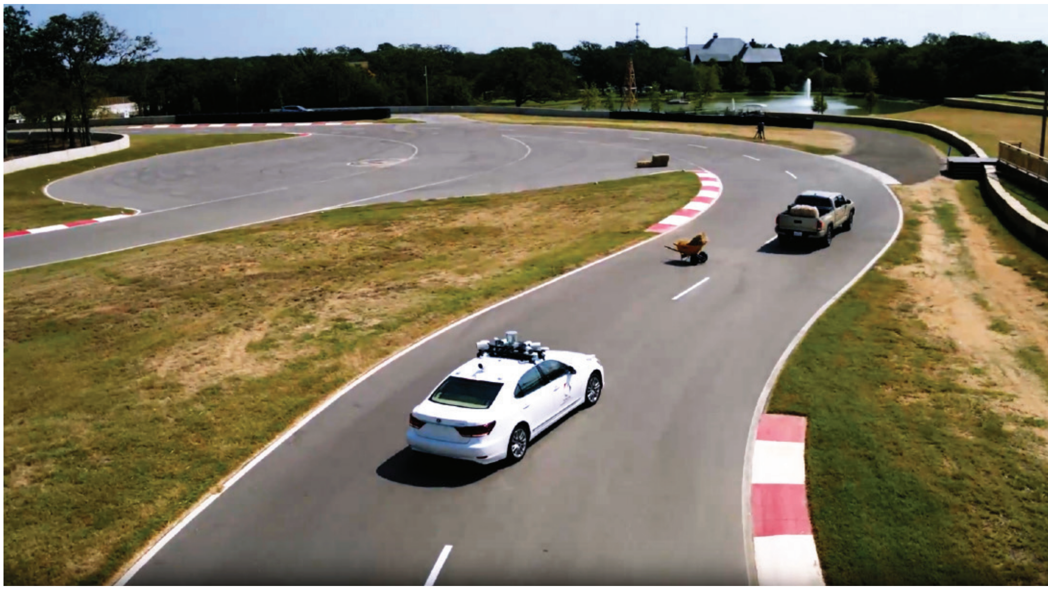
Ryan Eustice, PhD '05
Image: Joseph Xu

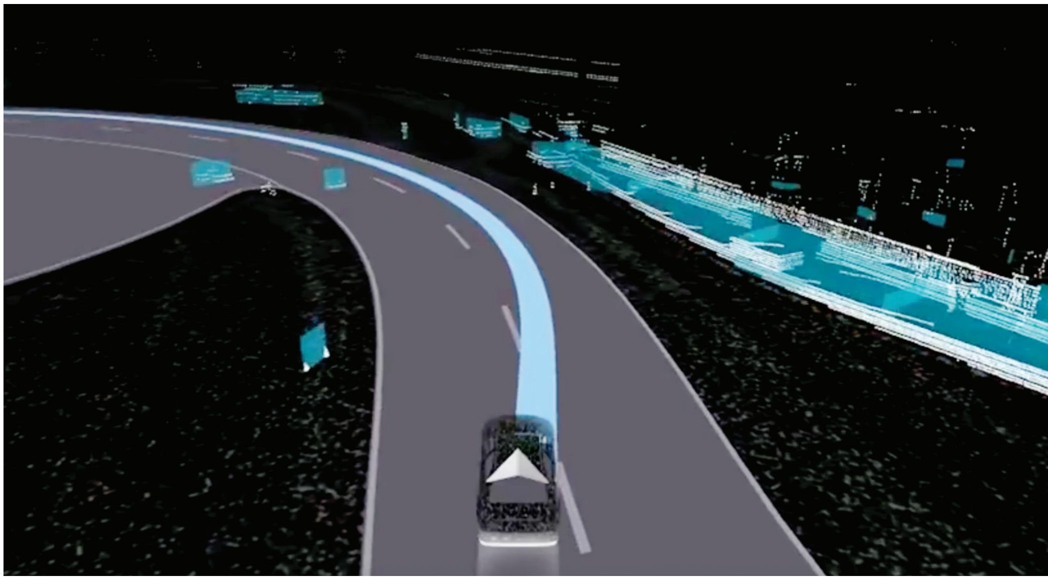
After receiving his PhD, Eustice made his way back to his home-state of Michigan. He was offered a faculty position in the University of Michigan's Department of Naval Architecture and Marine Engineering where he continued his work on underwater robotics. "I've been using some of the same technology that went into mapping the Titanic," Eustice explains. "I'm looking at how robots can be deployed near naval ships so they can do inspection tasks or map the below-water portion of the hull."

Shortly after arriving in Michigan, Eustice was asked to apply the technology he was building for underwater vehicles to cars. In 2007, DARPA – the Defense Advanced Research Projects Agency – announced their Urban Challenge to build an autonomous vehicle that can drive and navigate everyday traffic scenarios. The team from Ford Motor Company, a few towns over from Ann Arbor, were looking for someone with expertise in mapping, navigation, and LIDAR technologies. Eustice fit the bill.

The Ford Motor Company team finished as finalists in the 2007 DARPA Urban Challenge. Eustice continued to work with them for nearly a decade, before joining

Eustice and his team at Toyota Research Institute are developing an autonomous vehicle that uses a variety of sensors to understand its surrounding environment. The data generated could either be used to make the car fully autonomous in 'Chauffeur Mode' or help a human drive safer in 'Guardian Mode.' Images: Toyota Research Institute





Toyota Research Institute in 2016. At Toyota, Eustice leads a team developing a sensor-rich car built around artificial intelligence. Like many companies around the world, part of the team's research is focused on what they call 'Chauffeur Mode' – where the human is the passenger and the car is fully capable to drive itself.

But according to Eustice, this kind of automation could be used in other ways. "We are working on a technology stack that gets us to a full automation scenario, but at the same time we see a tremendous opportunity to use that technology in a different way," says Eustice. "Fundamentally, we want to build an un-crashable car."

With fully autonomous vehicles, the human has to be somewhat alert since the car is unable to handle all individually rare but collectively common scenarios that happen in day-to-day driving – a mattress flipping off a car in front of you or a crossing guard motioning for you to stop, for example. In those situations, human drivers need to remain alert in the event they have to take over steering. Humans are expected to watch the AI.

But Eustice and his team are developing technologies that flip that equation. "With 'Guardian Mode' we say 'Well let's imagine a system where we have AI guard the human,'" Eustice explains. It's a subtle change but has profound ramifications that can augment the human driver.

Eustice and his team have outfitted test cars with 360-degree sensing around the vehicle using similar technologies he worked with as a graduate student at MIT. Instead of mapping oceanic environments, he has one particularly lofty ambition: "The ambitious goal I have this with this team is to develop a car that is incapable of causing a crash."

Talking Shop:

Associate Professor Themistoklis Sapsis

Using Machine Learning with Physical Models to Predict Extreme Events

2017 was one of the most destructive hurricane seasons on record. Hurricane Harvey left the streets of Houston flooded. Hurricane Maria ravaged Puerto Rico, leaving millions without power for months. Hurricane Irma decimated the infrastructure of many Caribbean Islands.

The intensifying power and increasing unpredictability of Atlantic hurricanes have left meteorologists searching for ways to make more accurate forecasts and give people enough warning to prepare or evacuate. Themistoklis (Themis) Sapsis, associate professor of mechanical and ocean engineering and principal investigator at MIT's Stochastic Analysis and Nonlinear Dynamics (SAND) lab is hoping to improve our ability to predict extreme events like hurricanes. By using machine learning to enhance existing models, Sapsis is training computers to make more accurate and reliable predictions.

You began your academic career with a degree in naval architecture. How did you transition from naval architecture to the prediction extreme weather events?

I was always inclined toward mathematics so all of my research has been math oriented with applications in ocean engineering. After completing my PhD in mechanical engineering at MIT, I had a post-doc appointment at NYU's Courant Institute of Mathematical Sciences. I then came back to MIT as a faculty member with the idea of solving problems in ocean engineering by developing or utilizing new mathematical methods.

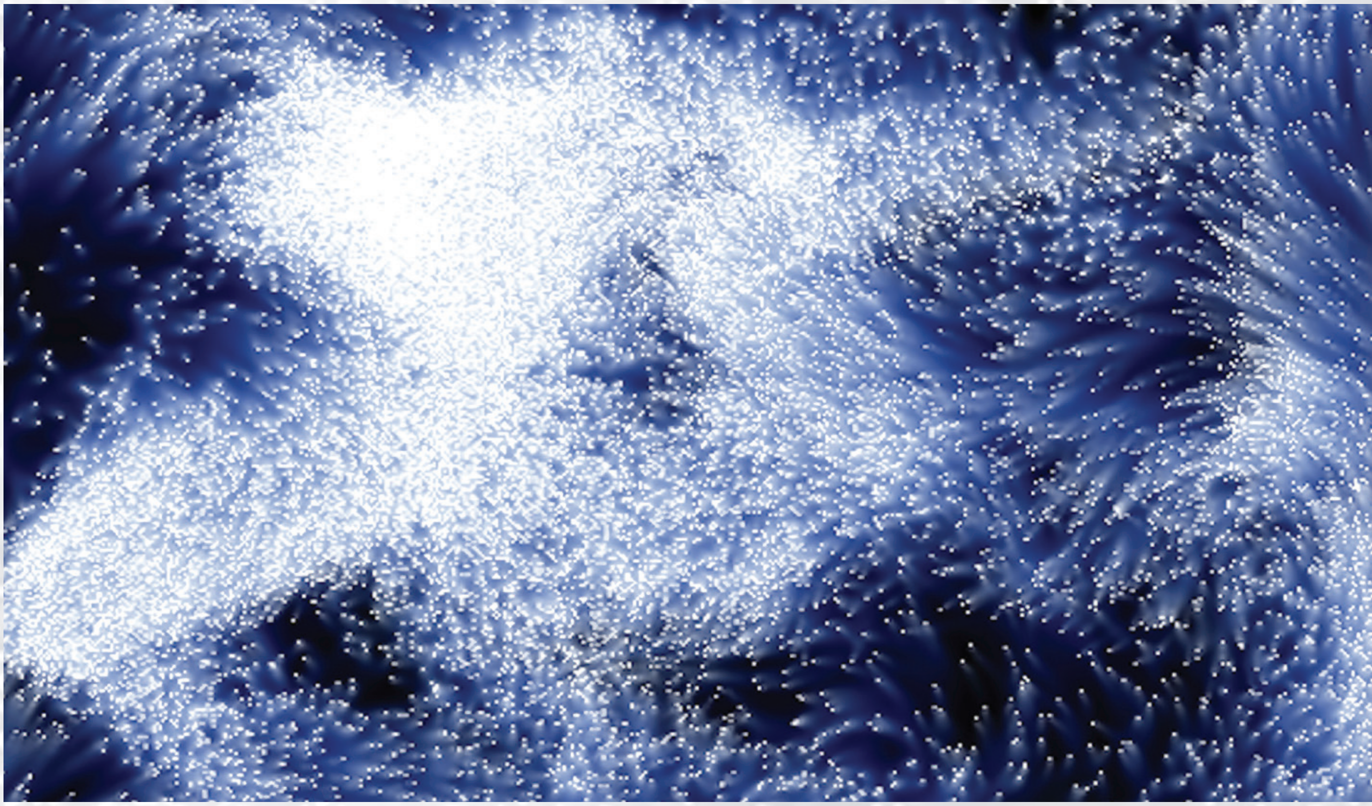
Associate Professor Themistoklis Sapsis
Image: John Freidah

One area my lab and I study is the general prediction of extreme events. We have done extensive work on the prediction of extreme water waves – also known as rogue waves – in the ocean, but we are also interested in extreme events in engineering and geophysical fluid flows. For engineering applications, we want to be able to predict when an extreme event will occur so we can apply control strategies that can suppress or avoid the event. I'm trying to push the envelope by taking math and ocean engineering into the machine learning sphere.

Why are current models for predicting extreme weather events like hurricanes not fully reliable?

There are already comprehensive models in place that people have been using to predict weather events like hurricanes and nor'easters. Our aim is to build a mathematical foundation that combines available data with these physical models more effectively so that predictions are more accurate when it comes to extreme events. The challenge is that for extreme realizations we do not have enough data available to train the models. Therefore, it is even more essential to build effective blending strategies between models and data. Another important challenge is the computational cost associated with the comprehensive weather prediction models that we hope to reduce through these blended strategies.

In addition to predicting extreme atmospheric events, Sapsis and his team aim to predict the motion properties of finite-size particulates moving in arbitrary fluid flows – such as bubbles in water.



How does machine learning help improve these predictions?

We formulate new machine learning algorithms that use data from high-resolution models, such as a reanalysis of weather trends that have happened in the past, to improve physical models. These algorithms have helped us train a neural network that enables machines to make predictions of extreme events for a prototype turbulent fluid flow that mimics many of the features observed in real atmospheric phenomena. The blended approach, consisting of the physical model and the machine, assigns a score, a probability, to different possible outcomes. In this way, the generated predictions take into account the available data but also respect the underlying physics. This approach is novel because we are trying for the first time to incorporate machine learning within existing equations.

How are you using this approach for events beyond fluid flows and water waves?

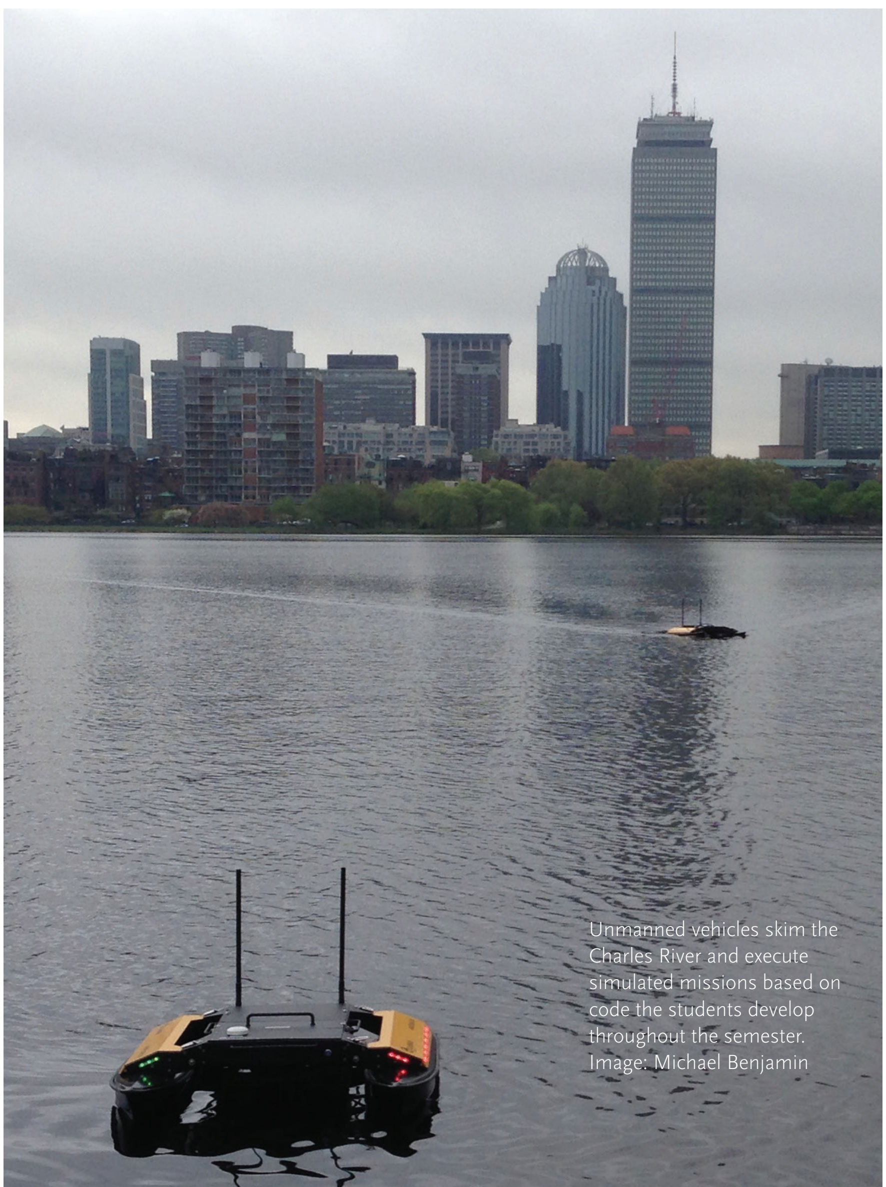
Another area my team and I are studying is trying to understand the motion of bubbles in fluid flows. Understanding how bubbles flow is extremely important when thinking about signatures of submarines, as well as how blood flows through the bloodstream to optimize drug delivery. Simulating how bubbles merge, split, and move is very expensive to do in a computer – especially if you're looking at the millions of bubbles that are generated around a massive ship propeller. We are trying to learn the dynamics of bubble motion on a small scale by complementing existing models with machine learning. So, just as with the geophysical systems, we are increasing the efficacy of pre-existing models and equations by incorporating machine learning to predict events at a much smaller scale than previously possible.

Class Close-Up:

2.680 Unmanned Marine Vehicle Autonomy, Sensing and Communications

By Mary Beth O'Leary

The melting of the Charles River serves as a harbinger for warmer weather. Shortly thereafter is the return of budding trees, longer days, and flip-flops. For students of class 2.680 (Unmanned Marine Vehicle Autonomy, Sensing and Communications), the newly thawed river means it's time to put months of hard work into practice.



Unmanned vehicles skim the Charles River and execute simulated missions based on code the students develop throughout the semester. Image: Michael Benjamin

Aquatic environments, such as the Charles River, present challenges for robots because of the severely limited communication capabilities. The need to use sound for propagating signals underwater limits the efficacy of remote-control communication with robots that are sent to explore bodies of water. "In underwater marine robotics, there is unique need for artificial intelligence – it's crucial," says course instructor, Professor Henrik Schmidt. "And that is what we focus on in this class."

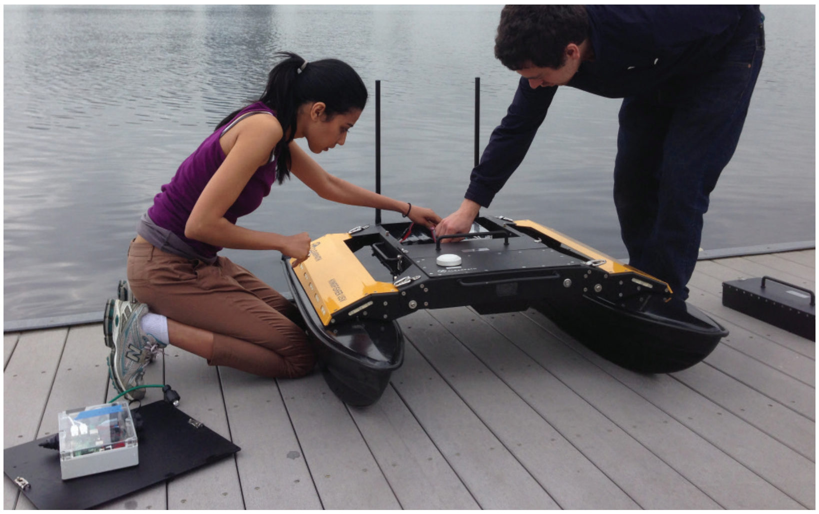
The class, which is offered during spring semester, is structured around the presence of ice on the Charles. While the river is covered by a thick sheet of ice in February and into March, students are taught to code and program an unmanned marine vehicle for a given mission. Students program with MOOS-IvP, an autonomy software used widely for real-life industry and naval applications.

"They're not working with a toy," says Schmidt's co-instructor, Research Scientist Michael Benjamin. "We feel it's important that they learn how to extend the software — write their own sensor processing models and AI behavior. And then we set them loose on the Charles."

As the students learn basic programming and software skills, they also develop a deeper understanding of ocean engineering. "The way I look at it, we are trying to clone the oceanographer and put our understanding of how the ocean works into the robot," adds Schmidt. This means students learn the specifics of ocean environments — things like oceanography or underwater acoustics.

Students develop code for several missions they will conduct on the Charles River by the end of the semester. These missions

Students make final adjustments before launching an unmanned marine vehicle named 'Gus.' Image: Michael Benjamin



In underwater marine robotics, there is unique need for artificial intelligence – it's crucial.

include finding hazardous objects in the water, receiving simulated temperature and acoustic data along the river, and communicating with other vehicles.

"We learned a lot about the applications of these robots and some of the challenges that are faced in developing for ocean environments," says Alicia Cabrera-Mino SB '17, who took the course in spring of 2017.

Augmenting unmanned marine vehicles with artificial intelligence is useful in a number of fields. It can help researchers gather more data on temperature changes in our ocean, inform strategies to reverse global warming, traverse the 95 percent of our oceans that has yet to be explored, map seabeds, and further our understanding of oceanography.

According to graduate student Gregory Nannig, a former Navigator in the U.S. Navy, adding AI capabilities to marine vehicles could also help avoid navigational accidents. "I think that it can really enable better decision making," explains Nannig. "Just like the advent of radar or going from celestial navigation to GPS, we'll now have artificial intelligence systems that can monitor things humans can't."

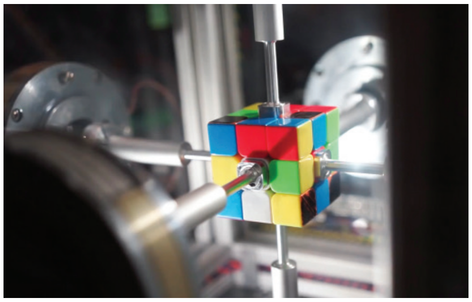
Students in class 2.680 use their newly acquired coding skills to build such systems. Come spring, armed with the software they've spent months working on and a better understanding of ocean environments, they enter the MIT Sailing Pavilion prepared to test their artificial intelligence coding skills on the recently melted Charles River.

As unmanned marine vehicles glide along the Charles, executing missions based on the coding students have spent the better part of a semester perfecting, the mood is often one of exhilaration. "I've had students have big emotions when they see a bit of AI that they've created," Benjamin recalls. "I've seen people call their parents from the dock."

For this artificial intelligence to be effective in the water, students need to combine software skills with ocean engineering expertise. Schmidt and Benjamin have structured class 2.680 to ensure students have a working knowledge of these twin pillars of unmanned marine vehicle autonomy.

By combining these two research areas in their own research, Schmidt and Benjamin hope to create underwater robots that can go places humans simply cannot. "There are a lot of applications for better understanding and exploring our ocean if we can do it smartly with robots," Benjamin adds.

News & Awards



A robot developed by students has broken world record for solving a Rubik's Cube. Image: Ben Katz/ Jared Di Carlo

Departmental and Research News

• Analysis conducted by Associate Professor Tonio Buonassisi in the journal *Nature Energy* provides a clear way to figure out the best type of solar panel for a given location and type of installation.

• A new model developed by Professor Anette 'Peko' Hosoi and published in the journal *Physical Review Fluids* predicts how hairs on a bat's tongue draw up nectar.

• A polymer thermal conductor developed by Professor Gang Chen could prevent overheating of laptops, mobile phones, and other electronics. The findings were published in the journal *Science Advances*.

• Using a design inspired by the paper-folding art kirigami, Professor Xuanhe Zhao designed an adhesive bandage that can stick to difficult places such as moving knees and elbows. The research was published in the journal *Soft Matter*.

• A new model developed by Professor Evelyn Wang and published in the journal *Nanotechnology* measures the characteristics of carbon nanotube structures for energy storage and water desalination applications.

• The Tata Center announced it will support a project by Associate Professor Amos Winter who will assess the socioeconomic and technical requirements for village-scale water and sanitation systems.

• In their annual university rankings, *US News & World Report* has named MIT MechE the number one graduate program in mechanical engineering for 2019.

• QS World University Rankings rated MIT MechE the number one mechanical engineering program in the world for 2018.

Maher Damak
Image: Sarah Bastille

Faculty Promotions

• Domitilla del Vecchio was promoted to Full Professor.

• Nicholas Fang was promoted to Full Professor.

• Ken Kamrin was promoted to Associate Professor with tenure.

• Jeehwan Kim was promoted to Associate Professor without tenure.

• Alexie Kolpak was promoted to Associate Professor without tenure.

Faculty Awards

• Professor Lallit Anand, Professor Stephen Graves, and Professor Yang Shao-Horn have been elected to the National Academy of Engineering.

• Professor Gang Chen has been elected to the American Academy of Arts and Sciences, one of the nation's oldest and most prestigious honorary societies.

• Professor Yang Shao-Horn has been named the first female recipient of the Royal Society of Chemistry's Faraday Medal in recognition of her outstanding original contributions and innovation in electrochemistry.

A new model developed by Anette 'Peko' Hosoi predicts how hairs on a bat's tongue draw up nectar.

• Professor David Wallace received the ASME Ben C. Sparks Medal for outstanding contributions that have transformed the way undergraduates across disciplines and cultures think about and practice mechanical engineering design.

• Professor Roger Kamm has been named the first recipient of ASME's Robert M. Nerem Education and Mentorship Medal for demonstrating a sustained level of outstanding achievement in education and mentoring of trainees.

• Associate Professor Kripa Varanasi was awarded the Frank E. Perkins Award for Excellence in Graduate Advising for serving as an excellent advisor and mentor for graduate students.

• Associate Professor Cullen Buie, Professor John Lienhard, Professor Warren Seering, Professor David Trumper, Professor Evelyn Wang, and Professor Kamal Youcef-Toumi were all honored with MIT's Committed to Caring Awards for making an impact in the lives of graduate students.

• Associate Professor Rohit Karnik received the School of Engineering's Ruth and Joel Spira Awards for Excellence in Teaching.

• Professor Ian Hunter has been elected to the National Academy of Inventors.

Student News

• Graduate student Maher Damak won the Lemelson-MIT Student Prize in the graduate "Eat It!" category for his work making pesticides stickier to minimize runoff.

• An interdisciplinary team of five MIT students, including MechE sophomore Claire Traweek, developed a solution to improve medical care for refugees as part of the Vatican's first-ever hackathon.

• A robot developed by MechE graduate student Ben Katz and EECS student Jared Di Carlo can solve a Rubik's Cube in a record-breaking 0.38 seconds.

• Senior Julia Rue received a Laya and Jerome B. Wiesner Student Art Award for outstanding achievement in and contributions to the arts at MIT.

Tonio Buonassisi has developed a method to determine when and where advanced photovoltaics would be economic to install.

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